Unfuzzing Design

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Publication date:
2019

Document Version:
Peer reviewed version

Document License:
Unspecified

Link to publication

Citation for pulished version (APA):
Bordal, S. A. (2019). *Unfuzzing Design: How progress is made towards unknown goals*. Designskolen Kolding.

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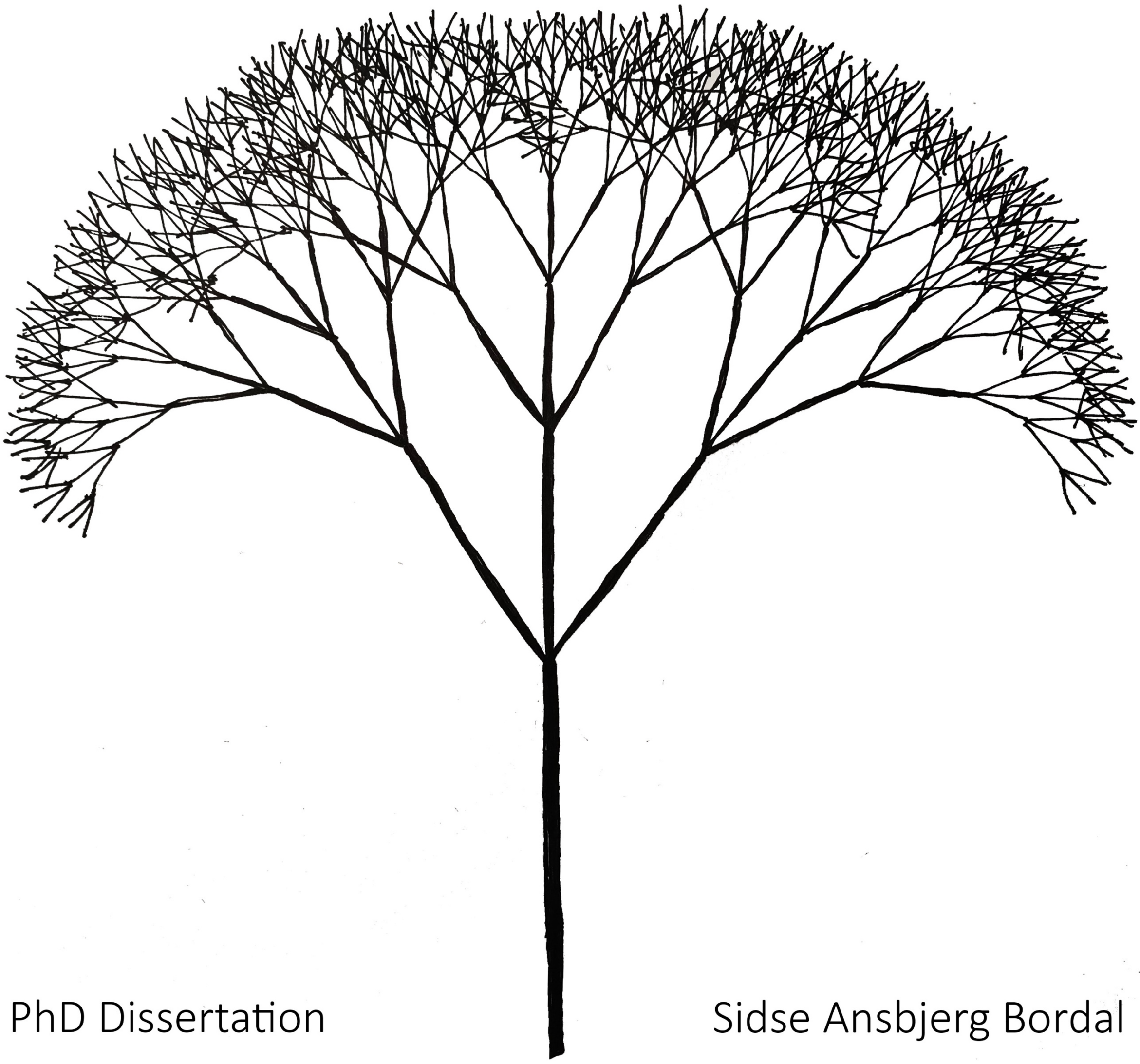
how progress is made towards unknown goals



PhD Dissertation

Sidse Ansbjerg Bordal

Unfuzzing Design

how progress is made towards unknown goals

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Sidse Ansbjerg Bordal

Unfuzzing Design: how progress is made towards unknown goals

PhD Dissertation

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Funded by:
The Independent Research Fund Denmark, Grant number DFF – 1321-00013

Design School Kolding
2018

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design skolen kolding

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Summary

The topic of this dissertation is design processes and how progress can be made in explorative processes, where the ends and the means are unknown. The starting point of such processes is under-determined tasks – tasks characterised by missing or vague information. Such tasks are poorly understood in current design theory, yet they are the prerequisite for all creativity, since missing or vague information is what makes room for something new to be created. Designers confront this kind of task every day but are often unable to describe what they actually do. Strengthened knowledge about explorative design processes can support design practice, validate the design profession, consolidate design-driven approaches to development outside the field of design, and furthermore serve as a foundation for the general understanding of applied creativity – not as a mental process, but as the actual *creation* that takes place when action is applied to material.

Likewise, this dissertation lays out the theoretical knowledge foundation for design and the concepts by which we can describe and understand design processes. The field of design theory is characterised by a number of conflicts and ambiguities. I propose a design theoretical perspective that contributes to a unifying reconciliation of these issues.

The dissertation is structured into four parts: In addition to the introduction Part I comprises a philosophy and method chapter underpinning the study. Part II reviews and points to conflicts in existing design theory. Part III introduces a system of terminology, proposing a new information processing perspective on design, aiming to reconcile some of those conflicts. Finally, Part IV describes the mechanisms of progress in design: how information is activated by the designer in the process of creation.

Part I

The aim to produce knowledge about what designers do reveals the philosophical assumption that this is, in fact, possible, that there is some element that underlies the diversity, complexity and seeming fuzziness of design practice: That explicit knowledge of mechanisms and underlying structures of designing can be divulged and described, and that design can, in fact, be explained in a form that is different from the actual execution of design. This assumption about design is aligned with Critical Realism (CR), which is the scientific philosophy that best characterises my understanding of the world and the ways in which we can come to understand it. CR entails assuming that reality is deep, and that structures exist beneath the surface of empirically observable events, the

nature and mechanisms of which can be uncovered. Likewise, the CR perspective implies the understanding that knowledge is always constructed in a social and historical context. Therefore, theory is never infallible, but merely a revisable approximation to the truth.

Methodologically the research leans on Layder's 'Adaptive Theory' (AT) approach, which draws on the fundamental assumptions of CR. The 'adaptive' part of the notion refers to the fact that theoretical understandings adapt to the incoming empirical data of the study, while the data themselves are at the same time filtered through, and thus adapted by, existing theory that serves as orienting concepts in the data analysis. AT is a multi-strategy approach to research which advocates for synthesis between well-known dualisms through cyclic shifts between e.g. agency and structure levels, empirical and theoretical focus, and inductive and deductive approaches to theory generation. Thus AT positions itself as a middle ground between theory-testing approaches and Grounded Theory.

The primary empirical study of the dissertation is a case study of ten Master's projects by product design students from fashion and industrial design at Design School Kolding. Each project represents a case, and the object of study in each case is the five-months-long design *process*. The Master's project is a self-defined project, which means that no requirements are given as to the theme or the resulting character of the project. The educational setting was chosen, because it is an accessible and structured context for a long, in-depth study of design processes. Also, its externally under-constrained circumstances represent a fruitful context and an extreme case strategy to study mechanisms related to under-determined tasks.

The progress of the case projects was captured in time lapses with approximately two-week intervals by means of different qualitative methods: observation of supervision sessions, interviews and collection of both written and visual documentation material. In total, the data set amounts to 1488 document pages of which 772 are primary data document pages transcribed from recordings and notes from a total of 63 interviews and 70 observation sessions. Additionally, the data set comprises 853 visual units, i.e. photos of the project material and activities.

Part II

Through literature reviews, the dissertation accounts for a number of conflicts in existing design theory, for example, the rift between different paradigms of design methodology, differences between design disciplines, creative tasks versus explicit description and reason, 'design thinking' versus design action, and the fact that many models of design black-box the concept of creative development, which leaves a gap noted by several theorists between the abstractness of concepts and the concreteness of specific solutions.

Another central conflict is linked to the prevalent conceptual understanding of design tasks as 'problems'. This conflict is indicated when the problem term is negated by prefixes such as 'ill-defined' in order to try to describe design tasks. Furthermore, not all designers solve problems in the conventional sense. This is for example often the case in fashion design. The problem focus entails a series of interlinked concepts, for example *solution*, *problem-solving*, *phases*, *spaces*, *constraints*, and *frames*. These concepts constitute a conceptualisation of design that characterises not only the discourse in which design is described, but also the boundaries within which new knowledge of design is typically generated.

Part III

Motivated by the problems with 'the problem' and the challenges that remain to understand design, and based on the empirical observations, I propose a new system of terminology of design, based on an *information* perspective on design. From the information perspective design can be seen as the acquisition, configuration and (trans)formation of information. Thus, the design process is seen as 'information processing' of under-determined tasks.

Information is the material used in *formation* – the building blocks of design. The smallest perceived unit of analysis is an *Information Entity* (IE). *Information* can be defined as *the meaning that a person ascribes to data.* In design, data can be understood as the material that the designer collects for her project. 'Information Entities' is a conceptualisation of data specific to a design process. Thus, *an IE is an item of data in a form that is perceived by the designer to be directly or indirectly amenable to transformation as part of a design process*. IEs can carry meaning in the form of *themes*.

'IEs' are a central concept introduced in this dissertation. 'IEs' replace the common 'constraint' notion in the conceptualisation of design. For example, IEs can take different ontic forms, including material, and, as opposed to constraints, which are characterised by their limiting *effect* on the freedom in a task, IEs are considered tangible resources used to build opportunities rather than narrow them down. The latter point implies an inverted perception of the typical perspective on design processes as a design *space* that is searched and narrowed down. In the information perspective, design is a *building* process, and the idea that a design 'solution' *exists* in the solution space is rejected. Instead the emergence of a final design is seen as a process of building *increasing* complexity and information and feature density.

According to the information perspective, the design task is considered a dynamic system of information, the content of which is conceptually delimited from its context. In the system view, information 'belongs to' a task if it is consciously recognised by the designer as being part of it. Thus, the designer has the role as a conceptual *boundary* and link between the design system and its external context. The system view implies that as long as information is considered as 'belonging to' the system by the task taker, the source from which it stems makes no difference. Thus, it reconciles the division between externally and internally imposed constraints in the study of design, and promotes the comparison of heterogeneous design tasks.

The dissertation demonstrates that IEs can serve different roles in the design process. This is empirically revealed when designers express a perceived lack of information to fill certain functions in their project, or a lack of useful functions for specific information, which has been sourced to, but not yet given a purpose in, the process. Those 'roles' represent a *function structure* in design, conceptualised as ITO (Input, Transformation, Output), which is a central contribution of this research. In the process of transforming information, *Input* refers to the material the designer wants to transform, *Transformation* denotes ways of doing so, and *Output* refers to the desired or required result of this transformation.

The ITO functions do not relate to specifications of a design goal, but to the *progress* of the design process. Thus, the ITO structure is particularly relevant to the handling of under-determined tasks with unknown goals.

The ITO model can be seen as a development from, and an alternative to, the co-evolution model of design as alternating between a problem and a solution space. A distinguishing feature of the ITO model is that it encompasses the function of *transformation* – i.e. methods and 'ways of doing' – as equally important as, yet separate from, what it is applied to and what it is intended to yield. Therefore, ITO represents a new fundamental distinction in design as an alternative to the prevalent distinction between problem and solution. This distinction resolves the problem with 'the problem'.

The ITO model is a generic model that provides a functional structure in which the content (the information) is considered variable data. The data is provided by IEs from the individual design projects, and the ITO structure remains stable independent of the data. Thus, the ITO model provides a unifying foundation for study, comparison, and theorising across very different design projects and design disciplines.

In under-determined tasks, information is missing or vague. Hence, information needs to be sourced to the design system. I call the act of adopting new information into the design system *Information Sourcing*. I account for how information is sourced into the design tasks studied and give a nuanced theoretical picture of information sourcing strategies.

Part IV

To shed light on the mechanisms of progress in design, I analyse the notion of 'development' in design processes, show how 'nonformation' – insights about what *not* to do – can be converted into information, and elaborate on how the concept of 'process' can be differentiated and understood. I suggest a distinction between three process conceptualisations that pertain to how designers *plan*, *account for* and actually *conduct* movement in design processes. These process conceptualisations are linked to different *process levels* of abstraction, between which designers must manoeuvre.

The notion of the design process and the design system are conceptualised in a unifying manner in the *design 'salami' model*. Like a salami, the content of the design process is delimited by its circumference and its length. The content can be viewed in the cross section of the salami, but is different dependent on where the design-salami is sliced. Slicing the design 'salami' represents an act of *managing information* through which designers create an overview of and pursue coherence between information in different process perspectives and on different process levels. The coherence is continuously (re)constructed in the process.

The concept of *Design Syllogisms* is a central contribution of this dissertation. Design Syllogisms describe the situations in which action is applied to material – information – in order to transform it, thus conceptualising the moving mechanisms of design. Design Syllogisms represent a development of the notion of a design experiment, implying a triadic distinction of experiments based on the ITO structure and similar to that of logical reasoning: deductive, inductive, and abductive. Both in Design Syllogisms and logical reasoning something new is derived from known premises. Yet, in traditional reasoning we infer something new from given propositions, whereas in Design Syllogisms, designers derive something new from tangible information entities. Therefore, Design Syllogisms can be considered 'reasoning with things'.

The concept of Design Syllogisms breaks with some common conceptions about 'logic' or reasoning of design in existing theory: that design is primarily abductive; that different inference types pertain to distinct *phases* of the design process; that it pertains to *arguments* relating to the value and persuasiveness of specific ideas or solutions; that it is *non-deductive*; and that design pertains to the realm of *thinking rather than acting*.

In the Design Syllogistic perspective, inferences of design shift continuously throughout the process, and inductive, deductive, and abductive reasoning are mutually supportive and equally important in design generation. Though deductive inference in relation to design is accused of being rigid and simplistic, the Design Syllogistic perspective implies that deduction is not incompatible with creative and explorative design processes, but rather potentially promotes creativity. The inferential nature of Design Syllogisms pertains to individual move experiments, where we find the mechanisms of actual change. Finally, in the Design Syllogistic perspective, material embodiment is considered integral to reasoning, as every inference is constituted by embodied information entities and the enactment of these. This perspective proposes a way to reconcile the conflict between considering the nature of design as 'design thinking' or as 'design acting'.

In Design Syllogisms two things become three, and hence more information is created than was originally there. Thus, Design Syllogisms are the mechanisms of progress and emergence of explorative processes.

Furthermore, Design Syllogisms offer an extension of some existing theories:

Since a Design Syllogistic move requires specific levels of informedness, filling certain functions to arrive at something new, Design Syllogisms can help to shed light on the notion of the 'sweet spot of creativity' as a function of 'constrainedness' in creative processes, proposed by Onarheim & Biskjaer. This 'sweet spot' is the spot between too few and too many constraints, in which an individual feels most creative. Design Syllogisms can support the understanding of how much information is just right.

The three types of Design Syllogisms (deductive, inductive, and abductive) are reminiscent of three empirically derived types of experiments mentioned by Donald Schön: *Exploratory*, *move-testing*, and *hypothesis testing*. Though not based on or identified from Schön's distinction, Design Syllogisms might be seen as an augmentation of Schön's theory. Schön does not explain why there are exactly three types of experiments, how they are related to each other, or the nature of the entities entering into these experiments. Therefore, my contribution does not only point to the distinction between three types of experiments, but also to the underlying structures that create this division, namely ITO and the logical forms of inference that are available, as well as the information that constitutes these inferences.

Resumé

Denne afhandling handler om designprocesser, og om hvordan fremdrift bliver skabt i eksplorative processer, hvor målet og midlerne er uspecificerede. Udgangspunktet for disse er underbestemte opgaver, som er karakteriseret ved manglende eller vag information. Denne type opgave er forudsætningen for al kreativitet og dermed design, eftersom manglende eller vag information udgør de 'huller', der levner plads til, at noget nyt kan skabes. På trods af dette, er underbestemte opgaver ikke velbelyste i den eksisterende designteori. Designere håndterer hver dag underbestemte opgaver, men ofte er de ikke i stand til at beskrive, hvordan de gør det. Større viden om eksplorative designprocesser kan være med til at styrke designeres praksis og autorisere designprofessionen. Derudover kan den styrke design-drevne tilgange til udvikling udenfor designfeltet samt bidrage til den mere generelle forståelse af anvendt kreativitet – ikke som en kognitiv proces, men som den faktiske 'kreationsproces', som finder sted når handling rettes mod materiale.

Afhandlingen handler også om det teoretiske vidensfundament for design og de begreber, vi bruger til at beskrive og forstå designprocesser med. Det designteoretiske felt rummer en række konflikter og paradokser, og i afhandlingen fremsætter jeg et designteoretisk perspektiv, som bidrager med et skridt imod en forsoning af konflikterne i en forenet designteori.

Afhandlingen er struktureret i fire dele: Del I indeholder, udover introduktionen, et filosofi- og metodekapitel, som underbygger undersøgelsen. Del II rummer en kritisk gennemgang af den eksisterende designteori og peger på nogle centrale konflikter i den. Del III introducerer et begrebsapparat, hvorigennem jeg anlægger et nyt databehandlings-perspektiv på design, med det formål at forsone nogle af konflikterne. Endelig handler Del IV om fremdriftsmekanismerne i design: Hvordan information aktiveres af designerne i den skabende proces.

Del I

Forskningsprojektets mål om at skabe viden om, hvordan designere arbejder, afslører samtidig den filosofiske grundantagelse, at det faktisk er muligt at skabe sådan en viden, og at der, nedenunder diversiteten, kompleksiteten og den 'fuzzyness', der omgærder design, virkelig er noget, der er værd at undersøge. Antagelsen er, at viden om underliggende strukturer og mekanismer i design faktisk kan udledes og beskrives i en anskuelig form, som adskiller sig fra selve designpraksissen. Denne antagelse er i tråd med den Kritiske Realisme (KR), som er den videnskabsteoretiske position, der bedst

karakteriserer min forståelse af verden og den måde, hvorpå vi kan opnå viden om den. I KR opfattes virkeligheden som dyb, og det antages, at der under overfladen af de observerbare fænomener er strukturer, som kan afdækkes. KR involverer også den opfattelse, at viden altid konstrueres i en social og historisk sammenhæng, og at teori derfor aldrig er ufejlbarlig, men altid blot en revidérbar tilnærmelse til sandheden.

Metodologisk læner forskningsprojektet sig op ad Layders Adaptive Teoretiske tilgang (AT), som trækker på de grundlæggende antagelser i KR. Den adaptive del af begrebet refererer til, at teoretiske forståelser tilpasses (adapteres) til de empiriske data, som forskningen bidrager med, mens selve dataene filtreres gennem, og således tilpasses den eksisterende teori, der tjener som 'orienterende begreber' i dataanalysen. AT er en multi-metodisk tilgang til forskning, der involverer en sammensmeltning af velkendte dualismer gennem skiftende fokus på for eksempel aktør- og strukturniveau, empiri og teori samt induktive og deduktive tilgange til teoriskabelse. Derved positionerer AT sig som en mellemgrund mellem hypotetisk-deduktive tilgange og 'Grounded Theory'.

Det primære empiriske studium i forskningsprojektet er et case-studium af ti designstuderendes afgangsprojekter på Designskolen Kolding. De studerende er alle produktdesignere indenfor mode og industrielt design. Hvert projekt repræsenterer en case, og forskningsfokus i hver case er den fem måneder lange *designproces*. Afgangsprojektet er et selvdefineret projekt, hvilket betyder, at der ikke er nogle regler for projektets tema eller resultatets art. Den uddannelsesmæssige kontekst muliggør på tilgængelig og struktureret vis et langstrakt, dybdegående studium af designprocesser. Tillige er de selvdefinerede opgaver frugtbare for studiet af underbestemte opgaver, idet de repræsenterer 'ekstreme cases' ift. dette fokus.

Fremdriften i designprocesserne er sporet gennem 'time-lapse' nedslag i casene ca. hver 14. dag, ved brug af forskellige kvalitative metoder: Observation af vejledningssessioner, interviews samt indsamling af både skriftligt og visuelt materiale. Totalt set beløber datasættet sig til 1488 siders dokumenter. Heraf er 772 sider primære data, som er transskriberede fra optagelser og noter fra i alt 63 interviews og 70 observationssessioner. Derudover inkluderer datasættet 853 visuelle enheder, dvs. fotos af projektmateriale og aktiviteter.

Del II

Gennem kritiske litteraturstudier redegør afhandlingen for en række konflikter i den eksisterende designteori, for eksempel kløften mellem forskellige paradigmer inden for designmetodologien, forskelligheder på tværs af designdisciplinerne, kreative opgaver kontra eksplicitte, rationelle beskrivelser, 'design thinking' kontra designpraksis samt det faktum at mange designteoretiske modeller black-box'er den kreative praksis, hvilket medfører en kløft, påpeget af flere teoretikere, mellem abstrakte idéer og konkrete løsninger.

En anden central konflikt relaterer sig til den fremherskende forståelse af designopgaver som 'problemer'. Denne konflikt synliggøres, når problemet kaldes f.eks. 'ill-defined' – med andre ord et ikke-problem – for at forsøge at tilpasse det til en beskrivelse af design. Ydermere er det ikke alle designere, der løser problemer i gængs forstand. Dette er for eksempel ofte tilfældet inden for modedesign. Problem-fokusset medfører, at design konceptualiseres gennem en række tæt forbundne begreber, fx *løsning*, *problemløsning*, *faser*, *løsningsrum*, *constraints* og *rammer*. Konceptualiseringen vedrører ikke alene den måde design beskrives på, men udgør også de rammer som ny viden om design oftest skabes inden for.

Del III

På baggrund af problemet med 'problemet', de stadige udfordringer ift. at forstå design samt de empiriske observationer, introducerer jeg et nyt begrebsapparat, som er baseret på et *informations*-perspektiv på design. Her kan design ses som erhvervelse, sammenstilling og transformation af information, altså 'information processing' eller databehandling af underbestemte opgaver. Information er det materiale, eller de byggesten, der bruges i *formationen* af et nyt designprodukt. Den mindste analyseenhed, der tages i betragtning, er en Informationsenhed (Information Entity) (IE).

Information kan defineres som den mening, en person tilskriver data. I design kan data forstås som det materiale, en designer indsamler til sit projekt. Begrebet IE er en konceptualisering af data, der er specifik for et designprojekt. Således er en IE *et stykke data, der har en form, som i designerens opfattelse er direkte eller indirekte modtagelig for transformation i en designproces*. IE kan bære mening i form af *temaer*.

IE er et centralt begreb, som introduceres i afhandlingen. IE erstatter det kendte begreb 'constraint' i konceptualiseringen af design. For eksempel kan IE have flere forskellige former, heriblandt materiel, og i modsætning til 'constraints', som er karakteriseret ved deres indskrænkende effekt på friheden i en opgave, betragtes IE som håndgribelige ressourcer, hvoraf muligheder opbygges, snarere end begrænses. Dette medfører, at det typiske billede af designprocessen som et design- eller løsningsrum, der afsøges og indsnævres løbende, vendes på hovedet. I informationsperspektivet anses design for en byggeproces, og idéen om at designløsningen *eksisterer* i løsningsrummet afvises. I stedet betragtes tilblivelsen af det færdige design som en proces, hvori kompleksitet, information og egenskaber øges og opbygges.

I informationsperspektivet anskues en designopgave som et dynamisk informationssystem, hvis indhold er afgrænset fra dets omgivelser. Information 'hører til' en opgave, hvis designeren bevidst opfatter informationen som en del af opgaven. Således har designeren rollen som *skillelinje* og link mellem designsystemet og dets eksterne omgivelser. Systemforståelsen medfører, at så længe informationen betragtes som tilhørende systemet, er kilden til informationen underordnet. Det betyder, at skellet mellem eksternt og internt pålagte 'constraints' udviskes i studiet af design, hvilket styrker grundlaget for at sammenholde forskelligartede designopgaver.

I afhandlingen viser jeg, at Informationsenheder kan spille forskellige roller i designprocessen. Dette forhold afsløres empirisk ved, at designerne udtrykker, at de mangler information til at udfylde visse funktioner i deres projekt, eller at de omvendt mangler meningsfulde funktioner til specifik information, som de har indsamlet, men endnu ikke fundet ud af, hvordan de skal bruge i processen. Rollerne repræsenterer en *funktionsstruktur* i design, som jeg kalder ITO (Input, Transformation, Output). ITO strukturen er en central del af afhandlingens bidrag. I databehandlings-processen refererer *Input* til det materiale, som designeren transformerer ud fra, *Transformation* betegner måden, hvorpå det gøres, og *Output* refererer til det ønskede resultat af transformationen.

ITO-funktionerne relaterer sig ikke til specifikationer for designmålet, men til fremdriften af designprocessen. Derfor er ITO-strukturen særligt relevant i forhold til at anskueliggøre håndteringen af underbestemte opgaver, hvor målet er ukendt.

ITO-modellen kan ses som en videreudvikling af, og et alternativ til, 'co-evolution'-modellen for design, der er beskrevet af Maher samt Dorst & Cross, hvori designprocessens udvikling beskrives som en vekslen mellem problem- og løsningsrum. ITO-modellen er kendetegnet ved, at den inkluderer funktionen *Transformation*, dvs. metoder og handlemåder. Disse anses for ligeså vigtige, men dog forskellige fra, det, de anvendes på, og det, de påtænkes at generere. Dermed repræsenterer ITO en ny grundlæggende distinktion i design, der udgør et alternativ til den fremherskende distinktion mellem problem og løsning, og som løser problemet med 'problemet'.

ITO-modellen er en generisk model, hvis funktionsstruktur kan rumme forskellige data fra forskellige designprojekter. Disse data betragtes som variable i modellen, der forbliver stabil uafhængig af deres karakter. Således bidrager ITO-modellen til et forenende grundlag, hvorpå forskellige designprojekter og -discipliner kan studeres, sammenholdes og forstås.

I underbestemte opgaver er informationen mangelfuld eller vag. Derfor er designere nødt til at tilføre information til designsystemet. Jeg kalder de handlinger, hvorigennem ny information tilføres designsystemet, for *Informationstilførsel* (Information Sourcing). Jeg redegør for, hvordan information tilføres i de studeredes designprocesser og nuancerer det teoretiske billede af informationstilførselsstrategier.

Del IV

For at kaste lys på fremdriftsmekanismerne i design analyserer jeg begrebet 'udvikling' i designprocesser, viser hvordan 'nonformation' – indsigter om, hvad man *ikke* skal gøre – kan konverteres til information samt uddyber hvordan begrebet 'proces' kan differentieres og forstås. Jeg foreslår en distinktion mellem tre forståelser af begrebet 'designproces' som knytter sig til hvordan designere planlægger, skildrer og udfører 'bevægelse' i designprocessen. Disse procesforståelser er koblet til forskellige procesniveauer af abstraktion, mellem hvilke designerne må manøvrere.

Begreberne 'designproces' og 'designsystem' forenes konceptuelt i en model, jeg kalder 'spegepølsemodellen': Som en spegepølse er designprocessens indhold afgrænset af dens omkreds og dens længde. Indholdet kan ses i pølsens tværsnit, men ser forskelligt ud afhængig af hvor man skærer design-pølsen over. Det at skære designspegepølsen over repræsenterer, at man *administrerer* informationen i projektet, hvorved designeren søger overblik over, og overensstemmelse mellem, information i forskellige procesperspektiver og på forskellige procesniveauer. Derved konstruerer designeren kontinuerligt *sammenhæng* (coherence) i processen.

Et centralt bidrag i afhandlingen er *Designsyllogismer* (DS). DS refererer til de situationer, hvori handling rettes mod materiale – information – for at transformere det, og således betegner DS fremdriftsmekanismerne i design. DS kan anskues som en videreudvikling af begrebet 'designeksperiment' og indebærer en tredelt distinktion af dette begreb, som baserer sig på ITO-strukturen og svarer til den sondring, vi kender fra logiske slutninger og argumenter, mellem Deduktion, Induktion og Abduktion. Såvel i DS som i logiske slutninger eller argumenter udledes noget nyt på baggrund af kendte præmisser; men hvor præmisserne i en logisk slutning eller et argument har karakter af udsagn, har de i DS karakter af håndgribelige informationsenheder. Derfor kan DS beskrives som at 'argumentere med ting'.

Begrebet DS gør op med designteoriens gængse idéer om logikken eller tænkningen i design, nemlig, at design primært er en *abduktiv* proces; at forskellige slutningsformer knytter sig til distinkte *faser* i designprocessen; at den vedrører *argumenter* om specifikke idéers og løsningers værdi og 'overtalelsevne'; at designprocessen *ikke er deduktiv*; og at den har at gøre med *tænkning snarere end handling*.

I DS-perspektivet skifter slutningsformerne kontinuerligt igennem designprocessen, og således er deduktive, induktive og abduktive slutninger alle vigtige og gensidigt understøttende aspekter af processens udvikling. Selvom deduktive slutninger er udskældte i designsammenhæng for at være rigide og simplificerende, så følger det af DS-perspektivet, at deduktion ikke står i modsætning til, men snarere kan være fremmende for, kreative, eksplorative designprocesser. Den slutningsproces, som en DS repræsenterer, angår det enkelte eksperiment og det udviklingsskridt, det udgør. Det er på dette procesniveau mekanismerne for udvikling beskrives, eftersom det er her, forandring sker. Endelig betragtes materialitet og ræsonnement som uløseligt forbundne i DS-perspektivet, eftersom hver slutning udgøres af håndgribelige informationsenheder og den måde, de sættes i spil på. Således tilbyder DS en forenende udlægning af karakteren af design, der bygger bro mellem tænkning og handling.
I en DS bliver to ting til tre, og således skabes der mere information, end der var før. Derfor beskriver DS mekanismer, hvorved formation og fremdrift drives i eksplorative processer.

DS kan ses som et udvidende bidrag til nogle eksisterende teorier:

Eftersom et udviklingsskridt, repræsenteret ved en DS, kræver en specifik mængde information, der opfylder bestemte funktioner, for at noget nyt kan skabes, kan DS hjælpe med at kaste lys på Onarheims og Biskjaers idé om det 'kreative sweet-spot", hvori et individ føler sig mest kreativ, relativt til mængden af 'constraints' i en proces. Sweet-spottet et det manøvrerum mellem for få og for mange 'constraints', hvor man oplever, at den kreative fremdrift har de bedste vilkår. DS hjælper til at forstå, hvor meget information, der er tilpas.

De tre typer DS (deduktiv, induktiv og abduktiv) minder om de tre empirisk udledte eksperimenttyper, som Schön har nævnt: E*xploratory*, *move-testing* og *hypothesis testing*. Selvom DS ikke er identificeret på baggrund af, eller bygger på, Schöns distinktion, kan de alligevel ses som en forlængelse af Schöns teori. Schön har ikke berørt årsagen til, at der netop er tre slags eksperimenter, hvordan de relaterer sig til hinanden, eller hvad karakteren er af de elementer, der indgår i eksperimenterne. Derfor peger mit bidrag ikke alene på distinktionen mellem de tre eksperimenttyper, men tillige på de underlæggende strukturer, der skaber denne opdeling, nemlig ITO, de logiske slutningsformer samt den information, som indgår i dem.

Acknowledgements

Thanks to those who made this PhD project possible: to the Independent Research Fund Denmark for funding the research project, to Design School Kolding for hosting the project, and to the PhD school at Design School Kolding and Aarhus School of Architecture.

Thanks to the Master's students from Design School Kolding and other informants for generously placing their work and their thoughts at my disposal for this research.

Special thanks to my supervisors Anne Louise Bang, Per Galle, and Balder Onarheim for their unceasing guidance and support, and to everyone else who posed challenging questions and gave valuable advice during my PhD – and, not least, to those of you, who knew when not to ask questions.

Love to the special two, who patiently wondered where I went every morning and when that book was going to be finished – and to you who were there for them and for me all along.

Reading Guide

This section contains some practical information about how to read and understand the text and the formatting of this dissertation.

Writing Style

The dissertation body text will shift between an expository and a narrating writing style throughout the chapters. Thus, where turning to previous experience or where otherwise considered supportive for the comprehension of the successive coherence of the research process, a more subjective, narrating style is employed.

Pronouns

Among my case designers, there is an even distribution of men and women. Among the fashion designers, four case designers are women, and one is a man. The opposite is the case for the industrial designers. When referring to a particular case designer, I shall use the appropriate personal pronoun *he* or *she* in accordance with the gender of the designer in question. Acknowledging that designers come in both genders, I shall, however, for consistency and simplicity, use the pronouns *she* and *her* when referring to 'a designer' in general.

Indications

Blue boxes contain exemplifying extracts from data that are constitutive or supportive of the findings.

In quotations:

- Text enclosed in square brackets, '[' and ']', conveys my interpretive or expository additions to support intelligibility or complete quotes extracted from their contexts.
- Text enclosed in brackets, '(' and ')', conveys explanatory information of relevance. This can for example refer to visual references or non-verbal action.
- Dots enclosed in brackets, '(' and ')', indicate omissions of text.
- Unbracketed dots '…' are the transcription indication for hesitation in speech or missing sentence closure.

References, Major Case Study

The major empirical study contains 10 case projects, each carried out by one design student. Every design student has been assigned a number between 1 and 10. As the cases are distributed between fashion and industrial design students, the initial f (for *fashion*) or i (for *industrial*) is continuously used along with the number to ease reading comprehension. For example, the industrial design student from case 3 is referred to as 'designer i3'. The cases are referred to by the design student's numbers.

Appreciating that the case designers are Master's students and not professional designers, I will however, for simplicity, refer to them as 'designers' or 'case designers' throughout the dissertation.

All the fashion designers share the same supervisor, who is referred to as 'fSupervisor' (fashion supervisor), and all the industrial designers share another supervisor, who is referred to as 'iSupervisor' (industrial supervisor). Additionally, some presentations and master classes are supervised by external supervisors, who are referred to as 'eSupervisor' (external supervisor).

Temporal Process Indications

Each case process is captured through a number of time-lapse 'snapshots' over time. When process progression is referred to as e.g. "midway in the process" or "one third into the process", this estimate is derived from relating the snapshot number in question to the total count of snapshots in the particular case studied and their distribution over time.

Figure 1 below is an example of the temporal distribution of snapshots and the time-lapses between them in case 6. Thus, in this example, snapshot 5 would be approximately midway in the process, which is captured by a total of 11 snapshots.

Figure 1: Example of distribution of snapshots throughout a design process

Data References

Data excerpts are referenced as exemplified by: (f1, 6, 31-37)
This notation is specified in the following order:

- The case number indicated by Designer f1, f2, i3 etc.
- The snapshot number

- The transcript protocol paragraph number in the f5/f4[1] file.

When referring to data with no protocol paragraph numbers (e.g. collected visuals or documents written by the designer, e.g. project descriptions), the data are referenced as exemplified by: (f2, 3)

References, Additional Interviews
When referring to informants outside the major case study, they are introduced individually and referred to by their title and a letter. For example, 'Industrial Designer A'.

Translation
The pool of verbal data is provided in both Danish and English. I have translated Danish data into English, when quoting or referring to it. The English translation therefore represents my own interpretation of the meaning expressed in the original quote.

All quotes have been proofread, which is why minor changes have in some instances been made to what was originally said or written in English by the designers.

Terms
In Danish, my mother tongue, we have a word which can seem indispensable when talking about design, and which I often miss when writing or speaking in English about design. In a verbatim translation, this word is 'form-giving'. The dictionary translates the Danish word 'formgivning' as 'design' in English. Yet, I will argue that 'form-giving', as used in Danish, is not synonymous with 'design'. The following attempt to define 'form-giving' represents my own appreciation of the word 'form-giving', and if the majority of Danish speakers should happen to disagree with the way I define it, then let it be merely stipulative for the use in this dissertation.

Like the word 'design', 'form-giving' can be used as both a verb – the act of giving form or shape to something – or it can be used as a singular noun, e.g. "I really like her form-giving", i.e. the way she has given form to something. However, 'form-giving' is more specific than the word 'design', as it refers to the actual, and visually perceivable, shape of an emergent object or the action of creating this shape. Thus, form-giving cannot refer to (the design of) something non-physical, e.g. services. 'Form-giving' is not 'styling' either. Styling is associated with the superficial decoration of

[1] f5 and f4 are the names of software programmes used for transcription and analysis respectively. (See page 48).

something, e.g. an already existing object, whereas ‘form-giving’ is associated with giving a form to, and epitomising the existence of, an object by building it from the inside-out or from the bottom-up. The word ‘form-giving’ will be encountered a couple of times in the dissertation.

Technical Terms

A few technical terms from the fashion design cases may need explanation:

Style: A piece of clothing, for example a pair of pants, a shirt, or a dress. A style may refer to a specific, known piece of clothing. For example, ”I have decided on these pants.” Or a style may refer to the idea of a piece of clothes. ”I can’t decide whether this style should be a top or a dress” or ”I need more voluminuous styles in my collection.”

Silhouette: An entire outfit and its collective visual expression. A ’silhouette’ can also refer to the outline of a shape, but more often it refers to the outfit in general, e.g. ”If we put these styles together, it would make a nice silhouette” or ”I will have to sew eight of my silhouettes.” Like a style, a silhouette can refer to a specific item or the concept of one. In the latter case, it can be difficult to distinguish between a silhouette and a style in the beginning of an explorative process. For example, a draping experiment can start out as one large piece of fabric draped around most of a body (dummy), filling a whole silhouette, and then later this silhouette can be separated into individual styles.

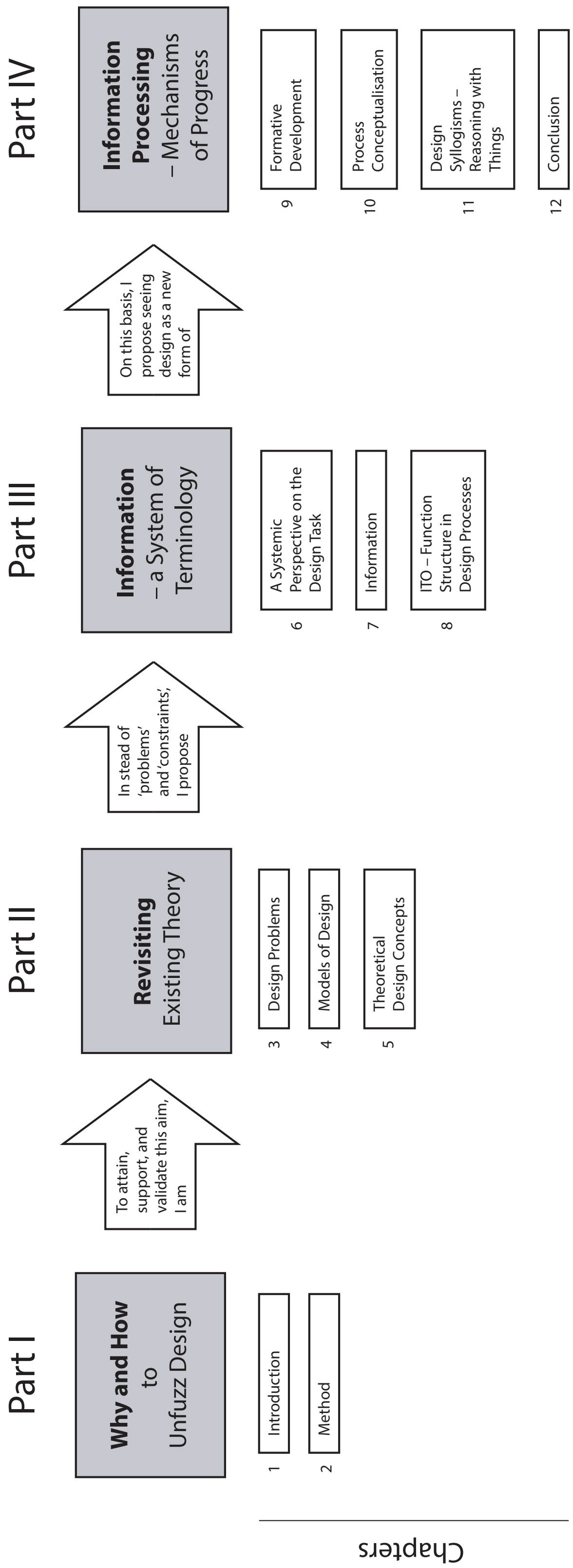
Stout/toile: Stout or toile is a plain linen fabric that fashion designers typically use for prototyping, because it is cheap and simple and not visually distracting. The words stout or toile can likewise refer to the process of working with the fabric in for example drapings, or to the draped style or silhouette itself. Thus, when designers refer to ‘toile’ it can mean, plainly, a prototype in fabric, not necessarily that it is made of the actual stout fabric.

Body: An actual body, the idea of a body, or something with the shape of a body (a dummy).

Realise: To sew something or have it sewn by others in the right fabric with the right trimming, so it becomes a finished piece of clothing. A realised style can possibly lack certain functional features, but will visually appear to be as the design intended.

Trimming: Trimming, or just trim, is all the non-fabric elements needed to make clothing, such as zippers, buttons, rivets, lace, etc.

Dissertation Overview



Part I: Why and How to Unfuzz Design

1. Introduction

The topic of this dissertation is the evolution of design processes. More specifically it is about the progress in explorative processes the ends and means of which are unknown. The starting point of explorative processes is under-determined tasks[2] , i.e. tasks with missing or vague information about what to work *with*, *how* to do it, and by what criteria the outcome should be assessed. Such tasks are the prerequisite for all creativity, since missing or vague information is what leaves room for something new to emerge. And this is the type of tasks that designers confront every day.

Taking the concept of under-determined tasks as a starting point, this dissertation investigates exploratively into the topic by examining existing design theory and by empirical investigation of design practice in the context of an educational setting.

The impetus for the investigation stems from my experience as a design student, from my subsequent work with academic research in design and innovation, and from my interest in the general tendencies in societal discourse and development in which design is playing an increasingly larger role. It also grew out of my personal sentiment of discontent with a lack of epistemic clarity about design, first as a practitioner, subsequently as a researcher. The field of design theory offers numerous equivocal and sometimes vague definitions, descriptions, explanations and assumptions – sometimes far removed from practice. Thus, my intention with this dissertation is to 'unfuzz' design, and make explicit how explorative design processes actually unfold. If, by the end of this dissertation, the reader finds that a small step has been taken along that path, this project will have fulfilled its purpose.

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[2] The intention of using the term 'under-determined task', rather than the more well-known and somewhat similar terms 'ill-defined', 'ill-structured' or 'wicked' problems, is to introduce a neutral term referring to tasks characterised by missing or vague information that is not related to the concept of 'problem' and 'problem-solving'. The notions of 'ill-defined', 'ill-structured' and 'wicked' problems do not carry the same meaning, though they are often used interchangeably. They will be described in Chapter 3 'Design Problems'.

I graduated with a Master's degree in Fashion Design in 2010. During my studies, I was part of an energetic study environment of dedicated and creative peers, working hard to improve our collections with each project and to excel as fashion designers. I was actually atypical in this environment. Early on, I became more interested in the design process rather than the product of fashion apparel itself. I realised that, although the process is the core engine of every design project – and no new results would be achieved without it – that process is immensely hard to grasp, and we students often shared our frustrations of feeling lost in a messy process of which we could make neither head nor tail. It struck me as a mystery that needed to be solved. Despite my interest in and study of design theory in Design School I was not particularly enlightened on the matter, since the prevailing theories were overwhelmingly founded on the concept of problem solving, a concept that my fellow students and I found it difficult to reconcile with our practice. However, or perhaps therefore, I was keen to find a more satisfying answer to the question of how design processes work.

After studying design, I was engaged in research in the context of design-led innovation and management.[3] Here the ambition is to transfer principles and practices from design to other domains, and in many cases this leads to very satisfying outcomes for the people involved – I have witnessed that myself. Yet, in my involvement with theory and projects, I have also met widespread, conceptual ambiguity and uncertainty regarding what design is, what it is not, and what it means to think, lead and develop by using design. It struck me that if we want to improve our understanding of design as a driver for development in other contexts, we must first comprehend the very core of design, and then transfer that knowledge to the relevant domains.

In our modern societies, disruption and innovation is on everyone's lips and agendas, and it is often stated that creativity is one of the most important resources we have to solve the many global problems. At the same time, there is a pervasive focus on goal-orientation, solutions, and process optimisations. Yet, if something essentially new and disruptively innovative is to see the light of day, it is necessary to travel along unknown paths toward unknown goals: through explorative processes based on under-determined tasks. If we focus on solving problems, we risk to merely repair the past

[3] From 2010 to 2014 I worked for Centre for Design, Culture, and Management and for the University of Southern Denmark, assisting and conducting follow up research on regional triple-helix projects aimed at design-driven business innovation.

within known concepts instead of defining the future by new ones. Therefore, we need knowledge about how to navigate in explorative processes.

Designers are masters of working with such explorative processes but are often challenged when trying to verbalise and explicate what they do. A great deal of value and knowledge is lost in that fuzziness.

A strong epistemic foundation of design and explorative processes is important, both within and beyond the field of design (this will be elaborated later). Hence, the motivation and aim for the research presented in this dissertation is to contribute to the understanding of design processes by proposing new perspectives on how designers work and how highly explorative processes unfold.

As will be expounded in this dissertation, existing design theory focuses on problems and problem solving as the primary descriptors for design tasks and design process mechanisms. However, as I will argue, these concepts are ambiguous and potentially troublesome as means to understanding design processes. Instead, this dissertation proposes an information-processing perspective on under-determined tasks to shed an alternative light on the act of designing.

Aim

The field of design theory is characterised by some conflicts: between different paradigms of design methodology, between procedural and propositional knowledge, between disciplinary differences in design practice, and, not least, between under-determined, creative tasks on the one hand, and explicit description and reason on the other.

With the ideal of a unified design epistemology as a guiding star, this dissertation seeks take a fledgling step towards it by proposing a new way of conceptualising design that might hold the potential to overarch some of the gaps. This is done by revisiting, and seeking to combine, different theoretical positions in design methodology, and by empirically studying a series of explorative design processes based on under-determined tasks in an educational setting across two different design disciplines. The specific aim of doing so is to contribute to the understanding of the driving mechanisms and the structure of explorative processes based on under-determined tasks.

In their intent to identify an ontology of design, Hatchuel et al. (2013, p. 148) have put forth the assumption that *”Provided there is a common core of propositions between* *design theories developed in different fields, this core can be seen as an ontology of design."* I do not share the principal assumption in this quote that existing theory necessarily spans the limits of the potential extent of design ontology. Yet, I agree on the integrative perspective on design ontology, as it is necessary for the pursuit of a holistic and encompassing design epistemology. In particular the idea that there is an underlying ontic core that connects what we have already learnt is convergent with the perspective held in this dissertation.

The aim of the present study is thus based on the assumption that different design projects share certain general characteristics in terms of which they can be described and compared, and that this commonality can be found in the way designers work in the design process.

Though there are differences between how novice and expert designer work (Cross, 2004), the empirical study of different designers residing on the same level of expertise, Master's students in the present case, might provide interesting insight to the common factors across otherwise heterogeneous design projects. These insights from the design educational context may serve as a ground for hypothesising and posing questions for further research about the shared characteristics of under-determined aspects of design tasks in a broader empirical context.

The aim of the study is furthermore based on the assumption that the structure and mechanisms of design processes are epistemically approachable and can be represented theoretically in a cohesive way that allows inclusion of existing competing perspectives on design. These assumptions will be elaborated in Chapter 2, section 2.1, 'Philosophical Ground'.

The aim of the dissertation is pursued by revising current design theory, including the concepts and assumptions by which design processes are described and understood, and by in-depth study and analysis of in-vivo design practice in an educational setting. Specifically, the study focusses on explorative product design processes characterised by an under-determined outset.

It is my intention to contribute to the theoretical field of design methodology with a practice-centred focus. This scope entails a broad interface with other theoretical areas, such as creativity, cognitive psychology, problem solving, decision making and innovation, but it is primarily centred on the practice of design and the concepts situated in this practice. In Kimbell's words, I want to study design thinking "from within" (2011, p. 286). However, I find the term 'design thinking' inadequate in the prevalent application of denoting 'general theory of design' (Kimbell, 2011). Rather, I find that 'practice' and 'action' are more descriptive concepts of the distinct core of designing. Hence, in this study, the mission to contribute to design theory has been approached without the intention to study the case designer's way of thinking, but rather to study their actions as well as the development in the material at which the action is directed.

The study constitutes a piece of theoretical basic research, primarily targeted at strengthening the epistemic foundation of design in the educational context, only derivatively aimed at promoting practice. Thus, I do not attempt to prescribe a way of designing, but rather describe how it is already taking place.

The dissertation does not engage in the discussion of how design (uncountable noun) should be defined, but rely on the existing definition by Galle and Kroes (2014, p. 216) that 'Design' is *"the kind of intelligent action that consists of proposing a novel idea for an artefact, so as to enable yourself or others to make one or more artefacts according to that idea."* Instead, I focus on describing what the case designers do, and implicitly this effort can be seen as a contribution to the characterisation of what 'design' is within the limits of the empirical context of the study.

Research Questions

My research comprises two intertwined tracks of study. Track 1 focuses on concrete design practice in an educational setting through which I seek empirically derived knowledge of how progress is made in student design processes, informed by theoretical concepts. Track 2 is a theoretical track in which I study existing concepts and build new ones in order to understand and develop the epistemic foundation of design. These two tracks each have their own specific question. A third question focuses on how the parallel search for answers to the first two questions brings synergetic insight to both.

1. Under-determined design tasks are poorly understood in current design theory and practice. What are the progress mechanisms and underlying structure of design processes initiated from such tasks?

2. Current theoretic design methodology is encumbered with a number of conflicts. What characterises this situation, and how might design methodology be conceptualised in a unifying manner?

3. Questions 1 and 2 are interrelated. How can the answers to them illuminate each other?

Terminology

Under-determined tasks
An under-determined task is construed as a task in which information necessary for its completion is missing or vague, i.e. complete information is missing about what to work *with*, *how* to do it, and by what criteria the outcome should be assessed.

Product design
Design whose output product is physical and tangible.

Process progress
Progress refers to advances in the formative development of the design process. Progress means that the content of the design process changes so that the emerging design is brought from one state to another on the path towards a final design. Progress will be explained in depth in Chapter 9 'Formative Development'.

Frontiers of Design Epistemology

There are several contributions to the understanding of design processes in existing design methodology. As will be discussed in detail in Chapter 3, two major paradigms of design research have been recognised as the *first generation* or the *hard systems methods* and the *second generation* or the *soft systems methods* (e.g. Broadbent, 2003; Rittel, 1972).

The first-generation perspective promotes a technical rational paradigm in which design problems are considered well-defined, stable, and dividable into sub-problems. The design process is therefore seen as a rational and structured analysis of the problem which then leads to the prescription of an optimal solution. In the second-generation perspective, problems are considered complex, ill-defined, unstable, and wicked (Rittel & Webber, 1973), and the process is thus iterative and trial and error-based, and the solution merely 'good enough'.

The first-generation theories have been crititised for not dealing with problems of relevance to reality. According to Schön – a representative scholar of the second-generation design methodology – the first generation left practitioners with a gap between theory and practice, or what he calls a 'dilemma of rigour or relevance' (Schön, 1983, p. 42). Quoting Schön, Galle (2011) elaborates that:

> Either you can apply sophisticated technical methods to relatively unimportant problems; or you can face the "messy but crucially important" problems that leave you to your own devices of "experience, trial and error, intuition and muddling through." The "messiness" involves such phenomena as "complexity, uncertainty, instability, uniqueness, and value-conflict," which do not fit methods of technical rationality. (Galle, 2011, p. 84)

Schön's response to the dilemma and the implied challenge is to shift epistemic focus; from knowing *that* to knowing *how*, in Ryle's (1949) distinction. In the technical rational paradigm, a propositional, or declarative, knowledge ideal was motivating the effort to account for practice in a form of knowledge considered distinct from that practice, whereas a procedural, or imperative, knowledge understanding underlies Schön's account of practice. Thus Schön (1983, pp. 49-69) maintains that knowledge is inherent in the action itself, while 'reflection-in-action' is a meta-level reflection upon that knowledge during action.

The study presented in this dissertation aims to understand design process mechanisms and structure within the empirical context of design education. Intrinsic to this aim is the assumption that it is possible to achieve propositional and explicit knowledge of designing based on, but different in nature from, the practice of designing itself. In fact, I shall argue in alignment with Marx (1971, p. 817) that *"all science would be superfluous if the outward appearances and essences of things directly coincided."* In other words, research into design only makes sense if the knowledge product of this effort is different from that of design itself.

The aim to make explicit the seemingly fuzzy process of working with an under-determined task reveals that I do not assume that there is an inevitable link between propositional, explicit knowledge on the one hand, and well-defined problems on the other, although the two are associated in the first-generation design methodology. It is apparent that under-determined tasks, on the surface, are more disparate and unpredictable than well-defined and determined tasks. Therefore, on the empirical level, the connection between a stable problem and a clear description of that problem can seem obvious. However, this link relies on a flat, empiricistic ontology. The viability of theorising – finding explicable patterns and structures – from a seemingly fuzzy phenomenon depends on how deep and stratified the reality is considered to be, and thus on which philosophical assumptions the investigation of the phenomena rests. The philosophical anchoring of this study will be expounded in Chapter 2, Section 2.1, 'Philosophical Ground'. Suffice it to say, for now, that it is based on a Critical Realist worldview, in which the ontic of investigation goes beyond the immediate fuzzy surface.

Arguably, Schön's contribution to the accumulated understanding of design processes has been substantial, but the design theory expounded by him and his contemporaries leaves a gap between the first and the second generation or the hard and soft design methodology. The second generation has not built extensively on the predecessors, but has largely gone to the opposite extreme, and this leaves some bridging to be done.

Bridging the Gap

Ideally, in a unified design epistemology, the gap between the paradigms of hard and soft systems methodologies must be bridged. From the Critical Realist perspective, theoretical disputes are a product of epistemic fallibility: Collier (1994, p. 51) says that *"Rival theories and sciences have different transitive objects (theories about the world), but the world they are about – the intransitive dimension – is the same; otherwise they would not be rivals".* And Sayer (2000, p. 10) complements *"When theories change (transitive dimension) it does not mean that what they are about (intransitive dimension) necessarily changes too: there is no reason to believe that the shift from a flat earth theory to a round earth theory was accompanied by a change in the shape of the earth itself."*

Because of the intransitivity of the object studied there are two ways to deal with new insights about this object: either paradigms must shift, or a synthesis must be created, encompassing all stances. The latter is the leading star that motivates and guides the undertaking of this project.

Design happens, and its processes unfold their mechanisms – even successfully so – regardless of what theoretical perspective, if any, we apply to grasp it. Thus, when two paradigms conflict in describing the same reality, it points to an epistemic insufficiency, the need for a bridge. This study aims to embark on the construction of a bridge by proposing a way to understand and express under-determined design tasks - in all their splendid mess and fuzziness – in terms of propositional and explicit descriptions. And to do so across disciplines of design practice that are very different in nature.

In this research project, I want to employ the merits of the first generation's philosophical underpinning: the technical rational paradigm, which deserves less criticism than it has received. In design methodology, the first generation has been criticised for dealing with problems irrelevant to a real-life context and for its inadequacy to handle complex societal problems (Bayazit, 2004). However, much of the theory from which the first generation sprang did not promise to do so:

In their book *Human Problem Solving*, Newell & Simon (1972) compare humans with computers in an Information Processing System analysis of human problem-solving capabilities. Here, they explicitly state that the analysis *"is restricted to the methods available in problematic situations, and does not include (…) the practical arts"* (1972, p. 847). Reitman (1965, p. 148) acknowledges that *"probably the largest percentage of human energies is devoted to problems (if the term is appropriate) that clearly fail to meet Minsky's [problem] criterion."* The criterion referred to is Minsky's (1961) definition of a well-defined problem, which sets forth that *"[to] each problem we are given some systematic way to decide when a proposed solution is acceptable."* Reitman thus explicitly acknowledges that most real-world problems are different from well-defined ones, and thereby implicitly admits that his problem-solving contribution was not meant to enlighten real-world problems. Jonassen (2000, p. 67) complains that researchers have long assumed that learning to solve well-structured problems naturally leads to learning to solve ill-structured problems. However, those researchers acknowledge that *"The real problem-solving activity involved with solving ill-structured problems is providing a problem with structure when there is none apparent"* (Simon, 1973), and that *"to solve an ill-defined problem, [is] in other words, whatever it takes to close its open constraints"* (Reitman, 1964, p. 314). Thus, the belief that *"in general, the processes used to solve ill-structured problems are the same as those used to solve well structured problems"* (Simon, 1978, p. 287) amounts, at worst, to the truism that if an under-determined problem can be converted to a determined one, consequently it can be solved in the same fashion. This truism admittedly does not shed much light on how under-determined, ill-defined problems are solved, but it does not pretend to, either. Perhaps, more representative of the technical, rational appreciation of ill-defined problems is Reitman's (1965) recognition that *"we lack systematic bases for dealing with ill-defined problems in ways analogous to those made possible with some types of well-defined problems"* (p. 148). Somewhat polemically it could be argued that the criticism should be targeted at those who assume that there is an intent to transfer the strategies of rational problem solving beyond the more stable contexts of, for example, computer and engineering design for which they were meant.

Even though the prescriptive agenda (Checkland, 1983) of the first-generation methodologists can be disputed, the technical, rational foundation of first-generation theories has value to offer contemporary attempts to understand design. After all, the simplifications for which the first-generation theorists have been critisised, are a sine qua non for theoretical constructions, and the hard system theories have, in their favour, dared and managed to attempt to account for some of the seeming fuzziness (Sanders & Stappers, 2008) and 'muddling through' (Schön, 1983, p. 43) of design processes.

The point I intend to convey is akin to what Alexander calls 'loss of innocence' (1964, p. 8). He states that the hard systems' use of logical pictures to represent design problems makes them easier to criticise, because the assumptions they are based on are brought out in the open. By contrast, intuitive and vague pictures are hard to criticise since they have exactly that nature and are thus protected of 'the security of innocence' (Alexander, 1964, p. 10). I am aware that the intent to make explicit descriptions of the under-determined tasks – and to wrestle with existing theory in the process – strips my contribution of such security and places it at risk of harsh criticism. Yet, I believe that this is what makes research develop (and worthwhile): that we place our ideas in exhibited position for others to criticise, so that they can be examined and possibly developed in the continuous approximation to better fit (e.g. appropriateness and explanatory power) between theory and the world that we seek to understand. Hence, I do not pretend that this dissertation contributes with any new 'truth' about design. Rather it seeks to humbly put forward alternative ideas and perspectives by which, hopefully, future theoretical discussions about design might be inspired.

Delineation of the Study

The empirical case study of this research project resides within an educational context at the Master's level. This context has been chosen because the Master's project tasks are open, fairly unrestrained, and freely defined by the individual design student and thus represent under-determined tasks, which is the primary focus of this study. However, for the same reason, the tasks studied may differ somewhat from professional design practice, where constraints may be imposed by managers, clients, users, legislators etc. Another point of potential difference is that student designers can be considered 'novices' and thereby differ from professional 'expert' designers in terms of their level of expertise, a factor which several studies have shown may influence their way of working (Cross 2004). However, it must be noted that in some of the studies that Cross refers to under the heading "Expert vs. novice designers" (Cross, 2004, p. 428), the difference in expertise level actually represents the difference between freshmen and senior design students, i.e. 'novices' and 'experts'. This is for example the case in studies by Atman et al. and Christiaans and Dorst (Cross, 2004, p. 429). Thus, whether the Master's students in the present study should be considered novices obviously depends on whom they are compared to, but, granted, in relation to professional designers they are indeed novices. Supposing that the differences between novice and expert designers – and hence implicitly the tendencies in expertise development –

apply generally (regardless of the novice/expert level studied), then it is plausible to assume that the Master's design students' way of working differ from professional designers', and hence that the findings from the empirical part of the present investigation cannot be transferred directly to professional design practice in general.

The purpose of the present research is to expand design theory (Yin, 2014, p. 21) and propose an explanatory framework (Layder, 1998, p. 26). Thus, the findings of this dissertation may be analytically transferable (Yin, 2014, p. 21) to other contexts that bear resemblance to the *local conditions* (Lincoln & Guba, 1985, p. 123) of the study, i.e. product design Master's students engaged in explorative processes based on under-determined tasks. According to Lincoln and Guba *"The degree of transferability is a direct function of the similarity between the two contexts*" so that *"If context A and context B are "sufficiently" congruent, then working hypotheses from the sending originating context may be applicable in the receiving context"* (Lincoln & Guba, 1985, p. 124). Thus, it might be hypothesised that the findings of this study lend themselves to description and explanation of design in similar educational settings working with under-determined tasks within product design. Likewise, the findings may serve as hypotheses or as analytical models for further study of design or of under-determined tasks in other contexts.

Though this research is undertaken with the vision of a unified design epistemology, I do not assume that such epistemology can be built in 'one take'. Rather, the aim is to take a step in that direction. I do not believe, either, that a unified design epistemology can be built from the study of student designers alone. However, if a unified epistemology is to be attained it should, in my view, be inclusive of these types of processes. The present study is based on the belief that this is currently not the case to a satisfying extent and on the vision that the theory needs to be expanded in order to accommodate this inclusion.

This dissertation combines the theoretical study track (2), in which I study existing theoretical concepts and positions in design theory, with a study of the processes of student designers (track 1), focusing on the 'shortcomings' of existing theory. Thus I seek to build an understanding of design that extends to include these kinds of processes as well. In an architectonic metaphor, this can be compared to the endeavour of connecting a couple of main buildings (positions in existing theory) with an annex (the Master's design students) by constructing a new roof that rests on the main buildings but overarches the annex as well (Figure 2). The point of such a construction is to encompass all the buildings that the 'architect' wants to connect, and even though the roof would collapse without the support of the main buildings, the annex affects the construction of the entire building. Thus, the annex (the empirical study of design students) has a vital impact on the way in which the main buildings (positions in existing theory) are connected.

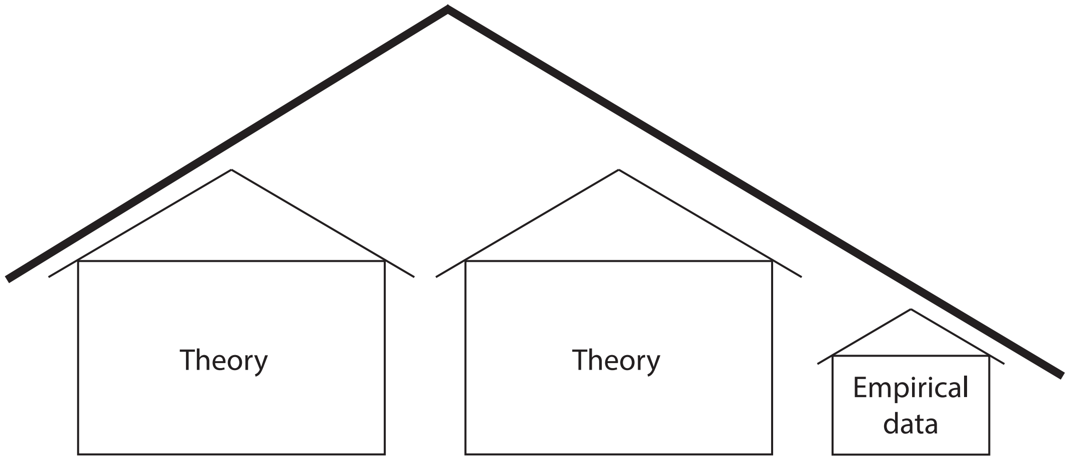


Figure 2: An overarching roof: How the empirical study of students contributes to a unified design epistemology

The particularity of the empirical study carried out in this project thus 'stretches' the theory in one direction. Another empirical study nested within a project with a similar vision of a unified design epistemology could presumably have stretched existing theory in another direction, resulting in another roof construction. In the light of this role, the empirical study provides insights and impacts the theoretical study track and the conceptualisation of design theoretical understandings.

As shall be elaborated in depth in Chapter 6, the present study conceptualises a design task as a system of information – an analytical scoping by which to understand the concept of a task and its content, towards which a designer takes action, and which eventually constitutes a final design. The designer – or task taker – is seen as the exchange point between the system and its surrounding context. This perspective likewise delineates the scope of this study, as the focus will be on the relationship between content elements in the design system, as well as the relationship between the system and the designer who receives, perceives and interprets the information that ends up constituting the system content. By taking this perspective, the contextual surroundings and the relationship between its agents – for example users, clients, reviewers, customers, and other designers – are outside the scope of this study. Though this choice is made deliberately in order to study specific aspects of design processes, I do not mean to diminish the importance of these actors and the context in which they reside. For example these actors can impose, or alter, what I shall refer to as 'formal constraints' (see Chapter 5), which are not considered the 'content' of the design system, and which may be determining for e.g. when a design process needs to come to an end.

Relevance and Contextual Delimitation of the Study

Propositional knowledge of design with the focus on under-determined tasks is relevant in different ways and contexts, both within and beyond design practice and theory. This section describes both the pertinence and delimitation of the study to the tangent areas of theory and practice.

Relevance of design knowledge for design practice

Typically, product designers communicate and persuade others of their skills by showing their products or product representations, traditionally in portfolios. But to comprehend and communicate about the preceding explorative process of creation and change, which is the inescapable prerequisite for eventually arriving at the product, designers need knowledge that is inherently different from the practical skills of making the progress happen. They need knowledge in the form of concepts by which they can verbally convey and intellectually comprehend the actions that they already master.

For designers, knowledge about the design process is relevant in both an external and an internal context:

In the *external* context, the design profession will gain consolidation, when the designer is able to articulate, 'sell' and argue for her ideas and solutions to others. This ability is necessary because design tasks, due to their under-determined nature, do not supply the option of picking the *optimal* solution out of a confined number of alternatives. Rather, the designer must choose a *satisfying* solution, i.e. a solution that is considered 'good enough' (Simon, 1969, pp. 64-65). Thus, designers are required to provide a justification, when presenting solutions to design problems (Goldschmidt, 2013, p. 43). Goldschmidt holds that *"The justification is meant to establish the appropriateness and demonstrate the advantages of that particular solution vis a vis any number of alternative solutions to the problem (that the problem-solver has not chosen although they may have been considered earlier in the design search)"* (p. 43).
Hence, the designer will have greater authority, higher impact and be more likely to convince others of the quality of her ideas and solution, if she can form the arguments that represent the underlying reasons for why she does what she does, when designing.

In the *internal* context the designer can attain a two-sided benefit by being conscious of her actions: it will become easier for the designer to identify her 'operant' (Stokes, 2006, p. xii), i.e. what she is already doing that works and leads to success, and thereby build up a tool box of successful strategies. Likewise it will expedite mastering of the 'first chorus' (Stokes, 2006, p. 8), i.e. mastering the requirements of convention in the disciplinary domain in which the designer works. On the other hand, it will also become easier for the designer to *challenge* both individual and domain-specific strategies, the first chorus, and thereby develop her individual designerly style of expression.

An explication of design process mechanisms is thus essential for the development of the design profession, both to authorize it as a professional discipline, and to help individual designers develop their creativity and designerly expression.

Another point is that if designers want to be able to work professionally with their skills of driving processes of change outside the context of traditional design practice, rather than designing products, they must understand and be able to communicate about this skill.

Relevance of design knowledge beyond design

I resisted the temptation to begin this dissertation by reciting that the global world is faced with immense and increasing societal and environmental challenges that call for innovative and sustainable solutions, and that the role of the designer as a facilitator of of co-created processes of change in a broad context is therefore more important than ever. However, I do not wish to diminish the significance of either the situation or the discourse that such an account suggests. A pervasive response is that concepts like design-thinking, strategic design, design-led business development, and design-driven innovation are gaining widespread footing as potential gateways to brighter future scenarios of various ventures. This causes the term 'design' to increasingly permeate the agenda of many different sectors, educations and conversations. This development has powerful, potential advantages, but at the same time it may lead to an erosion in terms of definition and epistemology: If the term 'design' covers almost everything, the risk is that it may end up meaning almost nothing.

As mentioned in the motivation for this research project, I contend that we must be deeply knowledgeable about design in order to transfer its principles beyond design, to other areas of development and innovation. A better understanding of design can ensure a more adequate use of the term or at least a clearer delimitation between different applications and definitions of the term. In the natural and quantitative sciences reliability of results is underpinned by concepts such as stability, consistency and predictability (Lincoln & Guba, 1985, p. 298) attained, for example by the precision of the measuring instruments by which something is studied. In the social sciences and qualitative studies, consistency can be pursued by the clarity of concept definitions. Hence, I will argue that a clear understanding and terminology of design practice will expedite comprehension in other fields or endeavours to which 'design' – or any branch of transformation of this notion – is transferred.

Under-determination

Design tasks are inherently under-determined or ill-defined (Archer, 1979; Dorst, 2004), though to a varying degree. If they were not, nothing new could be developed, and that is ultimately what design processes are about. Therefore, designers are masters in practically handling under-determined tasks. However, all tasks, not only design tasks, in which something new must be developed, are characterised by a degree of under-determination. Therefore, if we want to understand how to better deal with this kind of task in general, studying how designers work with a focus on highly under-determined tasks, opens a window to insight. There are a number of contexts in which the study of under-determined tasks is relevant:

Design-driven innovation

When design is transferred to other contexts and interpreted as a driver for innovation, it involves working and researching exploratively to reach new meaning-creating future perspectives (Verganti, 2014) or new frames by which to understand and solve problems (Dorst, 2015). In other words, the innovative development process is approached by transcending the scope of the familiar and already known. Lawson and Dorst quote Einstein, saying that *"we can't solve problems by using the same kind of thinking we used when we created them"* (Lawson & Dorst, 2009, p. 23). If solutions must be found outside the context in which the problem resides, then elements of the task must be sourced from outside the description of the problem, that is to say, if elements are lacking *in* the task, then the task is under-determined. Thus, handling under-determined tasks is part of, if not defining, what it means to work with design-driven innovation and development projects. Therefore, studying design processes with focus on under-determination can promote knowledge expansion in this field.

Creativity

Another area to which study of under-determined tasks is relevant is that of creativity. Creativity is central to design (Cross, 1995; Dorst & Cross, 2001; Lawson, 1980; Onarheim, 2012b), and design is often described as a creative process (Chan, 2016; Lawson, 1980). Thus, a study of design processes is implicitly a study of creative processes. According to Bauer and Eagan, design thinking even represents the epistemology of creative labor (2008, p. 64). The defining factor in the relationship between design and creativity is precisely this aspect of under-determination or ill-definedness, since ill-definedness is inherent in creative tasks (Jacob W. Getzels & Csikszentmihalyi, 1976; Simon, 1973; Stokes, 2006).

However, creativity theory is anchored in psychology and the studies of cognitive processes, whereas the focus of this study will be the application of action to matter in situated processes of practice – it will not try to get inside the heads of designers, but rather attend to what action they take, and what material that action is applied to. Theoretically, this perspective leans towards Tanggaard's (2013) 'socio-material creativity', in which situatedness as well as "materiality and artefacts are to be seen as substantial components of creativity in itself" (p. 20). Tanggaard thus stresses the importance of a close relationship between human beings and material tools in the creativity process of 'making the world' (p. 21).

Uncertainty

Under-determination of a task is closely related to the notion of 'uncertainty' in research of design cognition. Walter et al. (2003) provide a *"general definition of uncertainty as being any deviation from the unachievable ideal of completely deterministic knowledge of the relevant system."* (p. 5). This definition resembles Reitman's characterisation of ill-defined problems in which he states that parameters of the problem are left unspecified (Reitman, 1964, p. 314). The key difference between the two accounts is the nature of what is lacking: knowledge and parameter specification, respectively. This distinction places the two accounts on either side of a subject's interpretation of a situation, also referred to as a problem or system. Lack of knowledge and consequent (epistemic) uncertainty is on the internal, cognitive side of a subject's interpretation of a situation. Conversely, 'specification of parameters' is on the external side of such interpretation, as it accounts for traits of the task understood independently of a subject.

Irrespective of the difference between lack of knowledge and lack of specification, insight into handling of under-determined tasks might inform and inspire research about uncertainty. As declared by Lasso et al. (2016, p. 308), there is a need and significant potential *"for further research in the role of uncertainty perception as a driver for design activity and as a possible means for creating more cohesive design theory."*

As shall be expounded later on, the position of this dissertation is that we cannot study tasks detached from a *taker* of these tasks. Conversely, we do not need to study internal cognition of the task taker, in order to study the development of the task.

AI and Computational Creativity

Topical fields in our societal development to which knowledge of under-determined tasks and explorative development is relevant, are technological innovation, artificial intelligence, and computational creativity. The study of how humans deal with under-determined tasks touches upon a socio-technical aspect of a capability that machines have yet to master and theory has yet to understand more extensively.

A Normative Perspective

It appears to be an assumption in much theory dealing with uncertainty in design that uncertainty is something that should be reduced, see for example Paletz et al. (2017), and Lasso et al. (2016). However, Starkey et al. (2016) argue that *"people tend to choose feasible ideas over unique ideas because of their desire to reduce uncertainty (…) this early filtering of the most creative ideas may be detrimental for the creativity of the final conceptual design (…)"*. In extension of this verdict, it can be normatively maintained that work in extended compliance, rather than expediated restrain, with uncertainty and ill-definedness of the task may, in fact, further the creative development in design processes. This way of working is described by Armstrong (2014) as 'Black Sky Thinking'. Borrowed from space industry ventures this notion implies working without a fixed character at the edge of possibility. Contrary to 'Blue Sky Thinking', which means innovating by pushing the limits of possibility in existing practices, Black Sky Thinking pursues a movement into uncharted realms of the unknown with creative confidence while embracing risk (p. 30).

In summary, under-determination is a trait characterising not only design tasks, but any task of change and development in which something unknown leaves room for the pursuit of something new. Altogether – in the broadest perspective – knowledge about such processes of change is important to support the dynamic development of a better world. In my view, this means approaching ideals of humanism, sustainability, and collective sharing of resources.

Dissertation Structure

The dissertation consists of four parts. Part I comprises, apart from the introduction, a philosophy and method chapter, underpinning the study. Part II reviews and points to conflicts in existing design theory. It includes an account of the development of the historical design methodology, the concept of 'problem' in design, design models and central design concepts. Part III introduces a system of terminology, proposing a perspective on design tasks as systems of *information*. This terminology has emerged from continuous analytical interplay between theory and data. Part IV is about the mechanisms of progress in design; how the design system information is brought into play by the actions of the designer and used in the process of creation. This part incorporates the findings of the overall study.

2. Method

The method chapter of this dissertation is divided into three parts: First a section outlining the 'Philosophical Ground' and the assumptions on which the research was conducted. Secondly, a 'methodology' section introducing the *Adaptive* approach which links the philosophy with the way the research was carried out. The third 'method' section deals with the specific configuration and undertaking of my research. It is initiated by some general remarks introducing the reader to the study. Next, the section describes the two tracks of research characterising the study – a theoretical track and an empirical track. In the 'theoretical track' I describe my search for literature and how it was reviewed. In the 'empirical track' I report on why and how the empirical investigations were undertaken, as well as describe the nature of the data obtained. Likewise, this section includes findings from the pilot studies conducted, since these have been decisive for the development and direction of the overall study.

Finally, this chapter comprises a segment on 'Theory Generation', which expounds the approach by which data were analysed and theory generated from the empirical and theoretical studies.

2.1 Philosophical Ground

In this section, I will account for the philosophic anchoring and underlying ontic and epistemic assumptions that underpin and influence my view of the world in general and this research project in particular.

My aim to produce knowledge about what designers do is related to a discussion of whether design actions and design knowledge can, in fact, be explicated: whether we can "know that" about design, and not only "know how" to design (Ryle, 1949). Considering the nature of the study, which aims to uncover and make explicit some aspects of designing, I already assume a stance in the discussion. Presupposing the relevance of doing so altogether necessitates the assumption that there is, in fact, something underlying the heterogeneity and seeming fuzziness of design practice: that propositional knowledge of mechanisms and underlying structures of designing can, indeed, be derived and described, and that design can be explained in a form that is different from undertaking it. This assumption is the primary reason that I find design research worthwhile, as I agree with Marx (1971, p. 817) when he states that *"all science would be superfluous if the outward appearances and essences of things directly coincided."*

My epistemic assumption about design is based on a philosophical anchoring in Critical Realism (CR), which is the perspective on science philosophy that best characterises my understanding of the world and the ways in which we can come to understand it. CR assumes that structures exist beneath the surface of atomistic, empirically observable events the nature and mechanisms of which can be uncovered, and that these structures and mechanisms, from a transcendental realism perspective, are the objects of study (Bhaskar, 1975, p. 25).

CR is characterised by the twin concepts of what Bhaskar calls the *intransitive* and the *transitive* dimension. The *intransitive* dimension refers to the realism ontology of CR *"in which the object is the real structure or mechanism that exists and acts quite independently of men and the conditions which allow men access to it."* Thus, the ontology of CR is deep and stratified by the differentiation between the empirical phenomenon on 'the surface' and the actualised phenomenon and 'real' structures below (Bhaskar, 1975, p. 17). The 'real' is the deepest ontic layer in which relatively stable and enduring structures and mechanisms, which produce phenomena, reside. To illustrate the layered conception of reality, Gravity serves as a good example. Considered a *real* structure, Gravity works whether or not anything is falling at the moment. If the mechanism of gravity is *actualised* by something that does fall this does not necessarily mean that someone observes it or knows about it. Thus, Gravity exists whether or not we experience it empirically or understand it epistemically. We can picture the CR ontology (the *intransitive* dimension) as an iceberg which, like reality, is only partly exposed to our view (Figure 3).

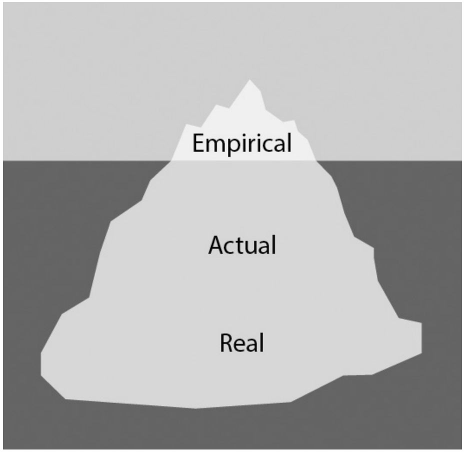


Figure 3: The stratified ontology of CR is like an iceberg which is only partly exposed.

Design also takes place, and even successfully so, regardless of our epistemic insight into the design processes. The object of study of my research is what designers do, and how they do it, when they design. On the face of it, this can manifest itself empirically as a versatile and irregular – a fuzzy – phenomenon. Yet, my interest lies beneath this surface, in the underlying, common structures and the resulting mechanisms across a range of apparently diverse design projects. As it is not possible to observe these empirically, they are reached transcendentally through analysis and theoretical generation on the basis of empirical events. This is described in the later section called "Theory Generation."

Where *"the objects of which (…) knowledge comes to be produced, exist and act quite independently of men"*, CR implies that *"knowledge is a social product, produced by means of antecedent social products"* (Bhaskar, 1975, pp. 16-17). Hence, the epistemology, or the *transitive* dimension, as Bhaskar calls it, of CR is considered relativistic and potentially fallible, as knowledge is always constructed in a social and historical context (Buch-Hansen & Nielsen, 2014, pp. 34-35) and is merely a revisable approximation to the truth.

In critical realism, theoretical disputes are ascribed to epistemic fallibility with reference to the realness (*intransitivity*) of the ontic world. When theories trying to convey knowledge about the same object disagree on the nature of that object, then at least one (and maybe both) is (partly) wrong. Collier expresses this point well when he states that *"Rival theories and sciences have different transitive objects (theories about the world), but the world they are about – the intransitive dimension – is the same; otherwise they would not be rivals"* (Collier, 1994, p. 51). Likewise, Sayer writes that:

> ”When theories change (transitive dimension) it does not mean that what they are about (intransitive dimension) necessarily changes too: there is no reason to believe that the shift from a flat earth theory to a round earth theory was accompanied by a change in the shape of the earth itself” (Sayer, 2000, p. 10).

Design theory is characterised by a paradigmatic rift between first and second generations of methodology. From a CR perspective, this strife likewise points to an epistemic deficiency, but the responsibility for this deficiency should not unmindfully be placed on the theory of the first generation. Rather it should be attended to with the aim to address both merits and mismatches on both sides in order to attain a unifying and coherent epistemology encompassing different perspectives.

2.2 Methodology

Methodologically, the research leans on Layder's 'Adaptive Theory' (AT) approach (Layder 1998), which implicitly draws on the fundamental assumptions in the CR paradigm, sharing its epistemological and ontological positions.

The ’adaptive’ part of the notion refers to the fact that *“theory both adapts to, or is shaped by, incoming evidence while the data itself is simultaneously filtered through, and is thus adapted by, the prior theoretical materials (framework, concepts, ideas) that are relevant to their analysis”* (Layder, 1998, p. 5).

Based on the transitive dimension of CR, any theory can merely be considered the 'latest stage' in an elaboration on theory in general, never a perfect end product. Knowledge is always achieved contextually, building on extant theory, and it is impossible to enter an empirical field without preconceptions (Layder, 1998, p. 9). Thus, Theory Generation (in a historic perspective) is seen as an ongoing process, continuously adapted to and shaped by individual research projects. In this process, (extant) theory enters an empirical research project as 'orienting concepts' and the ensuing (emergent) theory is the knowledge product, as portrayed in Figure 4 below.

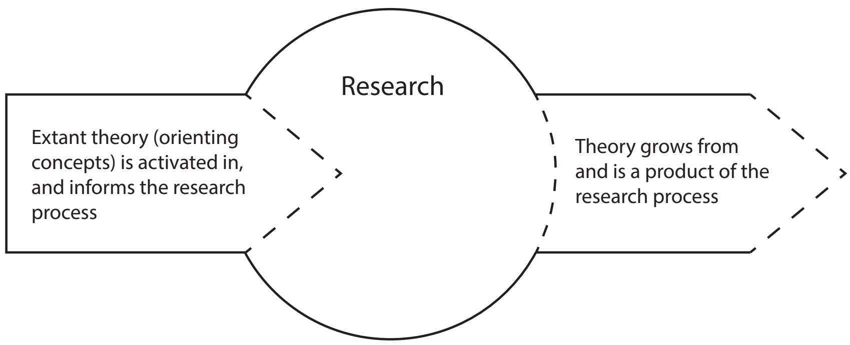


Figure 4: Theory informs and is a product of research

Adaptive theory positions itself as an *"amalgam of different influences and approaches that falls somewhere between what are variously referred to as deductive or theory-testing approaches on one side and inductive or theory-generating approaches on the other"* (Layder, 1998, p. 5), for example Grounded Theory.

This is expressed in the view that it is, on the one hand, not *"possible to approach research in a theory-neutral manner, and thus it is better to acknowledge, harness and attempt to control the inputs of prior theory"* (Layder, 1998, p. 4); thus the research process is not purely inductive. Instead the researcher must actively use orienting theoretical concepts as *"a preliminary means of ordering and giving shape to a mass of data"* (Layder, 1998, p. 24) in order to 'crank-start' theorising. Likewise, the researcher must display a general sensitivity to theoretical concepts throughout the research process.

On the other hand, the research process is not just deductive either. Since theory is not seen as something perfect or firm, it is not the role of research to merely test theory, but also to adapt and generate theory.

Claiming a middle ground position methodologically, in the acknowledgment that reality is complex, AT advocates a 'synthesis' between seemingly 'polar' concepts, for example general theory and empirical reseach; induction and deduction; structure and agency; micro and macro perspective; subjectivism and objectivism. These interact in dialogue and must be given equal weight (Layder, 1998, pp. 7-8). Layder argues that reality is deep (Layder, 1998, p. 98), layered (Layder, 1998, p. 133), and moderately objective (Layder, 1998, p. 141); thus his ontology obviously converges with that of CR. On the basis of this ontology, Layder points out that research should go deeper than the subjective 'life worlds' of actors and likewise examine the conditioning underlying structures and system elements , as well as the agency-structure relationship itself (Layder, 1998, pp. 140, 146). The validity of structural concepts is given by their capacity to explain and analyse the reality, not by the extent to which they mirror the everyday and meanings of subjective participants (Layder, 1998, pp. 91-92).

AT encourages an open and *"multi-pronged strategy (…) in terms of the employment of methods and techniques in order to maximize the potential for theory-generation"* (Layder, 1998, p. 42). The openness implies that no one discourse or approach should be considered sacrosanct, and that discourses must be seen as complementary rather than necessarily competing (Layder, 1998, p. 39). When employing a multi-strategy approach, it is important not to adopt an arbitrary or 'unprincipled' approach (Layder, 1998, p. 69), but to be systematic and disciplined. Thus, despite being *"much more tolerant of a diversity of standpoints and potential resources than is to be found within conventional approaches to theorizing in research",* AT does *"not underwrite an 'anything goes' approach"* (Layder, 1998, pp. 49-50). Rather, Layder argues, the adequacy and validity of research hinges on the enhanced scrutiny and powerful explanation of the complex social world that is facilitated and made accessible by the very means of the multiple-strategy AT approach (Layder, 1998, p. 142). The combination of multiple sources, strategies, and angles allows for triangulation by making *"as many 'cuts' into the empirical area and data as possible."* This, in turn, contributes to the cross-checks of research validity (Layder, 1998, p. 68).

In AT, theory generation is not limited to certain phases of the research process either (Layder, 1998, p. 25), but is an ongoing activity in the research process, and takes place in a three-way interchange between data, emergent theory and extant theory (Layder, 1998, pp. 55-56). Thus, theorising happens in a dialogue between induction and deduction (Layder, 1998, p. 111) and between available theoretical and empirical resources (Layder, 1998, p. 43). The theoretical resources are: *general theory* (also referred to by Bhaskar (1998 [1979]) as 'philosophy' or 'formal theory'), i.e. more abstract theory that is relevant to many empirical areas, as it applies to the fundamental nature and generic features of the phenomenon studied; and *substantive theory*, i.e. more specific theory that is relevant only to particular empirical areas (Layder, 1998, pp. 162-163).

Practical Implications of AT

What, then, are the practical methodological implications of the AT approach? In the following, I shall list some of the research process elements advocated by Layder. Later, in the "Theory Generation" section at the end of this chapter, I shall describe how the AT approach and its particular elements have influenced the process of analysing and theorising in this research project.

The central concepts of AT are extant theory, data, and adaptive (emergent) theory. As the research process is seen as a circuit of continuous interaction and effects between them, there is no right order in which to display elements or undertake activities through which theory is generated.

Orienting Concepts

Orienting concepts drawn from general or substantive theory or from related (non-theoretical) areas provide a heuristic and provisional 'route' to data interpretation, analysis, coding, and theorising (Layder, 1998, pp. 109-112). Orienting concepts provide the researcher with a means of ordering, giving shape to and imposing meaningful patterns on a mass of data (Layder, 1998, pp. 23-24) in a preliminary and non-dogmatic fashion. Orienting concepts may be discarded at any point during the data analysis, if they are no longer perceived useful as orienting devices (Layder, 1998, pp. 23-24).

Multi-strategy Data Collection

The researcher is encouraged to use multiple data collection methods. Among the qualitative methods mentioned are case studies, in-depth interviews, observation studies, and documentary research. The multiple strategy approach is a means to triangulate and maximise perspectives on the situation studied. Data should be sampled purposively and theoretically to attain rich information in dialogue with prior theory and analysis.

Layder advocates a 'Theoretical Sampling' strategy inspired by Grounded Theory. Theoretical Sampling is a data collection process controlled by the emerging theory in which *"the analyst jointly collects, codes, and analyzes his data and decides what data to collect next and where to find them, in order to develop his theory as it emerges"* (Glaser & Strauss, 2006, p. 45).

Circuit Research Process

The research process is a continuous circuit in which focus oscillates between (incoming) empirical data, extant theory, and the ensuing theorising in inductive and deductive manners respectively. Analysis, theorising and theory studies are thus continuous activities throughout the research process.

Pre-coding and Coding

Pre-coding *"such as underlining parts of text or putting an asterisk by certain sections of text in order to highlight their importance or relevance"* (Layder, 1998, p. 53) is done in an open-ended and tentative *"attempt to order and classify the data in some way which could be revised or confirmed at a later date"* (Layder, 1998, p. 54). Coding, i.e. *"applying particular labels and names to 'classify' sections of the text" and "Giving names to the 'main points'"* (Layder, 1998, p. 56), helps the researcher to familiarise herself with the findings and to start to *"define what is still missing and what, if possible, needs to be* *gathered or to become the object of search"* (Layder, 1998, p. 56), thereby giving shape to the data. Coding as well as pre-coding should not be too detailed, not going line by line, but rather focus on identifying *segments* of data *"as belonging to a certain category"* (Layder, 1998, p. 56). The researcher may have his own personal codes, but they must be "*readily convertible into a precise and general conceptual form"* (Layder, 1998, pp. 56-57).

(Pre)coding is a continuous process throughout the data analysis in which the researcher must remain open and receptive to new codes, unanticipated findings and novel theoretical ideas (Layder, 1998, pp. 55-56).

Memos

Memo-writing supports coding in the theorising process. Memos are notes reflecting the researcher's thoughts about e.g. particular sections of data or specific concepts at a given time in the research process, for instance in the form of sequential logbooks or separate documents made primarily for the researcher himself or herself. Memos *"ask questions, pose problems, suggest connections*" (Layder, 1998, pp. 58-59) as to how concepts and data fit together, and generate discussion and 'self-dialogue' between theoretical and practical issues. Memos is a way to explore *"whether and in what sense particular codes, concepts, and catergories really are illustrated (indicated) by data,"* and thus memos establish *concept-indicator links* (links between concepts and data), which are central to the dynamic of theorising (Layder, 1998, p. 59).

Typologies

Typologies are systematic classifications of phenomena in a particular category. Typologies *"clarify thinking, suggest lines of explanation and give direction to theoretical imagination*" (Layder, 1998, p. 74): Typologies force the researcher to ask questions about the data that facilitate comparative analysis. Reflection about the nature of the commonalities or differences between 'types' stimulates theoretical ideation and concept building. Typologies arrange observations and analysis systematically and allow elaboration of 'chains of reasoning' rather than one-off connections between concepts and data. The comparative aspect of typologies calls for inputs from and attunement to extant general theory, which spurs theoretical thinking, supports the *adaptation* of theory, and allows entry on to a structural level of explanation of phenomena (Layder, 1998, pp. 73-74).

Theoretical Elaboration

Theoretical elaboration is a way of generating theory by deriving new concepts, logically or empirically, from their association to prior core concepts in the analysis. The networks of concepts that are produced this way represent, at any state in the research process, the 'latest stage' of theoretical development and can be revised throughout the process (Layder, 1998, p. 130). Elaboration of concepts and concept-indicator links can give rise to provisional conceptual frameworks (Layder, 1998, p. 116) and theoretical models, which can *"guide and inform data analysis while allowing for the emergence of data and theoretical ideas which may lead to the reshaping (adapting or revising) of these provisional models"* (Layder, 1998, p. 99).

2.3 Method

This section describes the considerations, decisions and actions that characterise the way this research project was conducted. After some general remarks it describes the two tracks of research: the empirical track and the theoretical track. The final segment describes analysis and theory generation.

General Remarks

Some general circumstances and frames are characteristic of this study within which subsequent and more specific choices were made and particular activities undertaken:

Scope

From the inception of this study, I intended to focus the investigative (empirical) scope on product design, construed as fashion and industrial design. Firstly, this is the area of my personal expertise. Secondly, these two particular disciplines are an interesting match for a cross-disciplinary analysis, as they simultaneously represent similarity and difference. On the one hand, their commonality is that their output is physical and tactile, carrying both aesthetic and functional qualities. One the other hand, they arguably represent contrasting positions on Stacey and Eckert's continuum of constrainedness in various design domains (2010) due to differences in e.g. functional requirements. Thus, despite a common ground of comparison, they span the width pertaining to constrainedness in the field of design, conceivably allowing for a broader generalisation. Thirdly, with the aim to study the mechanisms of design at the core of its practice as a prerequisite for subsequent knowledge transfer to other fields, product design is the obvious place to start. Being directly founded on the arts-and-crafts tradition, product design provides a platform for studying design at its source of origin from where it has spread to other domains. This argument is analogous to the common notion that strengthening the mother tongue promotes the successful acquisition and development of secondary languages.

Development

A key factor in the development of this research project has been that it was independently initiated and defined, which is why it has had a low degree of externally imposed framing. The project has been, in its nature, explorative and endowed with the freedom to follow emerging, interesting traces along the way, provided they hinted at an enlightenment of the overall objective to understand explorative design processes and how designers work and make progress.

Before this research project started to unfold, the intended focus was on creative constraints and their nature, types and function in design processes. However, as the project evolved, it became clear that the 'constraint' concept is systemically interconnected with an entire mode of thinking about design processes. This mode rests on assumptions worth studying and questioning with the aim to strengthen the understanding of design processes. This motivated me to take a step back in my research scope and consequently in my process in order to be able to apply a fuller picture.

Structure

This 'full picture' has been approached bilaterally from the formation of two intertwined tracks of research. One is an empirical study of design practice through which I seek inductively derived knowledge of design process progression. The other is a theoretical track in which I study existing concepts and build new ones in order to understand and develop the epistemic foundation of design in a unified manner. In aggregate the tracks inform the contribution (Figure 5). The two tracks of research correspond to the AT perspective that theory should be developed in an interchange between theoretical and empirical studies and that it should focus both on substantive theory linked to particular practices and on general theory linked to their more general, underlying structures.

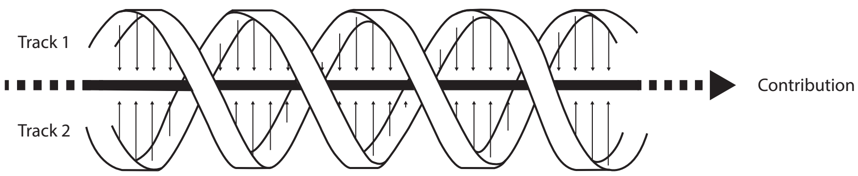


Figure 5: Two intertwined tracks of study

Nature

Despite being a designer by training, I have not embarked on a research project that by traditional standards would be considered 'Research through Design': I am not intentionally constructing or trying to change the empirical context I seek to understand. After having studied design processes unfold, however, I realise that there is a striking resemblance between them and my own research process. It lies in the way that something new, materially or conceptually, can take shape under extremely under-determined circumstances in which it is neither given where to begin, nor where to end. Thus, the way in which this study has been conducted, as a meta process to the ones investigated, has developed along with the insights gained. Although it may seem a bit lofty, it would not be entirely wrong to claim that the theoretical contribution of this dissertation is also the best description of the process by which the very same contribution was obtained.

Theoretical Track

As described, the research has been shaped into two tracks. The purpose of the theoretical track has not been a mere orientation and review of literature pertaining to design processes. Primarily, it has been an exploratory study and analysis of the prevalent theoretical understandings of design processes and their premises, as well as a scrutiny of the potential to synthesise new and more encompassing understandings from the existing insights. Thus, besides literature studies, the theoretical track comprises comparative analysis and abduction (or, as Bhaskar calls it, retroduction) (Bhaskar, 1975), in order to *"point to which necessary possible conditions and deep causal relations must by all accounts exist in order for this phenomenon/ action to take place ('the premise')"* (Buch-Hansen & Nielsen, 2014, p. 61)[my translation].

To accommodate the exploration of the theoretical positions, theoretical sources have been sampled, as if they were data, by the grounded 'theoretical sampling' strategy (Glaser & Strauss, 2006, pp. 45-77), rather than by a structured review scheme. Theoretical sampling is aimed at "generating *theory* whereby the analyst jointly collects, codes, and analyzes his data and decides what data to collect next and where to find them, in order to develop his theory as it emerges. This process of data collection is *controlled* by the emerging theory, whether substantive or formal. The initial decisions for theoretical collection of data are based only on a general sociological perspective and on a general subject or problem area (...) The initial decisions are not based on a preconceived theoretical framework" (Glaser & Strauss, 2006, p. 45).

In practice, this strategy means that the literature search has developed along with my reading. Originating in a search for literature on the concept 'creative constraints' every theoretical source has led me to new insights, steered my search in new directions and pointed to both concepts and references for further inquiry.

Comparing literature search with data collection has more than the functional purpose of explaining the methods by which it was done. The 'substantive theory' (Layder, 1998) or 'instrumental design theory' (Galle, 2011) of the project has a dual role in this research project: it is both theory, which informs empirical data analysis (in the empirical track), and a sort of data in itself from which the picture of design epistemology can be assembled and reconstructed (in the theoretical track). This dual purpose requires an emphasis on the meta-analytic, philosophical lens. This lens, informed by 'general theory' (Layder, 1998) or 'foundational design theory' (Galle, 2011) was described in the previous Section 2.1, 'Philosophical Ground'. Figure 6 shows how the general theory has been the lens through which I have looked at the substantive, instrumental design theory, which has in turn been a lens for studying design practice.

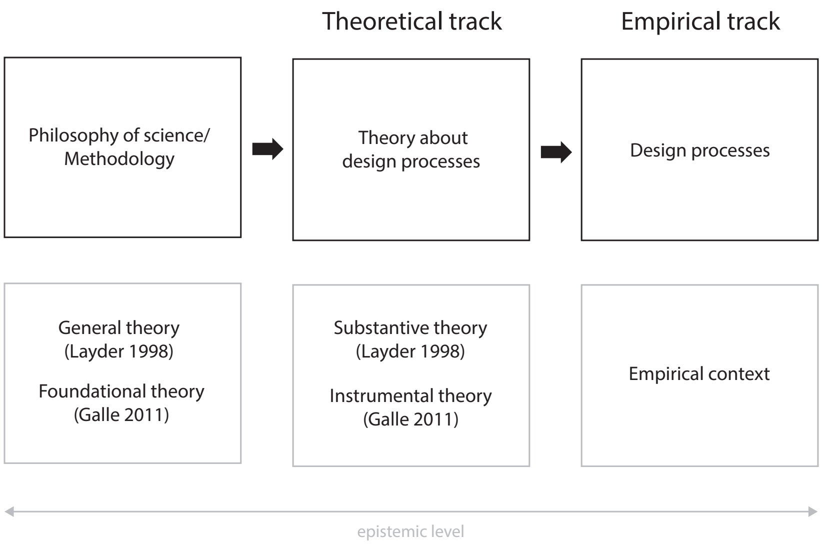


Figure 6: The three epistemic levels on which this project operates. Philosophy informs and provides the analytical lens to study theory about design processes. Theory about design processes informs and provides the analytical lens to study design practice.

Empirical Track

In this section I will describe the empirical investigations undertaken as part of this project, as well as the strategy for sampling and collecting. The empirical material, in combination with existing theory, comprises the input from which new knowledge can be concocted. The section will equally describe, in general terms, the cases studied[4] and account for the circumstances and framing of their in-vivo settings. The empirical data collection of this study comprises, in chronological order, an explorative pilot study, a pilot case study, and a major case study.

The Explorative Pilot Study

The explorative pilot study was conducted at the beginning of the research project and was aimed at a general orientation in the practice field. The purpose was also a methodological clarification as well as an evaluation of the prolificacy of the project scope. I interviewed both novice and master design professionals, and interviewed, as well as observed, the interactions between design students and educators who are experienced designers themselves.

I interviewed two recently graduated designers (one from fashion and one from industrial design), three professional designers with 5-20 years of experience (two from industrial design, one from fashion), and two design teachers, who are also designers (one from fashion and one from industrial design). Additionally, I observed supervision sessions between design students and supervisors on bachelor-level (three sessions from fashion and four sessions from industrial design).

On the basis of a semi-structured interview guide, informed by theoretical concepts (shown in italics below), the informants were interviewed about their background; their experiences with *frames* and (self-imposed) *constraints* in design processes; the typical course, challenges and strategies when carrying out a *design process*; the delivery, development and flexibility of the *design problem* or the task *frame*; their perception of enablers and barriers to *creativity*; and their experience with how the *level of design expertise* impacts the design approach.

[4] Individual descriptions of the cases can be found in Appedix 8.

Explorative Pilot Study Analysis

The interviews were all transcribed and read through several times. While reading, I made notes on interesting remarks in relation to the study of under-determined tasks, as well as on recurring themes. As the interviews were carried out by a semi-structured interview guide as described above, this structure also laid the groundwork for the categories of analysis. I did not stringently code the data from this small pilot study but compared the answers looking for patterns in the different categories with a specific focus on under-determined and unspecified task aspects and the handling of them. Having transcribed the interviews to digital format I was able to easily search for and compare elaborations on specific concepts across the data.

However, the observation part of this study was provisionally coded for themes related to design process evolution and frame/constraints. The insights were compiled and filed in the 'information stock' of the research project. As will be described in this dissertation (Chapter 7, 7.4), an information stock is a concept that can be used to describe compilation of information in an explorative process.

The examples below show how observation notes (in Danish) were coded with blue indications for processual development and frames. The red indications are my own comments denoting possible meanings and interpretations of the utterances, which were subsequently summarised and clustered below the cases. An excerpt from these coding procedures is shown below, and subsequently an excerpt from how concepts were provisionally extracted and clustered.

Explorative Pilot Study Design Student 1

Observation 24.04.14, ID3

Obs 1
S:
Arbejder med Madspild. Problemet er defineret på forhånd – løsningens art er ukendt
Emnet kunne gribes an på forskellige måder: Fx synlighed af mad vi køber, affaldssortering, opbevaring.
Hvordan kan man lave en løsning der optimerer mit køkken, som det er. Gøre det grønnere.

V: Relevant emne.
Gå efter at forstå 'hvorfor opstår madspild?', 'hvor sker det henne?' Identificere årsager til problemet

Du snakkede om den virkelig verden. Du sætter endnu en væg op i problemkassen: det skal ikke være helt radikalt nyt. Hold den åben - det godt kan være radikalt. Knyttet til specifikt proces-stadium? Ift. at lave noget, der virker i virkelige verden: måske kunne det være et sæt? Hvis du finder ud af, hvorfor og hvor det sker, kan hvert sted få en ting, der virker. Hvad er planen ellers? S: Vil bruge denne uge på at få mere retning på det praktiske, før det teoretiske V: Nudging… bog til diabetikere…. Folk der gør fjollede ting... Der er overlap i problemerne. S: Det kunne godt blive nudge. Også cradle to cradle. Ved bare at putte de der cradle to cradle principper over, så kunne det spille sammen. Kender du frankfurter-køkkenet? Det opstår i 1933. Østrigsk designer. Time-motion studies. Hvordan bevæger husmoderen sig i sit køkken? Hvordan kan vi lave et køkken, der fylder og koster så lidt som muligt, som er mest optimalt for husmoderen? Måske kunne det linkes. V: Jeg kunne sende brugerrejse til dig som værktøj. Relevant værktøj. Hvem bruger køkkenet, hvad optræder der af genstande? Sætte pletter på et kort. Lokalisere steder, hvor et stykke industrielt design kunne gøre gavn. Du kunne finde de steder hvor du kunne lave noget… Værktøj til at identificere problemerne lokalt – indsnævre problemet

Explorative Pilot Study Design Student 2

V: Ja, det er en ren æstetikopgave. Dem, der ejer [en bil], ved nogle andre praktiske ting. Dine medstudiners mening kan sagtens bruges. De har også en mening. Det er kreative mennesker, der kan tænke med. Der kommer måske andre svar ved at spørge nogen andre. Men der er ikke grund til at løbe over åen efter vand. S: Jeg var bare låst fast i at tænke, at de [jeg skulle spørge] skulle eje. Funktion. For at få rigtig gang i det skal jeg nok den visuelle vej. Form/æstetik V: Hvad med musikken? Hvordan gør du? S: Jeg finder forskellige genrer, lukker ned, bare lytter. Hvordan udledes form af musik? Intuitiv analysestrategi? Lidt ligesom i tidligere projekter. V: Tegner du bil med det samme? S: Nej, mere abstrakt… Ikke tænke løsninger med det samme. V: Er det din subjektiv fortolkning – indre/intuitive respons eller kvindernes musik? objektiv fortolkning – målgruppe/brug

S: Godt spørgsmål. Overvejelse om at gøre reglen mindre subjektiv/ intuitiv/ tilfældig. Forbinde reglen til brugen/ funktionen

V: Du har sagt, det skal være en sportsvogn. Skal musikken være powerful ligesom en sportsvogn normativ tilgang til, hvad en sportsvogn er – hvilke værdier den repræsenterer, eller kunne du finde det andre steder? Pumpende, agressivt udtryk ligesom en sportvogn har konvergens/similaritet – blive i "domænet". Eller kunne det være Haydn Divergens/kontrast – udfordre "domænet"?

S: Jeg vil lytte til forskellige genrer for at få difference, så de ikke blive for ens. Holde reglen åben

Excerpt of theme categorisation

Begreber:

Design space
Væg i problemkasse
Spille bolden op ad væg
'Holde den åben'
Designvalg

Form follows function

Koncepter
Koncepter kan enten være i kontrast til (divergere fra) eller i overensstemmelse med (konvergere med) det domæne, den tradition, der designes til/ ind i.

Eksempler på konceptuel divergens:
overføre principper fra et område til et andet
bruge robotter som formgivningsinspiration til en båd
lytte til forskellige musikgenrer som formgivningsinspiration til en bil.

Eksempler på konvergerende koncepter:
At bruge forbilledlige, gode objekter fra den maritime verden, maritime former, som formsprogsinspiration til en båd.
Lytte til musik med sportsvognskvalitet som man kunne forestille sig at høre/ at kvinden hørte mens hun kører, som formsprogsinspiration til en sportsvogn. (Musikken er stadig et delvist divergerende koncept, men der skabes tilnærmende konvergens).

Indikationer, konceptuel konvergens
Spille sammen
Linke
Sætte brikker sammen
Overlap i problemerne

Koncepterne kan bære forskellige funktioner – fx være formsprogsinspiration.
Der tales om at 'sætte brikker sammen', få ting til at spille sammen, linke koncepter og overlappende problemer. Måden, hvorigennem dette gøres, omtales 'metoden', som kan være flydende – formodentlig kohærent sammenhængende – og det må antages, at den i givet fald også kan være stakkeret/ mindre sammenhængende. Den metodiske sammenhæng kan skabes gennem regler, som fx form follows function.

Proces-flow
Flydende (metode)
Short cuts

Regler (constraints)
Udfordringer = Succesparametre
Overføre principper
Form follows function

Findings from the Explorative Pilot Study

From my perspective the explorative pilot study endorsed the idea and stressed the significance of investigating the handling of under-determined tasks. I found that in both fashion and industrial design, and at the design school as well as in industry, tasks involve under-determined aspects, though to varying degrees. The point was brought forward that an open attitude is vital for designers to maintain the ability to see situations with new eyes, and that such an open attitude will render any task more under-determined than if it is seen from a limiting, conventional perspective.

Several respondents perceived the concept of creativity as linked to a lack of determined information in the task, which thereby activates or necessitates the use of 'gut feeling' and subjective input to the task, like *"creating a coherence without necessarily knowing where that story comes from."*

Both the fashion and the industrial designers found it hard to argue in favour of what is referred to as 'soft' choices in design, i.e. decisions that are not determined by e.g. functional requirements, such as aesthetic choices. It was argued that it is easier to sell design ideas to clients, if they are defined on the basis of clearly formulated, functional specifications, since the arguments needed to sell them rely more on objective necessity than on subjective assessment, and insecurity is minimised for the client in a well-formulated process with ditto goals. Nevertheless, the informants converged on the point that working bottom up with explorative processes and under-determined tasks strengthens the design ability and the innovation potential of the outcome. It allows for new discoveries and takes away pressure from conventions of the category into which a design should fit. In fact, it was mentioned by a design educator that certain fashion companies actually prefer to hire design candidates from more artistic design schools, as these candidates are proficient in idea generation. The point was that it can be easier to rein in possessed creative skills from years of artistic schooling than extracting corresponding artistry from designers trained in more commercial compliance. As one recently graduated industrial designer, now working in industry, said about artistic design education: *"You learn to twist your brain and it gives* *you something to build upon."* Another point, emphasised by a design professional and educator, was that development of new manufacturing technologies, e.g. 3D printing, will provide a higher degree of freedom to any form-giving task, since it will eliminate many previous production constraints and consequently increase the need to understand explorative processes.

In the explorative pilot study, I saw that both industrial and fashion designers encounter some of the same challenges. Additionally, I found that the different perspectives across these disciplinary contexts hinted at a potential to expose the more generic nature of these challenges. This supposition is supported by the Grounded Theory approach to attain formal theory from comparative studies (Glaser & Strauss, 2006). Thus, I decided to carry on with the cross-disciplinary study of design processes.

In terms of methods, my experiences converged with my preconceived expectations: Observations of conversations about the design process, while it is ongoing, yield information about specific small subparts of the process that relates closely to practice and to the project; post hoc interviews provide rationalised reflections abstracting and overarching the design process. The subsequent steps I decided to take will be described in the following section.

Case Studies

In alignment with my realist position and my aim to uncover underlying mechanisms of design processes, I adopted an instrumental case study approach (Stake, 1995) in which the cases are considered means to understanding the world. In Healy and Perry's terms, the instrumental case study of participants' perceptions *"provide a window on to a reality beyond those perceptions"* (Healy & Perry, 2000, p. 120).

In this section, I will describe how the majority of empirical data were collected and account for the collection context and strategy. I shall discuss the pilot case study and the primary case study under one heading, as they are, in fact, different pieces of the same pie. Subsequently, I shall expound them individually.

Relationship between Pilot and Primary Case Study

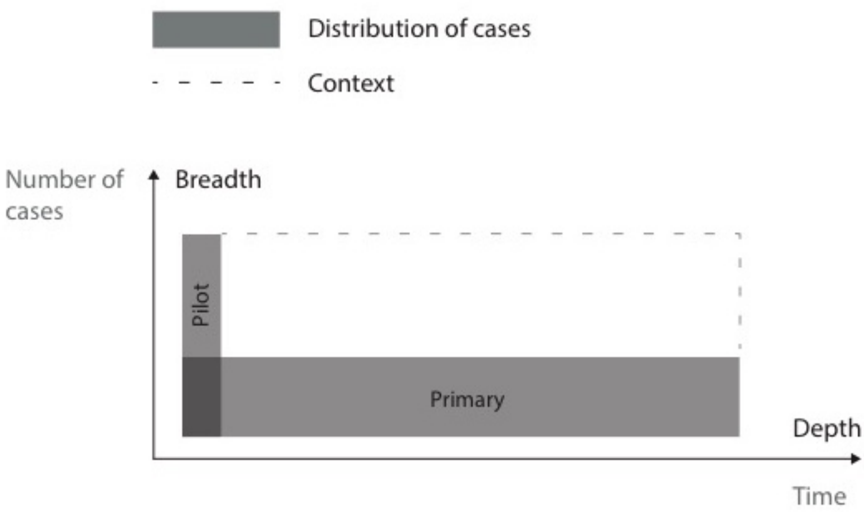


Figure 7: The distribution of cases in the pilot and primary case studies within the overall context of the study

As Figure 7 shows, the pilot case study and the primary case study represent different sections of the same context. That context is the graduate Master's projects of Product Design Master's students, i.e. Fashion and Industrial Design students, who graduated from Design School Kolding, Denmark, in 2015. The duration of the projects was five months. As displayed, the pilot study spanned the breadth of this group to a limited temporal extent, whereas the primary case study spanned the entire process length of a selection of these student project cases. I will elaborate on the quantitative details in the description of each section. Obviously there is an overlap of cases in the two study sections, since the pilot and the primary studies were carried out simultaneously. The distinction between their overlap is therefore merely analytic.

Case Definition

The cases studied were chosen from the selected context of Product Design Master's projects at Design School Kolding. Each project represents a case, and the object of the study in each case is the design *process*. Any immediate snapshot of the design process content over time is construed as the *design task* at that given moment. As a design task cannot be defined independently of the *task taker* (this will be elaborated in Chapter 6), and as progression of the process is dependent on the designer's actions, each case is inseparable from, yet not equal to, the designer undertaking it.

Since part of the objective of this dissertation is to argue and account for what a design process is, this limited definition of design processes must suffice for the time being.

Context, Fact and Frames

The Master's degree programme at Design School Kolding is a two-year postgraduate design degree valued at 120 ECTS points. The Master's project, or 'final project', is the culminating graduation project for which the students receive their final grades. The Master's project is typically the most comprehensive project the students undertake throughout their entire design education, both in terms of temporal extent, but likewise – based on an extensive number of conversations recorded and overheard – in terms of the level of expectation for the performance from the students themselves, their teachers and the external examiners.

The Master's project accounts for 30 ECTS points and is divided into two interlinked parts: *The practical component* (24 ECTS) and *the written component* (6 ECTS). The practical component is the task of the actual design; the written component is an academic thesis of approximately 14 pages. The theme of the thesis must in some way be connected to the practical part, so that the two parts ideally provide mutual support for each other. The two parts run in parallel; they start off at the same time, but the deadline for the written thesis is approximately one month prior to the deadline for the practical part (the oral examintion). The two components of the Master's project are assessed and graded individually.

The Master's project is self-defined, which means that no requirements are given as to the theme of the project or the character of the result. The formal requirements for the projects are few and identical to Fashion and Industrial Design: Students have to fulfil the learning outcomes stated in the course description, as well as the self-formulated goals in the project description. Moreover, it is a formal requirement that all students collaborate with at least one external partner of interest to the project.

According to the Head of Fashion education at Design School Kolding, the Fashion Design students are, however, influenced – but not obligated – by the convention that a fashion collection of eight silhouettes is an international standard, and that is also the minimum requirement, if they are going to participate in international competitions.

In my investigation of the student processes, I have focused only on the practical component of the design project. However, the theoretical component has been in the scope of interest to the extent that it has influenced the practical design work as consciously perceived by the design student. This has been the situation in some of the cases.

Choice of Context

There are three main reasons guiding my choice of studying design processes in an educational context:

Firstly, the student cases provide a widely accessible and structured context for a longitudinal, in-depth study of design processes. Many studies of design processes have been empirically based on shorter excerpts of design processes or limited design process experiments (see for example Dorst & Cross, 2001; Lawson, 2006; Schön, 1983; Wiltschnig, Christensen, & Ball, 2013), so the long-term involvement from the beginning to the end of design processes calls for more investigative attention. The intense, longitudinal involvement does not only resonate with the wish to study design processes as coherent entities, but also ensures rich data and reduces the risk of premature conclusions (Maxwell, 2008, p. 214-253, in Bickman & Rog, 2008).

Secondly, the educational setting represents an externally under-constrained environment for design processes, since students to a great extent define their own projects and design tasks with relatively few binding external requirements. This makes it a fruitful context to study mechanisms related to under-determined tasks. Under-determined aspects are, however, inherently part of any design process (Cross, 1995). Therefore, the choice of the educational context of the study, in relation to design practice in general, represents what Flyvbjerg denotes as an 'extreme/atypical case' selection strategy (in Brinkmann & Tanggaard, 2010, p. 475). According to Flyvbjerg, an advantage of extreme or atypical cases is that they can serve to demonstrate a point more dramatically and create more information (partly) due to the involvement of more of the basic mechanisms in the studied situation. Thus, extreme cases elucidate the deep causes behind a given problem and its consequences, rather than describe the problem symptoms and frequency, as a more representative case sample would have done (pp. 473-474).

Thirdly, the specific context of the Master's projects, provided temporal synchronicity and conditioned the projects by a shared set of constraints and circumstances, for example the time frame, the (approximate) level of education and experience of the aspiring designer, the (approximate) budget frames, as well as social, cultural and formal institutional norms, embodied in e.g. the school's official descriptions of the Master's Project's objective and learning outcome. This homogeneity of the case context serves to minimise the contextually related factors of potential variance and directs and allows the focus on content-related disparity and the search for inherent patterns. Thus, the in-vivo study of students' processes approximates some of the assets of in-vitro scientific experiments in which scientists *"arrange empirical events (…) so as to isolate the action of a single mechanism and thus identify it"* (Elder-Vass, 2008, p. 458). At the same time, it is crucial that the processes are not 'experiments' but real-life events driven by actual motivation, consequences and risks as perceived by the design students. This ensures genuine engagement from the involved subjects and enables the nature and richness of the material produced as well as the lengthy processual time span. Because the student projects are in this respect 'real' design processes, they arguably lend themselves better to analytical generalisation about design processes in general, than an experiment would have done.

Moreover, the temporal concurrence of the case processes has another favourable implication in terms of minimising researcher bias: Since the processes take place at the same time, obviously they have been studied in parallel. This means that they are all subjected to the same level of analytical and interpretational insight along the data collection process. Thus, no single case has been studied as a 'prototype'. Rather, the insights gained along the collection process has biased and benefited all cases.

A potential downside to the choice of context relates to the transferability of findings from the study of students to design in a more general sense. Though many, and influential, studies of design have focused on design students as subjects (Christiaans & Venselaar, 2005, p. 217), this is a relevant issue. In this study, the student design context is chosen, in part, due to its under-constrained environment, which inherently implies that the empirical context of this study deviates from that of professional design practice. Driven by the vision of a unified design epistemology, the aim of this research is to conceptualise design processes in a manner that can include both contexts. Thus, the working hypothesis is that studying very under-determined tasks may allow for greater insight into structures, mechanisms and strategies for handling such tasks and that these can be transferred to other contexts. However, exactly because the two contexts diverge, it is a question whether this can be done in a meaningful manner. This will be discussed further in the conclusion and may be a topic for further research.

Pilot Case Study

The pilot case study comprised a total of 23 cases. They were studied by observation of the initial supervision session with the practice supervisor and the theoretical supervisor, in-depth interviews with students, as well as through visual and written project material and project descriptions, one to two weeks into the project.

The pilot case study was initiated with the intent of studying only a selection of cases at length. It was therefore not meant as a means to evaluate whether to proceed or not, but rather to clarify *how* this study could be conducted and provide the best outcome. The pilot case study provided insights into how I could best approach the further study methodically and practically: I became familiar with studying and capturing this type of cases, for example where to sit during observations in order to minimise my intrusion but still have proper visual access; when to stop recording: it turned out that many valuable points were delivered after the formal session was over; how to ask questions that made respondents reflect; what kind of case material to expect, collect and possibly ask for. Likewise, I learned that 23 cases were far too many for one researcher to investigate in depth.

Additionally, the pilot case study served to identify some initial analytical challenges to which I could direct my attention and use as a 'handle' to open the door to the analytical process of the primary case study.

Pilot case study analysis

The pilot case study observations and interviews were captured by note-taking, while testing different approaches to the analytical process by inductively looking for themes in the notes relating to design process progress and constraints, both in individual cases and across cases. Some examples from the different approaches are shown below:

Example 1

This example features observation session field notes of an industrial design student with preliminary coding. The notes are coded in a moderately inductive manner, searching for themes and concepts, however always informed by orienting concepts relating to the research questions and aim. Bold is used in the notes to indicate interesting data parts and potential themes in the project. Underlined text indicates constraints. Bracketed text segments are my comments. Below the notes, identified themes related to the process and supervisor comments are noted. The themes are tentatively divided into these two areas, as the supervisor comments, oftentimes in the form of 'rules', represent a potential external constraint that may or may not end up determining some aspects of the process. The process themes are deemed more representative of the designer's own perception and conception of the design process and its development.

Designer i18 describes concepts in his project.

Medico? (Area)

Fear (problem 1, identified)
CT/MRI scan (type of product)

Scanning device

iSupervisor: Imagine the reader doesn't know anything about MRI/CT scan (PD). Part of the goal is to demonstrate an opportunity for improvement and show that this can demonstrate a potential to be effective.
At the moment the goal sounds more like a personal motivation. Broaden out to what the solution can achieve. Project aim to achieve: improvement in the CT scan.
Look at: The human factor, the technology in the scanner. Goal e.g.: improve the experience, e.g. **claustrophobia is a present and real concern.**

Designer i18**: different disadvantages: noise, claustrophobia (type analysis of problem causes)**

iSupervisor: Illustrate **problems for all the people involved with scanning. Part of PJ: identify un-met needs (problem 2, potential)**
Your research: **Methods. Mention common methods and approaches in ID. (ID way: clear process?)**
In the course description: demonstrate that you can identify a relevant project, carry through and account for a coherent process.
Methods: Research, analysis, human prototyping, maybe build a 'scanner', service sketches (story board). Use terminology for methods and approaches commonly used in ID.
Make a time line, break it into months. Purpose: point/frame of reference. It always changes. Allows you to visually observe the degree of change. How fast are you working? Don't stack it all up to the end. Manage time efficiently. Self-management tool. A visual one. Key points on calendar.
Three things companies want to know: quality, timing, cost.
Those things are vital in order to continue your work.
Other things: inspiration, network, sources (people you work with)

Related worlds: If you have a problem, (ask yourself) Where else in the world do we have the same kinds of problems? How do they solve it there?
Scanners: noise, claustrophobia. Where else: submarine, tunnels, mines. Are there actual tools that are used to mitigate this problem?

iSupervisor: Tell me where you are right now:

Designer i18: I'm beginning to understand what kind of PJ I'm working towards, subject, problem. Looking at what kinds of scanners there are.
I'm interested in scanning devices for humans. I have **already investigated existing scanning devices. Health care section. Target groups. I have listed these perspectives**. Some refer to medical, others to surface, inside of the body…

How can these scanners be implemented? What kind of technologies are they using? What is the purpose of having two almost identical scanners? CT/MRI? E.g. <u>You can't use a CT scanner on a pregnant woman or on children because there are x-rays involved.</u>
I looked at what scanners look like.
Some are for bones, joints.
Different types of scanners. Some are open, some look like sci-fi. <u>You have to have two magnets close to the joint (external CS)</u>
This one (points to picture) got more and more open as it was developed.
This one (points to picture) hasn't changed.

There are now silent MRI scanners (still loud). Investigation of sounds.
Digital.
This is kind of fun.
This is interesting. Also user friendly – you can be in kind of a comfort zone, be lifted off the ground. Sit like this…

iSupervisor: Talk to the people who are having it done, the people who operate it, interview, observe.

Designer i18: I've been to the nursing museum: Hospital bed: improved… there are developing technologies in all areas of medicine
I will/have to talk to a radiographer about the world of scanning.

iSupervisor: Understand the human side, usability, practicality, emotional facts. They are big machines. They need rooms that are sized for them. Understand the job of not only operating them but also prepare the patients for them. There is an important role for someone who takes care of the patients' wellbeing while being scanned. Find out what it is like to be scanned. Talk with patients. You can learn more in a couple of days by observing, following nurses, hear about pros and cons, about their concerns.
At hospitals things are run on tight schedules; there are unforeseen demands; this puts pressure on both patient and operator. Other factors (than just the scanner itself?)
The person is ill, someone is at work, additional factors, compassionate person, technician must keep time schedule. How does this balance out? **What other considerations are there? (problem 2, potential)**

Talk to companies

Designer i18: Philips, Siemens, General Electrics

iSupervisor: Talk to all of them, go visit them. They will have different viewpoints. It's part of your responsibility as a designer; you're not an expert in the areas; you're an expert at bringing knowledge together and design progression. Surround yourself with as much knowledge as possible. Start now; it may take a long time to get appointments in place.
It's a good idea to document this. Put it up on a board/wall, leave it up. To reflect, to see it. Computers cannot provide overviews. Display information. Standing back and reflecting helps you see all the various elements as a whole body of work.

Supervisor rules/themes:

- Broaden out
- Prove/test/ justify product (is it working/ likely to work)
- Goal must be more than a personal motivation
- Focus on human factors
- Field research
- Time management – allows to see a gradual change from original plans
- Understand the human side, usability, practicality, emotional fact
- Include many stakeholders – different viewpoints on problem (triangulation?)
- Designer = expert on bringing knowledge together and design progression
- Computers cannot provide overviews. Get information out/up. It helps to stand back and reflect – see it as a whole body of work, literally see connections

Project process

- Analyse area, list types
- I'm beginning to understand what kind of PJ I'm working on, subject, problem, explorative process)
- Analysis of scanners

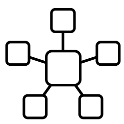
Example 2

In this example, after the moderately inductive coding of individual industrial cases, I resume recurring themes across the ID cases. The themes are, again, divided into supervisor statements and project process themes. (The ID and fashion down strokes [observations/interviews] were made on different days, following the supervisors' schedules). Bracketed text are my comments.

ID 15.11.14

Recurrent supervision themes:

- Prove/test/ justify/measure (relevance/function of) product (is it working/ likely to work?)
- Focus on human factors
- Research first, reflect later
- Timing aspect: What is right for the point in history? How can people adopt/adapt? MAYA principle. Future visions steering immediate development direction
- Goal must be more than personal motivation (external/objective/functional justifications). You can't pick a decision out of thin air. No random decisions (different insights inform your decisions). Validate decisions by relevant, rational needs/PRs
- The "ID way" (conventions). Clear process and methodology. List methodologies.
- Time management – allows you to see a gradual change from original plans
- Related worlds/analogy (method). Where else has a similar type of problem been solved?
- Computers cannot provide overviews. Get information out/up. It helps to stand back and reflect – see it as a whole body of work, literally see connections. Not having things on the wall kills creativity.
- Open up the subject. Paint the context
- Application context. Where can this be applied? (presupposes a certain degree of solution specification)
- "Conceptual justifications" – the idea exceeds the solution. Is part of a larger system
- Do field research. Learn from companies. Realistic/contextualised inspiration (from e.g. companies) – 'real world' problems (= justification?)
- Identify & include many stakeholders – different viewpoints on problem (triangulation?)
- Distinction between needs (rational) and concerns (emotional). Unmet needs = potential solutions. If there's no need, people don't buy.
- Physical form and/or systems/needs/HCD
- Realistic PJ or provocative/critical/commentating PJ
- Directions. One will stand out. Identify "hooks" in potential PJ's. Parallel work in several themes
- Network analysis (of superior (?) theme – what pertains to it?)



Recurrent project process themes:

- Theme: (Visions of) the future
- Replacements of themes/changes in project theme
- Working in several directions
- Working in one direction, but don't know if it's the right one
- Process convergence/divergence. Is it too early to narrow down? I need to research more (open up)
- Research + analyse area/company/existing designs, list types, categories, subgroups:

Example 3

Designer f11. In this example, the provisional moderately inductive analysis is likewise included in the field notes by means of different indications. Design concepts (what will later be named 'Information Entities' representing themes (see Chapter 7)) start to emerge in the data analysis as central nodes between which links are discussed. Having gained some experience in writing notes and precoding data in similar kinds of observation sessions, I have numbered these concepts, as they are introduced in the beginning of the supervision session, and I use these numbers to refer to these concepts whenever they are mentioned. To begin with, this numbering is a practical tool to faster note writing. However, the frequency by which the concepts and their relations are mentioned (which necessitated the numbering in the first place) will point me towards their centrality for the design process.

I have noticed a seeming hierarchy in these concepts, hence the umbrella symbol that indicates an 'umbrella' or 'mother' concept. I indicate rules or constraints by underlining passages in the text. PJ stands for 'project'. PD stands for 'Project Description'.

Womenswear collection

Modernism

1. Ib Geertsen, like paintings, beautiful as inspirations, missing deep meaning, afraid it's superficial

2. Georgia O'keeffe, modernist painter, like the way she paints, male female theme

3. Japanese design: Male/female, androgynous, simple -> would like to integrate it into project

Designer f11: Doubt, confusion how to approach PJ

Designer f11: Missing links between **1** and **2**. Feel link between **2** and **3** = male/female

fSupervisor: You pointed out you want to let go of Geertsen (**1**).
(helping/strengthening student choice)

fSupervisor: PD missing link with Japanese fashion (**3**)

Designer f11: 3 begins to fill more. 1 misses the 'organic'. 1 and 2 are missing a link

fSupervisor: If you don't like one thing, why not skip it? (Justification by preference)

Don't stick to things (just) because you chose them initially
Do more research. Find more inspiration. Find out how you could make it work.
You showed me the same two weeks ago

Designer f11: I'm stuck in it

fSupervisor: O'keeffe (**2**), what's her relevance in time? Maybe that can inspire you.
Look more into modernism. So much depth in it: lifestyle, revolution
(contextualise, make theme broader, go in depth)

*Talk about skipping **1***

fSupervisor: Make mood board
One artist represents more than one thing, combine colour, material, etc.
Get your hands on. Make sketches, look at/use fabric
Think about/work with how you can translate inspiration into something (clothes)
Find more inspiration

Designer f11: I have already found more inspiration. It's on my computer. I'm afraid (to show it/it's not good enough)

fSupervisor: Take it out, put it on the board (board as hierarchy top position, what is preferred, what is chosen)

Designer f11: Yes, maybe I should just DO something

fSupervisor: Form studies/sketching can also help you now
I would really look into the TIME of modernism

Talk about work on dummy (from another project). Often work with paper, shapes

Designer f11: I feel I have different techniques to discover shape and experiment with shapes

fSupervisor:

Work parallelly
Start to also work with material, colour, etc.

Designers always start with material, it has a long …?.. time
You're not stuck; you are in a research phase

Continue with something new. Research, read
Leaving **1** behind is already a step further
Build up a colour card
Form study of **3**. How can you link it to modernism?
Take a deeper look at **2**. Maybe she's the persona you design for?

When working with/from an artist, always combine it with something else (because the artist's work is already visual???)
Make time line.

Panic comes from lack of structure

If you make an overview of when you do the different things, then you can swap the different parts
What do you find fascinating in the themes?
Think about how you can translate them
For me this amount of material would not be enough, but some people can work from one picture
Create mood: summer, winter, colours…
I always make/work on several mood boards and then skip or combine them later. I pick out the one I most believe in and take the other one aside, but still work on it. In industry, there's not much time, so it is helpful to do it this way

Designer f11: I'm trying to open up my process in this PJ
Usually I work like bum bum bum bum (strict, stiff, rigid, pre-structured way)

N: Make fabric mood board

Book: Texture, flowers

Example 4

After going through the ID and fashion cases, I noted some of the similarities and differences across the cases that sprung to my attention:

Similarities

- Where can this be applied? (solution context)
- Realistic PJ or provocative/critical/commentating PJ
- Parallel work in several themes

Differences

Fashion	ID

Justification of decisions by designer's preference/taste/intuition (or randomly).	Justification of decisions by external/objective need/problem: Valid decision determinators: - reason - info - purpose - technology
1. *Student A: "Maybe I should bring materials and ask people so it's something outside me that decides? (...)* *fSupervisor: "It's wrong to let others decide, it's too risky/random. You should control that"* *2.* *Student B: "I found materials in my cupboard. I sat and nothing happened, and I just grabbed out for stuff"* *3.* *Student C: "I will try to take some textiles from my last project and include it in the process and see where it will take me"* *4.* *Student D: "I try to do something with things I find, I hope something will happen, that I will find a theme"*	*1.* *iSupervisor: "At the moment the goal sounds more like a personal motivation"* *2.* *iSupervisor: "Get different insights – that will help you make your decisions. You can't pick a decision out of thin air, but once you get information, you don't make a random decision: Logical areas, good reason, information, purpose, technology, makes sense to work with."*

The themes and concepts identified through the preliminary moderately inductive coding were filed to the 'information stock' of the research process.

With the preliminary analysis and the prevalent theoretical design concepts, such as problem and solution, in mind, I embarked on a visual analysis of the pilot cases, in which I mapped the relations between the project elements and concepts found.[5]

According to Rozanski & Woods (2012), visualisation can support the analysis of element interrelationships and reveal structures in the situation modelled. Hence, the purpose of drawing the cases was to make visible relations between case elements and explore the ways in which these can be structured and represented. It was my assumption that the visualisations would help to expose potentially interesting paradoxes, challenges and perspectives in relation to data analysis, which could catalyse progress in the analysis process and point to themes of interest in the data.

Through the preliminary analysis the pilot case study material had been analysed for hints of verbal and visual expressions about the under-determined task and its framing (constraints) and the progression of the design process. In the visual analysis an attempt was made, for one case at a time, to incorporate the obtained information into a visualised case model (Figure 8).

Below are some examples of the illustrations. They are replicated in a reduced size here, but can be found in their true size in Appendix 4. However, the readability of the individual words is not necessary to convey the impression of the heterogeneity and complexity perceived to characterise the data and thus the attempt to visualise it.

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[5] This section recurs in a slightly altered version in Chapter 8, Section 8.2, as I shall use it to describe how this analysis process served as a stepping stone to the development of the ITO framework presented in Chapter 8.

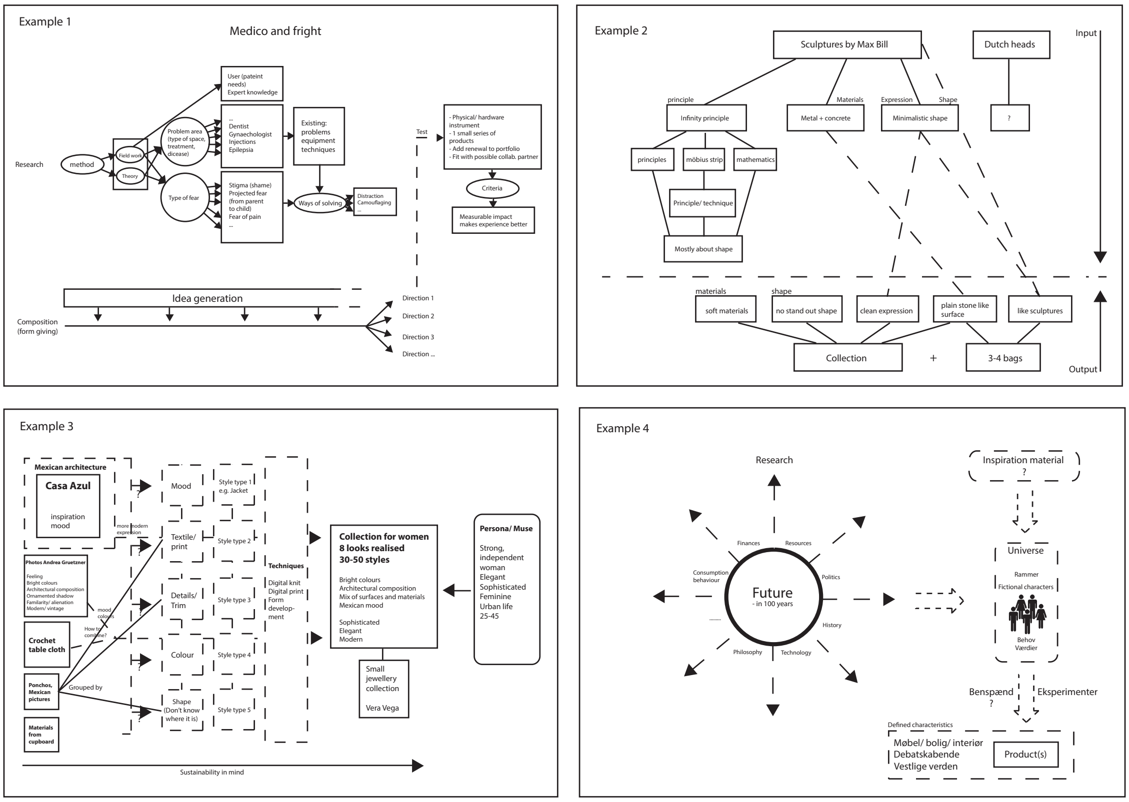


Figure 8: Illustrations of four of the pilot cases.

The case visualisations were not constructed on the basis of any template, but instead represent an attempt of inductive clustering of the concepts, themes and relations encountered in the preliminary coding of cases, based on orienting concepts related to design processes. For instance in Example 1 and 3, the case elements are sought organised by means of process time lines (visible at the bottom of the drawings), whereas in Example 2 the elements were arranged with the concepts of problem and solution in mind.

As expected, the attempt to illustrate the cases gave rise to a great deal of confusion and difficulties. These were helpful in the sense that they raised some central questions and challenged my preconceptions toward design processes:

First, I was challenged by the concept of solution. On the one hand, solutions were verbalised as affiliated with process termination. On the other hand, by being mentioned, they were, indeed, present and relevant concepts in the initial process state at which the cases were captured in the pilot case study. If I were to figuratively comprehend the design process, should statements regarding 'the solution' be situated at the end of the temporal process (e.g. a time line), despite their occurrence and consequently assumed relevance at the early process state? And how can design solutions be conceptualised to comprise the equivocality of being at once a concept informing a state in which it does not yet exist, as well as being the end result of the process? These questions led me in the direction of new theoretical studies, for example the 'co-evolution' theory in design, which influenced the further analysis of the primary case study.

The primary case study and its analysis will be described in the following sections.

Primary Case Study

For the longitudinal primary case study, a smaller sample of 10 cases was selected in order to allow for a more focussed in-depth study without a loss of diversity. These were chosen for different reasons:

Firstly, not all design students from the pilot case study were equally comfortable with being observed and interviewed: a few were not interested in further participation in the study, and others conditioned their participation on the restriction that I could not take pictures or record them. To allow for the richest possible data collection, I therefore chose among students who were reasonably comfortable with being studied.

Secondly, internally among them, the cases were chosen to represent a maximal variation strategy (Flyvbjerg in Brinkmann & Tanggaard, 2010, p. 475) within the relatively controlled framework. Thus, the ten cases were distributed equally between Industrial and Fashion Design, and within each discipline I chose, from a rather limited basis of early judgement, projects that seemed to involve different types of information, methods, and aspirations. An overview of the cases can be found in Appendix 8.

Data Collection

The case projects were captured in 10-13 time-lapse snapshots per case; the intervals between them were approximately two weeks. For the purpose of capturing the state and progression of the processes, different qualitative methods were applied: observation of supervision sessions, in-depth qualitative interviews, and collection of both written and visual documentation material. In total, the data set amounts to 1488 document pages of which 772 are primary data document pages transcribed[6] from recordings and notes from a total of 63 interviews and 70 observation sessions. Additionally, the data set comprises 853 visual units, i.e. photos of the project material and activities. Table 1 below shows a quantification of the data.

[6] The transcription was undertaken by myself and an assistant, using the transcription software called f5.

	Primary data								Secondary data		Total sum	
Data type	Interview		Observation				Photos		Material made/collected by designers			
Data sub-type	About general process	About process visualisation	Of supervision session	Of Plenum presentation	Of Masterclass	Of test exam	Of project material	Of process Drawing exercise	Written project description	Other project material**		
Counted unit	Number of interviews (number of transcribed A4 text pages)						Number of Photos*		Number (number of A4 text pages)	Number of collections (number of pages)	Text pages	Visual units
Designer f1	4 (39)	2 (26)	4 (14)	2 (7)	1 (3)	0	101	2	1 (3)	0	92	103
Designer f2	5 (30)	2 (45)	2 (5)	1 (6)	1 (3)	0	80	2	1 (2)	0	91	82
Designer i3	5 (22)	2 (24)	6 (27)	1 (2)	1 (2)	1 (2)	58	2	2 (8)	2 (50)	87	60
Designer i4	2 (18)	2 (36)	4 (17)	1 (2)	1 (2)	1 (2)	43	2	2 (3)	2 (26)	80	45
Designer f5	5 (32)	2 (29)	5 (14)	2 (9)	1 (3)	0	114	2	1 (2)	0	89	122
Designer f6	2 (16)	2 (28)	3 (9)	2 (3)	1 (3)	1 (2)	63	2	1 (2)	0	64	65
Designer f7	5 (42)	2 (23)	4 (12)	1 (2)	1 (2)	0	65	2	1 (5)	2 (82)***	104	149
Designer i8	4 (14)	2 (36)	4 (10)	1 (1)	1 (2)	1 (1)	70	2	2 (5)	1 (4)	69	72
Designer i9	5 (28)	2 (29)	5 (17)	1 (2)	0	0	75	2	2 (5)	2 (34)	81	77
Designer i10	6 (16)	2 (13)	6 (16)	1 (2)	1 (1)	1 (2)	66	2	2 (6)	2 (29)	56	68

*have been counted as visual units in the 'total sum'
** e.g. slideshow/ book/ research/ survey/ other
*** counted as visual unit

Table 1: Quantified data overview

A full visual overview of the data set including a timeline of the time-lapses can be found in Appendix 3.

The observation sessions were carried out as a 'fly on the wall' without interruption of the supervision conversation between student and supervisor. Sometimes, if the observation session left questions unanswered, I followed up with a subsequent interview. At other times lenghty interviews were carried out independent of the supervision session. The interviews were unstructured in the sense that they took their point of origin in and were led by the particularity of the 'present state' of the project, asking the designer to show me and describe what she was currently working on. Likewise, I asked the designer to tell me about the present moment in relation to 'last time' I studied them, and in relation to their planned activities. Of special interest to the query were situations of perceived challenges in the process.

In the beginning of the study, before trust was built between myself and the informants, I was not allowed to record all conversations (supervision sessions or interviews). For this reason, some conversations have merely been captured by thorough note taking. This was the case in 9 interviews, and 30 observation sessions. When cited in the dissertation, the entirety and the meaning of what was originally expressed in these conversations have been construed and reconstructed verbatim from the notes to ease reading flow and comprehension. These instances are marked 'reconstructed from notes'.

Later in the study, I was allowed by the informants to record nearly everything.

The primary data set of the study has not been collected by 'theoretical sampling' in the traditional sense, since the primary case study has focussed on specific design processes that are inherently confined, and because the time lapse frequency was semi-strict in order to study the cases on the same terms. However, when taking the pilot studies into account, the data collection has progressed and developed during the research process. Additionally, the primary case study stretched across a long period of time and evolved in parallel with the initiation of the analysis. Even though the data collection of the primary case study data has not been collected by a theoretical sampling strategy the way data have been included in the study, from the pool of collected data, has imitated the theoretical sampling approach. This will be elaborated in the 'Theory Generation' section.

Bias

When studying designers' processes, my presence and interview questions might unintentionally affect the design processes. In fact, Cardoso, Badke-Schaub, and Eris (2016) have found that in design situations specifically, 'high-level' questions, e.g. about reason and causality, can trigger 'inflection moments', implying *"a reframing of the situation at hand"* (Cardoso et al., 2016, p. 67). Though this connection is found in relation to questions posed by designers who are part of the team, it is not implausible to assume that 'high-level' questions posed by others, for example me as a researcher conducting a study of the design process, might sometimes affect the process in a similar manner.

Yet, other circumstances alleviate this bias, for example the fact that the designers are not studied in an experimental set-up, which means that they are potentially affected by multiple sources of which my questions make up only a fraction of external influence. Additionally, interviewing has not been the sole method used to capture the design processes.

Theory Generation

This section describes how data have been analysed and how knowledge has been generated from the research process.

In this research project, the adaptive approach manifests itself in an ongoing oscillation between theory studies, data studies and analysis, and Theory Generation. This is illustrated in Figure 9 below.

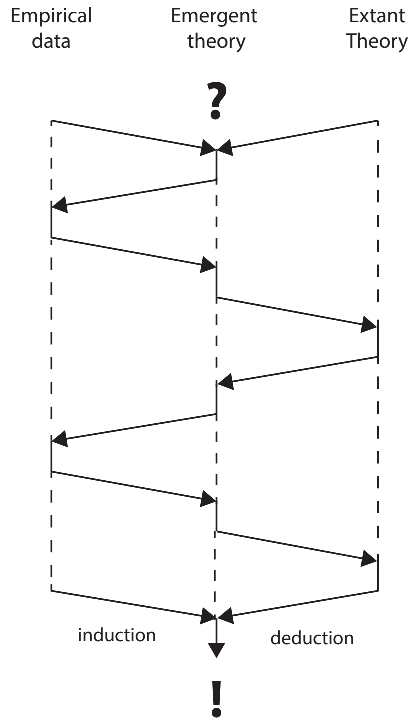


Figure 9: Oscillative movement of research focus

Figure 9 shows how the research process has shifted between inductive and deductive approaches in the generation of a new theory, and that every stage of Theoretical Generation has been an intermediary state shaped by continuous exposure to new inputs from empirical data and extant theory.

A roughly sketched account of how this approach has unfolded in my actual research process is included in Appendix 7.

In the previous section, I claimed that the inclusion of data in the analysis from the pool of collected data has imitated the theoretical sampling approach. The reason is that the collected data have served as a reservoir from which I have included data along the research process, not with the intent to exhaust all cases for all information, but with the aim to understand design processes. Thus, the latter has been the guiding light in the analysis process. In the iterative research process, I started out by employing one analysis strategy, based on orienting concepts, on one case. On the basis of the fit with empirical data, the emergent theory that underlies the analysis strategy has been revised and further shaped by extant theory. The new analysis strategy, adapted in accordance with the first round of data and related theory, has then been employed in analysis of the next case, and so on. Thus, more and more data have been included in the analysis until a point of saturation at which the explanatory power of the emergent theory behind the analysis strategy extends to all cases, and at which point no data encountered contradict the findings.

This approach to data analysis implies that all cases have been analysed on different grounds, since the understanding of design processes has emerged and changed with incoming, or rather absorbed, evidence. Likewise, it implies that some cases have been analysed more deeply than others, and that the first cases analysed have played a role more focussed on theory building, and that the last cases have played a role more focussed on theory 'testing', i.e. checking that the understanding attained applies to these cases as well.

The order in which cases have been brought into analysis has been chosen by the perceived richness of data in the cases and by the decision to shift between the two design disciplines represented by the cases.

I have conducted all data collection myself and witnessed the unfolding of all the design processes, and in this process, I have used both pre-coding and memos to capture ideas and indicated patterns. From this work, I have gained deep insights into all the design processes all along the data collection, and thus the entire pool of data has provided me with empirically derived orienting concepts for the analysis of individual cases. Likewise, it has equipped me with a pre-understanding that has hinted at interesting similarities and contradictions even prior to the formal analysis.

Analysis and Coding Approach

In this section I will explain how the analysis and coding of data has been carried out, and I will account for and exemplify how the explorative analysis approach has affected coding strategies throughout the research project.

It is a peculiar trait of my research that the way it has been carried out remarkably mirrors the processes studied, since both the research and the design processes are explorative in nature. Thus, despite the fact that my research is not a typical 'research through design' project, I believe that this could be a telling description for the way I have approached it: I have prototyped my way forward to approximate a meaningful explanation of features of design process development.

What I have prototyped is not physical models like in design, but analysis strategies that have increasingly developed into conceptualisations of design process development. When doing explorative research I see analysis strategy and emerging conceptualisations as two sides of the same coin: the more meaningful a way I find to split up the data, the more meaningful the concept categorisation for the emerging

conceptualisation. Let me, for the sake of simplicity, call the analysis strategy/emerging conceptualisation a 'prototype' in the following.
In general terms, the prototyping process has looked somewhat like this: Based on my preunderstanding of design I made a 'prototype'; I tested the prototype against part of the collected data; I let the data (part) challenge the prototype and provide me with new insights, questions, ideas, and themes; I related those to existing theory and let theory inform the building of a new prototype; this new prototype was again tested (against data), and so on (Figure 10). This has been an ongoing iterative process. As the Figure 10 shows, the data set as well as existing theory has been like two 'pools' from which I have pulled information into my research process (represented horizontally between them). The loop from one prototype to the next can be considered an iteration.

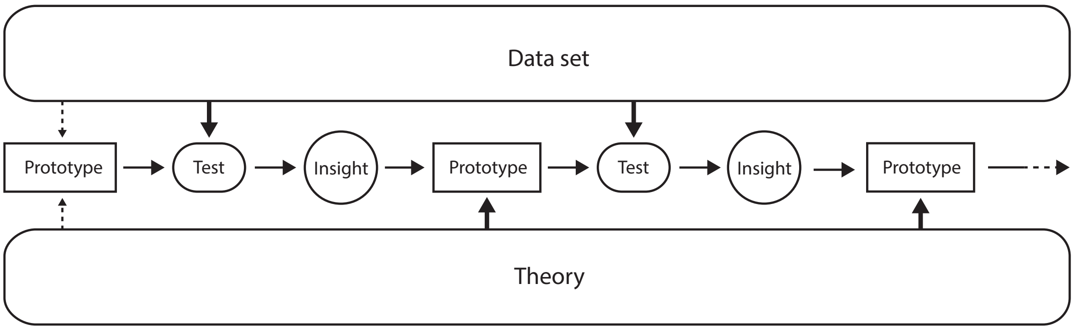


Figure 10: Analytical process

A prototype, in this research context, should be understood as a way of splitting up – of analysing – data, and thus at the same time a way of grouping data into the concepts that the analysis categories imply. A revision of a prototype can span anything from the inclusion of an additional concept (that has arisen from data and come to form part of the orienting concepts in the analysis of the next case), to a total shift in focus – e.g. the shift from looking for 'problem' and 'solution' in the data to looking for 'action' and 'matter'.
The criteria for judging the prototype is by its ability to provide some novelty in relation to existing theory and its ability to provide me, as a researcher, with new ways of looking at the data which, deemed on the basis of the preunderstanding gained in previous data analysis, hold the potential to extend beyond the specific case.

The prototypes were not tested on all data to the point of exhaustion, but rather on some data to the point of insight, e.g. the realisation of a better strategy or of the insufficiency of the present one. The analysis and coding strategy have been continuously evaluated by their ability to lead to new insights and have been revised accordingly. Thus the research process has been one by which I have been searching for the best strategy to analyse data, assuming that this strategy would at the same time propose new ways of understanding the data itself. The insights of all analysis and coding strategies tested have been accumulated and filed in the digital and mental 'information stock' (see Chapter 7, 7.4) of the explorative research process, and have thereby contributed to the shaping of subsequent analytical strategies.

Every time I have tested a new prototype, I have done so against a new part of the data set to make sure that it is exposed to and challenged by data that differ from the previously analysed data set on which it was founded and revised. When noteworthy changes have been made to the prototype, I have gone back to previous data and tested them again, which is why some of the early analysed cases have been reviewed and coded through numerous rounds. By using this approach the conceptual prototypes take into account more and more data for every time they are rebuilt. In the beginning of this process, the cases chosen for analysis were selected on the basis of their perceived richness of data. Throughout the research process new case data have been introduced based on the decision to shift between the two design disciplines represented in the study. Later in the process cases were included in a random order following this decision to shift.

The collected data have thus, as described in the previous section, served as a 'reservoir' from which I have, on an ongoing basis, included more data in the analysis along the explorative research process. Hence, the cases have been analysed on different grounds, and the analysis has not been undertaken with the intent to exhaust all cases for all information, but with the aim to exploratively approximate a conceptual understanding of design process development with the highest power of explanation as to meaningfully elucidate instances of development operations in the cases in general, and with the least amount of friction to the development of any one case.

As described in chapter 10.1, we can see explorative design processes in different ways: for example there is a difference between the way we carry out a process in small iterative steps of experiment (process conduct), and the way we rationalise and narrate about it afterwards (process account). My research process is indeed an explorative process as well, and if applying my own analysis tools the *process conduct* of this study has been an immensely colourful and extensive journey along which a myriad of different prototypes have been built, tested and abandoned again, as they did not fit properly with the data.

Shortcomings and biases of the explorative research method

The explorative research method implies a lot of experimentation and results in an accumulative and compound list of ideas and findings. It can be challenging, yet the attempt necessary, to select which of these findings, in aggregate, comprise the most cohesive contribution and logical process narrative – in other words, to make a connecting line between some of the many dots, which can be followed by other people. Just like in a design process, it would be almost impossible, and excessive, to reproduce in a process description every single step of exploration and insight along the actual process conduct. The 'dots' that are selected for the process account are those that, in retrospect, are considered essential for the development of the contributions, which in the end are deemed the best within the frames of the study. Yet, when digressive steps are left out in the process account there is a risk that the remaining ones convey the impression that findings were anticipated in advance or deliberately selected from the onset of the research process. Yet, the very opposite is the case in an iterative and explorative investigation. Therefore, this research method faces a challenge of clarity, especially when assessed within more established research paradigms. I seek to compensate for this by having explicated both verbally and visually the patterns by which the process has unfolded and by providing examples of analyses and coding procedures – also seemingly digressive ones – from different stages of the process.

The objective of this research project is to explore patterns across the very different design projects studied, as well as in the theoretical descriptions of design processes. This aim promotes and favours a focus on commonality rather than differences, which might be considered a bias in the research method. In the light of the research aim to propose a new conceptualisation of design processes that point in the direction of a unified design theory, the focus on commonality is, however, considered expedient.

In the explorative, adaptive research process there are oscillatory shifts between inductive analysis, theory emergence and deductive analysis. The forming of new orienting concepts and new analysis strategies from inductive analysis leaves a risk of a confirmatory bias: that findings from the data that have been analysed first will determine the nature of what is found in subsequently analysed data. However, one could speculate that this bias is also possible – though perhaps less obviously so – even if merely a single inductive analysis strategy is applied exhaustively throughout a data set. In the explorative research process, the emerging theory, and thus the concepts that inform further data analysis, is continuously adapted to 'intaken' data. This adaptation exposes and deliberates the influence that each new feed of data asserts on the existing understanding of already analysed data. If a single inductive analysis strategy had been applied throughout the data set, the same adaptive process – determining which data 'leap to the eye' – might have taken place in the unconscious cognition of the researcher, since one cannot avoid analysing the data in a specific order.

A factor that alleviates this bias in the present study is that data-driven analysis is continuously combined with theoretically driven analysis that provides concepts from outside the data set through which to build and validate an understanding of these data.

Choice of analysis strategy

Before elaborating on the specific analysis and coding procedures, I find it important to address a central and critical methodological choice that characterises this research project. It concerns the divide between basing data analysis on more established and standardised methods and theories, or, as is the case in the present study, building the analysis method while using it. This is what I refer to as an *explorative* method.

The explorative method has both strengths and weaknesses. A more standardised and well-tested method, applied more uniformly to all data, would have strengthened the comparability between findings from different cases at different stages of the process. Also, it would have resulted in a clearer and more structured transition from data to findings. On the other hand, a predetermined method might imply a limitation of the findings in the multiplex context of the study.

The choice of the explorative method has been made since it is my aim to approach the concept of under-determined tasks and design processes based on them, as openly as possible. Therefore, in my research process, I have let the method develop with the findings along the way, so that it has adapted to the complex reality I study. This allows for continuous emergence and maximises the potential for rich and nuanced findings.

The choice is based on the assertion that the strategies by which we analyse data also constitute a conceptual framework within which we can gain an understanding of the data. Thus, the development of the best possible analysis strategy can be considered to simultaneously be the development of the best possible conceptual framework for understanding the data. It is my assumption that the more we challenge and adapt this framework to the data, the more meaningful and inclusive is the understanding we can gain of these data. Over the course of the research process the concept of theory emergence can hence be seen as a gradual transition from analysis strategy to 'final' theory: from prototype to product.

The choice of an explorative research and analysis method likewise resonates with the objective to depart from the perceived conflicts associated with existing conceptualisations of design processes. Analysing design processes by the use of well-established theoretical concepts limits the ability to find and propose alternative ways in which design processes can be understood.

General analysis and coding procedures in the primary case study

In this section, I will first describe the analysis and coding procedures in more general terms before turning to specific examples of the analysis and coding procedures of the research process iterations in the next section.

In the research process, I have collected all data myself. If the specific down stroke (observation or interview) was not recorded, I made as many notes as possible, and if it was recorded, it was transcribed shortly after. In the beginning, I did all transcriptions myself. Later on, I had an assistant help me due to the vast amount of data.
Both in the data collection process and in the transcription process I made notes and memos on themes and how they were indicated by data. Thus the preliminary coding of data commenced already in the process of collecting them. This is exemplified in the description of the pilot case study analysis.

The analysis process has, as previously mentioned, oscillated between inductive analysis, theory emergence and deductive, theory-testing analysis. These three aspects are associated with different types of analysis and coding procedures and activities:

'Inductive' analysis:

The inductive analysis of data has been ongoing throughout the research process, though represented to a greater extent in the early analysis phases, where orienting concepts were fewer, data apprehension lower, and the prototypes frail. Yet, by maintaining an open attitude towards data and allowing them to continuously affect the understanding of design processes, inductive approaches remain present in the study. The inductive analysis involves reading through the case snapshot transcripts line by line with an open attitude to themes or concepts that for some reason stand out as interesting. In accordance with the adaptive theory, I have not coded every single line, but have focused on identifying themes in relation to my research frame.

This open attitude is, however, inevitably affected by my preunderstanding of data (since I have collected it, I have already heard everything said at least once), my preunderstanding of design practice, my preunderstanding of design theory, as well as my general knowledge and personality. Not least, it is – and obviously should be – affected by the research questions and aim. The reasons some elements stand out might be: the frequency with which they are mentioned in the case data; an implicit categorisation by the mentioning of several aspects of or approaches to something; the use of analogy or metaphors; that some statements shed interesting light on the handling of under-determined tasks, or that they converge with or contrasts statements encountered elsewhere in the data set. The themes and concepts that stand out are coded with tags using the analysis software f4 (see Figure 11 and 12). F4 is a simple analytical tool that allows for the gathering of multiple documents in a single file. Codes can be assigned to text bits across the documents in the file by means of coloured indications to which associated tags are created by the researcher. Subsequently, it is possible to search for tags individually and in combination across the documents in the file. Since every case has multiple document entries (one for each snapshot in the design process), each case has been given its own file.

There are two scenarios that characterise the inductive analysis in the research process. One is that the inductive analysis is carried out in its own right, without any intent to look for anything in particular, where the themes emerge from the data. Another is a more deductive search of the data with the intent to code or look for specific concepts or themes, but in that process something else stands out – and is given a code.

Figure 11 and 12 below show examples of the coding of cases in f4. As the codes applied to data from different analytical strategies accumulate throughout the research process, the tags representing them (the right-hand column) pile up as well and constitute a mix of (semi) inductively derived codes and codes from more deductively tested concepts. By the accumulation of tags, the coding concepts from the entire process remain in clear sight and foremost in the mind. In Figure 11, tags like 'tage med' (bringing along) and 'abstraktionsniveau' (level of abstraction) represent inductively derived concepts, whereas the codes 'problem' and 'solution' have been extracted deductively from the data. Other tags reside somewhere in-between, as they represent concepts that have indeed arisen from the data, but the realisation of which cannot be attributed to the particular data part alone, as it may have depended on the analysis of other cases and may have sprung to mind after a period of incubation after which the data was revisited with the idea in mind. Examples of this are 'nonformation' and 'constructive process'.

It is possible, in the coding process, to change the tag name and thereby the extension or nature of the category to which specific codes belong. This allows for the organic formation of clusters and categories while going through the text and for revision of the perceived nature of the relationship between individual codes that emerge.

As is apparent from the examples below, Figure 11 and 12 have different numbers of code tags. The reason is that the case in Figure 11 was one of the early analysed cases, and has thus – in accordance with the earlier described approach to data inclusion – received more attention and more rounds of coding than the case presented in Figure 12.

The column on the left-hand side shows the document entries in the f4 file. These documents represent the number (and content) of the snapshots – the down strokes – in the designers' processes. The bracketed text to the right of the document number shows what kind of data collection setting and/or method was used.

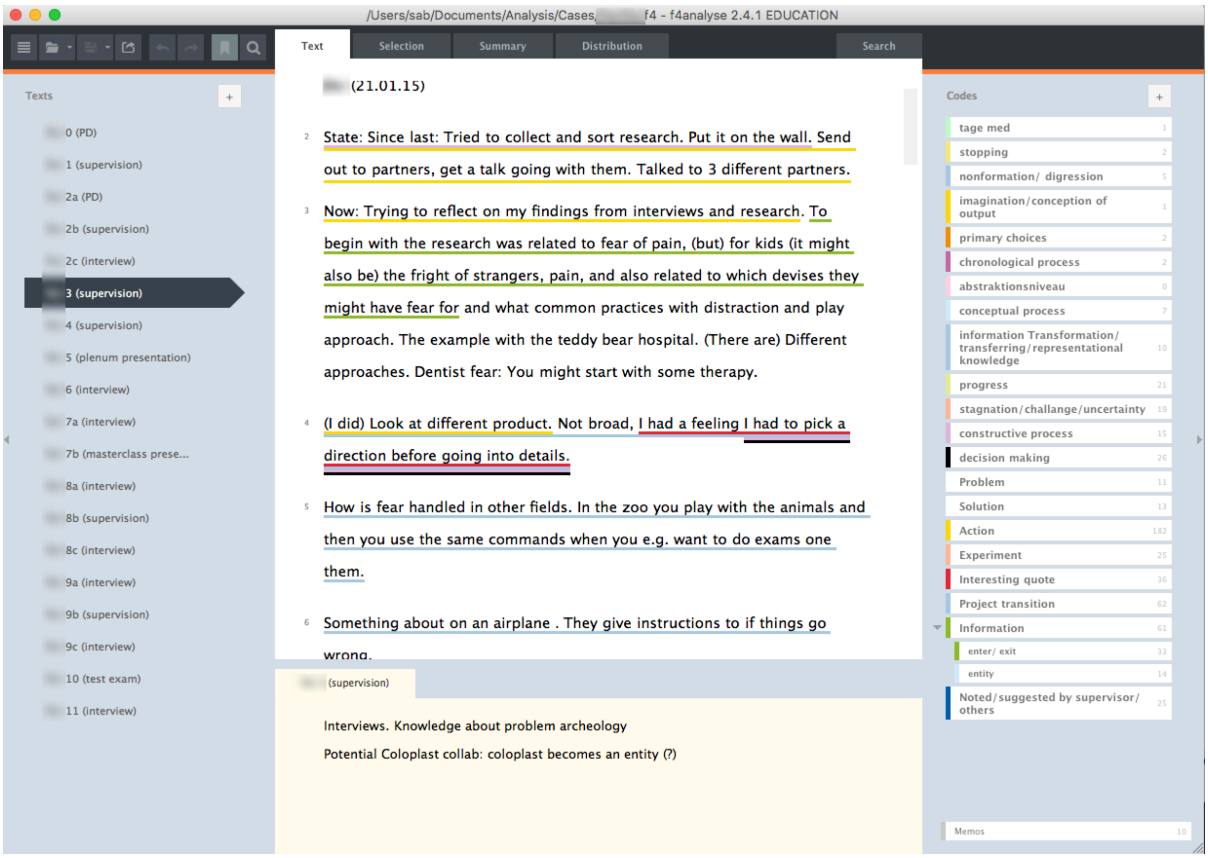


Figure 11: Example 1 of analysis in the f4 software programme

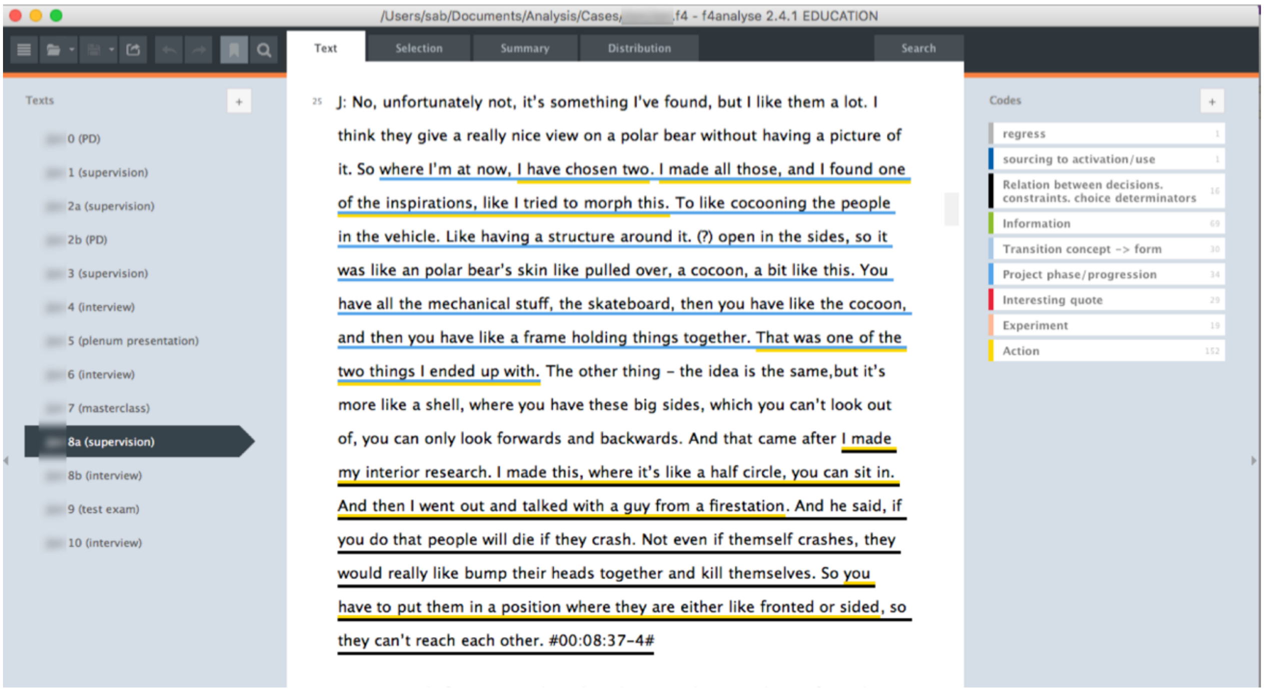


Figure 12: Example 2 of analysis in the f4 software programme

In the inductive part of the data analysis in the explorative process, many interesting findings (themes, ideas or hypotheses), of very different nature, arise, which can potentially be explored further and come to represent part of the main contribution of the study. However, since my (and any other) process is sine qua non limited by the condition that only one thing can be done at one time, some of the findings must necessarily be 'kept on hold' – in the 'information stock' – while others can lead directly into the, temporally, subsequent investigation. Conceptually, though, this diversity of findings can be portrayed as a parallel working process. Here, all the themes, in sum, and the perceived or hypothesised relationship (coherence) between them, affect the direction of the study and the emerging conceptualisation (in the form of new prototypes) of the topic of study for every new process iteration.

This is illustrated in Figure 13 below:

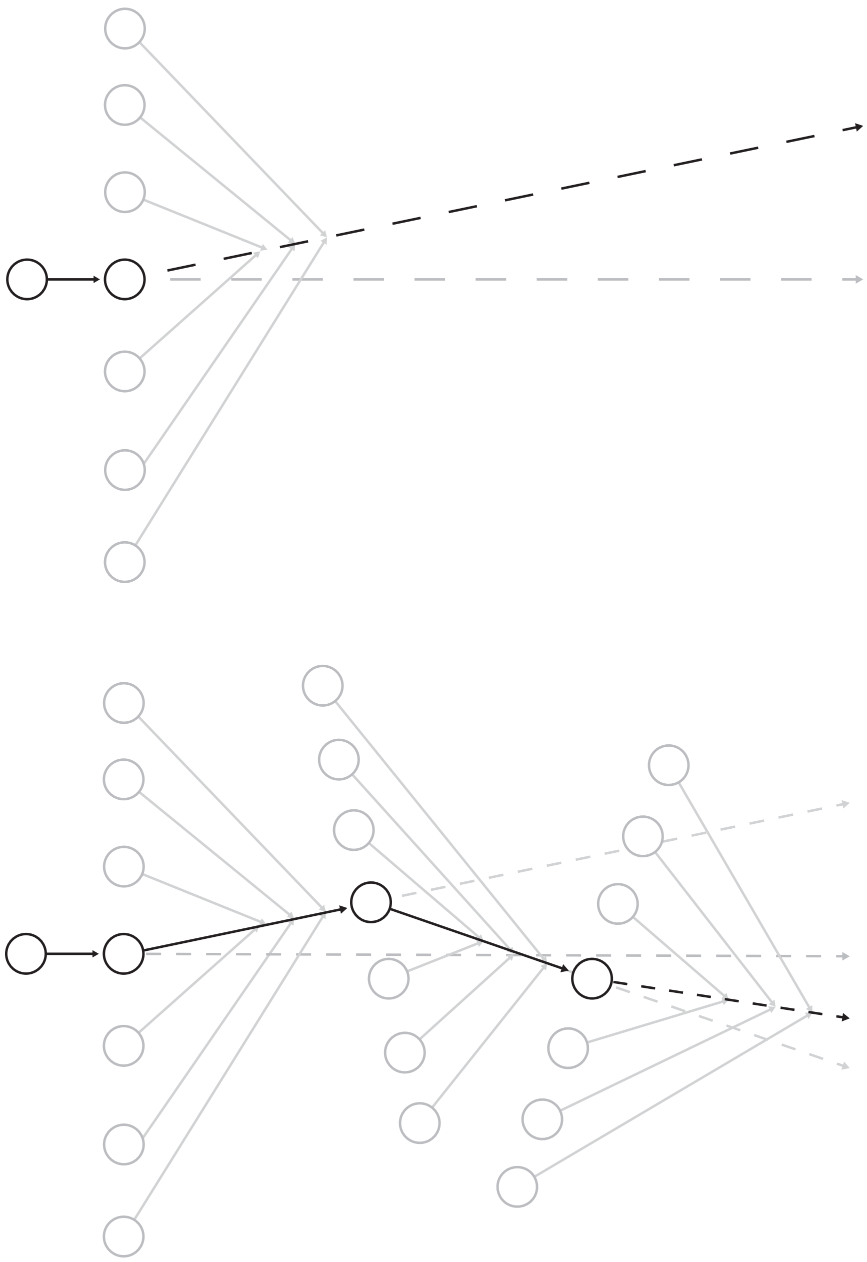


Figure 13: Parallel conceptualisation of explorative research process

In Figure 13, the horizontal dimension represents time and process progress. The black circles represent iterations in the research process. The grey circles represent the findings that emerge from every explorative iteration. The grey lines branching out from the grey circles visualise the idea that these findings, in aggregate, can be seen as affecting the direction of the overall research focus, almost in the same manner as a triangulation. The direction of research focus is visualised by the black arrows. The dotted grey arrows show, conceptually, how the research direction would continue, if not (allowed) influenced by new findings in the explorative process.

The model presented in Figure 13 was actually created as a prototype in the study of design processes that could describe the development in the design processes, but it was left out in the contribution, as it opened up a new path of research which – though definitely relevant – was deemed beyond the scope of the dissertation. However, I find it very illustrative for the unfolding of my own research process. Thus, yet again, a perceived parallel is drawn between the design processes and the explorative research process.

Theory emergence

The theory emergence is the prototyping part of the research process in which I develop the analysis strategies and conceptualisations of data. A central remedy in this activity has been my log book and multiple model sketches which I have kept and made throughout the research process, and in which I have captured and visualised emerging ideas about possible new analysis strategies/conceptualisations.

In the log book I write and visualise the ideas that emerge along the way. These ideas often revolve around the mapping of relations, e.g. *order*, *hierarchy,* or *causation*, between elements or concepts that (potentially) represent a situation in data or theory.

Prototyping can be informed by both theory and data. When, in the course of the analysis process, a prototype encounters paradoxes or problems in relation to data, I have registered them and used them to inform the subsequent prototyping activity.

In the prototyping part of the research, a myriad of ideas surface and help to explore, maximize, and nuance the perspectives on the topic studied. Yet, as explained, only some of them push forward the development of the process and only a fraction of them make it to the retrospective description of the research process.

An example of a prototype that was left out is shown in Figure 14. It depicts some of my work with a fledgling concept, 'Representational Experience'. The concept transpired inductively from the data, and relates to the use of analogy in the design process, for example represented in the data by the notion of 'related worlds'. Here the designer seeks to somehow substitute or simulate (user) experience about the not yet existing design by sourcing knowledge from other, existing situations that somehow are perceived to relate to the situation in the making. The model tentatively explores the ways in which the non-existing and the existing situations can relate to each other, and I found hints that these ways might relate to the other contributions in the dissertation, rooted in inferential structures. However, the work with this concept proved to be hugely expansive and would require opening up yet another vast theoretical area of analogy. At the same time, the concept would set out a different direction for the research than was intended, as it focussed more on sourcing than transforming information and additionally included a focus on users, who – despite their indisputable importance to design – are not the focus of this study. Hence, I decided to leave out the concept and save it for another time.

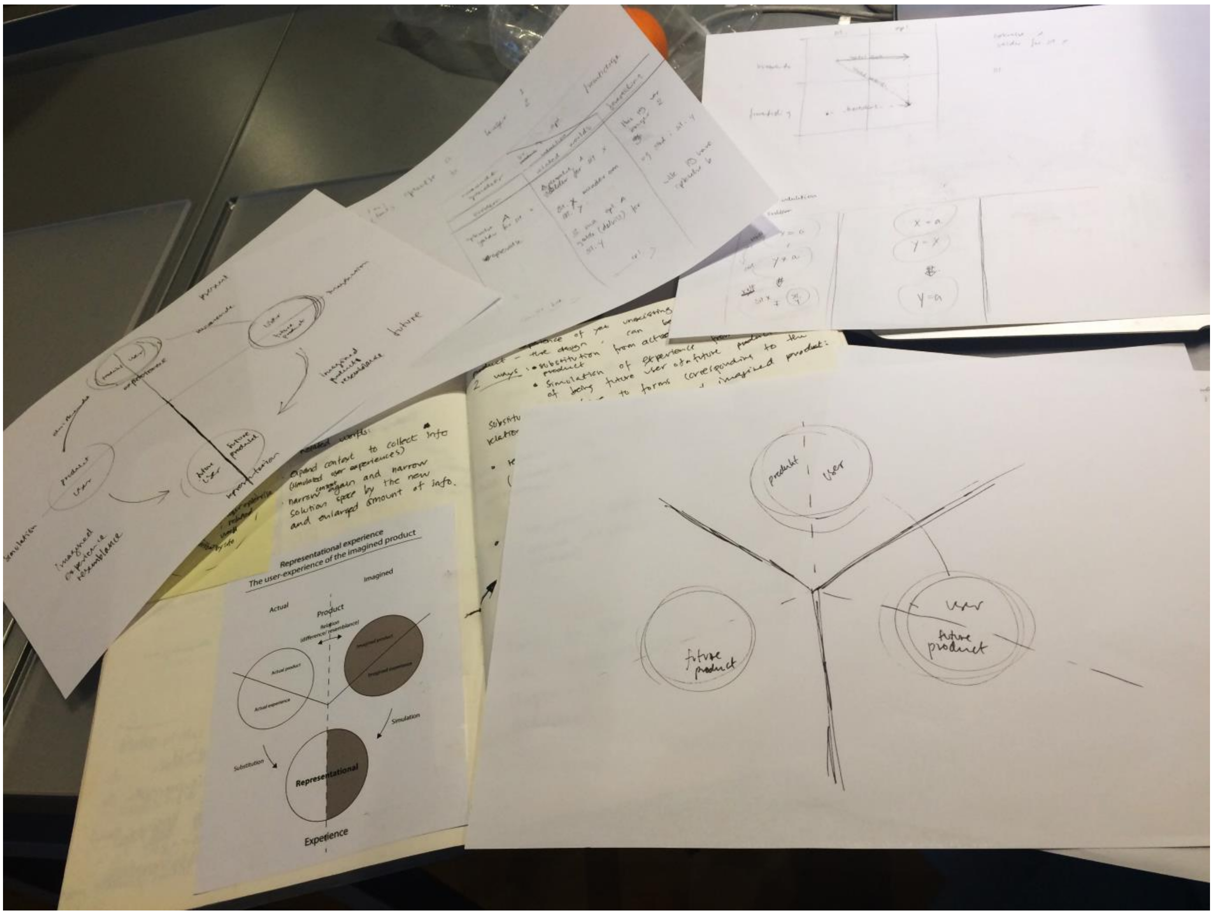


Figure 14: Example from log book and prototyping of a model that was eventually abandoned

Another example of prototyping is seen in Figure 15. It shows my initial attempts to visualise Reitman's (1964) problem solving theory and draw insights from it.

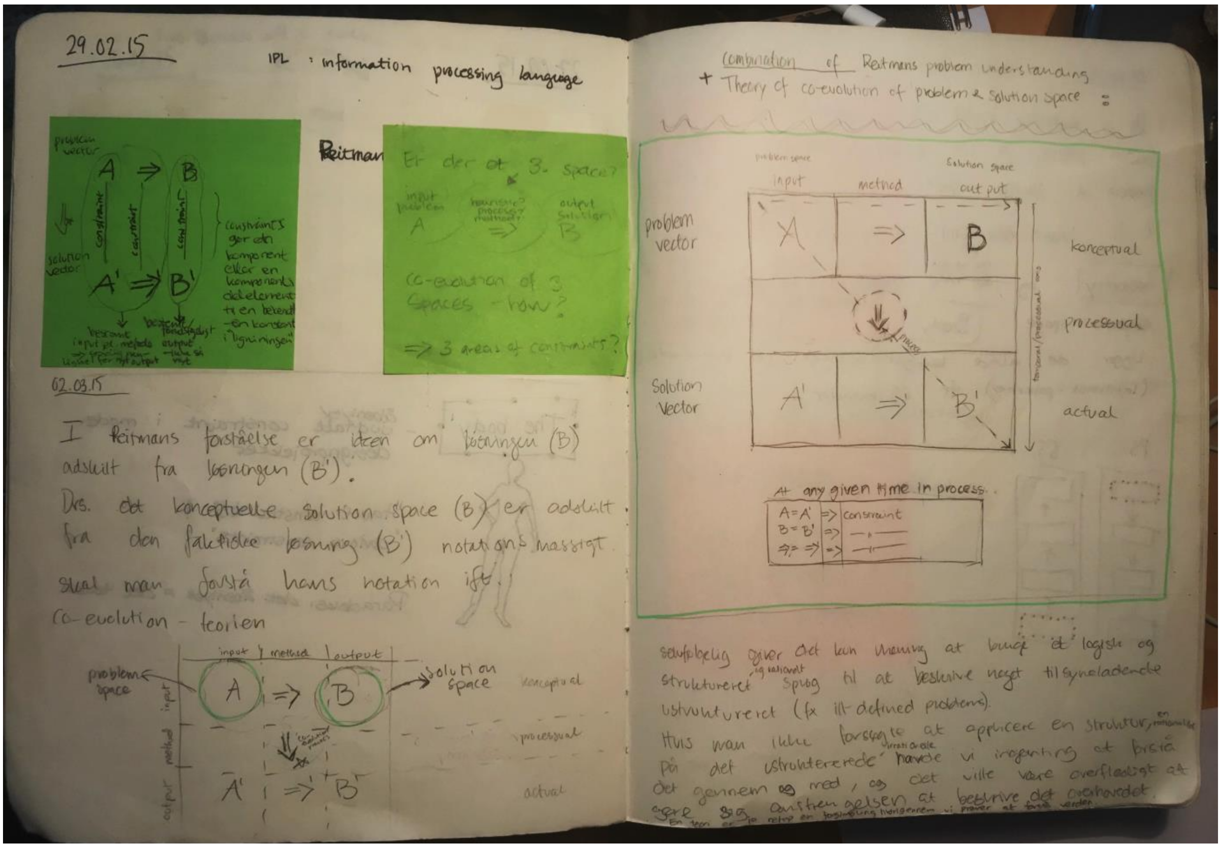


Figure 15: Example from my log book

For example, on the second green post-it note, I tentatively ask: “Is there a third space?” with an arrow pointing to the ⇒ symbol. This prototyping work has been central to the research progress and in the dissertation.

‘Deductive’ analysis

When a prototype has been revised or created the next step is to ‘test’ it, i.e. see if it provides novel insights and meaningful explanations of the research topic when applied to data. As a prototype often represents one or more concepts ‘in the making’, a solid definition has not always been formed, in fact, this definition might be shaped by the analysis, just as much as it shapes it. For this reason, the ‘deductive’ analysis is, in line with the adaptive theory, not purely deductive.

Overall, the ‘deductive’ analysis takes two forms in this dissertation:

1. One of the ‘deductive testing’ approaches is to read through data looking for instances that are perceived to fit the prototype categories or concepts. Instead of basing the analysis on predetermined concept indicator words deemed to be representative of the prototype categories, I approached this ‘testing’ more openly

based on the question: If I were to understand data in terms of these concepts and this frame, what kind of instances would fall under which concepts, and what kind of instances would challenge the frame? Which insights and discoveries would it provide me with about the data and about the present conceptualisation of the data? Reading systematically through parts of the data set, looking for instances associated with the concept helps shed light on potential concept-indicator links by which to determine search words to be applied in the second approach.

2. The second approach is a more structured search across the entire data set for instances representing the concept in question. This is done by using indicator words to find potential examples and then assess qualitatively whether they do, in fact, represent an example of the category or concept. Since each case has been given its own file in the f4 analysis software, the search across the entire data set requires that each file is opened and searched individually, or that the search is carried out on the hard disc search function across the case study files on the computer, which also works fine. The purpose of this approach is to explore qualitatively the nuances and nature of the concept in question.

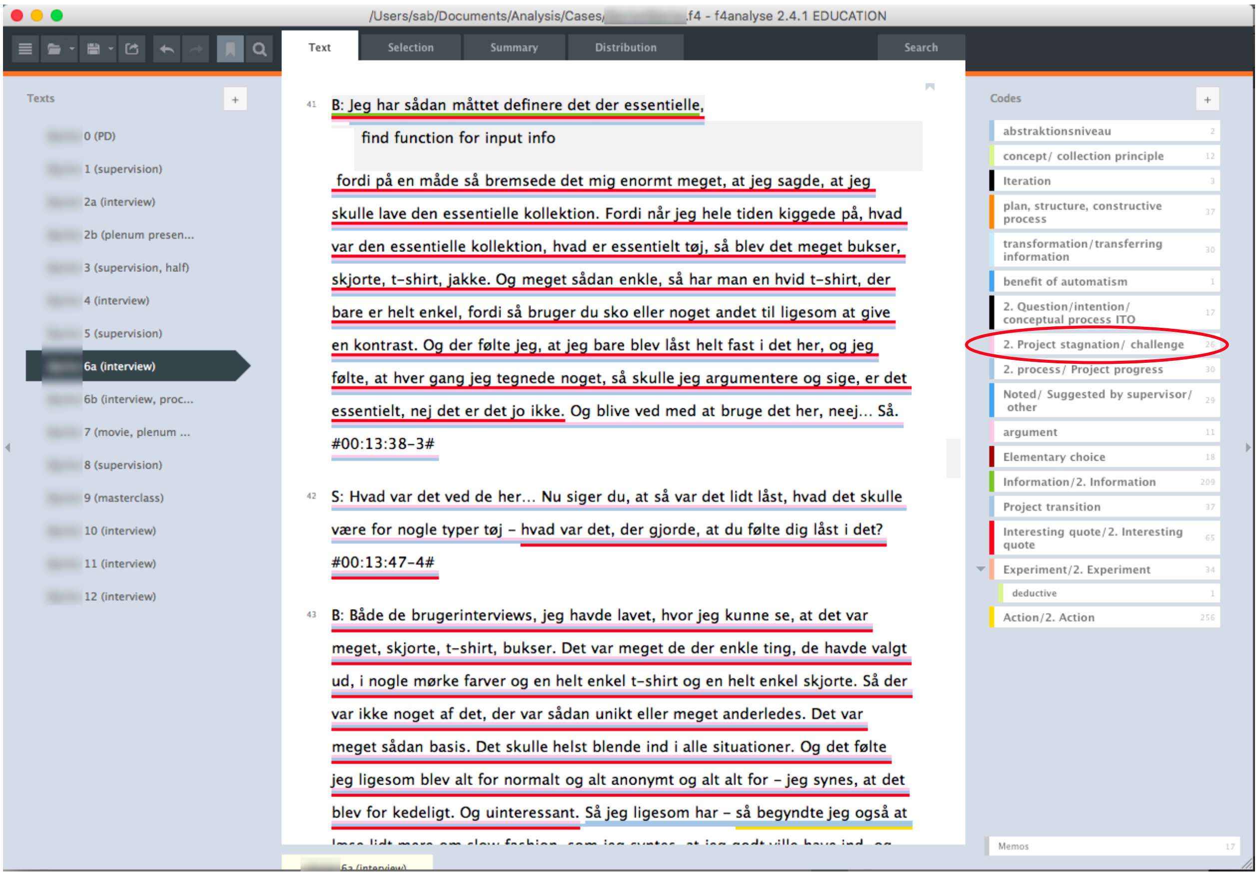
The majority of deductive analysis in the study has been undertaken for qualitative purposes: to explore the nuances and maximise the perspectives on the concepts studied, rather than with quantitative conclusions in mind, e.g. to count the frequency of occurrences.

An example of 'deductive' analysis can be found in my investigation of the concept of 'stagnation' in the dissertation. Here, I used the two 'deductive' analysis approaches.

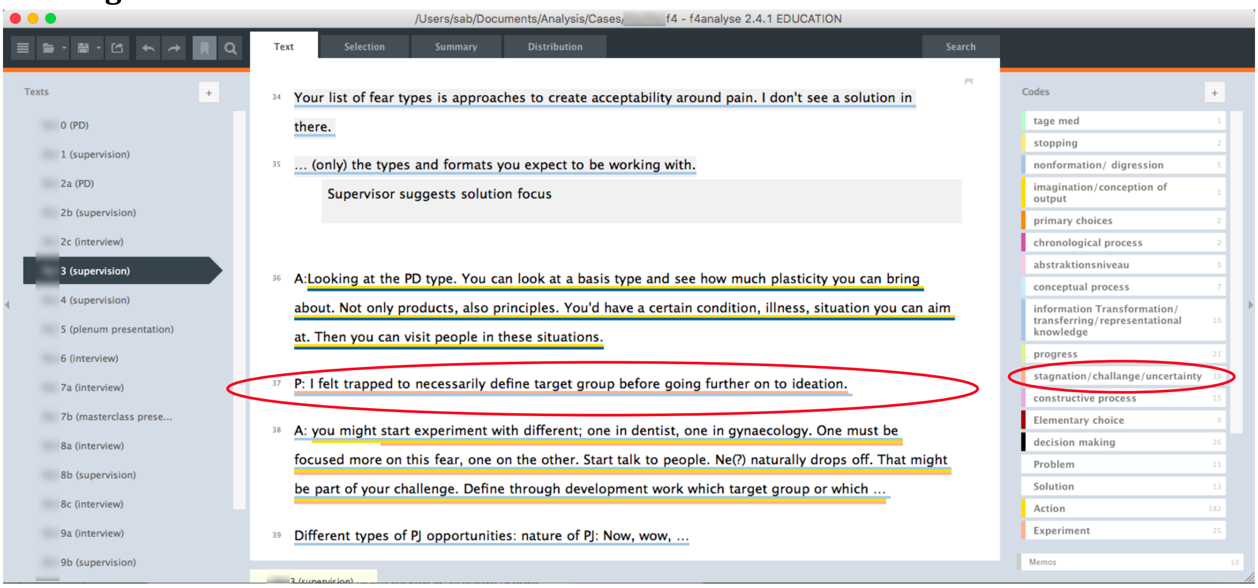
'Stagnation' has been an implicitly orienting concept from the beginning of the research process (though the term was assigned later), since it relates intrinsically to the topic of how processes move forward. In the case study analysis, it was first tagged with a code as an 'inductive' bi-product of other analysis endeavours in the first case analysed, and subsequently it became explicitly orienting for a 'deductive' analysis (approach 1) through three cases, before I shifted to a structured search approach (approach 2).

In the deductive analysis (approach 1), the stagnation concept was merely emerging. This can be seen in the pictures below, showing excerpts of this analytical approach in which the code tags (which later congregated to the concept of 'stagnation') are called something different in the cases.

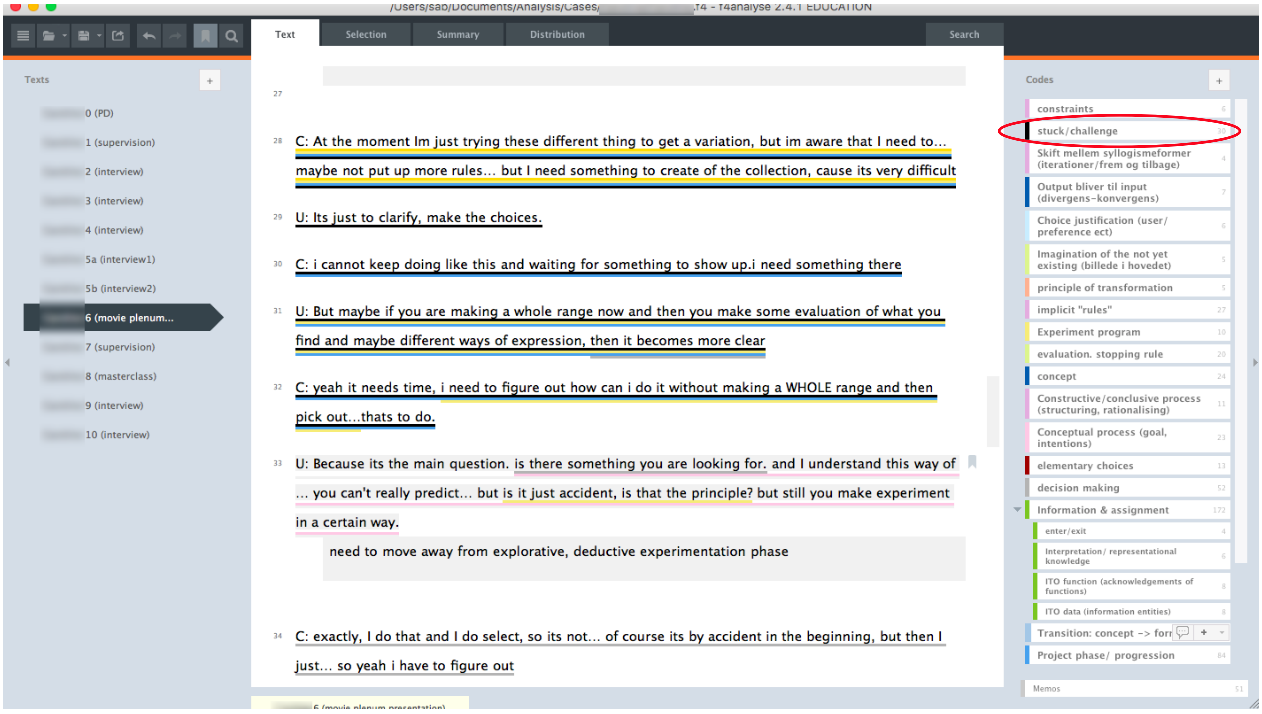
Designer f1



Designer i3



Designer f2



After coding data, I made a document in which I started to tentatively cluster the instances found. An excerpt of this document is displayed below.

Types/instances

Need information

External problem

Designer i3: *"I think it's hard to work in this kind of project where I haven't chosen which problem I want to solve."*

Technical knowledge

"I am a bit unclear as to exactly what kind of mechanics and technology has to go into the actual device" (i3, 7a, 116).

Target group

Designer i3: *"I felt trapped to necessarily define a/the target group before going further on to ideation"* (i3, 3, 37)*output information+phase shift

Function

"I haven't really started giving form to anything yet." (i3, 6,4). *"It is kind of hard to even settle on form, before you have the function"* (i3, 6, 43)

Form-inspiration

The following conversation is reconstructed from notes:
Designer f2: *"I feel lost in the concept. I am unsure how to interpret the pictures on the board. I can make clothing from those people-pictures on the board in combination with those pictures of a mattress. That's no problem for me."*
Interviewer: *"What is then the problem with doing it? Why do you feel lost?"*
Designer f2: *"Maybe I lack some form of inspiration in the project. I don't know if I should use classic clothing as reference."*

Physical material/fabric

Designer f2 is soon to go on a material (fabric) shopping trip. Thus she expresses that at the moment she is *"in kind of a waiting position with regard to materials"*. (f2, 3, 29)

Principles

Designer f2: *"[Generally] I feel fine about not having principles [of how to work], but in some parts of the project, I am not good at making things easy for myself"* (she knows that she could self-impose order to ease her task??).

Output information/evaluation criteria

Designer f2
"At the moment I'm just trying these different thing to get a variation, but I'm aware that I need to… maybe not put up more rules… but I need something [criteria] to create the collection, cause it's very difficult. (…) I cannot keep doing like this and waiting for something to show up. I need something there. (…) I need to figure out; how can I do it without making a WHOLE range and then pick out." (f2, 6, 28-32)

Designer f2
Designer f2 is retrospectively expressing the need for information in the conceptual process. This is a process level statement.
"I think I might have lost direction [in this project]. And that's why it has been hard to make decisions. So probably it's here I have had the biggest problem" (f2, 10, 264)

Designer f2
Designer f2: *"I think I am actually seeking something [an effect] that is not the tunnels, but maybe, I don't know, [a] small detail or something so that it doesn't have to be that big and voluminous…"* (f2, 6, 43)

Designer i3
"I felt trapped to necessarily define a target group before going further on to ideation". *phase shift

Need for concept

Designer f2
Designer f2: *"From the very beginning, I could have used that I was sharper in forming a concept. (…) I was very rambling in some way and like "is this it?" (…) So it was really hard to determine it."* (f2, 10, 77)

Need for input information

Designer f2*overcoming
Designer f2: *"I had experimented over and over again [with the technique]. And at one point I realised I needed a method to move on from there. So then I chose a point of departure that I could work from."*
Interviewer: *"Did you miss something to put into the technique? Was that it?"*
Designer f2: *"Yes, exactly"* (f2, 10, 288-290)

Designer f2 (input or transformation?)
"At one point I had experimented a lot and found this [top] shape that was funny. And then I had a hard time moving on, because, okay, what do I do [with the technique] in a pair of pants? What do I do in…? To create some variation" (f2, 10, 59).
She further explains:
"When I had to find out, ok there's something here that works, how do I then use it in the rest of my collection? So at one point I was a bit lost with regard to, like, okay how do I move on from here?" (f2, 10, 73)

Need for transformation information

Designer f2 has worked with a draping technique on the styles she is going to realise. The draping technique is very time consuming, and therefore she does not have time to carry on with that way of working for the rest of the (drawn) collection. She now needs a way to transfer principles from her draping work to the rest of her collection to be designed, without actually draping each style. She says *"I ran into a big challenge, when I came to sketching the collection itself, because somehow I did not realise, okay if I do this, then I know it will work. (…) I simply did not have time to experiment [with the draping technique] with all these things, and just explore (…) [I] just had to realise that it was a completely unrealistic project [to drape all individual styles]. So in that way I thought it was hard in this part"* (f2, 10, 157 - 161).

Designer f2

"I couldn't have tunnels on all of it [the collection], but what was supposed to happen on the rest of the styles? I wish I had had more time for that, to…" (f2, 10, 163)

Need to manage (hampering) constraints (symptom: too narrow frame), interpreting information (e.g. going from abstract to concrete: from processual to procedural information)

Designer f1
"I'm struggling with how sustainability should be (part of the project). It should be a part, not the subject. You can use it (the clothes) year after year. It's a challenge finding environmentally friendly material. I need to find a sustainable focus" (f1, 2b, 28-31).

Designer f1*(overcoming)
Designer f1 wanted to make 'the essential collection', but at the same time felt that this idea held him back, and that he *"was only allowed to make basic things like a simple white shirt, a black shirt or black pants. Where I didn't feel I had any scope of action as a designer or felt that I could contribute something new or show who I really was and what kind of aesthetics I had"* (f1, 12, 155). He said he *"didn't really know how to use it"* and was confused and unsure whether he should make *"a basic collection that was very minimalistic or take it in another direction"* (f1, 12, 155). Thus, he *"had to define the 'essential'"* to find out what it could mean in his project (f1, 6a, 41).
He says, *"when I continuously looked at what an essential collection is, what essential clothing is, then it was a lot about pants, shirt, t-shirt, jacket. Very, like, simple (…), and there I felt locked in this, and I felt that every time I drew something, then I had to argue and say, "Is this essential? No it isn't." (…) It [the clothing] had to be able to blend into every situation. And I felt that became way too ordinary and anonymous, and way, way too boring. And uninteresting"* (f1, 6a, 41-43).

Designer f1
In an interview, Designer f1 explains that sometimes during the project he has felt that he has lost himself, partly because of the steering simplicity in the mood board. He felt that *"perhaps I have peeled off too much of my personality in this thing. (…) I feel that it [the collection] has had to be so simple. And you could say that that is also what my mood board has been like, and the things I weighted to begin with, which I have then [later] felt was not really what I wanted"* (f1, 10, 114-132.)

Designer i3*
Designer i3 initially contemplates to do the project as a collaboration with a medical company. After having discussed different options with the company, he gives up the idea as he realises that the collaboration would constrain his project too much. He says, *"the areas they took me into were already well discovered (…) They are specialised in a very narrow field. I didn't find any obvious place where I could do something really good within these areas."*

Need experiment (experience) is also about missing information

Interview with Designer f2, regarding colour:
Designer f2: *"It is as if something is still missing. It needs to be worked out along the way."*
Interviewer: *"How do you feel something is missing?"*
Designer f2: *"Well… In the beginning I didn't have the yellow [from the foam material] and thus the colour combination was completely dead. But I don't know… I think maybe there needs to be another strong colour, it needs at least to be tested to kind of find out if something is really missing, or if it is just, like…"*
Interviewer: *"What does it mean that it needs to be tested?"*
Designer f2: *"That I need to sit and make samples/tests in the same scale, I think, where I can weigh how much or little of dark and light and what if I added some other colour, more green or whatever I have been working with, what does it then do? Does it do something that's good for it [the whole picture] or not?"*
(f2, 4, 41-43) example of epistemic uncertainty without plateauing as a way forward is already suggested by the designer

Afterwards, I conducted a structured search across the data set for instances that might be associated with this concept. The indicator words were taken from the previous analysis and were likewise theoretically guided by the concept of 'epistemic uncertainty' and indicator words found to represent this concept proposed by Ball et al. (2010).

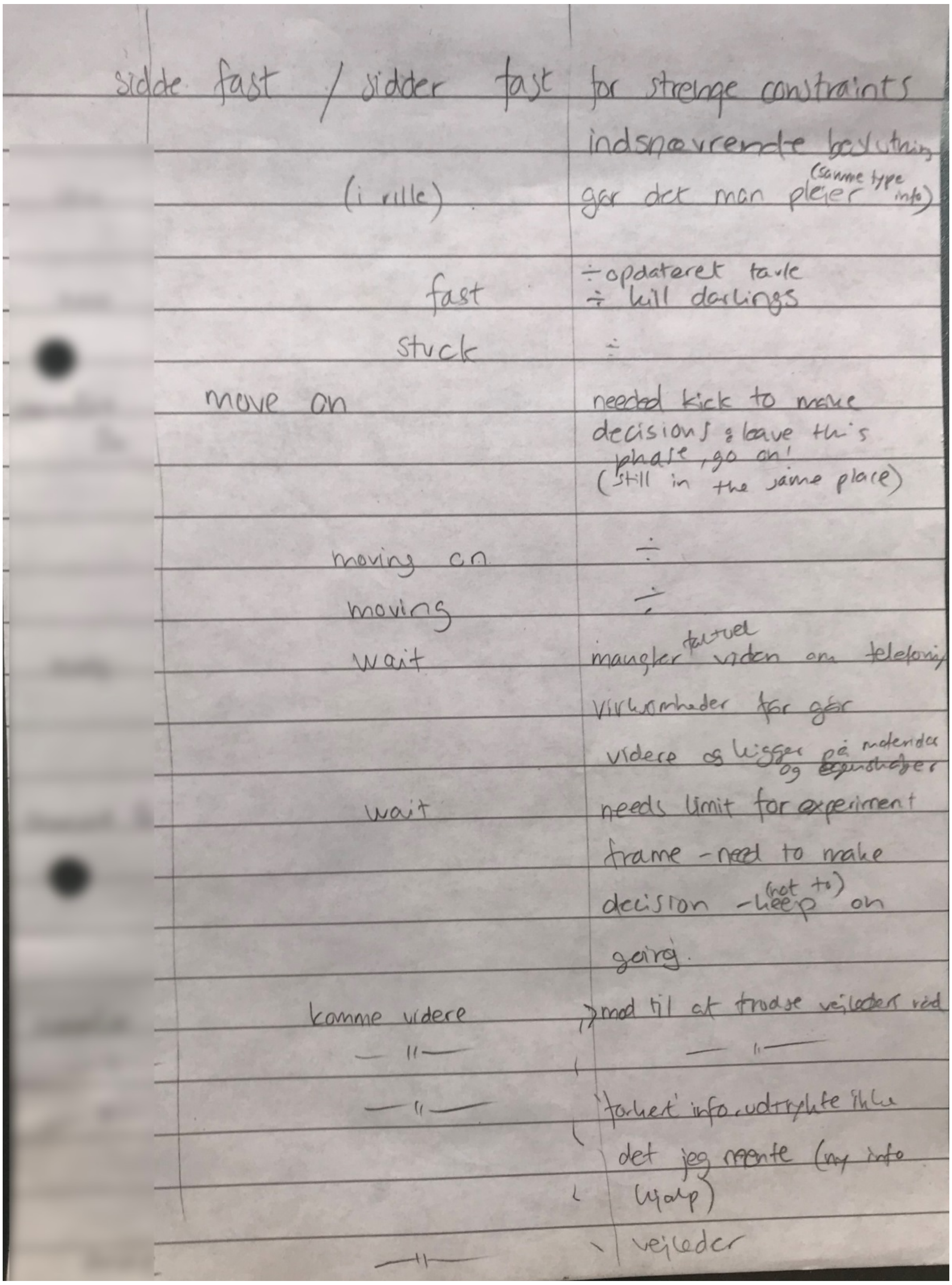
Because I found in the previous data analysis that statements about stagnation or challenges are sometimes phrased inversely (e.g. "I wish I was able to move on") or accompanied by statements regarding strategies for how to move on (hypothesised or reported in retrospect), I used both types of indicator words in the search for stagnation instances[7]:

- Stagnation: stuck, lost, waiting, difficult, unsure, insecure, doubt, don't/didn't know, same place, not sure, hard, struggling, missing, problem
- Move on: proceed, move on, continue, I need, have to

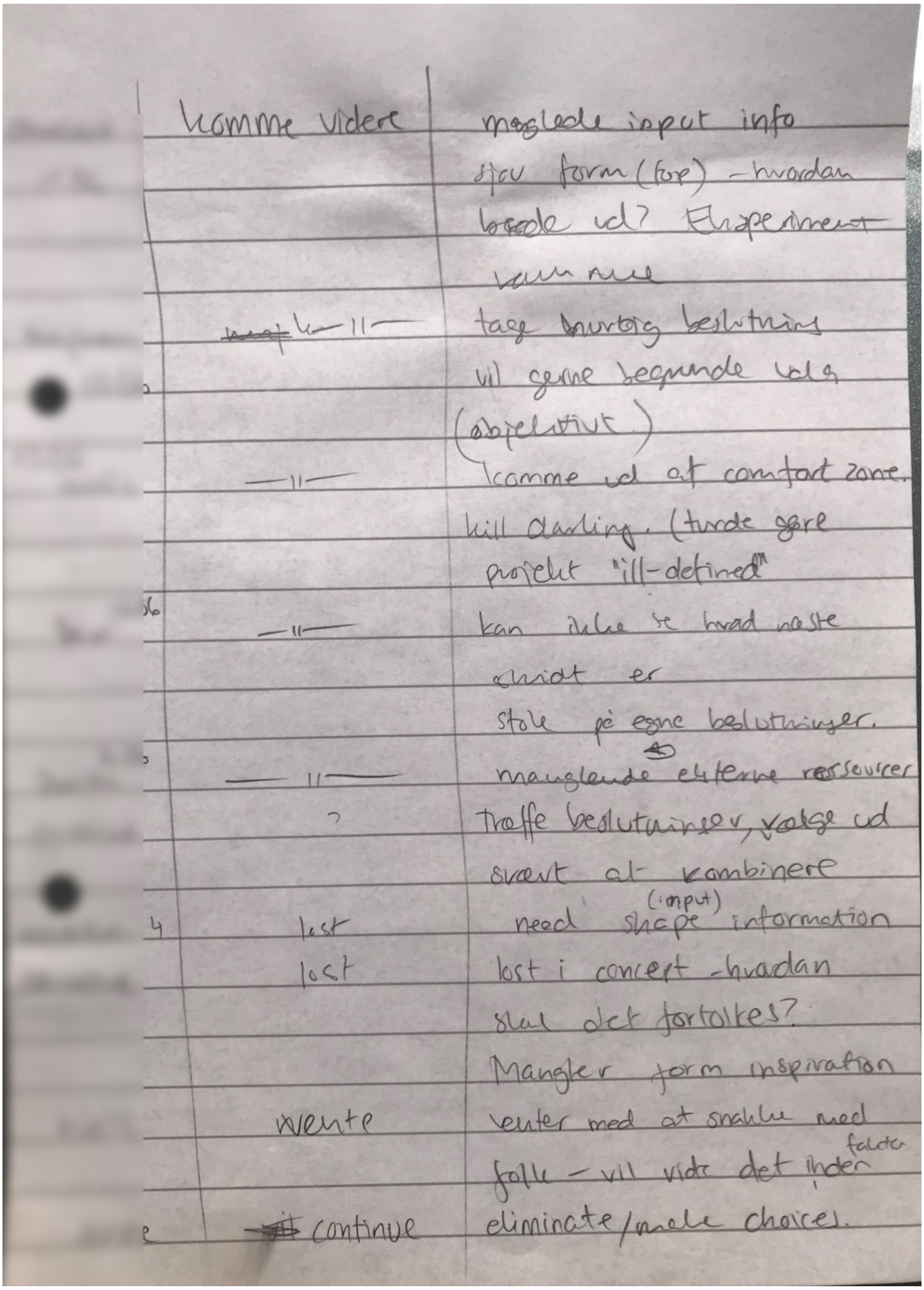
The instances were then assessed qualitatively for their relevance or representativeness of stagnation. The findings were listed in a (handwritten) table. An excerpt of this is shown below:

[7] I also used similar Danish words, which are not mentioned here.

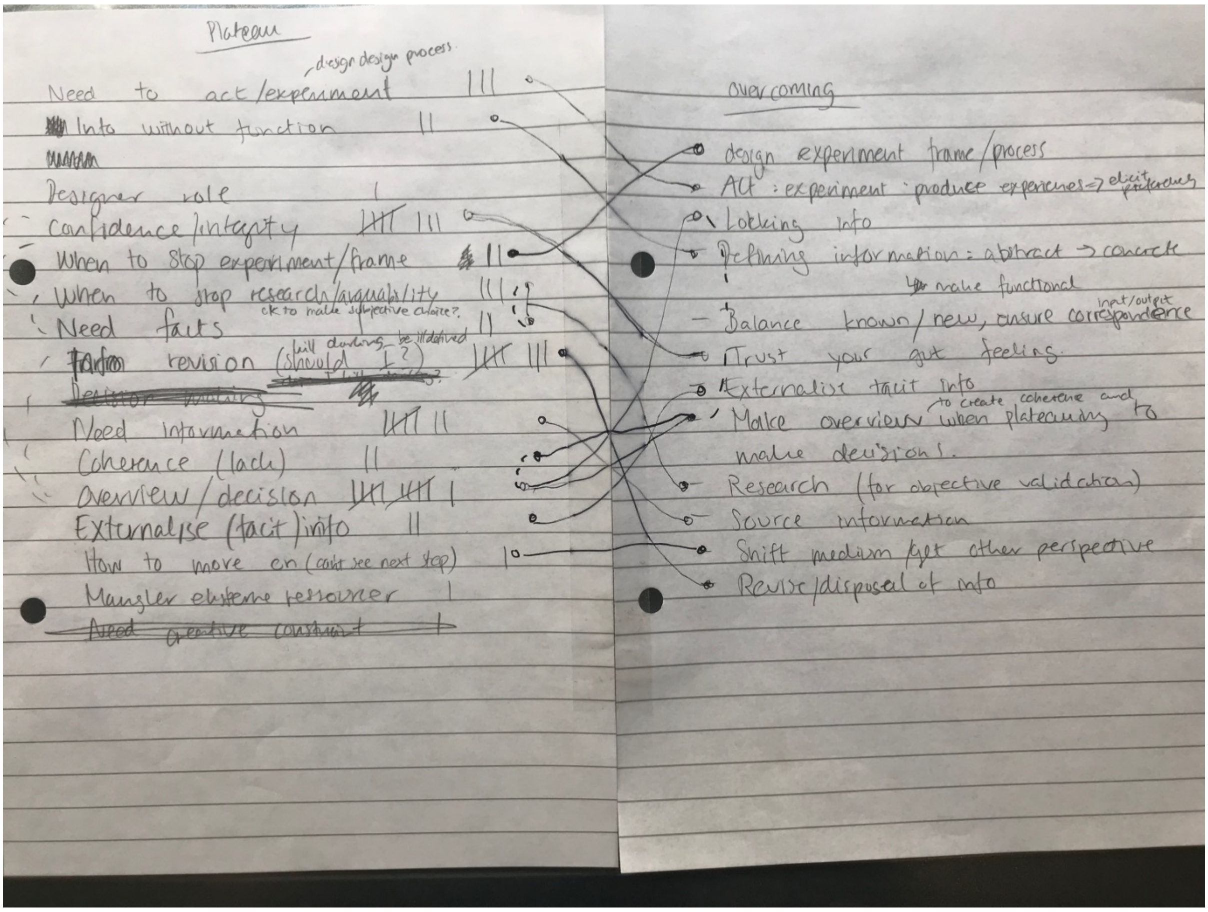
Designer	**Indicator word**	**Stagnation/ challenge type** (What is the challenge related to? Abbreviations based on the designers' words)



	sidde fast / sidder fast	for strenge constraints indsnævrende beslutning
	(i rille)	gør det man plejer (samme type info)
	fast	÷ opdateret tavle ÷ kill darlings
	stuck	÷
	move on	needed kick to make decisions & leave this phase, go on! (still in the same place)
	moving on	÷
	moving	÷
	wait	mangler faktuel viden om telefoni virksomheder før går videre og ligger på metoder og egenskaber
	wait	needs limit for experiment frame - need to make decision - keep (not to) on going.
	komme videre	mod til at trodse vejleders råd
	— " —	— " —
	— " —	forket info, udtrykte ikke det jeg mente (ny info hjælp)
	— " —	vejleder



From this list of stagnation and challenge types, I summed up the different kinds, clustered them into types and counted their frequency in order to find out which types were most frequent. See the picture below. Additionally, I compared the stagnation instances to types of 'overcoming'.



As the example shows, I analyse data deductively by the two approaches, and in the last picture I start to prototype by examining new connections.

As mentioned earlier, the deductive analysis approach is not purely deductive, even though it is instigated and based on specific orienting concepts and frameworks. The open approach to data analysis and coding allows for what we could call the 'back-talk' of the data, if using a design process analogy. This openness – together with the iterative analysis process and in line with the adaptive theory approach – lets new insights and concepts arise inductively from the data and asserts an adaptive influence on the emergent theory throughout the process.

In Appendix 9 I have shown a series of elaborated examples of the analysis and coding procedures through consecutive iterations of theory building (prototyping), deductive analysis, and inductive analysis.

General remarks

The two mutually informing tracks of research, with empirical and theoretical focus respectively, represent the acknowledgement of the deep and layered nature of reality and the need to combine substantial and general theory as well as perspectives of agency and underlying structures to maximise the explanatory power of emergent theory.

As the analysis and theory building in this study have taken place by constant comparison between extant theory and data in a continuous oscillation, the two tracks of study have been practically intertwined in the research process, and they have illuminated each other in a continuous exchange.

Theoretical studies have provided orienting concepts informing the theoretical pre-understanding of design, for example *constraints*, *problem*, and *solution*. As evident from the contributions of this dissertation, which depart from those concepts, they have been truly (and merely) orienting in nature and have served to 'crank start' theorising in a non-dogmatic manner.

The comparative examination of theories has inspired new, synthesised provisional frameworks, for example the framework of triadic co-evolution (Chapter 8, 8.2), which have guided analysis of data and comprehension of practice. Additionally, ongoing theory studies have helped, by comparative analyses, to sharpen and delimit the numerous concepts developed during this study.

The empirical study has emphasised inadequacies in the prevalent theoretical descriptions of design to unifyingly charactiserise design practice. In the course of the research process, aimed at understanding practice, insights were obtained from data which gave rise to new sets of orienting concepts, on the basis of which data were analysed. These were for example *Information* (material) and *Action*, and *Input*, *Transformation*, and *Output*. The insights obtained in the research process prompted the establishment of a new system of terminology foundational to design epistemology to replace the existing one.

Due to the deep ontology of Critical Realism and Adaptive Theory it is assumed that structures exist beneath the empirical surface. In this study, I have likewise 'transcended' the superficial heterogeneity and fuzziness of design processes and identified general structures, for example the ITO function structure (Chapter 9), and mechanisms, for example Design Syllogisms (Chapter 12).

By the inclusion of (general) theory in the typologies and models developed in the research process, I have been able to work transcendentally with the data: Instances of empirical findings have inspired me to include universal or theoretically established concepts or distinctions such as *internal/external* or *objective/subjective*, in the categorization of findings. The typologies have been built in the form of matrices or orthogonal classification schemes. These can be more comprehensive and conceptually exhaustive than the empirical findings themselves, whereby the data are 'transcended'. If for example a matrix spans more categories than are represented by the empirical findings, the categories can serve as new 'orienting concepts' for further data analysis or as a logical extension of empirically derived concepts. This is for instance the case with the development of the problem typology, which combines dimensions of 'complexity' and 'delineation' (Chapter 4, Figure 19 and 20).

Likewise, transcendence can take place when empirical findings or theoretical models are analysed comparatively. If an emerging framework is to be comprehensive enough to comprise the two things that are compared, it may need to extend beyond them both and be ascribed new meaning. This was the case with the triadic co-evolution framework, which was combined from two existing theoretical models (Chapter 8, Figure 40).

Given the philosophical grounding in Critical Realism, I adopt Healy and Perry's (2000, p. 122) criteria for qualitative studies within a realist paradigm. Spanning the elements ontology, epistemology, and methodology, Healy and Perry develop six criteria for judging research quality in qualitative research: Ontological Appropriateness, Contingent Validity, Multiple Perceptions of Participants and Peer Researchers, Methodological Trustworthiness, Analytical Generalisation, and Construct Validity. Table 2 below shows how the criteria are appropriated in my study.

Criteria			Healy and Perry's description[8]	Application in my research
Ontology	1	Ontological Appropriateness	A) Research problem deals with complex social science phenomena involving reflective people (Popper's world view 3). I.e. complex social phenomena involving reflective people; the world of ideas, art, science, language, ethics, Institutions. B) Selection of research problem, forexample, it is a how and why problem?	A) Although I (1) do not entirely agree with Healy and Perry's comparison between Popper's 3 worlds (Healy & Perry, 2000, p. 120) and the ontology of Positivism, Constructivism, and Realism, respectively, and (2) do find Popper's world distinctions a bit static in its ignorance of action, I do, however, consider my study object as pertaining to Popper's world 3 out of his three options. B) Since my problem is of explanatory nature, it matches the relevance of a realism study.
	2	Contingent Validity	A) Open "fuzzy boundary" systemsinvolving generative mechanisms rather than direct cause-and-effect. B) Theoretical and literal replication, in-depth questions, emphasis on "why" issues, description of the context of the cases.	A) Design processes are referred to as 'fuzzy' due to their complex nature and heterogeneity across projects. Like all social phenomena they are not stable, and causal impacts are contingent upon their environment. When, in this research, common traits are found among the various design processes studied, despite their dissimilarity, they reveal fuzzy boundary system mechanisms that work between the disparate phenomena and the underlying structures. B) By choosing a handful of cases from two very different design disciplines my case study design replicates both literal (within the same discipline) with the expectation of comparison of similarity, and theoretical (between the two disciplines) with the expectation of comparison of differences. During data collection, I repeatedly use in-depth interviews, yet I asked both what, how, and why the designers do as they do. The focus of the research is, partly, of an explanatory nature, in alignment with the 'why'-focus.
Epistemology	3	Multiple Perceptions of Participants and Peer Researchers	A) Neither value-free nor value-laden, rather value-aware B) Multiple interviews, supporting evidence, broad questions before probes, triangulation. Self-description and awareness of own values. Published reports for peer review	A) My value-awareness lies in, as Healy and Perry states, accepting "that there is a real world to discover even if it is only imperfectly and probabilistically apprehensible." Thus, neither a positivist, objective, value-free, nor a constructivist, subjective, value-laden relation to the world. B) My study includes numerous interviews and observations of supervision sessions. Besides, it includes supporting evidence in the form of visual and written documentation of case project progression. I apply triangulation in the data collection method as well inferential Theory Generation.
Methodology	4	Methodological Trustworthiness	A) Trustworthy: the research can be audited B) Case study database, use in the report of relevant quotations and matrices that summarise data, and of descriptions of procedures like case selection and interview procedures	A+B) All data are kept in both a physical and a digital database, which ensures good overview and access to the data respectively. In Appendix 3, I display a visual overview of my entire data pool. Further, I have sought a clear chain of evidence between data, method and findings, and to carefully elaborate on all procedures of the research.
	5	Analytical Generalisation	A) Analytic generalization (that is, theory building) rather than statistical generalization (that is, theory-testing). B) Identify research issues before data collection, to formulate an interview protocol that will provide data for confirming or disconfirming theory	A) Applying continuous inferential oscillation, as described in Adaptive Theory and resembling the Grounded Theory constant comparison method, the study seeks to continuously adapt emergent theory to incoming data, thereby building theory, though on a firm ground of existing theory, as prescribed by AT and CR. B) Data collection initiation and analysis is conducted on the basis of orienting theoretical concepts (Layder, 1998, p. 38), thus aiming to expand and generalise theory (analytical generalisation) (Yin, 2014, p. 21).
	6	Construct Validity	Use of prior theory, case study database, triangulation	In accordance with Yin, I apply three tactics for securing construct validity: With my multiple case study design and my method triangulation, I have multiple sources of evidence. I established a clear chain of evidence, as described above and I have continuously, during data collection, summarised with my informants what happened in their project last time we talked to align understandings. Additionally, I base my research on a solid base of prior theory.

Table 2: Healy and Perry's six criteria for judging research quality in qualitative research

Part II: Revisiting Existing Theory

This part consists of a critical literature review of prevailing existing design theory. Firstly, in Chapter 3, I introduce the concept 'problem', which is pervasive in design theory: its role along the development of design methodology, and the complications associated with it. Secondly, in Chapter 4, I turn to the theoretical context in which this concept is situated: the theoretical models by which design is described. In this Chapter, I likewise account for the way creative generation is often black-boxed in these descriptions. Thirdly, in Chapter 5, I delineate the interlinked family of concepts, which characterise the existing theoretical design descriptions, and which are centred around the concept of 'problem'. These concepts form the picture of the prevalent design process understanding.

3. Design Problems

In design theory design processes are commonly described in terms of problem solving. Hatchuel et al. (2013, p. 149), for example, state that *"Design has often been seen as a sophisticated, ill-structured or messy type of problemsolving."* However, there are many problems related to the concept of 'problem' in design which can potentially be a barrier to the development of a better understanding of design. This chapter will account for the role of the ubiquitous problem in design and design methodological development and subsequently discuss the problems with the 'problem'.

Problems in Design

When entering the field of design, whether as a practitioner or as a theoretician, one of the first concepts one encounters is that of the *design problem*. When action is taken on the problem, follows the concept of *problem solving* – a concept commonly used in design theory to describe the mechanism of travelling from beginning to end in a design process. These concepts – *design problem* and *problem solving* – permeate the design discourse referring to the tasks and consequent activities in which designers engage.

One way to understand and distinguish the 'problem' and its role in design is by examining how it relates to different stages throughout the historical development of design methodology. If we take the often used distinction between well- and ill-defined problems (Reitman, 1964) and have these terms represent the distinction more generally, it will signify the rift between paradigms characterising the discursive development of design methodology in a simplified form.

The first generation

Sprouting from the 1920s modernist and Bauhaus movements, design methodology as an academic field as well as the 'design methods movement' were, however, first established in the early 1960s with landmarks such as the first Conference on Design Methods held in London in 1962 (Broadbent, 2003, p. 4) and the first PhD dissertation published on design methodology – Christopher Alexander's *Notes on the Synthesis of Form* in 1964 (Bayazit, 2004, p. 18). Underlying and influencing the emergence of the field was the contemporary research paradigm of reductionism and technical rationality (Galle, 2011, p. 83). As a positivistic stance it emphasised the separation of research from its object, which was considered objectively knowable, independent of the practitioner's values and views (Schön, 1983).

In particular the fields of Operational Research and Management Science (Broadbent, 2003, p. 4), focussing on analytical methods to improve decision making, and Computer Science, including Artificial Intelligence (AI), influenced the early design methodology. AI research developed new computer technology aiming to make computers solve more complex and diverse problems after the manner of humans (Reitman, 1965, p. 4). This attempt is exemplified in the development of different information processing models, e.g. The Logic Theorist (Newell & Simon, 1956), and the General Problem Solver (Newell, Shaw, & Simon, 1959). The human mind and problem-solving abilities were studied by regarding people as Information Processing Systems (IPS) (Newell & Simon, 1972). It was in the light of this technical, rational development, and based on the belief that human decision making and problem solving could be analysed and captured as a stable, rational process (e.g. Polya, 1957; Reitman, 1964), that early design methodology arose.

According to Dorst (2004, p. 4), *"One of the basic assumptions of the theory of technical rationality is that there is a definable design problem to start with,"* and it directs *"systematically-ordered thinking concerned with means definition in well-structured problems in which desirable ends can be stated"* (Checkland, 1983, p. 667). This well-defined problem was directly related to computerization of problem-solving procedures in IPS's – machine or human. Rittel states that in order to programme a machine to solve problems all potential solutions have to be anticipated in advance, which is why all that problem-solving machines can do is merely reconfigure information already provided (Rittel, 1972 in Cross, 1984). In other words, all information has been provided in advance, and the solution can be found by searching a confined space of options.

The earliest paradigm of design methodology, also called the 'first generation' of design methodology – a term proposed by Rittel in 1973 (Vries, Cross, & Grant, 1993) – or the 'hard systems methods' (Broadbent, 2003), is linked to an understanding of problem solving coined by a technical rational model. That means that the problem is considered given and well-defined, the process of solving it is linear, stable, and rational, and the criteria as well as the nature of the solution is known in advance. In design methodology this entails the aim and the belief in the feasibility of systematising and externalising design methods (Bayazit, 2004, p. 18), dissecting the design process into discrete steps (Bürdek, 2005, p. 252), and 'scientise' design (Simon, 1969). Representatives of this generation are: John Christopher Jones (1963), John Luckman (1967), Morris Asimov (1962), Bruce Archer (1965), and, of course, the aforementioned Christopher Alexander. His 'pattern language' strategy (Alexander, 1964; Alexander, Ishikawa, & Silverstein, 1977) analysed and broke down problems into sub-problems and determined constructive diagrams turning requirements into form.

The second generation

In the 1970s a reorientation began in the field of design methodology (Bürdek, 2005, p. 256). The original founders of the first-generation method movement began to strongly dissociate themselves from design methods and turned away from their previous aspirations to rationalise and optimise design, from the 'omnipotence' of the designer (Cross, 2007, p. 2), and from the *"continual attempt to fix the whole of life into a logical framework"* (J. C. Jones, 1977). In fact, Christopher Alexander suggested to 'forget the whole thing' about design methods (Alexander, 1971).

The contemporary technological and socio-demographic developments in the western world was leaving societies increasingly heterogeneous and differentiated (Rittel & Webber, 1973, p. 167). This increased complexity entailed the need to expand the notion of design (Friedman, 2005), so that what was previously considered the *context* of design – the surrounding world – was included as an *object* of design itself (Bürdek, 2005, p. 258). This development caused a pervasive criticism of the positivist position and the first generation and its methods. For example, Reed and Evans (1967, in Broadbent, 2003, p. 4) complained that they were *"largely unable to address the 'unbound complexity' of the real world,"* and Rittel and Webber (1973, p. 160) objected that the classical paradigm of science and engineering was not applicable to the planning problems of open societal systems. Such problems were ill-defined and contextually complex, and Rittel went so far as to name them 'wicked'. They were characterised by being unique, having no definitive formulation, no criteria, no stopping or testing rules for solutions. In addition they were networked and interconnected so that any attempt to solve these problems would change the situation with which the solution was affiliated (Rittel & Webber, 1973). The new 'wicked' circumstances entailed that the understanding of the problem-solving process went from one of a linear and stable nature to one of unpredictable iterations in which the premise and the problem changes through trial and error experience and through conversation with the situation and the material (Lawson, 1980; Schön, 1983). The absence of definite requirements meant that the criteria could no longer be to find the optimal solution to a set of given requirements, but rather just to find a satisfying one. Simon (1969) gave this procedure the name 'satisficing' (p. 64).

To understand how this process unfolded researchers shifted their focus from distant, scientific and rational models of human decision-making and action to a focus on *practicing* professionals, whose particular enacted knowledge Schön (1983) named reflection-in-action', and to a direct study of these people in their engagements with the wicked or ill-defined tasks. Likewise, the increased societal heterogeneity and the wickedness of the pressing problems led to increased stakeholder involvement (Broadbent, 2003, p. 7) in participatory processes (Cross, 2007, p. 2), where shared learning ranked higher than goal-seeking (Broadbent, 2003, p. 8). Rather than questioning which problem to solve an approach increasingly gained ground to ask first for *whom* it was intended (Bürdek, 2005, p. 257). This shift to what Rittel (in Cross, 1984, p. 304) proposed to call the 'second generation', or the 'soft systems methods' (Broadbent, 2003) marked a paradigm shift, by model of Thomas Kuhn (1970), in design methodology.

On the one hand the introduction of the second generation was signified by arguments pointing to the aforementioned inadequacies of the first generation, as well as statements concerning the need to establish design as a discipline with its own scholarly merits and methods to tackle its own kind of problems, as set forth by e.g. Bruce Archer (1979) and Nigel Cross (1982). On the other hand, the second-generation design methodology was characterised by the empirical study of design practice, predominantly architecture, which gained ground with pioneers such as Bryan Lawson (1980), Omer Akin (1979), Jane Darke (1979) and Donald Schön with his ground-breaking book *The Reflective Practitioner: How Professionals Think in Action* (1983).

It deserves mention, however, that design research was branching along with the disciplines of its practice. Thus a field of systematic engineering design methodology developed parallelly in the 1980s (Cross, 2007, p. 2). This field applied computer-aided design, Operational Research models and systems analysis to their method development, and here the relationship between design research and computer science, especially cognitive science and AI, remained interconnected (Bayazit, 2004, pp. 26-27).

The following generations

There seems to be no consensus among design researchers about what characterises the obvious next generation of design methodology, though there is indeed agreement that the field is in transformation. In the late 1970s Geoffrey Broadbent proposed a third generation of design methods synthesising the best aspects of the first and the second generation based on Popper's 'conjectures and refutations' model. According to that theory the designer makes design conjectures that must be open to refutation and rejection by the people for whom they are made (Cross, 1984, p. 306). John Broadbent (2003) suggested the concept of *evolutionary systems* in which design has a 'fuller societal purpose of an evolutionary guidance system' as a replacement for the soft systems methods. Cross (2007), in his account of the expansion of the design research field, points to 'Design Thinking' as one of the major developing areas. Bayazit (2004) notes the significant growth in doctoral design research and philosophy as areas of methodological development. Perhaps the multiplicity of perspectives and development strands in design methodology could be explained by John Broadbent's idea that these paradigms shift with exponentially growing frequency (2003, pp. 9-10). Or perhaps any period in time will face the challenge of labelling itself before it has passed. One thing is certain, however: ongoing and potential directions of developments in design methodology are manifold.

Co-evolution

To account for the development in the understanding of problems I shall point to another path of development in design methodology in which the perspective on the problem has undergone a notable change, namely 'co-evolution'. The theory of co-evolution of problems and solution spaces in design processes was developed by Maher (1994) and Maher & Poon (1996) on the basis of genetic algorithms. It has been further advanced and popularised by Dorst and Cross (2001) and recently by Wiltschnig, Christensen, & Ball (2013) in a contribution –"Collaborative Problem–solution, Co-evolution in Creative Design" – that won the Design Studies Best Paper Award that year.

The basic logic of the co-evolution theory of design is that problems and solution spaces co-exist at any given state of a process, and they co-evolve in a continuous and mutual relationship of affecting and adapting to each other through a transforming fitness function, where each space state is defined by the current state of the other space. Rather than viewing the problem as a matter of process initiation and the solution as a matter of process termination, this theory implies that both problem and solution must receive equal consideration from the very beginning and all the way through the design process.

From the above account of design methodological development three dominant types of process understanding can be elicited. A conceptual visualisation of the three types can be seen in Figure 16.

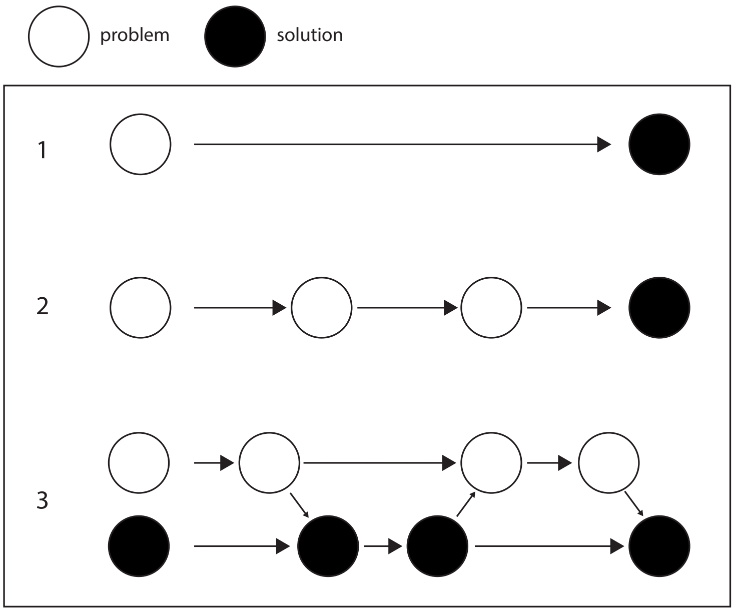


Figure 16: Three types of problem-solution processes.

Figure 16 shows three different notions of the relationship between problem and solution, resembling the paradigmatic development in design methodology. Process type 1 reflects the linear process of the hard systems methodology, where the problem is given at the outset and the solution is the destination of the process. Type 2 reflects the iterative process of the soft systems methodology in which the problem changes throughout the process, and type 3 reflects the notion of co-evolution of problem and solution throughout the design process.

The Problem of the 'Problem'

The problem concept has become well-established in the realm of design and is more often than not left undefined and undisputed. However, the problem term is not an unequivocal concept by which to understand design processes. This section will address and discuss problems with the problem concept in design.

In his eponymous paper, "On the Problem of Design Problems," Dorst (2004) points out that most *"process-focused design methods seem to incorporate strong assumptions about what design problems are"* (p. 2). Such implicit assumptions about design problems come to represent and perhaps even direct the way we can understand the very nature of design. Thus, if we wish to achieve a further understanding of design, a good place to start is to recognise and question the assumptions underlying the existing beliefs. As I will argue in this section, the concepts of *problem* and *problem solving* represent obstacles with regard to attaining a comprehensive epistemology of design – one that can consolidate the ground of learning, practicing, and studying design across disciplines.

In the aforementioned paper, Dorst (2004) points to at least three problems of design: First of all, Dorst problematises the fact that implicit assumptions pervade the concept of design problems. These are a consequence of what he calls 'the blind spots' of design methodology: the first of these is the absence of research into and understanding of the design problem concept; the second is the under-determination of design problems that make them difficult to analyse and compare and hence hard to capture and typologise theoretically. The third blind spot he mentions is the problem of determining which part of what we normally call the design problem is the actual design problem. Here Dorst refers to what he calls problematic situations and to Dreyfus' notion of 'breakdowns' in the normal, fluent problem-solving behaviour to describe situations of particular challenges. These challenging situations are related to surprise and require design choices (Schön, 1983) as opposed to routine action, and thus such situations could represent a revised and narrower definition of 'design problems'.

With his paper, Dorst initiates an important analysis of conceptual and philosophical problems with the design problem. In the following, I shall discuss some additional problems with the problem of a different nature:

Inconsistent interpretation

Sometimes a seemingly shared conceptual framework for understanding the relationship between problem and solution in design can obscure an inconsistent interpretation of the concepts. For example in the aforementioned accounts of co-evolution there is no clear consensus of how to define a problem and a solution: In a study of the design process for a train litter disposal system, Dorst and Cross (2001) refer to the designers' idea to "keep newspapers separate" – a functional requirement – as a "core solution idea" (p. 434). This is in direct opposition to Maher and Poon (1996) for whom functional requirements are indicators of the 'problem space' (p. 6).

Articulation of problem

Closely linked to the interpretation of the problem is the articulation of the problem. Many different aspects of a situation can be seen as an expression of a problem.

By analysing the aforementioned study of the design of a train litter disposal system described by Dorst and Cross (2001), Table 3 shows how different aspects of a design situation can be perceived as an articulation of a problem. Besides having different potential articulations, the problem is also characterised by an underlying ideal in contrast to which the problem is perceived.

Design Problem articulation		**Design example Dorst & Cross (2001)**
Commision	Given design task	Design litter disposal system for train
Conflict	Identified discrepancy from ideal	Newspapers are left behind Cleaners complain of mess
Commitment	Specific commitment to approach ideal	Litter disposal system should have separate newspaper holder
Complication	Identified obstacle to approach ideal	*The budget for litter disposal systems has been cut severely down*
Ideal	Preferred state of post design context	No mess in the train

Table 3: Design problem articulation

This raises the questions: Is a problem defined by specifications of the requirements that constrain the solution, by obstacles to achieve a preferred state or ideal, or by the identified current discrepancy from this state?

Not all design tasks are problems

Not every design project is motivated by or deals with what from a general perspective would be considered (solving) an exterior problem, such as relieving injection-related pain and anxiety in diabetic children, or resolving issues of contaminated water resources in Guinea. If the design task is endowed with a high degree of freedom, as was the case for my fellow fashion design students and myself at the design school, and which is generally the case in author-driven design (Eggink, 2009), the task can be initiated from the designer's motivation to express herself and explore new creative possibilities. Graham Wallas, the originator of the first creativity model, writes that the stages of much very important thinking, like poets or composers do, *"are not very easily fitted into a 'problem and solution' scheme."* He mentions that the success of such thinking can be *"the creation of something felt to be beautiful and true rather than the solution of a prescribed problem"* (Wallas, 1926, p. 54). The stages of his model will be mentioned in Chapter 4, 'Models of Design'.

Conceptual inadequacy

A critical issue with regard to design problems is that, despite the widespread use of the *problem* term in design theory, the way it is used reveals its inadequacy: The problem term is repeatedly preceded, negated, and invalidated by the prefixes that are added to it. The most prevalent of those prefixes are 'ill-defined' (Reitman, 1964), 'ill-structured' (Newell, 1969; Simon, 1973), and 'wicked' (Churchman, 1967; Rittel & Webber, 1973). Obviously, these prefixes serve to alter a preceding, original meaning of a problem as well-defined, well-structured, or tame/benign. Such well-determined problems are defined by the presence, and clear definition, of information describing the task and the evaluation criteria of its solution. This conception of the problem comes from the theory of problem solving on which design theory was initially built. It is well captured by Newell and Simon's (1972, p. 73) description of what it means to have a problem: *"Certain information is given to the problem solver: information about what is desired, under what conditions, by means of what tools and operations, starting with what initial information, and with access to what resources."*

It seems somewhat paradoxical that in order to make a concept fit the design situations, which we seek to explain, we must negate it. This leaves many theoretical descriptions of design dependent on notions which are merely residually defined from the concept of 'well-defined problems' – a concept that theorists generally agree is not characteristic of design tasks. This oddity gives rise to the speculation that perhaps 'problem' and 'problem solving' are not the best concepts to use to describe the act of designing.

The practical problem and the formal problem

Problems can be perceived in different ways. One way is what I shall call an 'every-day' use of the word 'problem'. The 'every-day' problem is a broad, universal concept referring to a discrepancy to an ideal in the context external to the person who experiences the problem. This is similar to what Polya calls a 'practical problem' (Polya, 1957, pp. 149-154). An example could be that my roof is leaking. Jonassen (2000) defines a problem by giving it two critical attributes: (1) *'an unknown entity in some situation (the difference between a goal state and a current state)'*, and (2) that *'someone believes that it is worth finding* (…) *Finding the unknown is the process of problem solving*' (p. 65). Obviously, as I prefer a non-leaking roof, I am motivated to find a way to stop the leak.

Another way problems can be understood is by the concept of 'formal problems'. A formal problem implies more theoretical definition of the problem. Polya calls such problems 'mathematical problems' (Polya, 1957, p. 149). Through information processing language, Reitman (1964) describes these types of problems as three-component vectors of the form [$A \Rightarrow B$], where A is an input and $\Rightarrow$ is a transforming process by which A is turned into an output, B (p. 288). More simply put, such a problem is characterised by the *presence* of given and definite information about what input to do something to, what operations to apply, and what criteria the result should be judged by. This resonates with Newell & Simon's (1972) definition: *"To have a problem implies (at least) that certain information is given to the problem solver: information about what is desired, under what conditions, by means of what tools and operations, starting with what initial information, and with access to what resources"* (p. 73).

The difference between formal problems and every-day problems can be exemplified by the difference between solving a sudoku and running out of gas while cooking.

Displacement of under-determined problems

'Ill-defined problems' (Eastman, 1969; Reitman, 1964), 'ill-structured problems' (Newell, 1969; Simon, 1973) and 'wicked problems' (Buchanan, 1992; Churchman, 1967; Rittel & Webber, 1973) are the three most prevalent notions used – often interchangeably – in design discourse to describe problems that are under-determined in one way or another. On the surface, the three notions have a shared characteristic of representing a distinction between two types of problems with dichotomous properties. One is under-determined, and one is determined or 'well-determined'. To describe what I call the 'displacement' of the under-determined problems, I shall explain how the three notions describe – and differ in terms of – the under-determined problem and its relationship to the concept of 'determined problem' and 'solution'.

Ill-defined problems

The notion of an ill-defined problem was first introduced by Reitman (1964). According to Reitman, the notion of an ill-defined problem is characterised by open attributes, meaning that one or more parameters of the problem are left unspecified. Further he asserts that what it takes to solve an ill-defined problem corresponds to whatever it takes to close the open attributes that represent the under-determination of the problem, i.e. the missing or incomplete information characterising the problem. In other words, Reitman claims that solving an ill-defined problem does not mean arriving at a solution, but simply arriving at a defined problem (p. 314). Thus Reitman contends, on one hand, that it is not possible to solve an ill-defined problem, and, on the other hand, that 'problem solving' ipso facto means solving its counterpart, the well-defined problem.

Reitman defines well-defined problems as ones where problem and solution criteria can be specified without open constraints. Applying the IPL-V information processing language (Newell & Simon, 1961), Reitman represents problems as three-component vectors of the form [A, B, ⇒] denoting sets of which the elements [A', B', ⇒'] are found to be the solution (Reitman, 1964, p. 288). This corresponds to Eastman's description of the well-defined problem as more or less well-specified and characterized by an operational formulation, which means that the problem can be described by an entity, A, that must be translated into another entity, B, by an operator ⇒. In Eastman's definiton, an ill-defined problem lacks part of the problem specification, for example *"a formal language for describing the problem space, operators for moving through the problem space, or it lacks the precise expression of an acceptable goal state"* (Eastman, 1969, p. 669). Targeting such tasks the problem solver must, in align with Reitman (1964), *"specify the missing information before search of the problem space is possible"* (Eastman, 1969, p. 669), since the basis for deciding whether a proposed solution is acceptable is a well-specified set of operators, providing adequately closed constraints (Reitman, 1964, p. 301).

If we take Reitman's and Eastman's statements literally, the paradox appears that the 'solving' of ill-defined problems is actually not problem *solving* at all, but rather problem *definition*. Not until a well-defined problem is formulated would the process of dealing with it be an act of problem solving (Figure 17).

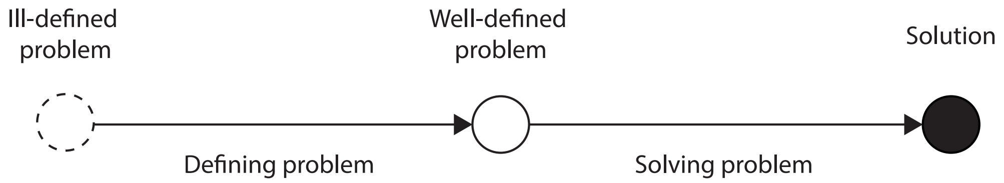


Figure 17: Interpretative model of Reitman's and Eastman's description of 'solving' ill-and well-defined problems. 'Solving' an ill-defined problem is in fact a process of problem definition. Solving a well-defined problem is a process of problem solving.

How the problem definition is undertaken is not particularly clear. According to Reitman (1964, p. 299), the necessary 'constraint proliferation' to increase problem definition 'proceeds from a variety sources', but he argues that it is unreasonable to expect that heuristically based distinctions to search for the 'solution' will appear equally critical to all observers. With regard to the evaluation of the outcome he states: *"No solution to an ill-defined problem can count on universal acceptance,"* since *"it may well turn out that setting of these open constraints acceptable to one individual are unacceptable to the other"* (Reitman, 1964, p. 302).

Ill-structured problems

The terms 'ill-structured' and 'well-structured' problems were introduced by Newell (1969) and Simon (1973) and have been used by many others (e.g. V. Goel, 1992; Guindon, 1990; Voss & Post, 1988). Most well-known is Simon's (1973) contribution "The Structure of Ill Structured Problems" where he states that the boundary between well-structured and ill-structured problems is vague and cannot be formalised, since the characterization of the problem depends on the properties of the problem solver. Simon explains, *"any problem solving process will appear ill structured if the problem solver is a serial machine that has access to a very large long-term memory of potentially relevant information" (p. 197).* He thus distinguishes his definition of the under-determined problem from the 'ill-defined' problem (Reitman, 1964) by confessing to a more constructivist view of the delineation of the problem: that the under-determination of the problem is not a feature immanent to the problem itself, but is dependent on the interpretation and competency of the solver. This means that Simon considers any problem space potentially exhaustible, and the feasibility of carrying out this search depends on the power of the problem-solving system. A computer, through a method of brute force, could search immense spaces in a short time, whereas a human being would give up on the prospect of a potentially never-ending search, or apply rules of thumb – heuristics – to suspend large areas of the space to be searched. The system's perception of own coping capacity would thereby determine the perceived ill-structuredness of the problem. In this context, we could discuss whether, for example, a computer, unceasingly calculating decimals of Pi, is solving a well- or ill-structured problem.

Therefore, Simon contends, a formal definition of a well-structured problem is impossible. Instead, he suggests requirements that a problem must satisfy in order to be regarded by the problem solver as well-structured: The solution must have a definite testing criterion, all problem states, problem state changes, problem knowledge, and potential problem laws (of the real world) must be represented in at least one problem space, and the information and processes involved must be effectively available to the problem solver within 'practicable amounts of computation'. Based on the premise of the relative problem nature, Simon claims that these criteria are not absolute, but merely representative of a relationship between characteristics of the problem and the problem solver, and *"phrases like 'practicable amounts of computation' are defined only relatively by the computational power (and patience) of a problem solving system"* (Simon, 1973, p. 183). Simon notes that the common definition of ill-structured problems would be as a residual category to well-structured problems, i.e. as problems that lack structure or determination. For this reason, the ill-structured problem should be considered a continuum of degrees of 'structuredness' or determination between total well-structuredness and its opposite.

Simon characterises design problems as ill-structured. He notes three important features of ill-structured problems: (a) incomplete and ambiguous specification of goals, (b) no predetermined solution path and (c) the need for integration of multiple knowledge domains (Dorst, 2004, p. 4). According to Simon, solving of the ill-structured design problem is related to information collection and creation of structure in the task. This can happen by decomposing the task into various problems components and by 'evoking' requirements during the design process that can be *"applied in testing the design of its components".* During design work the problem can convert itself from an ill-structured to a well-structured problem through 'evocation from memory' (Simon, 1973, p. 190). What exactly is evoked, Simon leaves unspecified. He concludes that *"We can make here the same comment we made about playing a chess game: the problem is well structured in the small, but ill structured in the large"* (p. 190).

Wicked problems

It is often mentioned that Churchman was the first to introduce the term 'wicked problems', since it occurs as early as in his 1967 guest editorial publication of the journal *Management Science*. Rittel and Webber's most cited account "Dilemmas in a General Theory of Planning," in which the notion also occurs, was not published until 1973. However, in the publication from 1967, Churchman writes that:

> "Professor Horst Rittel (…) has suggested in a recent seminar that the term "wicked problem" refers to that class of social system problems which are ill-formulated, where the information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing. The adjective" wicked" is supposed to describe the mischievous and even evil quality of these problems, where proposed "solutions" often turn out to be worse than the symptoms" (Churchman, 1967, p. 141).

This quote thus sheds light on source as well as the meaning of notion.

Churchman states that the potential extent of a wicked problem is uncertain but that *"membership in the class of non-wicked problems is restricted to the arena of play: nursery school, academia and the like"* (Churchman, 1967, p. 141). Churchman cites Rittel for suggesting that diverse attempts have been made to 'tame' wicked problems by e.g. operations research and management science, by trying to generate an aura of good feeling or consensus, or by "carving off" a piece of the problem and finding a rational and feasible solution to this piece while leaving the rest to someone else (Churchman, 1967, p. 141). Churchman considers the latter morally wrong (p. 142).

The above-mentioned taming methods are very heterogeneous, both in terms of their operators and the outcomes. Therefore, their primary common denominator is the motivation: the desire to tame the problem, which in this description appears somewhat similar to solving it. In 1973, Rittel and Weber expanded on the notion of the wicked problem (Rittel & Webber, 1973). They maintained that the term 'wicked' is *"not meant to personify the properties of a social system by implying malicious intent,"* but rather used *"in a meaning akin to that of "malignant" (in contrast to "benign") or "vicious" (like a circle) or "tricky" (like a leprechaun) or "aggressive" (like a lion, in contrast to the docility of a lamb)"* (p. 160).

Wicked problems are described as planning problems for large social systems to which the wickedness is inherent. Rittel and Webber (1973, p. 159) state that planning tasks are considered ties connecting systems into networks in which outputs from one become inputs to others and in which there is no obvious problem centre and point of intervention. According to Rittel and Webber, a wicked problem consists of clusters of intractable problems, for example:

> "…that of defining problems (of knowing what distinguishes an observed condition from a desired condition) and of locating problems (finding where in the complex causal networks the trouble really lies). In turn, and equally intractable, is the problem of identifying the actions that might effectively narrow the gap between what-is and what-ought-to-be" (1973, p. 159).

Wicked problems are distinguished from the 'tame' or 'benign' problems of the natural sciences, which *are* definable and separable and may have solutions that it is possible to find. The problems of governmental, social, and political planning are ill-defined and rely upon elusive (political) judgment for resolution. Examples are the location of a freeway, the adjustment of a tax rate, the modification of school curricula, or the confrontation of crime (Rittel & Webber, 1973, p. 160). 'Tame' or 'benign' problems are for example problems of mathematics, *"such as solving an equation; or the task of an organic chemist in analyzing the structure of some unknown compound; or that of the chessplayer attempting to accomplish checkmate in five moves"* (p. 160). These problems are characterised by a clear mission and clear solution criteria.

Rittel and Webber distinguish ten properties (1973, pp. 161-167), also considered solution barriers to planning-type problems. These properties pertain to either problem formulation, solution criteria, or problem premises.

There is no definitive formulation of a wicked problem, since it is interconnected with and symptomising a network of other problems. How we understand and explain an individual problem determines the nature of the problem's resolution, which in turn determines what information is needed to understand the problem.

Solutions to wicked problems are not true or false but good or bad. There is no guarantee of a solution and no criteria of knowing whether all potential solutions have been considered, and thus there are no stopping or testing rules for solutions.

Wicked problems are all unique, and because solution attempts change the world in which the problem resides, every attempt counts significantly, which is the reason why the planner *"has no right to be wrong"* (Rittel & Webber, 1973, pp. 166-167). Rittel and Webber admit to having *"neither a theory that can locate societal goodness, nor one that might dispel wickedness, nor one that might resolve the problems of equity that rising pluralism is provoking"* (p. 169). They believe that attempts at a reconciliation of the paradox between social values and individual choice will be considered to be biased against both (this could also be called democracy), and that neither of the two escapes the truism of political value judgment (p. 169). Rittel and Webber conclude that wicked problems are never solved, but at best merely re-solved over and over again (p. 160). Thus, *'idealized'* and systematised planning strategies stemming from *"the classical paradigm of science and engineering"* are inapplicable when dealing with these problematic planning situations (pp. 159-160).

The notion of the wicked problem distinguishes itself from the 'ill-defined' and 'ill-structured' problem by not assuming any transformability between the wicked and the tame problem. Neither source of information provision (as in the ill-defined problem) or power of solving system (as in the ill-structured problem) can transform the wicked problem into a more tame problem that can be targeted with 'usual' means, since it is "inherently wicked" (Rittel & Webber, 1973, p. 160).

Table 4 below shows a comparion of the three notions and the distinction between the problem 'under-determination' they represent.

Definition source	Reitman 1964	Simon 1973	Rittel & Webber 1973
Underdetermined problem term	**Ill-defined problem**	**Ill-structured problem**	**Wicked problem**
Definition	Open attributes One or more parameters left unspecified	Residual definition: All problems that are not well-structured, problems that lack definition, Incomplete and ambiguous specification of goals, no predetermined solution path	Structural planning problems for large societal systems, interconnected problem networks, conflicting values of stakeholders
Example	Composing a fugue	Designing a house	Location of a freeway, the adjustment of a tax rate, the modification of school curricula, the confrontation of crime

Determined problem term	Well-defined problem	Well-structured problem	Tame/ benign problem
Definition	Closed attributes, all parameters specified, operational formulation: Vector [A => B], vector components are sets of elements that comprise the solution	Defined, clear mission and solution criteria, solution must have a definite testing criterion, representational problem space, information and processes available to the problem solver within practicable amounts of search	Problems which are definable and separable and may have solutions that are findable
Example	Finding proof for a theorem in the elementary propositional calculus	Mathematical problems, equations, game of chess, discovering the proof of a theorem in formal logic.	Solving an equation, analyzing the structure of some chemical compound, the chess player attempting to accomplish checkmate in five moves.
Solving of under-determined problem	Solving of ill-defined problem = problem-definition: Closing open attributes => making it a well-defined problem, only well-defined problems can be solved	Decomposing problem into smaller well-structured problems, evocation (of something unspecified) from memory, collecting information	Social problems are never solved. At best they are only re-solved—over and over again, design problem and solution are linked in such a way that in order to think about the problem the designer has to commit to some sort of solution
Relationship between under-determined and determined problem	By solving an ill-defined problem it is transformed into a well-defined problem	The ill-definedness of the problem depends on the power of the solving system	The wicked problem can never become tame, the wicked problem is inherently different from a tame problem

Table 4: Comparison of the three problem notions and the distinction between the 'under-determination' they represent.

The determined problem

The under-determined problems described above depend definitionally on the concept of a determined problem from which they differ. In other words, the challenges of solving under-determined problems, represented by the described prefixes added to the problem term, are based on the analogy of solving 'well-determined' problems. The incentive to add prefixes reveals that the challenges designers are faced with do not resemble determined problems, and that the way they work does not fit the matching concept of 'problem solving'. Hence, the prefixes are added to negate or relax the original problem term from which the new terms were coined.

Ascription of under-determination to a problem depends on what we believe to be the default nature of a problem. The three sets of dichotomies between determined and under-determined problems described above all intrinsically assume that the underlying default problem is a determined, formal problem, as opposed to an every-day problem, which is not be as strict. One central difference between the every-day problem and the formal, well-determined problem is that the former does not need prefixes to relax its definition, since the definition already includes almost any application imaginable.

Displacement

If placed on a continuum of definition or constrainedness (Reitman, 1964, pp. 300-301; Stacey & Eckert, 2010), ranging from a high level of definition and constraints to a low level of definition and constraints, a determined problem is the ultimate high end of definition and constrainedness. At the other end of this continuum we find their under-determined counterparts: ill-defined, ill-structured and wicked problems. As apparant from the comparison shown in Table 4, the definiton of the well-determined problem is rather symmetrical across the three notions. What differs between the three is the under-determined problem that is considered dichotomous to the determined one. In other words, the comparison shows an ambiguity, as the three under-determined problem types do not relate symmetrically to the determined problem. Rather they expand from a joint centre of determination as three displaced continuums of different conceptual distinctions, as shown in Figure 18.

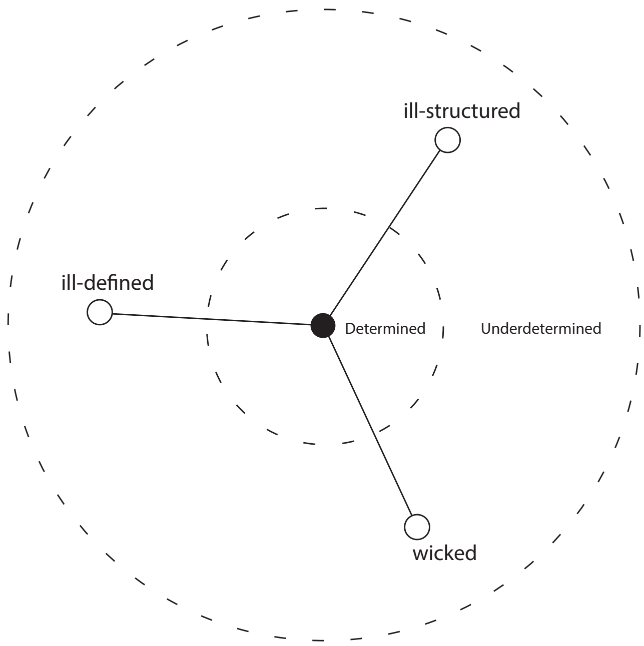


Figure 18: Displacement of under-determined problems.

The conceptual distinctions that represent the relationship between the determined and the under-determined problem in, and the difference between, the three notions are:

- Delineation of problem (ill-defined problem)
- Power of solving system (ill-structured problem)
- Complexity of context (wicked problem)

Processual and structural problems

Taking into account the above-mentioned distinctions, when studying how human beings design, the 'system solving power' becomes less important, since – given an average level of intelligence – the range of differences between their structural behaviour is small compared with man-made IPS's (i.e. computers) (Newell & Simon, 1972, p. 865). Thus, the distinctions between context complexity and problem delineation remain the essential problem differentiation factors.

The diagram in Figure 19 below shows how the two concepts 'context complexity' and 'delineation' can be spanned as continuum axes in an orthogonal classification scheme providing four quadrants of problem types.

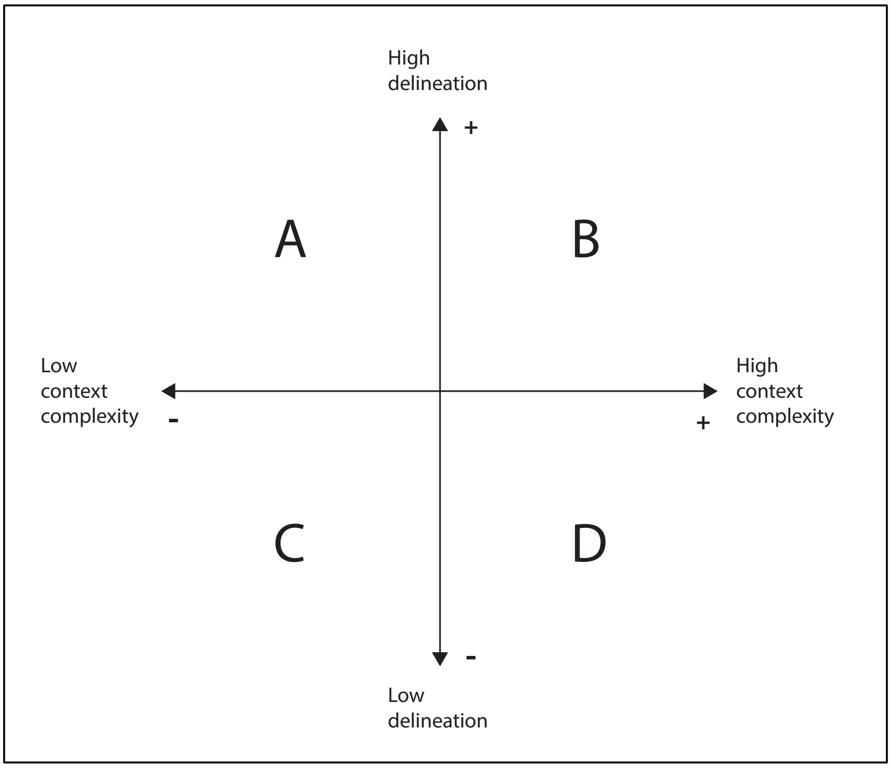


Figure 19: Two axes of conceptual problem distinction. Four quadrants: A, B, C, and D.

The *context complexity* distinction represents the complexity of the environment in which the problem is situated. In the case of high complexity this environmental context includes many potential, given (and possibly contradictory) constraints that could influence to the problem. If the complexity is low there are few or no given constraints that *need* to be taken into consideration in relation to the problem.

The *delineation* distinction represents the limitation of information or constraining factors to be considered within the problem formulation. If the delineation is high, these factors are encircled, and the problem thus more well-defined; if the delineation is low these factors have not been encircled.

The four quadrants represent four archetypical problems: A, B, C and D. The four problem types can also be represented as in Figure 20.

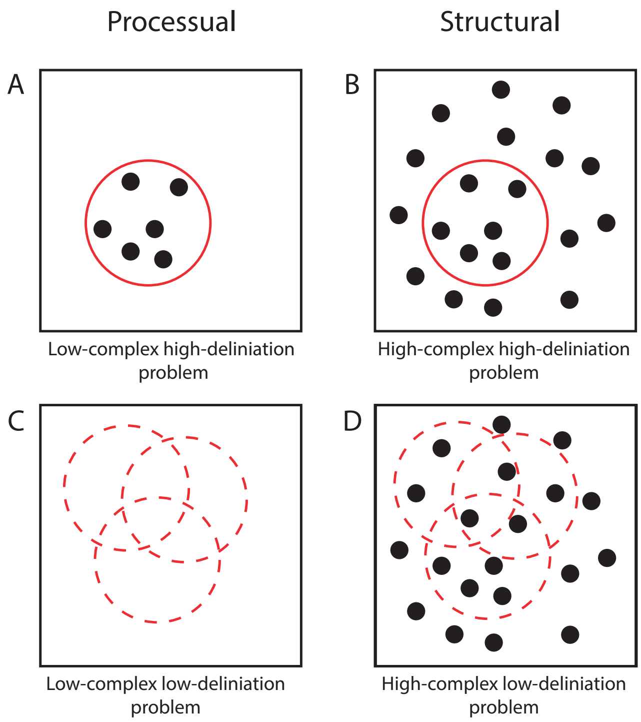


Figure 20: Four archetypical of problems A, B, C, and D.

Figure 20 displays four archetypical problems with different properties. Since they are archetypes, I shall first characterise them by the extreme examples:

Problem A is a *Low-complex high-delineation* problem. This means that there is a low complexity of constraints influencing the problem context. The ones that are present are the ones encircled by the high problem delineation. This type of problem resembles a formal, determined, or tame problem, which could for example be a mathematical problem such as a proof for a theorem. All necessary information and requirements are provided in this type of problem, and it is well-delineated, since all that is provided is to be considered, and all that is to be considered is provided.

Problem B is a *high-complex high-delineation* problem. In this problem type, there is a high complexity of potential constraints and information in the context in which the problem is situated. However, the problem to be dealt with is well-delineated, which means that the factors to be considered in the particular problem have been encircled and limited from their complex surroundings. This type of problem could for example be a well-defined, deductive research programme, taking into account only certain factors of many potential ones when studying their relationship with or effect on a specific phenomenon. In this type of problem it is presumed that the solution could be a rejection of a hypothesis, since the early delineation from other potential influencing factors would hinder a reframing (Dorst, 2015; Schön, 1983) allowing for inductive findings.

Problem C is a *low-complex low-delineation* problem. This type of problem has a very low contextual complexity, since no or few externally imposed constraints define what information or what requirements are to be taken into consideration. The delineation is also low, which means that it is not specified which of the potentially few constraints to attend to. If there are none, the low delineation is obvious. This type of problem could for instance be Reitman's (1964) example of an ill-defined problem: the composition of a fugue. In this task, the composer is given a conceptual, but not finite category that the solution must fit into, but no other pieces of information or requirements have been given.

Problem D is a *high-complex low-delineation* problem. This type of problem is situated in a context of high complexity which means that many potential (and possibly conflicting) constraints and requirements could assert influence and be taken into consideration with regard to the problem. The delineation of these potential problem factors is low or noneexistent, and no criteria of how to encircle them are given. This type of problem is similar to Rittel & Webber's (1973) wicked problems. It could be, as they themselves exemplify, an objective of crime confrontation in a society.

Given this typology, there are two distinctions that are interesting to note in relation to design:

The first is the distinction between the low-delineated problems and the high-delineated problem. Design problems and creative problem in general are always characterised by under-determination and low problem delineation (Dorst, 2004; Simon, 1973; Stokes, 2006). Therefore, with the present design context in mind, the low-delineated half of Figure 15 is the most interesting.

The other distinction is more remarkable. It is the one between low context complexity and high context complexity. On Figure 20, I have named this distinction Processual/ Structural:

The *structural* problem represents a situated 'external' problem – a problem recognised in the world. In design, this type of problem could, for example, be to design noise-reducing furniture for open office spaces, to design authority-inducing uniforms for parking attendants or to apply design thinking with the aim of preventing bullying in primary schools.

The *processual* problem represents a non-situated, 'internal' problem – a problem of travelling from A to B in a design process characterised by no or limited information about the goal or how to get there. This type of problem, as opposed to the challenge of managing many potential sources of information and requirements, is the problem of having few or none at all. It is having no 'problem' to solve. In design, this could for example be the design of an haute couture fashion collection, a branding campaign for a band, or the creation of a signature line of jewellery.

Revisiting Table 3, the Dorst and Cross 'train litter disposal system' case, the two problem types can be compared as follows (Table 5):

Design Problem Type and articulation	Structural Design example, Dorst & Cross (2001)	Processual
Commision	Design litter disposal system for train	Accomplish design process from A to B
Conflict	Newspapers are left behind Cleaners complain of mess	Discrepancy from ideal Current state ≠ B (Design process not yet completed)
Commitment	Litter disposal system should have separate newspaper holder	Choices made in the progression towards B
Complication	The budget for litter disposal systems has been cut severely down	Design process progress towards B is hindered by obstacle
Ideal	No mess in the train	Preferred state of design process = B (Design process completed)

Table 5: Articulation of structural and processual design problems

The structural and processual problems, in a design practice context, relate to what Eggink (2009) and Verbrugge (2012) call Demand- and Author-driven design. Demand-driven design responds to the need of someone or something. It is focussed on the client, guided by marketing and communication, structured by processes and methods, and adopted to the existing as ‘invisible’ design. Author-driven design is motivated by the designer’s desire to express herself. Therefore, the design has the ’style’ of the maker; it aims to stand out as special, fashionable, and showy; and it depends on ‘creative finds’. (Eggink, 2009, p. 110).

Obviously, the problem categorisation shown in Figure 20 is analytical and simplified, and no problem would conceivably fall solely into one of these classifications. The different problem types in the framework could in fact be considered to represent different problem stages over time in a design process, provided one subscribes to the understanding that problem delineation increases through the process (Reitman, 1964). For example, Designer i3 in my study describes that framing constraints on his task “*has come along the way gradually with that I have chosen a problem”* (i3, 6, 16).

The distinction between different types of problem under-determination has generally been understated in the design theoretical discourse; yet this conceptual clarification is important if we want to have more accurate conversations about design and get closer to an understanding of how the different types of problems can be tackled. Recently Dorst (2015) has published an account of how to frame innovation in which – with reminiscence of Schön (1983) – he provides an account of under-determined problems of the *structural* kind. Still further research is needed, and especially into under-determined problems of a *processual* nature. Thus, the dissertation at hand will focus on design tasks that, if understood in problem-solving terms, could be called a processual problem type C, a *low-complex low-delineation* problem.

It is evident from the account in this chapter that the problem concept in design is equivocal and, in fact, quite problematic. The problem perplexity outlined in this chapter is in itself a problem that makes the term 'problem' of little use as a means to clarify the mechanisms driving design processes. The pervasive focus on problems in design theory obviously characterises the present discourse of design, but the incoherence and indeterminacy of the problem concept may also determine and limit the possible epistemic understanding of designing.

Despite having *mentioned* the word 'problem' numerous times throughout this chapter, my assertion in this dissertation is that if 'problem solving' is a problematic concept to describe design processes, it may not be the best one to use. With this chapter about problems, and by the announced focus on *low-complex low-delineation problems,* I have outlined, and positioned myself on, the problem-map, because it is the map that is currently available to get an overview of, and talk about, positions and distances in the landscape of design methodology. However, in my further quest to unfuzz design, I will not *use* the term 'problem'.

I will claim, like Samuel L. Jackson in the movie, *Jackie Brown*: *"It ain't no problem, it's more like a situation."*

4. Models of Design

In design theory and related theoretical areas there are many different models of design. Chakrabarti and Blessing (2014) emphasise that the phrase Models of Design can be interpreted in two different ways. The two authors distinguish between Models *in* Design, referring to models used in the process of design, e.g. sketches and prototypes, and 'Models *of* Design', referring to *"models that are used to describe or prescribe how design is or should be (carried out)"* (2014, pp. 10-11). For the purpose of positioning the research at hand among the existing accounts of design processes, the focus of this section will be on process-centred Models *of* Design and the assumptions on which they rest. I shall refer to this type of model as *process models of design*.

The assumptions are important to address, as they expose underlying ontic and epistemic positions in the theoretical design discourse. Therefore, this chapter will introduce a selection of design models, and the following Chapter 5 will delineate some of the prevalent concepts of design that influence the discussion and understanding of design.

Relationship between Models and Theory

Models of design processes obviously focus on design processes in terms of content, but in their structure they do not differ from scientific models in general. They are often visualised, conceptual representations of a theory about design processes. Goel and Helms (2014, p. 3) define a scientific model as *"an interpretation of a target system, process or phenomenon that proposes or elaborates on the processes and mechanisms that underlie it."*

The concept of 'models' is closely related to 'theory' and the definition and purpose of theory. According to Goldschmidt (2014b, p. 433), the relationship between a model and a theory is that a model is *"a simplified and schematic representation of the essence/skeleton of a theory."* She further clarifies that *"a model in design research specifies the main components of a design theory and the relationships among these components."*

Based on these definitions, a model can be seen as a simplified representation of a theory which is itself a representation of the process and the mechanism of the reality it describes.

Guided by the ideal of a comprehensive design epistemology the present dissertation pursues a contribution inspired by Gero and Kannengiesser's (2014) definition of design theory, stating that *"a design theory should describe any instance of designing irrespectively of the specific domain of design or the specific methods used."* (p. 267).

Types of Models

According to Chakrabarti and Blessing (2014), design process models – ignoring the philosophical meta-research on the subject – can largely be divided into two categories: theoretical and empirical. This division is based on the observation that *"Design research is 'pulled in two opposing directions – towards scientific rigour on one hand, and a greater relevance for professional practice on the other'"* (p. 6). The theoretical models are models contributing mainly to the theoretical development of the design field, and the empirical models *"describe empirical contributions that inform theoretical developments and their verification"* (pp. 2-3). However, there are additional parameters on the basis of which design models can be differentiated, for example, the distinction between the context from which a model is generated (theoretical/ empirical) and its intended application, and also how to accomplish this. Thus, I suggest a *descriptive/ prescriptive* analysis category which could relate to the application and purpose of design models. This is relevant, since not all theoretically derived models intend to make a mere theoretical contribution. For example Christopher Alexander's Pattern Language is a theoretically derived construct but is, indeed, aimed at, and prescriptive for, design practice application (Alexander et al., 1977).

In their book, *Anthology of Theories and Models of Design'*, Chakrabarti and Blessing (2014) present a collection of significant models of design, however mainly pertaining to the field of engineering design. After having reviewed a more diverse sample of 25 process models of design, I shall suggest a rough, overall distinction between predominant, yet often overlapping, types of models of design. These are: Engineering/Computational Models, Design Academic Models, Analytical Models, Consultant Models, and Creativity Models.

Likewise, I have found that the models represent certain types of configuration. The most predominant is a phasic and linear pattern, in which the model suggests that phases of different activity or focus succeed each other over time in the design process with varying numbers of feedback loops between two or more stages. Additionally, there are examples of cyclic, dyadic and networked patterns. 'Cyclic' patterns represent ongoing circulation between certain activities or foci across temporal development. 'Dyadic' patterns represent a bilateral, and mutually dependent, alternating development of two different, conceptual areas of the design task along the temporal process development. Networked patterns are comprised of a number of nodes – model elements – and links between them. Network patterns do not assume any direction by which to move between model elements in the design process. Rather they provide an overview of potential or necessary elements and their relationship in the design process. Such elements could be actions, problem requirements, actors, etc.

These types of configuration are not meant to be exhaustive or definite, but merely analytically guiding.

Table 6 below displays a brief summary of the design models reviewed in the present study[9]. The collection of design models reviewed is by no means an exhaustive or a pre-structured sample. Rather, it represents the discursive ground that I have encountered

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[9] A more comprehensive review overview can be found in Appendix 6.

in my purposeful exploration of the answers to my research questions, through literature studies and engagement with the design research community. I cannot claim that the objectives driving this exploration, or the scope of insight into the field of design research attained, is either objective or complete. Yet, from the perspective that I have taken, in the aim to understand design processes, these design models constitute a pervasive part of the foundation based on which design is understood and new research is built.

Type	Author, year Model/ publication title	Disciplinary Domain	Theoretical/ Empirical (origin)	Prescriptive/ Descriptive (aim)	Model configuration nature	Nature of model elements	Problem nature at process outset
Engineering/ computational	*Polya 1945 How to solve it*	Heuristics, Problem solving, Mathematics	Theoretical	Prescriptive	Phasic linear	Activity	A practical 'problem to find' Defining problem by choosing appreciative data and conditions
	Altschuller 1956 TRIZ	Systems engineering	Empirical	Prescriptive	Problem analysis Heuristic principles	Activity Product requirements	Known problem-situation
	Simon 1969 The sciences of the artificial	Engineering design	Theoretical	Prescriptive	Iterative, looping	Activity (very abstract level)	Satisficing problem Design goal criteria must be given
	Gero & Kannengiesser 1990, 2004 FBS-model	Domain independent	Theoretical (tested empirically)	Descriptive + means to develop design tools	Phasic linearity Looping	Links between activities Idea development	Well defined outset (changes through the process) Starts with requirements
	Suh, 1998 Axiomatic design theory	Engineering/ systems design	Theoretical (Based on logic)	Prescriptive	Phasic linear	Product requirements (Domains) Activites (mapping)	Well-definable problem
	Nigel Cross 2000 Engineering Design Methods: Strategies for Product Design	Engineering design and product design	Theoretical/ empirical (unclear)	Descriptive	Phasic linear	Activities Idea generation	A given brief, but ill-defined problem. Determined requirements of output.
Design Academic	*Alexander 1964 Notes on the synthesis of form*	Architecture	Theoretical	Prescriptive	Linear Analysis-Synthesis	Activity Idea development	Choosing well-defined problem (misfits) from an under-determined problem.
	Bruce Archer 1965 Systematic methods for designers	Industrial design	Theoretical	Descriptive model, prescriptive technique	Phasic linear with iterations	Activity Development of ideas	Design begins with need => constraints => problem => solution constraints
	Marcus/Maver model (1969/1970) (in Lawson 1980)	Architecture	Theoretical	Prescriptive	Phasic linear with loops Increasing detail-focus	Development of ideas	A well-defined problem
	John Christopher Jones 1970 Design methods	System design	Theoretical	Descriptive	Phasic linear	Activity Idea generation	Ill-defined problem Brief = starting point (but later revised)
	Alexander, Ishikawa, & Silverstein 1977 Pattern language	Architecture	Empirical	Prescriptive	Network Increased detail-focus	Activity Problem components	A well-defined project

	Darke 1979 Primary Generator	Architecture	Empirical/theoretical	Descriptive	Phasic linear Iterations Narrowing down	Idea development	Imperfectly understood problem Framing by imposing generator
	Lawson 1980 How designers think	Architecture	Empirical/ theoretical	Descriptive	Cyclic, iterative	Development of ideas Problem/ solution focus	Design problems are unclearly stated. Often misleading initial expression
	Schön 1983 The Reflective Practitioner	Practitioners in general Architecture	Empirical	Descriptive	Cyclic conversation with material	Behaviour (system)	Unique, unstable, interconnected problem situations
	Dorst & Cross 2001 Co-evolution of problem and solution spaces	Industrial design	Theoretical origin, but empirically tested	Descriptive	Dyadic alternation between two spaces	Problem/solution focus	Problem has certain amount of vagueness and inconsistency Start: Exploring problem space
	Lasso et al. 2016 A model of designing as the intersection (…)	Design management	Theoretical (Based on other theories)	Descriptive and Prescriptive	Structural network Iterative loops	Activity Behaviour (system) Mental stages/idea development	Uncertain Problem
Analytical	*Goldschmidt 2014 Linkography*	Design cognition	Theoretical	Descriptive for design process, prescriptive for analysis process	Network of links Dyadic alternation between divergence and convergence	Relations between ideas	Ill-structured and ill-defined problem that must be explored in the early process.
Consultant	*IDEO (Nussbaum 2004)*	Design consultancy Design-led innovation	Empirical	Prescriptive	Phasic linear	Activity	Problem given by client: Someone wants to improve something.
	UK Design Counsil 2005 Double diamond	Design-led Business Management	Empirical & Theoretical (based on Banathy, 1996)	Prescriptive	Phasic linear Iterations Divergence, Convergence of idea diversity	Activity Idea development	Starts in one point by a trigger (insight or idea). Broad exploring for problem, need or opportunity.
	Verganti 2008 Design driven innovation	Design-driven business management	Empirical	Prescriptive	Phasic linear Connected in a loop by actor relations. Iterated with new project.	Actors Activities	Starts with the wish to develop something and keep the business competitive.
	Dorst 2015 Frame innovation	Design management	Empirical	Prescriptive	Phasic linear Dyadic alternation between analysis and creation Zooming out and concentrating	Actors Activity	Paradoxical problem. 'Design-abductive' outset: *What* and *how* are unknowns, desired outcome (value) is known. Problem is reframed in the process
	Knapp et al. 2016 Design sprint (Google Ventures)	UX design	Empirical	Prescriptive	Phasic linear	Activities Idea development	Given challenge selected by Sprint Master
Creativity	*Wallas 1926 The art of thought*	Creativity	Theoretical/ empirical	Descriptive	Phasic linear	Activity/ mental stages	Assumes an initial problem
	James Webb Young 1940 A Technique for Producing Ideas	Creativity	Empirical (based on personal experience)	Prescriptive	Phasic linear	Activity Mental stages	Assumes implicitly an identified end goal and target group
	Amabile 1983 Creativity in context	Creativity	Empirical	Descriptive	Phasic linear (algorithmic)	Behavior	A discovered or presented problem. Some goal defined.

Table 6: Review summary

In the following, the identified five model types are described and exemplified:

Engineering/Computational models

Engineering/Computational Models are typically aimed at very complex and technical problems with too many variables for the human mind to juggle without assistance, often, but not necessarily, in the domain of engineering design. The computability of these models implies that known data from determined sets can be algorithmically processed and that the product of this process can be evaluated from an established set of criteria. For this reason, design decisions can be deemed right or wrong and are central to designing. The underlying assumption is that problems are, in principle, fairly well-defined – i.e. information is available to hypothetically compute a number of alternatives from which one must be selected. However, due to this quantitative complexity, the problems are practically unwieldy and the solution must be assisted by e.g. algorithm, axioms, theorems and heuristics. In his book, *The Sciences of the Artificial* (1969), Simon argues that

> "…although a set of available alternatives is "given" in a certain abstract sense (we can define a generator guaranteed to generate all of them), it is not "given" in the only sense that is practically relevant. We cannot, within practicable computational limits, generate all the admissible alternatives and compare their respective merits. Nor can we recognize the best alternative (…)" (p. 65).

Simon calls the procedures of solving such problems 'satisficing', which are supported for example by heuristics. Simon describes the satisficing situation with the 'needle in a haystack' metaphor: *"The time required for a search through a haystack for a needle sharp enough to sew with depends on the density of distribution of sharp needles, but not on the total size of the stack"* (p. 65).

Two central representatives of Engineering/Computational Models are Gero and Kannengiesser's 'Function-Behaviour-Structure' (FBS) model (2004), which has been under development since 1984, and the Axiomatic Design Theory (ADT) (Suh, 1998). Both of these models portray design activity as links between stages represented by different aspects of a product and its context, and the requirements imposed by these aspects, particularly the separation of a function and its physical expression, 'Design Parameters'. A common characteristic of both models is that the generative synthesis is not in focus. The 'synthesis' step in the FBS model, or the 'creative conceptual work' involved in the 'mapping' step from 'what' to 'how' in ADT (Suh, 1998, p. 205) is not itself explicated.

Problems related to Engineering/Computational Models are often characterised by seeming contradictions between technical requirements. Resolving such contradictions can be done by analogical reasoning. To compensate for the limited experience in the individual human problem solver as a source of the analogy some models suggest finite sets of heuristics or principles. This is well exemplified in Altschuller's TRIZ – theory of inventive problem solving (Orloff, 2006). TRIZ originally proposed 40 solution principles derived from the study of patented ideas and their problem-solving principles. The adequate solution principle can be found by identifying the problem contradictions and their intersection in a contradiction matrix consisting of 39 factors squared.

The heuristic approach is also found in ADT, which, on the basis of two general axioms, defines 27 theorems for the design of large flexible systems. Likewise, Polya bases his model of problem solving on heuristics in the book, *How To Solve It* (1957).

Engineering/Computational Models often approach tasks analytically assuming that problems can be divided into sub-sets, which can then be resolved individually. The key concern in this procedure is to secure low dependency between sub-sets of variables to avoid conflicts and compromises when parts are reassembled into a whole design. Such an analytical task dissection is described by Cross in *Engineering Design Methods – Strategies for Product Design* (2008), in the C-K Theory (the Concept-Knowledge Theory) (Hatchuel et al., 2013), and in ADT (Suh, 1998).

Design Academic Models

The term Design Academic Model does not imply that other types of models are not academic. Rather, the name indicates that this type of model originates in the relatively young field of academic design research. And that academic design *research* – however closely linked to design *practice* – differs from design practice, since the purpose of the former is to gain intellectual insight into the latter.

The separation of Engineering/Computational Models from Design Academic Models reveals that in this context 'design' is perceived differently from typical 'engineering design'. 'Design' includes the more artistic and soft design disciplines taught at design and architecture schools. The adjectives 'artistic' and 'soft' do not in and of themselves provide a very clear understanding of the shared features of the disciplines contained under the heading 'design'. What 'artistic' and 'soft' refer to, however, is the problem understanding.

Roughly put, 'engineering design' problems are relatively well defined with a high degree of constrainedness. These problems lend themselves to quantification and calculation, their solution criteria are well established, and thus decisions made in the process can be right or wrong. 'Design', on the other hand, deals with tasks that are under-determined and scarcely constrained. In these tasks, information about what to do something *to*, *how* to do it, or *where* to end up is incomplete. This is the 'softness' of the task, and this is what leaves design with creative and 'artistic' freedom in the task. As mentioned earlier, the degree of design problem constrainedness can be considered a continuum from low to high, which is why the distinction between problem constrainedness in 'engineering design' and 'design' is not clear-cut, but fluid. Likewise, the distinction between 'Engineering/Computational Model' and 'Design Academic Models' is approximate, since, in fact, they overlap.

As mentioned, shared features can be found across Engineering/Computational Models and early Design Academic Models from the first-generation design methodology, where problems were considered more well-defined than in later theoretical developments in design methodology.

One example is the heuristic approach, which is found in both model types. Particularly between TRIZ and Alexander, Ishikawa, and Silverstein's 'Pattern Language' (1977) there are interesting points of comparison: Both models propose a finite set of heuristic principles, and in both cases this set is derived empirically from studies of best practice. Each in their way these principles serve to resolve problem conflicts when applied in accordance with the prescribed procedures. Likewise, the heuristic principles are linked to the concept of analogy in both models.

The principles or 'patterns', as they are called in 'Pattern Language', compensate for the naturally limited experience of the individual designer. They provide the designer with analogies from existing solutions to problems of similar nature in an accessible way. Polya (1957) also connects heuristics and analogy. However, to Polya analogy is not epitomised by the use of heuristics, rather analogising is seen as one heuristic among several.

Furthermore, Engineering/Computational Models and early Design Academic Models both approach problems by analytical dissection into sub-problems. Alexander, in *Notes on the Synthesis of Form* (1964), Archer, in his *Systematic Methods for Designers* (1965), and Jones, in *Design Methods* (1970), are concerned with procedures of problem analysis and the independence of variables across sub-problems. The aim is to avoid conflicts between them or compromises when synthesising the solution in its entirety. In fact, Alexander's 'Pattern Language', based on the principles proposed in his *Notes on* *the Synthesis of Form* (Alexander, 1964) can be considered a recipe to steer clear of this potential threat. The systematic procedure of working with Pattern Language allegedly secures the independence of variables between sub-problems, or patterns. Thus Alexander et al. encourage the builder to *"Take one pattern at a time (…) The sequence of the language will guarantee that you will not have to make enormous changes which cancel out your earlier decisions"* (Alexander et al., 1977, p. 464).

Overall, like engineering models, early Academic Design Models are typically sequential and linear in nature with iterative back-loops. They generally portray the design process as phasic with focus on the development stages and activities. As the problem is fairly well-defined from the outset, the process proposed by the models is usually initiated by problem analysis, followed roughly by a pattern of generation of partial or alternative solutions, evaluation, and decision.

One main difference between engineering models and early Design Academic Models is that the latter assume a less quantifiable nature of problems than the former. A good example of this is found, again, in Alexander's *Notes on the Synthesis of Form* (1964). Alexander applies mathematical set theory to describe the relationship between different levels of problem dissection. Yet, in Alexander's conception a set can be *"as abstract or as concrete as you like."* For example, *"a lemon and an orange and an apple form a set of three fruits, a collection of relationships like fatherhood, motherhood, brotherhood, sisterhood forms a set"* (p. 78). He concludes; *"the great power and beauty of the set, as an analytical tool for design problems, is that its elements can be as various as they need be, and do not have to be restricted only to requirements which can be expressed in quantifiable form"* (p. 79).

A noteworthy fact is that the understanding of the concept 'problem' in different types of models is not merely a matter of what kind of task they deal with from a realist perspective. The problem understanding in a model can equally be viewed from a constructivist perspective as an attitude towards or creation of the problem. This can be witnessed in *Notes on the Synthesis of Form* (1964) in which Alexander proposes *"a simple way of picking a finite set,"* i.e. a well-defined problem, from a task that had initially a *"potentially infinite set of requirements."* Considering *"requirements from a negative point of view, as potential misfits"* between a form and its context, a well-defined problem of finite requirements is created by taking *"just those relations (…) which obtrude most strongly, which demand attention most clearly, which seem most likely to go wrong"* (Alexander, 1964, p. 26). Alexander shares the idea of picking a well-defined problem from a limitless one with Polya (1957).

Later Design Academic Models provide alternatives to the phasic linearity of the early Design Academic Models by proposing cyclic, networked, and dyadic depictions of the design process. A cyclic depiction is seen in for example Schön's 'reflective coversations'. Here, the design process is described as an ongoing 'conversation with the materials of a situation' in which the designer alternately 'sees' and 'moves' (Schön, 1983, pp. 137-140; 1992, p. 5). In *How Designers Work* (1980, 2006) Lawson also depicts the design process as a continuous cyclic movement between the traditional categories of analysis, synthesis and evaluation, but without *"any starting and finishing points or the direction of flow from one activity to another"* (Lawson, 2006, p. 48).

A networked model configuration is seen in e.g. Lasso et al.'s 'model of designing as the intersection between uncertainty perception, information processing, and coevolution'. As the name indicates this model proposes relationships of different cognitive and enacted aspects of designing. Reportedly, the process starts with a mental stage of uncertainty perception, but includes no further directions of the links between model nodes, and the *"loops proposed by the model can happen several times until the designer finds a suitable solution*" (Lasso et al., 2016, p. 307).

'Pattern Language' also represents a network of a different kind, but consists of problem components on several layers of subdivision and the interrelations between them. The model likewise implies a sequence of dealing with design aspects of gradually increased detail. A similar movement towards detail focus is seen in what Lawson (1980) terms the 'Markus/Maver Map of the Design Process'. It was developed on the basis of RIBA's design maps by Markus in 1969 and subsequently by Maver in 1970, and it suggests that in the development of narrowing down the scope to the detail level, the process iteratively undergoes a linear sequence of phases: Analysis, Synthesis, Appraisal (evaluation), and Decision (Lawson, 1980, p. 26).

Another way of perceiving the 'narrowing down' of a process is applied by Darke (1979). Darke sees design *"as a process of 'variety reduction', with the very large number of potential solutions reduced by external constraints and by the designer's own cognitive structures"* (p. 38). Darke coins the term 'Primary Generator' to denote a designer-imposed conjecture, concept, or constraint which initiates the design process. This 'Primary Generator' provides the *"greatest variety reduction of narrowing down of the range of solutions"* in the design process (p. 38).

The conception of narrowing down a solution space was not new, though, but has firm roots in problem-solving theory and the concept of set search (Newell & Simon, 1972). Accordingly, Reitman (1964, pp. 288-289) describes problems with sets and solutions as elements of those sets. Finding a solution hence requires that the initial set is narrowed down to a single one of its elements. Newell and Simon (1972, p. 94) describe that *"with each new piece of relevant information that he is able to apply (…), the problem solver cuts down the size of the problem space by limiting himself to a more relevant subspace."*

A well-known example of a dyadic model is seen in Dorst and Cross's (2001) co-evolution model, based on Genetic Algorithm (M. L. Maher, 1994; M. L. Maher & Poon, 1996). In this model, the design process shifts between problem and solution spaces. These spaces co-evolve in a continuous and mutual relationship of affecting and adapting to each other through a transforming fitness-function, for each space state defined by the current state of the other space.

The pattern of dyadic alternation is also found in the C-K Theory where the design process develops in alternate expansion of two cognitive spaces: the 'Concept Space' and the 'Knowledge Space'. Dyadic alternation is also seen in Linkography (Goldschmidt, 2014a), as will be described below.

In general, on the basis of the review, it is evident that Design Academic Models to a large extent stem from the field of architecture. Additionally, they are typically descriptive in nature in contrast to the other types of models. The aim of descriptive models is to contribute to the knowledge of how the design process unfolds rather than proposing a way to design.

Analytical models

An analytical model is a model that suggests a way to analyse design processes, rather than describing the design processes themselves. Goldschmidt's Linkography (2014a) is an example of such a model. Linkography is a method of studying, analysing, and notating how designers generate ideas by identifying design moves and the links between them. This pattern can be expressed in a 'linkograph'.

Though Linkography is not a model of design, but design analysis, certain features found to characterise design processes are exposed. Goldschmidt describes that design evolves over a large number of small steps: 'Design Moves'. A high degree of links with an equal distribution of link direction (backlinks and forelinks) manifests a 'good fit' and congruence in the design synthesis which is related to the quality and creativity of the design process. Overall, the design process is described as shifts between divergence and convergence of ideas.

Consultant Models

Consultant Models are well-specified, prescriptive, activity-centred models. Consultant Models have two primary purposes: to guide people, e.g. non-designers, through a design or innovation process and/or to communicate and give reassurance to clients and collaborators about the development of the design process. Consultant Models are therefore often involved with applying design principles beyond the scope of traditional design practice, and thus related to notions such as design consultancy, design thinking, strategic design, and design-led business development.

The pattern of divergence and convergence, as encountered in Goldschmidt's Linkography, is found more explicitly represented in the 'Double Diamond' Consultant Model. This model was developed by the British Design Council (Designcouncil.org.uk, 2005). The 'Double Diamond' Model features two successive rounds, or 'diamonds', of divergence and convergence of the idea or concept being developed. The 'Double Diamond' structure comprises four sequential phases: Discover, Define, Develop and Deliver. In Dorst's (2015) 'Frame Innovation' Model, developed upon studies of professional designers, we find a similar pattern of divergence and convergence, or, as it is described, 'zooming out' and 'concentrating', over the course of an entire innovation project.

The term Divergence – as a way to explore as many ideas as possible – also appears as the third step in the Design Sprint Model (Knapp, Zeratsky, & Kowitz, 2016), coined by Google Ventures, based on the Agile framework and IDEO's concept of Design Thinking. Less explicitly, the concept of 'convergence' is part of IDEO's design model, described in 'The Power of Design' (Nussbaum, 2004). Here it is represented by the fourth step 'Refining' in which choice is 'narrowed down' to a few options.

The 'Design Sprint' Model, the 'Double Diamond' Model, and most other Consultant Models reviewed feature a sequence of action steps. Different models suggest different numbers of steps, dependent on the nature of the steps, as well as their level of detail or abstractness. The starting point and end point of these models, however, coincide more or less. The starting phase is about investigation into the existing situation, the problems, needs, and context. The end point is focussed on getting the design out in the real world, evaluating and validating it. In IDEO's design model, the first and last steps are called 'observation' and 'implementation', in the 'Double Diamond Model, as mentioned above, they are called 'discover' and 'deliver', in the 'Frame Innovation' Model they are called 'archaeology' and 'integration' and in the 'Design Sprint' Model, they are called ‘understand’ and ‘validate’.

Yet, between the initial and the end steps the models vary. Typically, the models feature steps that involve generation of ideas, generation of material (e.g. prototyping), and definition/decision. Different models suggest different sequences of those steps, for example IDEO’s design model suggests brainstorming and prototyping before refining, whereas the ‘Design Sprint’ Model proposes idea development and decision before prototyping.

The nature of the steps in Dorst’s ‘Frame Innovation’ Model differs from other Consultant Models but incorporates traits from both Engineering/Computational Models and Design Academic Models. For example, the ‘Frame Innovation’ Model suggests the step ‘Paradox’ in which to identify the contradictions in the problem that make it hard to solve. This problem paradox or contradiction is, as described earlier, central to the TRIZ model as well. Another step and key concept in – and eponymous to – the ‘Frame Innovation’ Model is ‘frames’. Reframing a problem means seeing it from a different perspective than the one in which it was created. A frame is thus an abstract analogy, through which new solutions can be found. Hence, frames are closely related to the concept of analogy as we have seen in TRIZ, ‘Pattern Language’, and Polya’s ‘How To Solve It’.

Besides suggesting design process steps, the Frame Innovation Model describes design as oscillating between analysis and creation as well as zooming in and out between abstraction and detail. Thus, this model can likewise be described in terms of dyadic alternation.

One Consultant Model has yet to be mentioned: Verganti’s ‘Design-driven Innovation’ Model (2014). To Verganti, ‘Design-driven Innovation’ implies creating radically new meanings, a radical change in the emotional and symbolic content of products, rather than innovation based on technological development alone. Meaning is created in close interaction with the ‘design discourse’ of the professional ‘interpreters’ in an expanded innovation context, and in the end – if successful – it will be adopted by consumers and users. The ‘Design-driven Innovation’ Model (2014) distinguishes itself from the other Consultant Models reviewed by the nature of its model elements. Rather than consisting of steps of actions of idea development, it is configured as a network of actors in the innovation context and the proposed interactions with them in the process.

The process of ‘Design-driven Innovation’ consists of three steps: ‘Listening’ to the design discourse; ‘Interpreting’ the design discourse in relation to own proprietary insights, technologies, and assets to develop a unique proposal; and ‘Addressing’ the design discourse, i.e. evoking discussion and adopting the novel vision among design discourse interpreters to spur consumers' readiness for the novel proposal. While addressing the interpreters, the product is developed and sent to market.

Though the model steps are linearly sequential, the ends are connected in a loop representing the relationship between actors and context. The loop is reiterated in every new development project undertaken.

'Design-driven Innovation' shares some features with the 'Frame Innovation' Model. Both models are more focussed on the context and on the actors with whom the concept of a new proposal or solution should be adopted than on the tangible formation of that concept. This focus is evident in the proposed steps.

Creativity Models

Creativity Models are not directed at design in particular but at creative processes in general, and their focus is on the cognitive processes involved in creativity.

Among the Creativity Models included here is Wallas's creativity model from his book *The Art of Thought* (1926). It is supposedly the very first Creativity Model and is still often cited. The four stages by which Wallas describes the creative process are: 'Preparation' in which the problem is investigated in all directions; 'Incubation' in which there is no conscious thinking about problem; 'Illumination' which describes the appearance of an idea, and 'Verification' which involves testing the validity of the idea and reducing it to an exact form.

In his booklet guide *A Technique for Producing Ideas* from 1940, Young (2016 edition) suggests a similar but prescriptive model of five stages. His model diverges from Wallas's mainly by proposing a precedent stage, in which the individual is 'gathering raw material', i.e. mental resources from which to build new combinations. The subsequent stages are similar in nature to Wallas'. Characteristic of these models is the 'incubation' phase, where *not* working with the problem is assumed to unconsciously prompt idea generation.

Slightly different is Amabile's descriptive model of creativity from her book *Creativity in Context* (1996), first published in 1983. Amabile's model features five stages: 'Problem or Task Presentation'; 'Preparation' (building up/ reactivating a store of information relevant to the problem or task); 'Response Generation' (generating response possibilities by searching through available pathways and exploring features of the environment relevant to the task at hand); 'Response Validation' (assessing response correctness/appropriateness against knowledge and criteria in the domain); and 'Outcome' (decision-making on the basis of the previous stage). Though Amabile's model is a description of creative behaviour and not a prescriptive design model, the sequence of steps bears close resemblance to the Consultant Models, especially IDEO's design model.

A key concept in Amabile's model is 'motivation'. The individual's level of motivation in the task, together with the degree to which the goal has been met, determines whether the process has ended or the steps should be reiterated.

The Black Box and the Gap

Many models are vague and non-explicit when describing phases relating to creativity, development, synthesising, and generation. One could say that these phases are often black, or at least shady, boxes.

A clear example is Jones's (1992, p. 66) 'Transformation Phase', which is characterised by *"pattern-making, fun, high-level creativity, flashes of insight, changes of set, inspired guesswork; everything that makes design a delight."* According to Jones the transformation process is characterised by intuitive 'Black Box thinking' (p. 69), which cannot be exposed and defies rational explanation.

Bruce Archer describes this part of design as *"the real crux of the act of designing – the creative leap from pondering the question to finding a solution"* (Archer, 1965 in Cross, 1984, p. 75). Archer relates the creativity in design to subjective value judgement which is why he states that *"in some way it is a contradiction in terms to try to codify creativity"* (p. 75).

These stances are linked to an epistemological discussion of design: whether we can know *that* or only know *how* (Ryle, 1949) when it comes to design, i.e. whether we can obtain propositional knowledge about design or need to 'suffice' with the procedural knowledge embedded in the practice.

Archer does, however, attempt to describe the nature of the creative phase by turning to science for analogy, making comparisons with quantum theory and wave mechanics to convey the point that *"laws of nature are arbitrary, or (...) there are no laws at all"* (p. 76). He concludes that *"with scientists taking this sort of view of science, designers should be unembarrassed at accepting the transience of design"* (p. 76). Archer describes the mechanisms of the creative leap as those of discovering physical laws: *"if enough people think hard enough about a problem for long enough, somebody, somewhere, will hit on an apt solution"* (p. 76). Despite Archer's valuable attempt to explain the creative phase, it seems that his conclusion is more of a justification of the inexplicability of creative leaps than an actual explanation of these leaps.

Lawson (2006) briefly describes synthesis as *"characterised by an attempt to move forward and create a response to the problem – the generation of solutions."* (p. 37). He exemplifies such a move with one made in a game of chess after evaluation of the current situation. In reality, however, he acknowledges that synthesis happens in interaction with analysis, where 'manipulating solutions' can prompt discovery of requirements (pp. 44-45). This statement, however, is not accompanied by a description of the solution manipulation.

In the 'development' or 'divergence' stages of Consultant Models it is typically suggested to use specified or unspecified design methods. In the 'Develop' stage of the Double Diamond Model, the design team, together with partners, *"refine one or more concepts that will address the problems or issues identified during the Discover and Define stages. Design development methods used here include creative techniques and methods such as brainstorming, visualisation, prototyping, testing and scenarios. (...) At the end of the Develop stage, the design process will have brought the product development team to a stage where the product or service is ready for delivery to production."* Even though a collection of design methods might help design practice, it does not, however, help the general *understanding* of the mechanisms of idea and design generation.

In Wallas's (1926) model of the creative process solution ideas are produced beyond the designer's control, as they arise from the unconscious mental state of incubation, rather than as a result of transformative actions by the individual.

In Alexander's *Notes on the Synthesis of Form* (1964), the synthesis phase is that in which *"a form is derived from the program"* (p. 84), the programme being the structure of the decomposed problem attained by analysis. In the synthesis phase, a structure of diagrams is made to match the structure of the programme. The diagrams together make up the solution and embody the 'realisation of the programme'. To be useful and constructive a diagram must comprise both physical implications and foreseeable functional consequences. A simple example is the sphere: *"It expresses, among other things, the physical implications of the need to enclose as large a volume as possible within as small a surface as possible. It also expresses the implications of the requirement that a number of things be equidistant from a single point."* Hence, in Alexander's conceptualisation of synthesis, the form arises from the necessary consequences of the requirements given in the problem. This is a logical and explicit description of how design takes shape. However, it presumes a well-defined problem with ditto functional requirements.

I find that Schön (1983, 1992) provides one of the most satisfactory accounts of *generation*. He describes design generation by the term 'move'. This generation is not referring to a phase in the process, but is rather an ongoing activity. Moves are small actions made and tested towards the material, whereby the material of the situation is changed and new material is generated. Initially the course of these action steps is 'seeing' the situation as something familiar (analogy). The course can be adjusted by the 'back talk' of the material in an ongoing 'conversation'. Moves can take the form of experiments, and Schön suggests different types of experiments: exploratory, move-testing and hypothesis testing.

In general, what the black boxed design model phases do not explicitly account for is how to bridge what seems to be a gap between the abstractness of concepts and the concreteness of specific solutions, for example, how information is transformed into form.

This gap has been noted by Kroes (2002, p. 298), who distinguishes between a functional and a structural description of an artefact. He deems it crucial to the understanding of the nature of design processes to answer the question: *"How can we account for the fact that designers are able to bridge the gap between a functional and a structural description of a technical artefact?"* Kroes claims that it is *"not clear how these two are related to each other and how it is possible to go from one conceptualisation to the other."*

Dorst (2004, p. 2), too, has described this gap. He quotes Meijers (2000) for saying that *"'needs, requirements and intentions' and 'structure' belong to different conceptual worlds."* Dorst states that this entails a 'rift' between 'the design problem' and 'the design solution' as well as a 'conceptual rift' between 'need' and 'form'. These different conceptual worlds are also recognised by Archer (1979, p. 348), who asserts that *"the relationship between design problem and design requirements and design provision lies along one axis and the relationship between design problem and design solution lies along another axis."*

Alexander (1964) also comments on the issue of connecting abstract thought with physical form. He builds the defensive argument that logical thought does not cause rigid shape creation. Alexander states:

> "No shape can be more a consequence of the use of logic than any other, and it is nonsense to blame rigid physical form on the rigidity of logic. It is not possible to set up premises, trace through a series of deductions, and arrive at a form, which is logically determined by the premises, unless the premises already have the seeds of a particular plastic emphasis built into them. There is no legitimate sense in which deductive logic can prescribe physical form for us." (Alexander, 1964 p. 7)

This dissertation seeks to look inside the Black Box of this generative part of design processes and understand the operations by which designers do, in fact, overcome the rift. Thus, I aim to describe creativity, not as a cognitive process, but as patterns underlying actions and their appliance to matter, by which something is actually *created*.

In Chapter 12, I shall return to position the contribution of this dissertation in relation to existing design theory.

5. Theoretical Design Concepts

In design theory, certain concepts stand out as central to the way design is described and understood. A valid example is the following quote from Goldschmidt (2013), which employs many of those concepts: *Problem solving*, *frames*, *search*, and *space*:

> ”Once a design task is put forth, a problem-solving process is initiated in which solutions are sought while problems are being framed and reframed (…). Since design problems are (…) typically ill-defined and/or ill-structured, this process takes the form of a search. The search is conducted in a design space (…)” (p. 44)

We have already encountered the majority of the central design concepts in the previous Chapter 4. In this chapter, I shall list and condensate the most prevailing of these concepts in order to depict the contours of the existing theoretical understanding of design processes.

Problem

The concept of ‘problem’ has already been dealt with in depth in Chapter 3. Therefore, this is only a brief summary. ‘Problem’ is a concept pervasively used in design to describe the outset and motivator of a project. It is related to the concepts of *problem solving* and *solution*. In design, the term ‘problem’ is often preceded by prefixes such as ill-defined, ill-structured and wicked, in the recognition that design ‘problems’ are under-determined, i.e. they lack information and/or delimitation. It is this problem trait that makes design tasks creative tasks and design problems different from formal, determined problems.

‘Problem’ can also be understood in an all-inclusive, every-day sense, as a deviation from a desired ideal, that we find it hard to do something about.

Fitness

The concept of ‘fitness’ relates to the relationship between problem and solution. It was introduced by Alexander (1964), who said that every design problem begins with an effort to achieve ‘fitness’ between two entities: the form in question and its context.

Thus 'fitness' refers to the relationship between a form to be designed and the context to which it should fit – a relationship that Alexander (pp. 15-16) calls an 'ensemble'. A good fit can be understood in terms of its counterpart, a bad fit. When something fits badly it brings itself to our attention as a tangible problem, e.g. a kitchen that is hard to clean, or a house with a front door that is hard to find (pp. 22-23). A good fit can be seen as a state of equilibrium in the system in which changes in the context impose a need for change and adaptation in the form.

Simon (1969) describes a similar relationship between the inner and the outer environment of an artefact and its adaptability. He writes that "*An artefact can be thought of as a meeting point – an 'interface' in today's terms – between an inner environment, the substance and organisation of the artefact itself, and an "outer" environment, the surroundings in which it operates. If the inner environment is appropriate to the outer environment, or vice versa, the artefact will serve its intended purpose."*

Co-evolution

Co-evolution is likewise a concept that asserts a relationship between problem and solution. It comprises the idea that a design process evolves in an interchange between the structuring of a problem and solution spaces. Thus, problem and solution co-evolve over time in the design process as opposed to being related to the beginning and the end of the process, respectively. Co-evolution is not an unfamiliar idea to earlier design theorist; however, it has been conceptualised in design theory by Maher (1994), Maher and Poon (1996) and, in particular, by Dorst and Cross (2001).

According to Dorst (2004, p. 2) episodes of co-evolution is *"the creative engine of everyday design practice."* Hence, creative process steps occur when bridges are built between and link the problem and the solution spaces in the process development.

Constraints

Constraints are closely linked to problems and their solutions. Constraints can be seen as both the factors that make a problem a problem and also as descriptive for the solution to be attained. Archer notes that *"There can be no solution without a problem; and no problem without constraints; and no constraints without a pressure or need."* (1965, p. 59). Thus *"the attributes defining the description [of a problem] may be viewed as constraints on the problem solution, and therefore, indirectly, upon the problem-solving process"* (Reitman, 1965, p. 168).

According to Onarheim (2012b, p. 16), constraints are *"explicit or tacit factors governing what the actor(s) must, should, can and cannot do; and what the output must,* *should, can and cannot be."* Constraints can likewise be considered *"limitations on action [that] set boundaries on solutions"* (Vandenbosch & Gallagher, 2004, p. 198), or *"bounds on acceptable solutions*" (Suh, 1998, p. 205). Hence constraints can be said to *"help structure the solution path by limiting (precluding) and directing (promoting) search in a problem space" (Stokes, 2006, p. 4).*

The concept of constraints can be differentiated in various ways. Elster (2000) distinguishes between Intrinsic (in e.g. material), Imposed (by external sources) and Self-imposed (by the designer). Lawson discerns 16 different types of constraints spanning three dimensions: Generator (related to the source of the constraint), Domain (related to flexibility of constraint) and Function (related to the nature of the constraint). Stokes (2006) proposes four main types (and no less than 44 sub-types) of constraints: Domain (rules and conventions in a domain), Talent (genetically determined potential), Cognitive (physiological limitations in the brain) and Variability (requirements of novelty).

Stacey & Eckert (2010) propose that the level of problem constrainedness varies across different professional domains in a 'continuum of constrainedness' from over-constrained (i.e. engineering) to under-constrained problems (i.e. artistic creation). Reitman (1964) described a similar continuum spanning the definedness of a problem from well-defined to ill-defined. Ill-defined problems are characterised by unspecified or open constraints (Reitman, 1964, p. 314). Therefore, the concept 'constraint' is inseparable from the term 'problem definedness'.

Constraints can be deliberately self-imposed by the designer in order to spur creativity. This is expressed in the concepts 'Constraints for Creativity' (Stokes, 2006), 'Creativity Constraints' (Onarheim, 2012b), and 'Decisive Constraints' (Biskjaer & Halskov, 2014). The relationship between constraints and creativity is ambiguous, according to the above authors, since constraints appear to *"play a dual role as a catalyst for both delimiting and opening creative activities by simultaneously restraining, obstructing and narrowing down the solution space as well as enabling, promoting and emancipating creative intentions"* (Biskjaer, Onarheim, & Wiltschnig, 2011, p. 29).

For this reason, Onarheim & Biskjaer (Onarheim, 2012b, pp. 122-123) theorise that there is a 'sweet spot' of constrainedness in which *"the participants perceive that the intensity of the present constrainedness is particularly conducive to creative performance,"* and which thus holds the potential for experiencing creative flow (Csikszentmihalyi, 2007).

I would suggest yet another differentiation between 'content' and 'formal' constraints. 'Content' relates to *what* we do and what we do it *to*. 'Formal' relates to circumstances under which we can do this, e.g. boundaries set by time, money, and abilities. This differentiation is relevant, as I will explain later, in order to develop the understanding of 'content' away from 'constraints' into what shall be called 'Information Entities'.

Spaces

There is a close relationship between the conceptualisations of constraints and spaces. Boden (1990, p. 82) notes that *"Constraints map out a territory of structural possibilities which can then be explored,"* and Coughlan and Jones (2008, p. 446) observe that *"in design constraints are commonly identified as a basis for bounding the design space in which solutions must fit."*

There are many different notions of conceptual 'spaces' related to design processes. Some, non-exhaustive, examples are described here.

'Problem space' is rooted in problem-solving theory and cognitive psychology. According to Simon ((1969) 1996 edition) it is the *"space in which the search for the solution can take place"* (p. 108). Newell & Simon *(1972)* describe a problem space as *"the way in which the subjects represents the problem internally"* and as *"the space in which his problem solving activities take place"*. These activities are not only the *"actual behaviours, but the set of possible behaviours from which these are drawn"* (p. 59).

Also related to problem solving, Boden (1990, p. 78) describes a 'search-space', such as in chess, as highly structured with many possible actions and with potentially complex preconditions. It can be understood in terms of a search tree of which the branches comprise all possible action sequences leading from one legal problem state to another. However, a search tree maps the paths, whereas a search space maps the locations. Heuristics can be used to prune the search tree.

'Solution space' is another space concept linked to design that is approached as 'problem solving' or 'search' (Dorst & Dijkhuis, 1995, p. 262). According to Dorst and Dijkhuis the 'solution space' is defined by the stable problem definition, and the designer surveys it to find a solution. Its scope is limited by *"the information processing capacity of the acting subject."* This definition resembles Newell and Simon's definition of the 'problem space'.

However, a 'solution space' in relation to design is more often construed in line with Biskjaer and Halskov's interpretation, in which the solution space corresponds to 'the designer's creative space of action'. They remark that specific choices prune this space and thus "*ensure the project's progression toward a final design"* (2014, p. 30).

In design theory, there are several examples of the use of 'solution space'. It is often not formally defined but applied to denote a conceptual space that is explored and narrowed down during the design process, and in which a solution can be found (See e.g. Eastman, 1969; Eckert, Stacy, Wyatt, & Garthwaite, 2012; Lasso et al., 2016; Sutcliffe, 2013; Troiano & Birtolo, 2014; Wyatt, Wynn, Jarrett, & Clarkson, 2012).

'Problem and solution spaces' can also be seen as inextricably connected, as is the case in theories of 'co-evolution' (Dorst & Cross, 2001; M. L. Maher, 1994; M. L. Maher & Poon, 1996; Wiltschnig et al., 2013). Wiltschnig, Christensen & Ball define the problem space as *"the required behaviour of the design"* and solution space as *"the potential structural combinations that constitute the design"* (p. 516).

Another pervasive space concept is that of 'design space'. This space is interpreted differently among theoreticians.

According to Woodbury and Burrow (2006) a 'design space' is a vast network structure of design alternatives and possibilities to be explored by the designer's traversing path in the process. MacLean et al. (1991, p. 203) define a 'design space' as a 'space of possibilities'.

Biskjaer, Dalsgaard and Halskov (2014) describe a 'design space' as a space that is *"co-constituted by the designer and the conditions of the design project"* including the creativity constraints that govern the outcome. Thus, *"it changes not only according to these conditions, but also when designers learn more about the situation"* (p. 456).

To Heape (2007), the 'design space' is constructed, explored and expanded in the design process. He describes it as a *"fluid, dynamic, emergent and systemic whole of interweavings"* that is continually structured and restructured to reflect the change of a design task (pp. 6-7). It appears that to Heape the 'design space' is a holistic arena of interaction, inqury, movement, place and doing.

Schön (1992) uses the term 'design world' to describe a distinctive conceptual space, constructed by the designer, in which the design process takes place: *"A design world may be unique to a designer, or it may be shared with a larger design community; to what degree unique or shared is always an open question, to be explored anew in each instance of designing"* (p. 4).

Roughly put, 'conceptual spaces' in design can be divided into two types: a conceptual space of ontic realism that is explored and searched in the design process to find a solution; and a conceptual space of ontic constructivism that is created and expands with the actions and moves of the designer throughout the process. The former is predominant in design theory.

Search

The *search* action is related to a space that is explored and searched. Search can be understood as the movement along certain paths in the space to be searched or explored. Though the idea of searching a space is traditionally related to formal problem solving, the term 'search' is also pervasively applied in a more abstract and inclusive sense by theoreticians describing the nature of design practice, for example as the 'search' for solutions or alternatives from which to choose solutions (See e.g. Askland, Ostwald, & Williams, 2010; Ball, Evans, & Dennis, 1994; M. L. Maher & Poon, 1996; Onarheim, 2012a; Perttula & Sipilä, 2007; Valkenburg & Dorst, 1998). Simon (1969, p. 69) for example, says *"design procedures in the real world do not merely assemble problem solutions from components but must search for appropriate assemblies."*

Satisficing

Related to the concept of 'search' is what the search is *for* – eventually the design solution. To deem one particular solution superior to others, or to simply declare it found, requires an assessment strategy – some criteria for when to stop the 'search'.

In problem-solving theory, what is sought is the optimal solution. This can be found when all information is present in a well-defined problem, which allows the problem solver to identify and assess a finite set of alternatives and make 'right' decisions concerning the solution on the basis of given criteria. This process is called 'optimising'. Optimising can be defined as the process of minimising or maximising a quantitative measure, e.g. maximising the performance or minimising the price of a design object.

In design, however, problems are under-determined, and therefore the designer cannot identify all potential design solution alternatives in a task. Neither can she evaluate the ones she *does* generate against a given list of criteria of the outcome. Therefore, the designer must apply another principle to end the process. This principle is to settle for what is *good enough* (Rittel & Webber, 1973, p. 162) – or in Simon's words: 'satisficing' (1969).

Woodbury and Burrow (2006, p. 79) express it as follows: *"Against the vastness of the design space, it is clear that we cannot hope to exhaustively optimize. Even a vanishingly small subclass of the design space is, in general, also vast, so that design problems are examples of what Simon (…) calls "satisficing"."*

Frames

In design theory, the concept of 'frames' is typically construed in one of two ways.

In the first way, the frame is understood as a border or delimitation of a task, similar to the totality of constraints on a task. This perspective is represented by e.g. Elster (2000), who conveys the point that self-imposed constraints, or self-binding, eliminate options and thus provide a narrower frame in which to exercise and contribute 'artistic value' (p. 178). Likewise, Coughlan and Johnson (2008, p. 446) state that *"In design, constraints are commonly identified as a basis for bounding the design space in which solutions must fit"* and thus that constraints *"can be identified and used to frame the process."*

The second 'frame' interpretation represents a way of understanding and defining a problem and its relationship to the context in which it sits. This way is represented by Dorst (2011, p. 525), who says that frames are

> "complex sets of statements that include the specific perception of a problem situation, the (implicit) adoption of certain concepts to describe the situation, a 'working principle' that underpins a solution and the key thesis: IF we look at the problem situation from this viewpoint, and adopt the working principle associated with that position, THEN we will create the value we are striving for."

Schön (1991 [1983]) also represents this 'frame' conceptualisation. He holds that when practitioners frame *"the problem of the situation, they determine the features to which they will attend, the order they will attempt to impose on the situation, the directions in which they will try to change it. In this process, they identify both the ends to be sought and the means to be employed" (p. 165).*

The concept of 'frames' is closely related to 'reframing', which, as implied, means substituting a new frame for an existing one. In the latter understanding of frame, reframing implies 'stepping back' (Kokotovich & Dorst, 2016) or 'zooming out' (Dorst, 2015) to look at the context in which a given problem materialises as a problem. From this higher level of abstraction, it is possible to shift the perspective on the task from outside it. The new perspective must provide a way of understanding the task – a frame – by which the traits of the task, which used to be contradictory and problematic, can now be comprised and resolved.

The two understandings of the term 'frame' are closely related, as the second type of 'frame' is determined by the first 'frame' type. Hence, the possibility of reframing the understanding of a problem depends on the flexibility of task constraints to widen the task context and shift perspective. As described by Zimmerman et al. (2010, p. 313) reframing design problems implies *"broadening the scope of design activity."*

Phases

As we have already seen in the design model review, design processes are often construed as phasic. Phasic process conceptualisations assume a contingency between design activities (and their products) and the temporal progression of the process.

The phasic conceptualisation is especially prominent in the Consultant Model and prescriptive models in general, which makes sense, since pledges of steady, episodic progression and delivery is a yet unrivalled way to 'sell' a design process. This is the case whether the aim is to guarantee development in an innovation process, e.g. in design-driven innovation workshops with non-designers, or the aim is to promise partial delivery of a design project, e.g. to reassure clients who buy the service of a designer or a design consulting agency.

A set of successive phases might, however, not be the single most valuable way to work with and understand design processes. The phasic structure serves in many cases as an outer structure affecting the development of the content which the phases end up comprising. This is unquestionably valuable if a team of non-designers must be lead through a Design Sprint process in just five days. Yet, it is – and in the author's opinion should be – a part of designers' education and competencies to be able to create and develop their way of working – to design the design process itself.

Thus, working with and understanding design as a way of moving, as well as creating an awareness of the nature of this movement, can be constructive to the designer's abilities; not only to achieve great goals, but also to excel in the ability to drive and grasp the process of change on the journey towards these goals.

As we have seen in this overview of very familiar design theoretical concepts, they are all interlinked. These concepts, to a great extent, make up not only the way we talk about, but also the way we understand design. Even in design theory that does not position itself anywhere near the first generation of design methodologists and the paradigm of technical rationality, we find the same terms pervading the discourse: design problem; search for solution; design space; constraints and frames; process phases, and so on. I do not mean to suggest that they are altogether inadequate. However, in light of the challenges that still remain to understanding design, it is the aim of this dissertation to revisit the current design epistemology and explore the profitability of challenging some of the conceptions that govern it.

Part III: Information – a System of Terminology

Having introduced the study in Part I and described the theoretical background and conflicts in Part II, in this Part III I shall propose a system of terminology for design that will contribute to the development of the understanding of the design process. Chapter 6 introduces the concept of a design task as a system of information; Chapter 7 establishes a system of terminology based on the concept of 'information', whereby design is conceptualised as information processing; and Chapter 8 accounts for a functional structure, ITO, found to underly the information perspective of design.

6. A Systemic Perspective on the Design Task

As expounded earlier, the 'design problem' can be a challenging concept to apply when talking about and seeking to understanding design. I shall therefore use the term design *task* instead. This section will provide an in-depth explanation of the concept of a design task.

The Difference between a Problem and a Task

Substituting 'task' for 'problem' requires an exposition of the perceived difference between the two concepts.

According to Pahl et al. (2007) the difference between a task and a problem is that the former "*imposes mental requirements for which various means and methods are available to assist. An example is the design of a shaft with given loads, connecting dimensions and production methods*" (p. 46). Though this statement holds some truth, it needs to be nuanced. Indeed, because of its under-determination, a design task holds the *potential* to invoke 'mental requirements' in the designer. The reason is that we adhere to a set of conventions related to the concepts that are available for us to describe and understand our surroundings. For example it is a convention that a tool should have a shaft, and such a shaft should have certain qualities and a certain appearance. However, at the same time I shall argue that it is the fundamental task of a designer to challenge those conventions and create something new which will lead to new concepts being developed. The designer must defy the tendency of confirmatory bias to constrain her perceived decision options – to resist those mentally imposed requirements – by constantly challenging existing concepts and ask what other options might be available. Alexander (1964, p. 95) says that *"one of the designer's first tasks is to strip the problem of the preconceptions"* that are evoked by the 'name' or the concept by which the task is described, e.g. to design a "town" or a "kettle."

If the 'imposition of mental requirements' mentioned by Pahl et al. is seen as a result of a flexibility to subjectively interpret a task, it follows that the task is perceived to have fewer or more flexible constraints than a problem does. This is not the distinction pursued in this dissertation by using the term 'task' instead of 'problem'. Rather the term 'task' is applied to accommodate the diversity of design projects and the fact that not all design tasks are what I have previously termed *structural* problems, i.e. situated, 'external' problems. Depending on how a problem is defined, *some* designers can be seen as working with problems, but *all* designers work with tasks. Thus, I consider the concept of a 'task' more general and inclusive than the concept of a 'problem'. In other words, the extension of the concept of a problem lies within the extension of the concept of a task. A design task, in the applied terminology, can range anywhere within a continuum of constrainedness (Stacey & Eckert, 2010) as long as enough aspects are left unspecified to render a design process worthwhile.

Task Constrainedness and Trans-disciplinary Comparison

In order to find common ground on which to compare design tasks across disciplines the focus should be directed away from trans-disciplinary discrepancies, e.g. divergent purposes served and disparate outputs produced, and instead directed towards points of comparison. Such a point of comparison is incorporated in the concept of constrainedness. In the next chapter (7) I shall introduce and use the terms *Information Entities* and *Information Density* as substitutes for constraints and constrainedness, since the term constraint is not fully adequate for the intended application. However, for the nonce, I shall primarily use the term 'constraint', since it is the closest well-known term in the existing design theory.

When viewed through the concept of task constrainedness, every task can be seen as constituting two basic factors: freedom and restriction. Freedom means that no information is provided that determines what to do or what not to do, and hence there is freedom to apply any option of choice. Restriction means that information is provided about what to do or what not to do, and hence the freedom of choice is restricted.

Freedom or restriction is admittedly a rough dichotomy, representing a binary understanding of constraints as either rigid or absent. Since constraints are often portrayed to have varying degrees of flexibility, the binary construal deserves some argumentation, which will be presented later in this chapter.

As the task develops over time, it must transit from a state of abstractness to an end state of ultimate particularity (Nelson & Stolterman, 2003), which means that choices must be made by which to particularise. Irrespective of the initial level of task constrainedness, freedom of options must be renounced along the process, since making a choice means to lose the opportunities that another choice would have provided (Schwartz, 2007). Hence if no or only partial restrictions on what to include and what to exclude are given in the form of externally imposed constraints, the designer must add them herself (Guindon, 1990, p. 72). From this perspective, constraints have the same impact on the task regardless of whether they are self-imposed or externally imposed, which is why I shall later propose a unified conceptualisation of the term constraints. Likewise, the initial level of task constrainedness can be seen as a matter of ratio between the factors of freedom and restriction, shared by any design task.

This contention serves as the first step to juxtapose design tasks across disciplines. In the next chapter (7) I shall further expand on the basis for comparing seemingly disparate design task.

The Design System

Studying design process development from a perspective of constrainedness has certain implications for the definition of a design task.

It is often said of constraints that they are (externally or self-) *imposed* on a task. In order to deem anything *imposed* on a task, it must be imposed from a source – someone or something – outside that task. Hence, the concept of constrainedness requires that we see the task as an entity, which is conceptually delimited from its context. As a consequence, we can see the design task from a systemic point of view. The concept of 'system' is here construed in a broad sense as a group of interrelated elements forming a collective entity (Collinsdictionary.com, 2017a).

The design system is dynamic, i.e. the content of it can transform, and open, i.e. new content can be brought into it or existing content can leave it. The state of the system can be expressed as the immediate or 'frozen' content-situation of the task at any given point in the process between changes of the system. The content of the system can be pictured as the constraints on – or the information in –the task. Thus, from an information perspective, the design system is a *system of information*.

The system conceptualisation is reminiscent of Schön's 'setting' of problems, in which *"we select what we will treat as the "things" of the situation"*, thereby setting *"boundaries for our attention"* in the task. Schön explicates that "*we name the things to which we will attend and frame the context in which we will attend to them"* (1991 [1983], p. 40).

According to Schön, the "things" of the situation are characterised by the practitioner's mandate to 'select' them. That implies that the 'situation' of the problem setting does not include, but is rather circumscribed by, possible externally imposed constraints of which the designer has no control. However, in accordance with the stated contention in the previous section, self-imposed and externally imposed constraints should be treated under a unified conceptualisation. This implies that the boundary of the situation, or design system, delineates both selected and externally imposed 'things' of the situation. Still, the design system is seen as the conceptualisation of the 'things', or the matter, of the design situation, which is one of the two main analytical focal points of this study: Information (matter) and Action.

Invariably, the constrainedness perspective and derived system conceptualisation of design tasks means that the notion of *boundaries* must be discussed. Hence, we must look at the relationship between the system, the designer, and the context.

The designer's role in the system

If a task is characterised by a certain degree of constrainedness it means that *somebody* must receive and perceive this task as subjected to, or contains, these constraints. For example, a task can be given to a design company by a client; the design company's chief designer can pass on the task to a staff designer with more constraints attached to it. This staff designer can then pass the task on to an assistant designer with additional constraining directions. Thus, we cannot speak of any objective level of constrainedness of a task alone, but only of constrainedness of the task of *somebody* – a *task taker*. The task taker can be an individual designer or an *equal group* of designers. An *equal group* is understood as a group whose members share a common task and have a certain, and equal level, of mandate to manoeuvre and make decisions on the task. The constraint level of a task is hence a concept that solely makes sense in terms of its relationship to the *task taker* who receives and perceives the constraints and who carries out the task, or part of it.

The task of a task taker resembles what Dorst (2004) calls a 'situated problem'. Dorst likewise distinguishes between the 'local' design problem – the design problem as faced by and seen through the eyes of the designer – and the 'overall' design problem. He also claims that the subjectivity of the local design actions is a matter that confronts us when we try to understand design problems. He concludes that *"Seen from this perspective, 'the design problem' as such does not really exist as an objective entity in the world"* (Dorst, 2004, p. 8).

On the same subject Simon (1973, p. 182) proclaims: *"Criteria are not absolute, but generally express a relation between characteristics of a problem domain, on the one hand, and the characteristics and power of an implicit or explicit problem solving mechanism, on the other".* The 'power' of the 'problem solving mechanism' relates to traits of the individual problem solver, in this case the task taker, and could, for example, refer to the ability to manoeuvre and make decisions.

Reitman (1964, p. 301) states that *"To the extent that a problem situation evokes a high level of agreement over a specified community of problem solvers (…) it may be termed unambiguous or well defined with respect to that community."* Hence, Reitman too acknowledges that problem definedness, or constrainedness, can be perceived differently by different communities of problem solvers or task takers. However, whereas Reitman equals strong agreement between problem solvers with well-definedness of the problem, I shall argue that a group of task takers can agree upon the constraints of a given task, regardless of the constrainedness of that task. Therefore, agreement does not indicate a well-defined problem or task, but is rather a possible indicator of group equality.

As illustrated in Figure 21 below, the task taker, or designer, is neither inside nor outside the design system. The task-taking designer is the conceptual *boundary* of, or link between, the design system and its external context. This role is enacted by the designer in that she receives and perceives external constraints regarding the task and self-imposes constraints onto the task. This implies that only elements which are consciously recognised by the designer as pertaining to the task can be part of the system. Though circumstances or constraints of which the designer is yet unaware might eventually affect the design process, they cannot be contained in the system or dealt with as part of the task, until the designer realises that they should be.

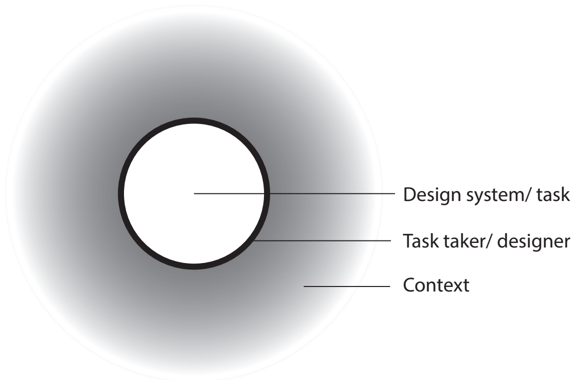

Figure 21: The designer represents the boundary between the design system and the external context.

System context

The context is everything outside the design system. From this context, constraints can be imposed and information can be sourced into the system. I shall explain the concepts of *information* and *sourcing* later on.

The constrainedness of the task indicates the relative freedom of choice for the task taker at any stage in the process.

At the outset of a design process the 'system' is already, or must be, provided with constraints from outside. These constraints can be self-imposed by the task taker or given by other actors or circumstances as external constraints. Constraints can enter or exit the system throughout the process. At any given time in the process, external constraints can be imposed from the outside beyond the control of the task taker, as the task system is not closed, but always embedded in, and susceptible to, influences of various contexts, e.g. the social, the economic, and the physical.

The imposition – and nature – of such constraints can affect and alter the constraint situation of the design process considerably. However, the *source* of the externally imposed constraints will make little difference to the altered task situation, and hence to the task taker. Whether a constraint is a requirement set forth by a client or a boss, or is immanent in physical laws influencing the task situation, i.e. what Elster (2000) calls 'inherent constraints', makes little difference to the acuteness of the altered circumstance or to the function of constraining and informing the task situation in question. I will refer to this as 'agential symmetry' between constraint generating sources.

Agential symmetry

The systemic scope of the task (Figure 21) implies positioning social agents external to the task in the design process. From this perspective potential constraint generating sources, e.g. people or circumstances external to the system, attain 'agential symmetry', to borrow a telling term from Latour's (2005) Actor Network Theory (ANT). By this I mean that constraint generating sources of different kinds, whether human or circumstantial, are viewed as carrying equal potential to affect the design system of information by providing, removing, altering and fixating constraints. This changes the immediate design situation. With the symmetry follows that it is not the constraint *source* that is in focus, but rather the *effects* of the constraints on the design system task. If, for example, a project contains the information that a certain design object should be green, and this information is perceived as a fixed constraint by the task taker, it does not matter if this information was given by the command of the chief designer, the result of a user preference investigation, the lack of other available alternatives or, for that matter, by the randomness of throwing a coloured dice.

What does matter to the design task, however, is the extent and nature of the constraints, or, as I shall prefer to call it, the *information* imposed on it. The particular character of the information in the design system determines the nature of what can be produced from the conjunction and manipulation of it. Obviously, a car design project is impacted differently by information of availability of repellent and durable seat padding material than by the information about the car package[10], which determines wheel and engine position and proportion.

The nature of a constraint is, obviously, determined by its generating source, but it *is* not the source. A constraint generating source is only affecting the design system if, in fact, it imposes detectable information onto that system as received or perceived by the task taker. Thus, the constraint sources are only affecting the design system by virtue of the constraints they impose.

By the argued symmetry of constraint generating sources, these sources can be 'black boxed' when looking at the design system of information. The design system needs merely to be conceptualised with a single exchange point to its contextual surroundings. This exchange point is the task taker, by whom the extent and qualitative nature of the design task is construed (see Figure 22).

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[10] A 'package' is an industry term for the basic architecture of a vehicle, determing e.g. position of the engine, transmission and passengers.

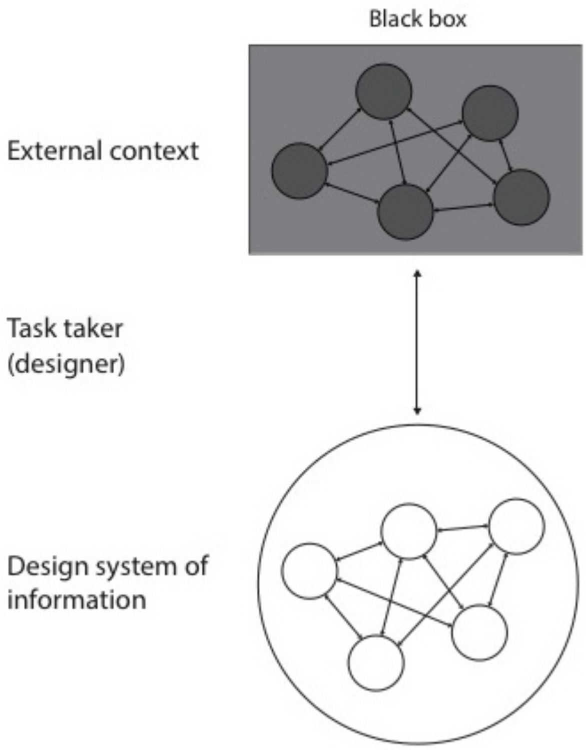


Figure 22: Relationship between the design system and its context.

Nuances regarding the designer's role in relation to the design system is discussed from a cybernetic perspective in Appendix 1.

A binary constraint perspective

The description of constrainedness in design processes above does not touch upon the potential graduation of constraint rigidity and flexibility. Although the lexical definition of the term 'constraint' is the clear opposite of the notion of flexibility, meaning *binding* and *compulsion* (Dictionary.com, 2016), it is nevertheless differentiated in respect of this very matter in many applications, not least design theory. Thus, for example, Gedenryd (1998, pp. 73-74) differentiates constraint rigidity according to the source of its origin, by what he calls the '*source of control principle*'. This principle suggests that *"the further away from the designer the source of a constraint is located, the less control of it does the designer have, and the less flexible is the constraint."* This implies that constraints can potentially be negotiated with the sources from which they stem, and that they are more likely to be negotiable if the source is proximate and accessible to the task taker.

However, two premises provide congruence to the seeming discrepancy between potential constraint flexibility and the binary conception of constraints as either rigid or absent, brought about by the system perspective presented here. Firstly, the negotiation of constraints takes place outside the information system, where the task taker must obtain insight about the constraint determinance from the constraint generating source before attributing it a place in the information system. Secondly, as mentioned above, the state of constrainedness of the task situation must be captured as an expression of the immediate or 'frozen' picture of a given task state between changes of the system, i.e. changes in the material and content of the design situation brought by the designer's moves, or by the management – e.g. replacement – of system content.

As I shall return to later, 'moves' require a temporary fixation of the information that comprises the outset from which the changing move is made. This means that even potentially negotiable constraints will be construed and treated as inflexible, if they are indeed part of the design system at the given stage from where the move is made. In other words; in any actual, individual move made by the designer, upon any given state of content in the design process, constraints are treated as being either there or not – they are either adhered to or they are not. Only after the move can the designer choose to revise constraints if such liberty of action is available to her.

Alternatively, constraints can be 'blackboxed' or removed (Onarheim, 2012b) as a strategy to manage and stabilise the constraint situation. It deserves a mention that this strategy can also be applied to non-negotiable constraints as a progress catalysing strategy in the event of heavy constrainedness (Onarheim, 2012a).

Task Delimitation

As described, the task taker can be seen as the conceptual boundary between the design system with its content and the external context surrounding it. This relationship was illustrated two-dimensionally in Figure 21. However, a design task can only be described two-dimensionally if we perceive it as a 'frozen' snapshot of its content between the changes to the task brought about by the designer's moves.

In reality, a task changes throughout the design process due to the open and dynamic character of the system. Thus, content changes both in qualitative and quantitative terms – the latter understood as constrainedness. This circumstance is encapsulated by the way I define a process, as a sequence of changes over time. The temporal factor thus adds a third dimension to the picture of design. Time, however, like the scope of the task content, is not an endless dimension but has a confined extent. We can envision the entire design system as a salami sausage: it has a confined lenght and a circumscribed content that looks different every time it is cut. (See Chapter 10).

The third dimension, process span, necessitates that the notions of *beginning* and *end* of the design task must be described.

The beginning

The beginning of a design task can be construed in both a temporal and an analytic manner. Temporally, the design process begins when the task is given to or taken on by the designer (see Harfield, 2007). Analytically, the beginning of the design task can be characterised by the boundary of what information is perceived to relate to the design task and what lies outside it.

The sources of external constraints reside outside the design system; yet the constraints themselves can be already part of the design system when the task is received, or it can be imposed on it along the way. There is no need or option for the designer to take deliberate actions or make choices to bring these constraints into the system.

However, as a creative design task is characterised by some degree of under-determination, it is necessary to impose constraints or information to the task other than that given by external sources. To set off a process, a task must at least comprise enough information to enable the designer to envision a design move. (See chapter 11).

Obviously the less externally imposed information in a task, the more constraints or information needs to be imposed by the designer. The sourcing of such information represents a choice. Well into the process information is often chosen by a perceived relationship to other information that is already part of the system. However, in the beginning of the design process there is often little or no information in relation to which such choices can be made. The reasons for these particular choices are therefore rooted outside the design system. To the design system they are *Elementary choices*. These kinds of choices are to the design process what 'elementary processes' (Newell & Simon, 1972, p. 29) are to computational information processing, namely basic units of information of which subsequent actions are compounded. Elementary processes are *"not further analyzed in the theory into still simpler processes"* (p. 29) because such further analysis resides outside the scope of scrutiny. Therefore, in the case of *Elementary choices*, a boundary of analysis is drawn as to what is part of the design process, and what is not. *Elementary choices* will be analysed later on in this chapter, in Section 7.6.

The end

Because there is no *right* solution to a design task, there is no definite criteria for when to end a design process. Thus, there is no way of determining whether the configuration of content in the design process is optimal. However, as mentioned earlier, I distinguish between *content* and *formal constraints*, and it is often the formal constraints that determine when the content configuration is the best *possible*, because it provides the circumstantial confines by which to make that judgement, for example, when the designer is running out of time.

This issue is described by Rittel and Weber (1973) in their account of 'wicked problems'. Such problems have no 'stopping rule'. Rather the designer, or 'planner', terminates work "*not for reasons inherent in the "logic" of the problem. He stops for considerations that are external to the problem: he runs out of time, or money, or patience. He finally says, "That's good enough", or "This is the best I can do within the limitations of the project", or "I like this solution", etc."* (p. 162).

Lawson (Lawson, 2006, p. 55) expresses a similar sentiment that there is *"no natural end to the design process. There is no way of deciding beyond doubt when a design problem has been solved. Designers simply stop designing either when they run out of time or when, in their judgement, it is not worth pursuing the matter further."*

From the perspective of the design system of information one can say that a task is terminated when the design system contains all the information that plays a role in the conceptual or physical configuration of the final design. This means that all necessary information to finalise the design has entered the system and that all information superfluous to it has been left out (see Chapter 8, 8.2 and 10, 10.3).

Where are the Humans?

Though the system perspective on the design task might be criticised for dehumanising design, it does by no means disregard the importance of the designer(s) or other actors influencing the project. As described, the conception of a task is completely dependent on its taker by whom it is received and interpretively perceived. Likewise, the designer imposes constraints onto the task, the nature of which is dependent on the person imposing them. Furthermore, the designer possesses the sole power to act towards and with the information in the system and therefore there would be no change and no design process without her. In fact, the study of under-determined problems, which is the subject of the dissertation at hand, is precisely the study of tasks that only humans are so far capable of handling. They cannot be computed or calculated by mathematical models. The system merely represents an analytical scoping by which to understand the matter of a task content, towards which a designer takes action, and of which a final design is eventually constituted.

This dissertation addresses the relationship between content elements in the design system as well as the relationship between the system and the designer. The contextual level and the relations between its agents have been 'blackboxed' for two reasons. Firstly, because this part of the design process has already been covered thoroughly by studies of collaborative design (See e.g. Christensen & Ball, 2016; D'Souza & Dastmalchi, 2016; A. Dong, Kleinsmann, & Deken, 2013; Kokotovich & Dorst, 2016; Mattelmäki, Brandt, & Vaajakallio, 2011; Paletz et al., 2017; Stompff, Smulders, & Henze, 2016; Svihla, 2010; Valkenburg & Dorst, 1998; Wiltschnig et al., 2013; Zahedi, Tessier, & Hawey, 2017); secondly, because – as argued – the constrainedness or information perspective implies that the afferent influence of a constraint or piece of information about the design task is the same irrespective of its source of origin, insofar as it is perceived as vital by the designer.

7. Information

As previsouly stated, the study of design processes presented in this dissertation focusses on action and matter. The 'matter' is captured by the design system of information. As argued in the previous chapter (6), the design system is construed as a system of information, and design can therefore be construed as information processing.

The information perspective on design provides a unified conceptualisation of constraints from disparate sources, which is conducive for comparing seemingly disparate design tasks, since they are characterised by different compositions of different constraints. The current chapter is devoted to explicating the concept of *information*.

In design processes, designers deal with many different kinds of information provided by different sources. Designers are given requirements or constraints, they conduct research, collect data, gather inspirational material and develop concepts, all of which becomes part of and inform the design process. Even though these pieces of information differ in terms of their generating source, they all inform the potential movement and progress in the design process. Information is, eponymously, the matter used in *formation* – the building blocks of design.

As in any analysis, when studying and analysing design, we separate a "*material or abstract entity into its constituent elements"* with the purpose of studying its nature, features and relations (Dictionary.com, 2017). Such analysis requires that we define the analytical units into which we separate the whole and from which new conceptual distinctions and categories can be made. Thus, in the analysis of the design process from the ‘system of information’ point of view, the need arises to name and determine the smallest perceived unit of information. I will call such a unit an ‘*information entity*.’

7.1 Information Entities

To a certain extent, the term ‘Information Entities’ (IEs) shares common ground with the existing notion of ‘constraints’. In lexical definitions a ‘constraint’ is defined as *“something that controls what you do by keeping you within particular limits”* (Dictionary.cambridge.org, 2017) or simply *“a limitation or restriction”* (Oxforddictionaries.com, 2017). Different design theoretical perspectives on ‘constraints’ have already been described in Chapter 5. However, ‘constraints’ generally refer to factors limiting the search for solution ideas (Ball, Onarheim, & Christensen, 2010; Simon, 1973) and can thereby be said to constitute frames delineating a design or a solution space (Simon, 1969; Wiltschnig et al., 2013). Thus, ‘constraints’ simultaneously inform and limit the space of design possibilities and direct the process towards a particular design (Ball et al., 1994; Joyce, 2009; Stokes, 2006).

There are several reasons to introduce IEs as a replacement for ‘constraints’. Firstly, the term ‘constraint’ has negative connotations: In relation to creativity, ‘constraints’ take on a dual role and may, in fact, restrain the creative process (Amabile, 1996; Biskjaer et al., 2011; Joyce, 2009; Stokes, 2006), and in some fields, e.g. the ‘Theory of Constraints’ management philosophy, ‘constraints’ are perceived as weak links hampering systems and processes (Goldratt & Cox, 1984). Applying the more neutral term IEs allows for a less value-laden approach to and communication about the design process. Secondly, in several respects, I find the notion of ‘constraints’ inadequate to describe design.

I shall first account for the perceived inadequacies and the differences between ‘constraints’ and IEs. Subsequently, I shall set forth a definition of IEs.

Distinction between ‘Constraints’ and ‘Information Entities’

Scope

In existing theory ‘constraints’ are widely defined as limitations or restrictions on design process actions and solutions (Biskjaer, 2013; Onarheim, 2012b; Vandenbosch & Gallagher, 2004). In this definition, the constraining information solely pertains to *actions,* i.e. how things are done, and *solutions,* i.e. the outcome, in design. However, as I shall discuss in depth in the next chapter (Chapter 8), a design process (on several levels) involves three different types of information – or rather, functions that information fill. Besides information about *how* to act and *what* the solution should be like, design also involves information about what kind of *input* to work *with* and transform *on*. Thus, I find it productive to introduce another concept that can cover all three kinds of information functions.

Function

As mentioned, 'constraints' are often seen as limitations on a space in which to search for solutions. Thus, 'constraints' are characterised by the limiting *effect* they have on the perceived space of options – they are understood by what they *do*, not by what they *are*. Despite its simplicity, Figure 23 supports the explanation of this point. The outer black circle illustrates the solution space: the totality of possibilities that are open at the beginning of a design project. The black dot in the centre represents the particular design solution at the end of the process. The grey area is considered possibilities or solution space that has been eliminated by 'constraints' that narrow down the search for the solution by limiting options. 'Constraints' are thus defined by the limiting *effect* they have on the solution space, represented in the illustration by the remaining white part of the solution space.

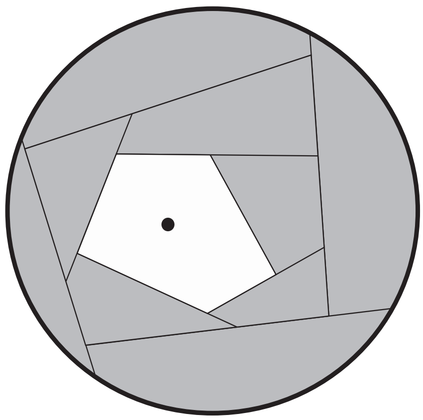


Figure 23: Abstract illustration of the effect of 'constraints'

The concept of 'Information Entities' (IEs), on the other hand, is detached from the concept of solution space. As information is necessary in a design process, IEs can be considered a *resource* by means of which the design can take shape. Describing the relationship between the two concepts, constraints and IEs, with a building metaphor, IEs can be seen as tangible bricks, whereas 'constraints' can be seen as the instructions about what and how we can and cannot build.

Purpose

Another difference is that, while 'constraints' are injunctions linked to some specific action or end, IEs do not necessarily have any particular initial purpose. When viewing IEs as bricks we can imagine the following example: Say you want to build a little house. You do not know exactly what the house will look like; that will, among other things, depend on what materials you can get to build with. You go for a walk, and you find a brick here and a brick there. You do not know how, where, or even whether these bricks will eventually be part of your house, but you find them too good to leave behind, so you take them back home. Now they are available to you as resources for your building project, even though you have not assigned them any function in that project. You might even end up having to give them away, although you liked them, because there is just no right spot for them in the house.

Similarly, the role of IEs in the design process will depend on their relationship to each other as well as on how the designer interprets and activates them.

I am not saying that the design task cannot possibly be influenced by factors beyond the designer's awareness, for example cognitive limits or physical forces. Yet, these factors are not analysed here as part of the design task, since they are not considered unique to the task. Rather, they are regarded as general in terms of the context in which the task is imbedded and by which it is influenced. Borrowing Reitman's (1965) expression, such factors are not considered part of the 'immediate problem' which is distinguished from the 'total problem matrix'. Though Reitman sees problems as represented by cognitive structures, his conceptual distinction is still useful. He describes the 'immediate problem' as represented by those aspects that are "*present only for the duration of work on the particular problem, after which they largely disappear,"* and the 'total problem matrix' as *"those aspects that he [the problem solver] brings with him to the problem situation and afterwards takes away, largely unchanged"* (Reitman, 1965, p. 290).

Perceivability

In design, the notion of 'constraint' can represent any implicit or explicit factor governing the design process, be it cognitive, physical, technical, aesthetic, social, etc. Thus, these 'constraints' can be both implicit and unrealised by the designer, but still have an influence on the design process.

As opposed to a 'constraint', an IE cannot be unrealised or unrecognised by the designer. IEs are, at any given moment in the process, represented verbally and/or visually and are perceived by the designer as part of the design project. The designation of the term 'information entity' requires that the entity is, in fact, (potentially) informative to the design process, which, in turn, requires the designer's realisation of the IE. Even though the designer can experience a lack of, or a need for, information in the design process, any yet unrealised information, which will eventually fill this need, should not be understood as an 'information entity' until the designer has recognised the need and imposed on the design system some manifestation of that need.

Nature

'Constraints' typically take the shape of an articulated statement directing and requiring, by commands or prohibitions, what should or cannot be done.

IEs, on the other hand, can take different forms. They can be material, visual, verbal (represented for example by written words or statements), or, like 'constraints', articulated statements of requirements or desire. Hence, just like the earlier example that the 'task' was a broader term than the 'problem', but potentially included it, IEs is a broader concept than 'constraints', but at the same time inclusive of 'constraints' as they are typically construed.

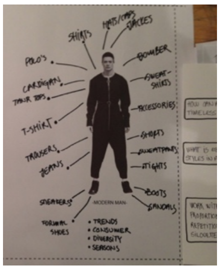
Definition of 'Information Entities'

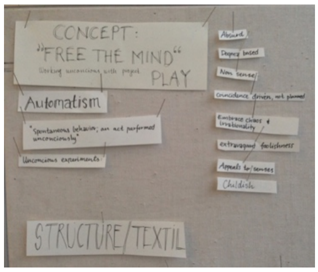
The concept of IEs has emerged from a bottom-up inductive analysis of the data, and, in a broad sense, we can understand IEs as the observable 'things' designers work with. IEs are thus the content of the design system. They may or may not have an immediate purpose in the system or necessarily relate to other information in the system. IEs are considered resources in the design process; they are the building blocks used in the *formation* of the design.

As described above, IEs diverge from 'constraints' in scope, function, purpose, perceivability, and nature. IEs are not differentiated by the source from which they stem, and they can have many different forms, among these material and visual. For this reason, the concept accommodates the comparison of design tasks across individual and disciplinary variations.

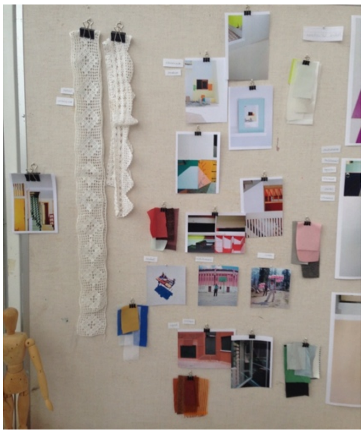
The following examples illustrate how IEs appear in the empirical data.

- When verbalised, the IEs are typically captured by adjectives, nouns, and proper nouns. When visualised, they take the form of (clusters of) e.g. photos, sketches, material samples, and written words.





- Material displayed on the designer's project board or chronicle is IEs.



- Any word mentioned frequently or with great emphasis in conversations about the project may be an IE. Thus, word counts or word clouds[11] (Figure 24) can give indications about IEs.

Figure 24: Word cloud

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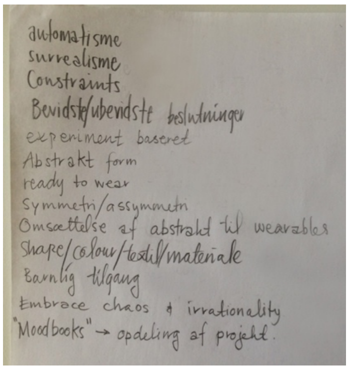
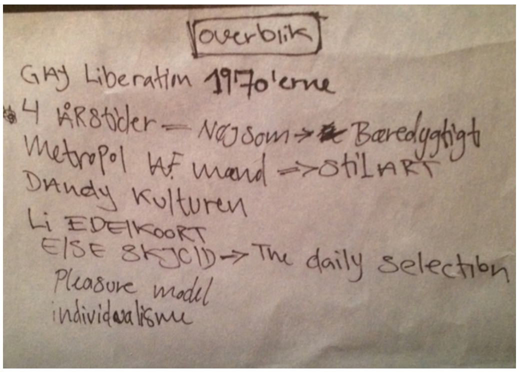
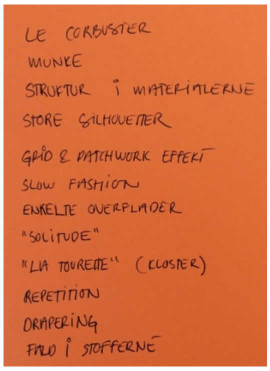
[11] Word-clouds are visual representations of quantitative word counts in documents. The word cloud examples shown in this dissertation serve solely illustrative purposes and have not been used as analytical tools. Therefore, I will not discuss any methodical considerations or implications of the use of word clouds. Yet, for the record, the word clouds shown have been subjected to a stop-word revision based on frequency and qualitatively assessed relevance of the remaining words.

- If the designer is asked to write a list of key words that characterise her project, this list will point to IEs.







Data

Understanding design as processing of information requires a definition of information. *Information* can be defined as *"the meaning that a person ascribes to data"* (Eriksen, Helms, & Rømer, 1971, p. 11), where *data* is *"a formalised representation of facts or ideas in such a form that it can be communicated or transformed by some process"* (Eriksen et al., 1971, p. 11). In design, *data* can be defined as the material that the designer collects for her project (see Figure 25). 'Information Entities' are a conceptualisation of data specific to a design process. Thus, *an IE is an item of data in a form that is perceived by the designer to be directly or indirectly amenable to transformation as part of a design process*.

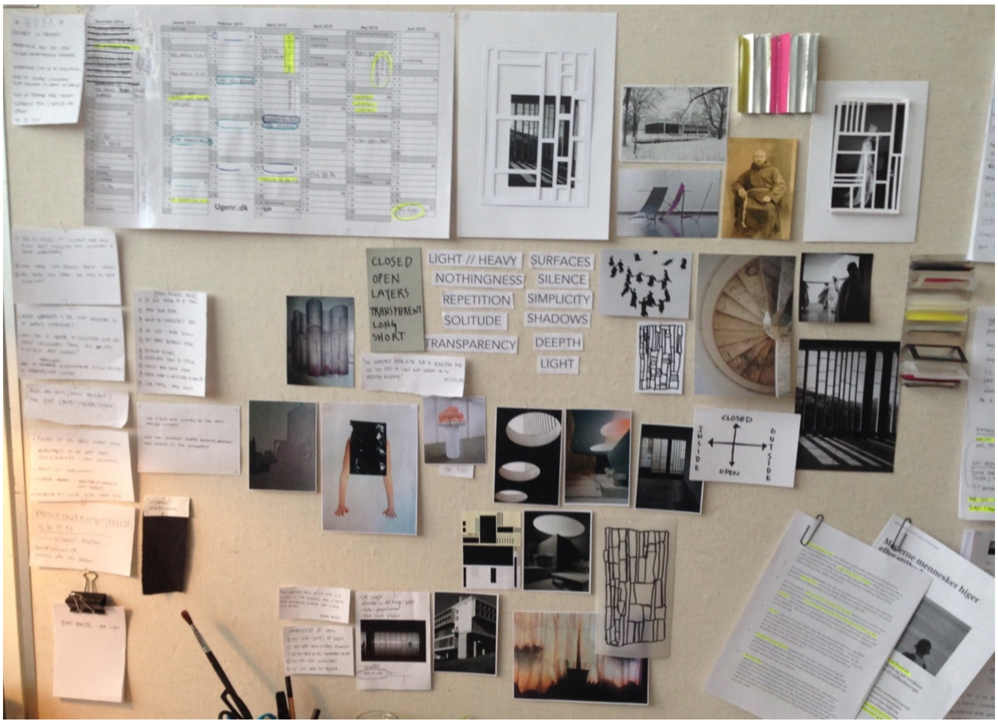


Figure 25: Example of a board full of data; Information Entities (Designer f1).

Themes

In the above definition of information, a distinction is drawn between *data* and the *meaning* a person ascribes to a piece of data. Analytically, we can make a similar distinction in design: Where IEs are conceptualised as pieces of data that can *carry* meaning, the meaning itself has been observed to predominantly take the form of a *theme* in the design processes studied. A *theme* is a central piece of information – an important subject or unifying idea (Collinsdictionary.com, 2017b).

In the data, the term 'theme' is often used interchangeably with the term 'concept'. Yet, my analysis has shown that the term 'concept' is also used in design to mean 'solution idea', and additionally the notion of 'concept' has a philosophical definition dissimilar to the ways 'concept' is used in the design context. For this reason, and for the purpose at hand, I shall use the term 'theme'.

The design cases studied render themes as key ideas that can be interpreted in many ways and embrace several functions at once. Thus, by the designer's associative interpretation of them, themes can serve as generators of IEs. Therefore, themes are connecting, explaining and justifying choices and information in the project, including sub-themes, i.e. particular meanings linked to IEs subsumed under the main theme.

Examples of themes in the design cases:

Designer f1

Designer f1 talks about a theme in his project, 'sustainability' and how it is interpreted in many 'layers' in his project:

Designer f1*: "I work with layers of sustainability. Some are in the material, some are in the style – a function. I'm working with the detachable pocket [that can come] on and off as you like. [And with] zero waste patterns, [that leave] no leftovers."*

Designer i3

Designer i3 describes a theme when he says that *"there are some ideas that have more 'flesh on their bones' than just a plain, simple idea. Maybe it's a combination of some simpler ideas which are conjoined and give a picture of what the product should be able to do in the end, both aesthetically and functionally. (…) A conjunction of ideas and the qualities of the final product"* (i3, 6, 6-8).

This quote reveals that the theme can inform more functions, e.g. both aesthetics and functionality. It has more 'flesh on its bones' than other ideas, meaning that IEs can be elicited from it. Thus, it conjoins 'simpler ideas'.

Designer f5

In an interview, Designer f5 explains her reason for 'bringing along', through the process, three specific pictures from a series of initial inspirational pictures: The three pictures refer to a theme in her project. Likewise, she explains that the rest of the IEs in her project comes from – or 'dribbles' from – that theme.

Designer f5: *"It [the pictures] was my core concept. It was what explained my whole concept. It became too much [with the whole series of pictures], because the others [pictures] told other stories too. (…) They [the three chosen pictures] have it all. They have 'alienated familiarity', they have the colours, they have the 'ethnic' element, they have the 'modern ornamentation', they have the 'shadows', they have the compositional narrative, they have the lines (…) And then it's just a concept."*

Interviewer: *"Concept understood in what way?"*

Designer f5: *"They are, simply, the whole thing. Everything dribbles from there. (…) none of it [the additional information] has just popped up. Everything [else in the project] is something I have felt by looking at them [the three pictures]. It's something they [the three pictures] have told me."*

Interviewer: *"So everything else has arisen from these (points to the three pictures)?"*

Designer f5: *"Yes, in a way they are my muses that are always with me."* (f5, 5a, 65-77)

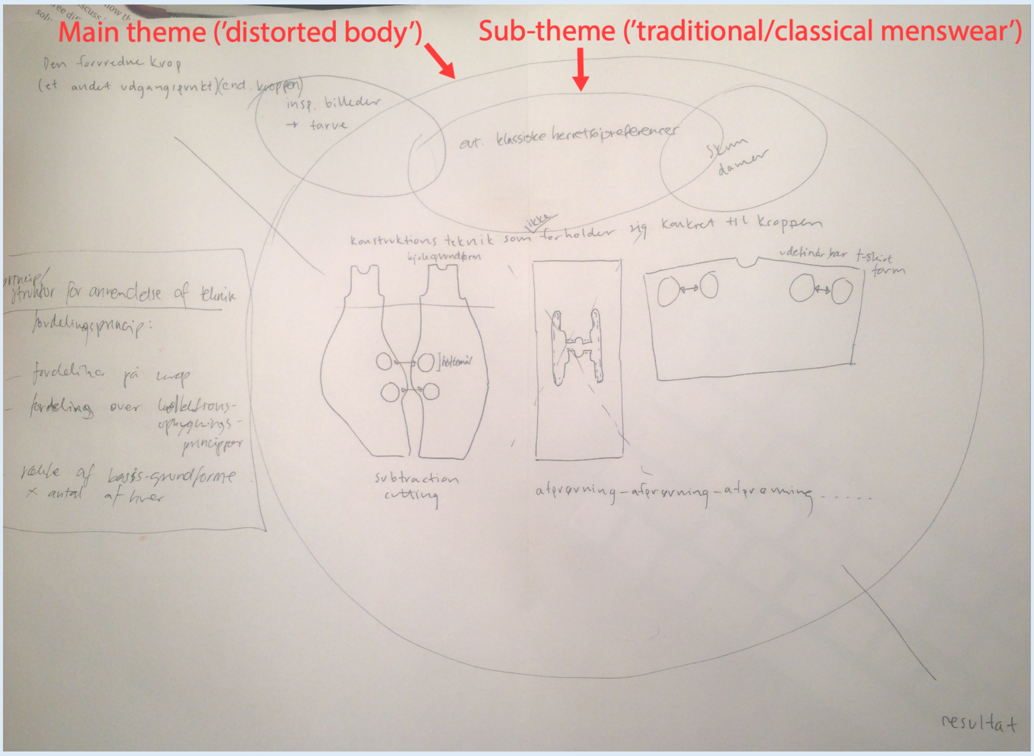
The interview with designer f5 shows that the sub-themes 'alienated familiarity', 'colours', 'ethnic', 'modern ornamentation' and 'shadows' are all comprised under the main theme that the three pictures represent to Designer f5.

Designer f5 further says about the three pictures: *"I have this (points to the three pictures), this is me, that's what starts the process. It is my essence. And then I pull some extracts from there. (…) I play a game of association when I work"* (f5, 11, 138-140).

Designer i10

Designer i10 talks about her project and her use of paper as material. She says that the paper *"is kind of connected to everything, it is after all the theme in it".* (i10, 6b, 1)

Designer f2
Designer f2 refers to theme and subtheme in the following quote. She explains her project with an illustration. She says that she has a *"concept in the concept that is about references to very traditional menswear. (...) So I want to draw a big circle that is called "main" [concept], and then inside that circle lies another concept."* (f2, 5a, 15-19)



Theme Negotiation
In design, the relationship between the theme and the IEs – the meaning and the data – is not given but (continuously) constructed. For this reason, designers can have a theme without IEs or IEs without a theme. Thus, a theme can be derived by ascribing meaning to IEs that are already found and are part of the design system, or IEs can be obtained by their perceived association to a given theme. (See Chapter 10, 10.3)

As a theme is an idea with a certain meaning to the designer, the designer can choose to replace one or more IEs representing it without regarding the theme or idea itself as fundamentally changed. She can simply find a better way to represent that idea.

Examples:

Designer f1
”now I need to focus on the mood board. That it fits with the collages. (…) It’s just some different pictures. So I don’t feel I’m changing my entire concept and my visual point of origin. I just feel that it’s [about] taking the right pictures” (f1, 10, 160-166).

Designer i8
Designer i8: *“The colours up there (on the colour board representing ‘the four seasons’), I’m going to dismiss those.”*
Interviewer: *“Ok, (…) So have you discarded that inspiration material alltogether?”*
Designer i8: *“No, I haven’t discarded the four seasons, I just dismissed that sketch.”*
Interviewer: *“Ok, will there be a new one?”*
Designer i8: *“Yes.”*

Conversely, the main theme can shift. This can take place as an act of perceived specification or broadening of the original theme. If, for example, a sub-theme turns out to capture more precisely an idea, originally held by the main theme, the sub-theme can become the new main theme, and hence the meaning has been specified.

Examples:

Designer f5
”The ’Architecture’ turned out to be something completely different than I thought. I thought it would be more inspired by buildings (…), but i realised that it was more about shadows and shapes. It’s ’shadows’ that is my theme” (f5, 5a, 45).

Designer f7
”The main concept and theme (…) has been ’surrealism’, and then I have found ’automatism’ under that theme, and that’s what I have been working from, and what has been the concept” (f7, 5, 4).

Designer f1
”I have decided not to work with ’ modernism’ as a broader concept, and (…) I am more specific and say that it is more about Le Cobusier’s monastery in South France and then the Barcelona Pavilion by Mies van der Rohe” (f1, 10, 83-84).

If a specific theme does not comprise or provide perceived potential to generate enough new information, the designer can seek to broaden the theme by finding a ’superior’ theme that is inclusive of, but not limited to, the original theme. Such an act is often referred to in design theory as ‘reframing’ (see Dorst, 2015; Schön, 1983), a concept I will return to in Chapter 10, Section 10.3.

Examples:

Designer f5[12]
In this supervision excerpt, Designer f5 and the fSupervisor discuss broadening the theme ’Frida Kahlo’s House’ to ’Mexican Architecture’ in general.
Designer f5: *“I need to be inspired by different things… Reading could also help me.”*
fSupervisor: *“Leave the Frida Kahlo house out and focus more on architecture, structure, detail. Inspire yourself more broadly.”*

Designer i3[13]
Designer i3 explains how his research has led him to broaden his theme ’fear’:
”My idea was that typically you would fear pain or something scary. I have had my eyes opened to another side of it. For example, people wearing a stoma bag. They may fear a reduced quality of life, fear of not fitting in, of not being sexy. Fear is a bit broader than I thought at first glance.” (i3, 2c, 2-5)

In the process of design transformation IEs can ‘break loose’ from a theme associated with them and – by the designer’s interpretation of them – end up carrying new meanings and represent new themes. Similarly, a theme can be replaced by an entirely new theme or discarded altogether.

Information in Practice

Though an analytical distinction can be made between data and meaning, in practice however, designers do not presume such a division. The case designers seem to view design process information as an amalgamation of meaning and the IEs expressing it. Also, they uphold no stringent distinction between abstract, detailed, single or multiple IEs representing a theme.

Because designers do not distinguish strictly between IEs and themes, they often call individual IEs by the same name as the theme they refer to. One could say that they ‘thematise’ IEs. For example, Designer f6 has named some information in her project ‘Balinese Worlds’ (Figure 26). When mentioning ‘Balinese Worlds’ she may not only refer to the meaning she mentally ascribes to the ‘Balinese Worlds’, but also to written words, pictures, materials, a detail in a Balinese dress, or certain features in her emerging design that have arisen from the original ‘Balinese’ inspirational material. Vice versa, Designer f6 may point to a specific IE, e.g. a picture, but refer to the thematic meaning it carries.
Hence, both the conceptual meaning of ‘Balinese Worlds’ as well as the IEs representing

[12] Quote reconstructed from notes.

[13] Quote reconstructed from notes.

that meaning – individually as well as in aggregate – are to Designer f6 the 'Balinese Worlds'.

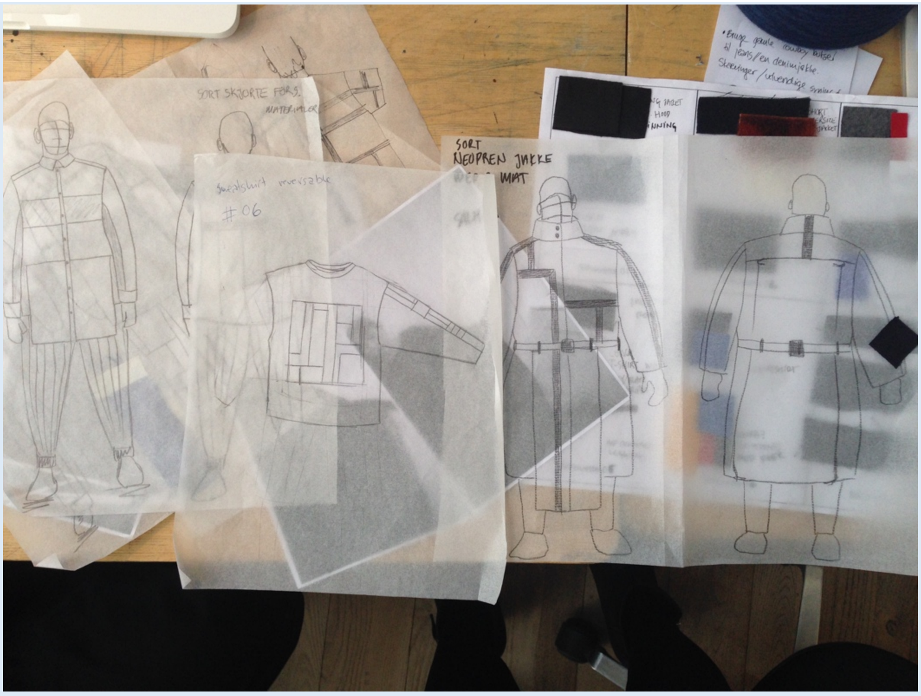
Figur 26: Designer f6's 'Balinese Worlds'

In this study, the main focus is on the design actions and the material to which those actions are applied. Designers cannot work hands-on with themes and meanings, but only with IEs, 'things'. When referring to particular IEs in the dissertation, I shall use the names they are called by the designers.

Furthermore, when I speak of 'the information present at a certain stage of the design process' or similar expressions, 'information' should be taken as a shorthand for the information as observably represented by the current collection of IEs of the project.

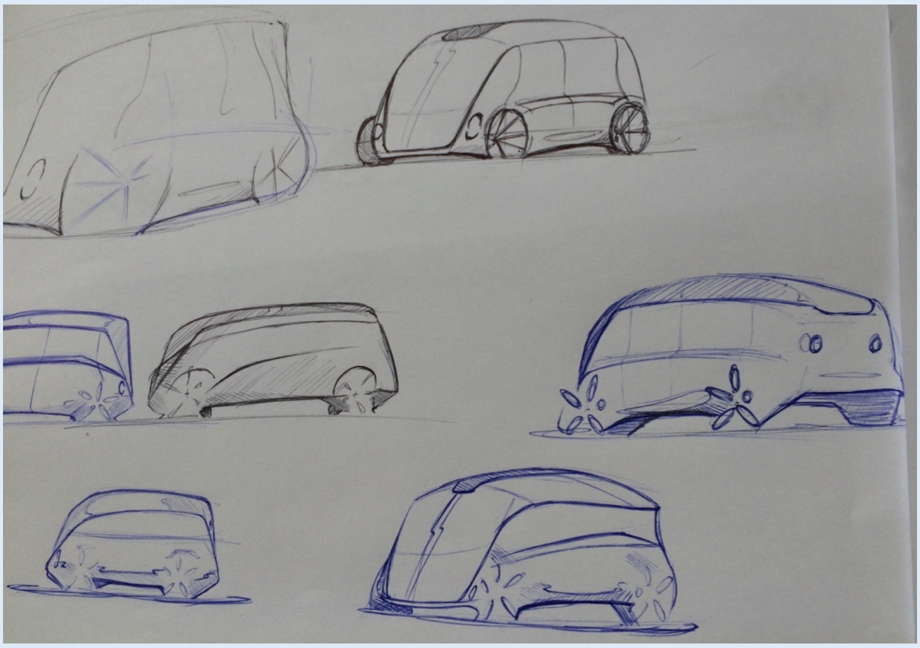
The peculiar amalgamation of information is found across various cases, and is expressed in the following quotes:

Designer f1
Designer f1 is adding geometrical cut lines to his design in order *"to still have the modernist and geometrical elements"* (f1, 5, 43-44) in his collection. Hence, the geometrical cut lines that Designer f1 adds to his clothes constitute his theme 'modernism'.



Designer i4
In a supervision session, the iSupervisor asks Designer i4 *"Have you still got the polar bear in it [the design]?"* Designer i4 answeres: *"Yes. Like... the shoulder line of this neck and a split of the roof – it's still there."*

This excerpt shows that Designer i4 considers certain material manifestations from his pictures of the polar bear as constitutive of the theme 'Polar Bear'. (i4, 8a, 20-21)



Designer f6
Designer f6 is designing an avantgarde dance collection. She has the theme 'Basic Sports Apparel'. She explains how the 'Basic Sports Apparel' is still part of the design: *"For example (…) in this one [jacket]… It will get a sporty draw string and straps, things like that, so that it will still be sports apparel-ish."* (f6, 7, 159)

Related Theoretical Concepts

Other theoreticians have introduced and distinguished concepts, apart from the 'constraints' concept, that are related to the IE concept and thus deserve mention.

For example, Eastman (1969, pp. 671-672) differentiates between the concepts of 'Constraints' and 'Design Units' (DU). In Eastman's terminology, a *"constraint is a function applied to a solution state and returns a Boolean evaluation,"* i.e. it evaluates whether or not the solution is acceptable. DUs, on the other hand, are *"all physical elements that were considered or manipulated during problem solving."* Eastman introduces DUs as known entities in the equation of analysing ill-defined problems in which goals and processing languages are variables. Eastman, too, acknowledges the importance of including material and physical objects in the information processing system. However, Eastman's DU category is restricted to known physical things that are (considered) part of the design solution like for example a bathtub and a toilet in the design of a bathroom (Eastman, 1969, p. 688). Thereby it differs from IEs, which can be any type of data and expression of meaning. Furthermore, the notion of DUs is also applied to things which, in the design process, are not yet actually *there* as physical things, e.g. the sink, the towels, and the children's dirty clothes in the bathroom design. IEs can also *refer* to things that do not exist, but only if these 'things' are manifested as and represented by data in the design system.

With the conceptualisation of IEs, focus is directed toward the smallest perceived units of design analysis. Goldschmidt (2014a) has likewise directed attention to what she calls 'microscale analysis' in her linkographic study of design 'moves'. Yet, Goldschmidt, in her publication *Micro View of Design Reasoning* (2013), suggests an even smaller unit of analysis than moves: "*Most design moves are composite – they are made of smaller units of thought, which we call arguments. (…) Arguments are the building blocks of moves."* (Goldschmidt, 2013, p. 45). Goldschmidt thus claims that 'arguments' are the smallest units holding a comprehensible concept (Goldschmidt, 2014a, p. 43).

However, I will argue that IEs are even smaller units. They are the entities of which 'arguments' are built. This will be elaborated in-depth in Chapter 11, 'Design Syllogisms'. However, I do not see design arguments as pertaining particularly to the realm of thought, but to action and to matter – IEs – on which the action is brought to bear.

Another concept that bears similarity to IEs has been introduced by the collective (A.Telier, 2011) in their book *Design Things* (A.Telier, 2011). The authors propose the concept of 'constituents' to denote the diverse artefacts and representations through which people interact with an object. For example, 'constituents' of a villa can be stones, plants, wood pieces, models of the furniture, bricks, plans, perspectives, frontal views, details, etc. (A.Telier, 2011, p. 57).

'Constituents' *are* not the object designed, but they allow for interaction with and discussion of the object. The potential and eventual embodiment of a design is just one constituent among others: A design object can exist even if it has no final, physical embodiment (A.Telier, 2011, p. 59).

Like 'IEs', 'constituents' is an inclusive concept that embraces design elements of varying natures. Yet, 'constituents' represents a phenomenological concept depicting the different ways and manifestations in which – and through which – a design object, whether finished or in the making, can be represented and understood. The conceptualisation does not focus on what ‘constituents’ themselves are built of or the process of doing so. Thus, a ‘constituent’ is a more abstract and compound unit of analysis than an IE.

Information Fluctuation

IEs are not fixed in the design process. The entire information situation, as well as individual IEs, can shift and change throughout the design process.

A perceived information situation, i.e. the density, nature and composition of information, in the design process will always be a ‘frozen’ snapshot, the content of which depends on when in the process the snapshot is taken. Ipso facto the information situation of the design system, as well as the IEs themselves, changes whenever the designer acts towards and with the IEs constituting the information situation. Figure 27 conveys an impression of how the information content changes throughout the process.

Figure 27: Word clouds of four supervision sessions at different times in Designer i4’s design process. The word clouds hint visually how the IEs, and thus the information situation, in the project develop and change over time.

Building with Information

The introduction of IEs as building blocks of design processes implies an inversion of the typical theoretical perspective on design processes. From the typical perspective a design process, initiated on the basis of a design problem, is conceptualised as a phasic *search* for a solution in a design or solution *space* of possibilities that is narrowed down by ‘constraints’ and frames. This perspective implies starting with a broad or infinite array of possibilities and then gradually limiting these possibilities towards the final design by excluding options (Figure 28).

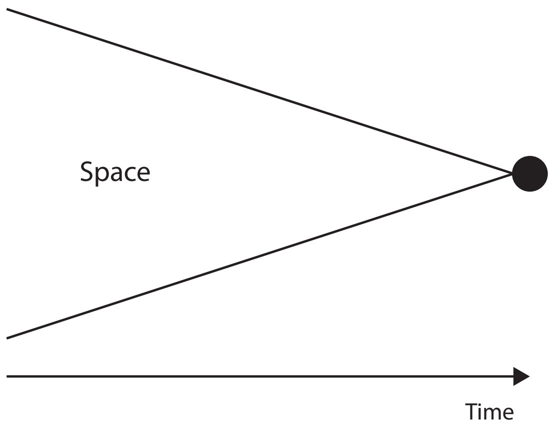


Figure 28: Simplified model of the typical theoretical perspective on design processes – narrowing down of a space

Based on the information perspective proposed here, the design process information is conceptualised as tangible ressources and building blocks from which the design is compiled. From this perspective, the design process starts out with the first single piece of information, and as the information content changes and accumulates through the process the final design is increasingly particularised. This is conceptually, and very simplistically, illustrated in Figure 29.

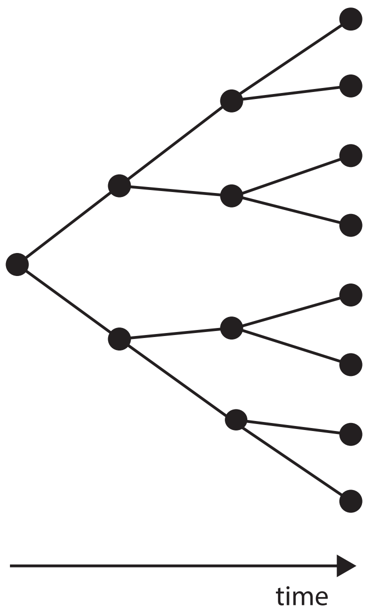


Figure 29: Simplified model of the information perspective on design processes: Information as building blocks

7.2 Information Functions

As mentioned earlier, IEs may or may not fill an immediate purpose in the design system. A purpose is given with the interpretation of an IE assigning it to a function in the process. Since, as we shall see, functions of IEs can change, IEs can be assigned to and serve different functions in the design process. 'Function' is not understood in a formal, mathematical sense or as related to utility aspects of a design, but merely in the meaning of having a 'role' to play. When dealing with design we will obviously encounter instances in which the word 'function' means practical utility and functionality. I believe, however, that it will be clear from the specific context which definition is intended.

The idea that information can fill certain functions implies that there is an underlying structure of functions to be filled in which IEs can assume a place and thus a purpose in the design process. Characteristic of the relationship between information and functions is that IEs can be seen as potential *actors* and the functional structure as a system of *roles* they can be assigned and play in the design process.

The relationship between information and functions, and consequently the idea of a functional structure, was discovered from the empirical studies.

In this section, I shall account for the identified relationship between information and functions. In Chapter 8, I shall account for the functional structure itself, which has been found to characterise design processes.

In the empirical studies, I often encountered comments from the designers about the perceived lack of or need for information to fill certain functions or conversely about the lack of or need for functional positions in which to place specific information that had not yet been given a purpose in their processes.

The following examples from the data show such expressions:

Designer f1
Fashion designer f1 has a theme and IEs of 'sustainability' that he wants to somehow use in his project. However, he needs a way to use it, a function for it in the process. He says *"I'm struggling with how sustainability should be [part of the project] ... It should be a part, not the subject. (...) I need to find a sustainable focus"* (f1, 2b, 28-31). This quote is an example of the lack of a function for an IE, namely 'sustainability'.

Designer i8
Industrial designer i8 wants to design shoes. He is in a supervision session with his iSupervisor, having a conversation about his theme and IEs, 'the 70es'.

iSupervisor: *"You have been investigating the '70es?"*

Designer i8: *"Yes, I don't know how much I can use of the '70es right now. Maybe colour-wise…"*

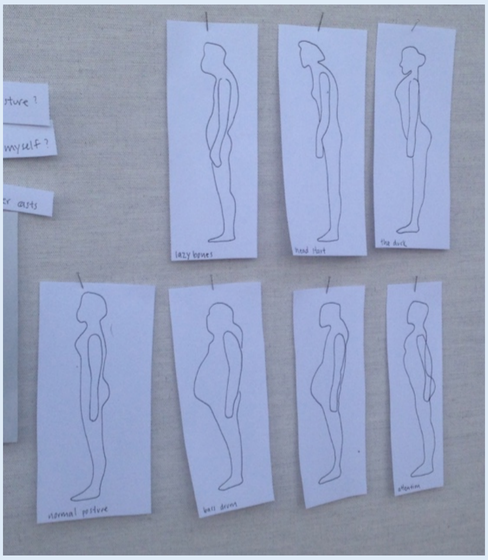
iSupervisor: *"There were other interesting things happening in the '70es – they were quite provocative…"* (i8, 2, 28-30).

This snippet of conversation shows that the IEs about 'the '70es', have not yet been assigned a purpose. Designer i8 is considering the possibility of letting 'the '70es' inform his choice of colours, whereas his supervisor is challenging him to consider other potential functions of that theme and IEs.

Designer f2

Fashion designer f2 says she feels *"lost in the concept"* in terms of how to interpret the information she has taken into her process designing a collection. She suggests that she is *"missing, maybe, some form [inspiration] in the project."* She is contemplating to *"take in a reference to classic clothing,"* i.e. bring in more information to fill the function (f2, 2, 14-18). This is an example of the realisation that certain information is missing to fill a function in the process, namely that of form inspiration.

Subsequently, Designer f2 mentions that she is *"considering to use the [IEs] 'body deformities' to deconstruct clothing from,"* and that she would like to use it as a sort of *"rule or dogma"* in her project (f2, 2, 19-20).



This reveals that she is also faced with a contradictory issue, namely to find some function for the IEs, the 'body deformities', that is already part of her project but with no assigned purpose so far.
Designer f2 later reveals that she has been missing functions for more IEs: *"Pictures of mattresses, and [pictures of] Comme des Garcons. There were many unknowns that I did not know how to use"* (f2, 3, 3).

Designer i4
Industrial designer i4 is designing a concept for self-driving taxis. In snapshot 4, Designer i4 says: *"I feel fairly confident about the travel concept. Now it's just all the emotional and the creation of shape that needs to come in…"*. Designer i4 describes his research so far, that *"It's all written down in numbers, so it's very dry. Now comes this emotional 'what is it that this thing should say and signal outwards?' and I have begun looking for the name for the project. (…) And I find that it's harder than I thought it would be to come up with a name"* (i4, 4, 50). This excerpt from Designer i4 reveals the lack of and need for IEs, so far referred to as the 'name' for the project. Seemingly, this name should serve to conceptualise and inform what he calls the 'emotional' part of the project, which has to do with shape creation and expression of the design.

Designer f5
Fashion designer f5 is designing a collection. She has an IE, a specific fabric that she wants to use, but she needs a function for it: *"I have a wish to use this material, and I don't know where to stuff it in"* (f5, 5b, 30).

Designer i10
In her project, Designer i10 wants to work with the use of paper in future interior design. She talks about the early experimentation in her project. She says that she is approaching the experimentation by doing whatever comes to her mind. For example, she has started to weave in paper yarn; an IE in her project.

She is working *"from scratch"* and *"tries to get the material in my hands and see what I can do with it – what is it capable of?"* This reveals that no purpose has necessarily been assigned yet to the things she works with, as is the case with the paper yarn.

The designers also declared that the purpose of some information, initially intended for something specific, could shift once it was actually used or 'activated', as will be described later on. This purpose shift implies a reinterpretation of the IE. The shift is ascribed either to a recognised *excess* of information for the function initially intended, or to a recognised *lack* of information in the new function in which it is eventually activated.

The following examples show how IEs shift purpose.

Designer f1

Fashion designer f1 explains how an IE, a specific picture, is given a different role than first intended in his process, as it is activated in his process. Originally, Designer f1 intended one function, namely to inform shape, for the IE, but he ends up activating it in another function, informing colour, because he lacks information for this specific function. The quote below describes how: *"The colours come from the mood board. This picture was [originally] picked because I liked the shape. I have looked at a lot of pictures. I have put others up [on the mood board] that were mostly dull. If I had to pull colours from them, it would be difficult. It would be mostly black and white. Therefore I have gone back and have found older [earlier] pictures. And so they have re-entered the process because of the colours. It has been the plan the whole time that I should find colours, but those [colours] from the other pictures were not the ones I wanted for the clothes"* (f1, 4, 9-10).

Here, Designer f1 explains that in order to find the colours that he wanted for his clothes they should be 'pulled' from a source (picture), which he was missing. A source originally intended to inform shape turned out to contain information that could inform colour.

Designer i9

In his project, Industrial Designer i9 wanted to work with reduction of noise and disturbance issues in open offices environments. One main IE and theme of his project was 'phone calls'. Designer i9 describes the development of his project and how the central 'phone calls' shifts to be about 'control': *"I started out with these 'phone calls'. And I just think I have been introduced to the fact that it's about much more. Fundamentally it's about the fact that you are so exposed [in an open office], and it is the environment itself that discourages you from withdrawing and for example making phone calls, but also just withdraw and do some concentrated work where you are not disturbed all the time. So I have realised, that the more control employees have over the stimuli from their surroundings, the happier they are"* (i9, 7a, 18).

Designer i8

Industrial designer i8 designs shoes, and he talks about the development of a key idea, a 'side closing' in one of his shoes, intended for the fall season: *"that one (points to shoe), it was like (…), it would be really cool if it could have this (points) closing and have it be water resistant, because it [the closing] is not over here (points to the middle)."* Here Designer i8 describes his pursuit of a functional effect – water resistancy – by moving the closing of the shoe from the conventional top position to the side.

However, he ends up realising *"But it [water resistancy] has nothing to do with that [the position of the closing]. (…) it was the idea to start with, that on the 'fall shoe', with* *sleet and rain, it would be nice to have it [the closing] on the side, (…) but it… I mean rain will come in here [on the side] as well."*

The reason he let the closing stay on the side of the shoe, although it did not serve its initial function, is *"because I find that I can argue that it [the closing] was very androgynous and very classic [thereby relating to other themes in his project]. So I felt that the shoe could bear to have that closing, without having to necessarily explain why it is there"* (i8, 12, 197-203). Thus the 'side closing' has shifted from having a functional purpose to a more expressive purpose, in line with other themes in the project.

Designer f1

Fashion designer f1 talks about one of the inspirational sources for his collection, the IE and theme 'modernistic building'. He says that he was initially inspired by its colour, surface, and structure. However, he describes that it has *"changed a bit from being mostly about the outside of the buildings, which I thought was pretty cool, then I have maybe [started to] looked at the composition/compound of the buildings."* He elaborates that this new focus concerns *"the thing about the construction, and that you can see how the building is assembled"* (f1, 6a, 27-31). Thus, from intending to let primarily the *appearance* of the 'modernistic building' inform his design, it changes function and becomes informative for the *construction* of the clothes.

The examples above articulate a perceived need of, lack of, or a misfit between information and function. Firstly, they reveal that an opposite situation must be attainable in which a perceived adequacy of information and a relational fit between information and function has been achieved. Secondly, the actuality of this relation, and the fact that it can shift to be a more adequate match, as exemplified above, demonstrates that there must be some underlying structure of functions in a design situation.

The IEs can readily be empirically recognised, since they are a visible part of a designer's work. They are the things we can mention, see, and even touch – they are the matter or content of the design process. However, the idea of a functional structure in which the information is enacted cannot be perceptually experienced, but merely inferred from the designer's statements about a lack of information and a misfit. Thus, the functional structure is surmised from the rationale that if information can be lacking or a misfit exist, there must be another structure of functions in relation to which the perceived lack of information or adequacy, or a perceived fit or misfit, is recognised.

The actions undertaken by takers of under-determined tasks, as represented by the design projects studied in my research, expose such a functional structure. Hence, when there is sparse information about the task to begin with, it prompts the task taker to *source* information to the design system to a degree that is instrumental for the designer to make the process progress. In other words, the lack of information actualises, but does not produce, the structure of functions that needs to be filled and which causes the designer to introduce IEs to the process, e.g. by imposing what is often called 'constraints'.

The functional structure is not considered an order *imposed* onto the task by the self-imposition of constraints, as suggested by McDonell (2011). Rather, in a realist perspective, the information sourced into a project is ordered to fit a pre-existing structure. The structure is not physical in nature or empirically perceivable. Thus, it is only accessible as an object of study through the analysis of patterns in what *can* be studied empirically, namely design system information, and how it is *sourced*, *assigned*, *activated* and *transformed* by the designer's actions in the design process. These concepts will be described later.

7.3 Information Sourcing

Right from the beginning of the design process designers start to *populate* (i3, 1, 37) or fill the design system with information. I shall call the process of adopting new information to the design system 'information sourcing'. By sourcing information to the system, the information becomes an IE in the design system. Thereby sourcing is the act of letting information cross the boundary between the outside and the inside of the design system. As Polya says describing what he calls a 'practical problem', *"we take stock of the available relevant information, we collect more information if necessary"* and use the data which *"could contribute appreciably to the solution*" (Polya, 1957, p. 152).

The designers in the data set often refer to the act of sourcing, usually verbalised as bringing or taking *in* something:

Designer i10
Designer i10 talks about another designer who has inspired her: *"I use him as inspiration. He has these ten minimalistic principles. I have **brought them in** [as inspiration for design projects] for several years"* (i10, 7b, 16).

Designer f5
*"So you see (she points to a style), it's kind of the same front piece, but it needs a tuck up, because there is an extra colour, so that it doesn't become too much colour blocking, so I can **bring in more colours**"* (f5, 9, 75).

Designer i4
Designer i4 talks about a polar bear that has inspired his design of a self-driving taxi: *"I think I am most inspired by the back [of the bear]. Because it has this lump (…) I will try to* ***take it in*** *in my creation of shape (…)"* (i4, 6, 279).

Designer f7
Designer f7 has done a study of men's wardrobes. He explains how they will be used in his project. *"I'll take the best from the wardrobe study. Other things can* ***come in*** *as well, which they [the men from the study] didn't choose. Something I* ***add.***"

'Information sourcing' is a central action in design as well as in any creative process. A common characteristic of creative design processes is that the initial task is ill-defined (Dorst, 2004; Simon, 1973; Stokes, 2006), and creativity is often referred to as problem 'finding' (Campbell, 1960; J. W. Getzels & Csikszentmihalyi, 1975; Okuda, Runco, & Berger, 1991) in which *"the individual finds, defines, or discovers an idea or problem not predetermined by the situation or task"* (Nickerson, 2004, p. 395). This ill-definedness of the task and incompleteness of information is precisely what leaves room for something new to be found and achieved in the process. Thus, it is not a deficiency of the task but a necessity in the process of development and creation. The room that the missing information leaves open must therefore be filled with something that is not given in advance but which can bring novelty to the outcome. This is done by sourcing and transforming of information. Not all 'free space' is filled with fixed information all at once; rather sourcing happens throughout the process.

'Sourcing of information' thus marks a central difference between handling creative processes in contrast to formal problem-solving processes of e.g. mathematical problems. Simon (1969, p. 77) states that *"All mathematical derivation can be viewed simply as a change in representation, making evident what was previously true but obscure. This view can be extended to all of problem solving – solving a problem simply means representing it so as to make the solution transparent."* In this type of formal, well-defined problem, which is fundamentally different from any design task, it is evident that no new information is needed and no sourcing takes place, since nothing new occurs.

Sourcing is related to the notion of 'research' – a term commonly encountered in the data set – which expresses the act of looking for something with or without an idea of what it is. 'Research', in this context, should be understood in line with Frayling's (1993) *Research for Design*, i.e. research that is undertaken with the purpose of informing the design process and an eventual design.

In phasic design models research can be seen as a separate and temporally confined activity preceeding any creative, synthetical or design-generating activity. Rooted in, and dependent on, this process understanding it is sometimes noted that 'sourcing', or researching, is a 'pre-design activity' (J. C. Jones, 1992, p. 65). This view might likewise be a result of a narrow perception of the nature of research as 'fact-finding'.

However, based on the more encompassing notion of IEs, 'sourcing' is introduced to denote the intake of information into the design system. With this concept I diverge from the idea of information retrieval as a confined, temporal phase. Instead, I lean towards Eastman's (1969) point that designers must 'mix' *"information retrieval with [information] arrangement processes."* Eastman writes that *"Sometimes (…) only further inputs allow isolation of relevant design information"* since *"most further inputs are gained from cues identified while processing other parts of the problem."* 'Mixing' the two processes allows the designer to encounter those 'cues', as well as identify new queries beyond, and possibly reinforce, *"those made with the originally available information."* In the present perspective, these cues translate into the designer's realisations, already examplified, of missing or excess information.

'Sourcing' is the procedure of bringing new or more in-depth information into the design system without any deliberate attempt to alter the information. Thus, 'sourcing' provides an important distinction from the procedure of changing information and generating something new from it, which will be discussed in Chapter 11 'Design Syllogisms'. After discussing and nuancing some aspects of information in design processes, I will return to examine approaches to information sourcing in Section 7.6.

7.4 States of Information Engagement

Information can assume – and shift between – three different states of engagement throughout the design process: 'passive', 'assigned' and 'activated'. These states will be elaborated in the following.

When IEs are sourced into the design system at the beginning of an explorative process, they are often not immediately assigned any function. Rather they often rest in what can be described as an information refrigerator or 'stock' of passive information that is saved for later potential use. IEs can be sourced to this stock of passive information when the designer finds them potentially interesting or thematically relevant, however, without knowing how or whether they will be assigned any function and used.

The following examples show how information is sourced to the passive information stock without assigning it a function.

Designer f1

Designer f1 has an IE, a 'Monk', in his design of a clothing collection. He reveals that he did not at first know what role the 'Monk' should play in his process. This becomes obvious as, midway through his process, he notes that *"I think I know what it is I liked about these monks… I mean, what is it – it was something about some drapings, which I felt I liked, but I didn't want to do a… use it so literally…"* (f1, 6, 19). The quote does not reveal how or whether Designer f1 eventually ends up using the 'Monk', but it reveals that he sourced the IE to the design system without knowing why he liked it and how it should be used.

Designer i3

A little more than halfway into his process Industrial Designer i3 has realised the need for more information to inspire his shape creation and has started sourcing new information without knowing if he is going to use all of it. He says: *"For now, I have started with a very broad form inspiration search. So it's not… just because of these pictures I have shown in there… it's not the same as saying I am going to go that way"* (i3, 7a, 74).

Designer f2

Fashion Designer f2 describes how information is 'random', i.e. has no specific function in her process[14]:

"[I] start out with pictures and random material. It's not random at the time [when I find/choose it], but I realise later that it is. [Then I need to] find out what works and what doesn't."

Designer i4

Designer i4 talks about how a sketch became part of his project even though he did not really know to begin with what he liked about it or how he could use it: *"That sketch I made… it's actually my mouse pad. I always have a piece of… a pad of paper that I use as a mouse pad when I work (…). And I made this [sketch] on that. And I said to myself, "it's really cool," but I didn't really know why, and it wasn't what I wanted at the time, so I tossed it aside and then sketched it a bit [again], and tried some different things. And then I came up with this [sketch]"* (i4, 8b, 13). Besides exposing the sourcing of a passive IE to the system the excerpt exemplifies a shift in the engagement state of the IE, as it is 'tossed aside' and later 'sketched back in' and then, through several attempts of 'trying different things', activated in an assigned function.

[14] The quote is a reconstruction from interview notes.

Designer f1
Designer f1 went out to buy fabric. He explains that he had a list in order to keep track of what he had bought and still needed to buy but that he *"also bought stuff I just liked and thought that I'll [probably later] find an application for"* (f1, 4, 5).

Designer i3
Designer i3 explains in an early process interview that he is *"researching in different directions, on different companies, to gain more breadth before making the choice"* on what specific direction to take his project (i3, 2c, 21-22).

In a later interview Designer i3 reprises that *"in the beginning, I basically just tried to find some different pictures without knowing exactly what they would give me"* (i3, 7a, 108).

When an IE is given a purpose, a function, in the design process, we may say it has been 'assigned' to it. Assigned information differs from activated information in that information can be initially assigned to a function but end up not being activated and used. The concept of 'assignment' merely implies the intent or plan of use, whereas 'activation' of information is the actual 'use' of an IE in the process. 'Use' is understood in the sense that some action has been imposed upon the IE to transform the content of the design system.

IEs can enter the design system at any state of engagement. It can be sourced as a passive element, to serve an assigned function, or directly for activated use. Theoretically, IEs can shift endlessly between the different states throughout the process. For example, a designer might initially source a 'passive' IE to her system, because she finds it interesting but without knowing how to use it. Then after a while she might assign a function to it, only to later realise that it could not be used the way she intended anyway, and then it resumes a passive state or leaves the system altogether. The following is an example of how the state of engagement of an IE can shift.

Designer f2
In the following quote, Designer f2 describes how her IE 'foam ladies' have been assigned, passified and re-assigned in her design process:

"[I] went in one, a second, and a third direction. Now it's more about distortion and wrenching of body posture: Humpback, crooked back. There are links back to the original inspiration. The [IE] foam ladies have been out a bit, and are on their way back in. What they were connected to before did not lead me in any direction" (f2, 3, 2).

Later in her process, Designer f2 had made numerous draping experiments and samples. From the total amount of material produced in these experiments she chose to take some of the ideas for her eight silhouettes to be realised a step further. Afterwards, Designer f2 had to draw an entire collection of more than the eight silhouettes. Asked how the rest of the collection came into being she said: *"Some of*

them [the styles] were taken, not directly… but from some of the samples I had discarded … or not discarded but chosen not to realise. So that's where they were taken from" (f2, 10, 196-197).
Some of the information that has been generated has been rejected to serve the purpose for which it was initially produced, namely the realised silhouettes, and has been 'out' of, or passified in, the system. However, with a lack of information to inform a second purpose – the rest of the collection – it is re-activated.

When an IE is assigned and activated, it changes role from a passive, potential information resource to an active information resource playing a role and thus fulfilling a function in the design process. The relationship between passive, assigned and activated information is expressed in the following example.

Designer f2
Fashion Designer f2 explains how she imagines that her passive information will be assigned and activated: *"The pictures [on the board] are probably going to give me an idea about the form [of the emerging design] (…) I probably won't take anything literally, but the way they are shaped…"* (…) *"They [the pictures] will [also] play a role in terms of colour and structure (…) The colours come from the pictures. They [the pictures] are chosen for the form, but they will form the spine in a temporary colour scale that can be worked up from there"* (f2, 3, 21-27).

When an IE has been activated it does not necessarily stay active throughout the design process. Even when the result of a process move is not rejected, the information activated in it can resume a passive state as the process progresses. An IE resumes a passive state if the content of the design process changes to the degree, so that the IE is no longer visually or conceptually perceived as part of the current process content or the narrative about it was achieved. However, the meaning, i.e. the theme, represented by the IE, typically remains an active part of the process narrative thoughout the process. The 'narrative' of the design process is further treated in Chapter 10, Section 10.1.

7.5 Information Levels

When subscribing to the assumption that information fills functions in the design process there are obvious lower as well as upper limits to how much information can productively be an active part of a design process. At any given process stage the required functions must be adequately filled with information in order to stimulate process progression. If too little or inadequate information is present, there is a perceived lack of and need of information – functions are not filled, and information must be sourced. If too much information is present there is an information surplus compared to the functions to be filled – some IEs must be discarded. The idea of a level of adequate information is found conceptualised in some existing theoretical contributions. Galle (1989) introduces the concepts of over-, under- and well-constrained problems in relation to computational methods of architectural design. Onarheim & Biskjaer employ the concept of a 'sweet spot of creativity' (Onarheim, 2012b, pp. 122-123), which refers to the level of task constrainedness at any given time in a creative process, when an individual perceives the highest potential for creativity. The 'sweet spot of creativity' represents the perceived potential for creativity as a function of constrainedness, where the sweet spot area resides somewhere between too few and too many constraints, as shown in Figure 30 below.

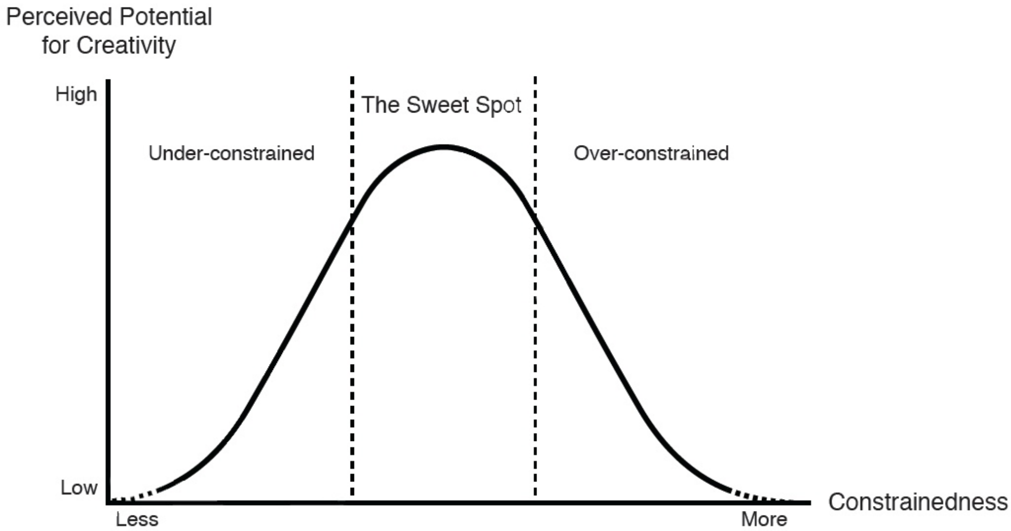


Figure 30: Biskjaer and Onarheim's (2012b, p. 123) bell-shaped model of the perceived 'sweet spot of creativity' as a function of constrainedness.

The sweet spot implies that at any stage in the process a certain level of constrainedness or information will make the designer or creator feel more capable of creating and thus more capable of progressing in the process.

If combining the notion of the 'sweet spot' with that of an information function structure it can be surmised that the 'sweet spot' for creative performance is not an entirely arbitrary and subjectively perceived measure. Rather the instrumentality of the information present in the design system to spur process progression is contingent on the fulfilment of the required functions at any given stage in the process. In other words, there is a reason that a certain level of information is conducive to the progression of the process.

Because there can be too little, too much, and inadequate information in the design system, some concepts must be introduced by which to nuance and address these issues:

Information Density

Information density refers to the general load or quantity of information in the design system of passive, assigned, and activated information. The information density does not address the experienced adequacy or instrumentality of the information to spur process movement. Thus, the information density is not itself very crucial or interesting in a design process. What is of interest is the *distinction* between the information density of a task and the informedness, as shall be described below.

Informedness

Informedness relates to the density and adequacy of IEs in relation to information functions at any given time and stage in the design process. We can talk about three different levels of informedness: under-informedness, over-informedness, and well-informedness. Characteristic of the desired well-informed design system is that the information available is experienced by the designer to be instrumental for process progression. This construal is reminiscent of Dorst's (2004) contention that a well-structured problem 'leads' the designer through the design process. This situation is the *"normal, fluent problem solving behaviour"* of which the steps are *"quite logical, routine and implicit"* (p. 7). This is in contrast to situations of 'breakdowns' in which this flow is interrupted.

The well-informed state and the progression that follows can only be experienced if the system is not at the same time under- or over-informed.

The informedness of a design system is not a stable condition. Firstly, the informedness of the system can change with every generative step in the process that changes the information content of the system. Secondly, a design system can, locally, be both under- and over-informed at the same time. It only makes sense to talk about the concepts of under- and over-informedness in relation to a structure of functions. Let me explain by using an analogy from the labour market:

In some sectors in our society there can be a scarcity of labour and many vacant positions, since there are too few candidates to fill them, for example in production. Simultaneously, there can be high unemployment rates in other sectors due to too many candidates for too few positions, for example in the creative sector.

In both instances, it only makes sense to talk about too few or too many candidates in relation to the number of positions provided. If the number of positions were immediately adapting to the number of candidates at any time, the notion of too few or too many would be irrelevant.

Similarly, a design system can simultaneously be under- and over-informed in relation to the 'positions' or different functions to be filled in the design process. This occurs if there are too many IEs assigned to one function and too few to another.

As mentioned, the design system can also have a high information density but still be under-informed. If a designer's design system possesses a lot of passive information, such as factual knowledge about some issue, but she has no idea of how to activate it, e.g. creating some shape based on that information, her system has a high information density, yet is at the same time missing information, since the information present is not perceived to be adequate to fill the function in which it is needed in order to make progression.

In the following examples designers account for perceived over-information in their system.

Designer f1

Fashion Designer f1 has faced a redundant theme and IE, the 'essential wardrobe', in his process, which means that he has more information than he has functions. He describes that lacking a function for the IE has caused inertia in his process and that it eases his process when he finds a function for it. The function is found when he realises that the 'essential wardrobe' resides under, or should be merged with, another IE in his process, 'sustainability': *"I had to redefine the concept of 'essential', because telling myself I had to make 'the essential collection' (...) was really preventing me from going forward, I felt completely locked in this, and I felt that every time I drew something, I had to argue and say "Is this essential? No it isn't" (...) So I think I have redefined this 'essential' concept to a more 'durable' collection. (...) [The fact] that I changed it from 'the essential' to maybe more like a 'slow fashion' collection (...) made me much more relaxed, [feeling/knowing] that I could do it – that I could argue for all styles in relation to 'slow fashion', whereas, if I had to argue in relation to 'the essential', it would be very difficult."* (f1, 6, 40-55).

Designer i8

In a supervision session between Industrial Designer i8 and the iSupervisor the topic of too much information is brought up by the supervisor. The iSupervisor says to Designer i8: *"Maybe you have too much information. If you overload it... if you add too much [information], people forget it. Add one or two significant things. It gets confusing, diluted. Rather one really strong, attractive concept in a shoe"* (i8, 6, 23). The 'board' below shows some of the themes in Designer i8's project.

Designer f6
Fashion Designer f6 realises the over-information in her system: *"I did want many colours, but eventually I had five different blue nuances (…), I realised I couldn't get them all to… I mean it would be way too messy if all materials had to go into a style in some way. And that was the same thing I was struggling with when I was sketching and had to decide "ok, which materials and colours go to which place?" It was just a total colour palette [mess]."*

In a supervision session, the fSuperviser and eSupervisor had said *""wow, you have many materials." It was there I realised it. Because I could see, when they said it, that "oh, that's the reason why I have been struggling with finding a nice… or having some nice styles" – all of it had just become muddled. And I was thinking, "that's frustrating," but it wasn't something I thought I could do anything about."*

Designer i9
Designer i9 explains that *"Suddenly I could see that all my research led in so many different directions that I could potentially focus on. And make a concept. And so that was the choice I had to make, "okay, I need to opt out of some things to target other things."* He realises he has too much information and that he needs to deselect some of it.

Designer i4
Designer i4 has defined some aspects about his self-driving taxi system, e.g. 'electrical car', 'taxi', and 'Volvo'. He describes that these IEs are like *"walls that I put up for myself, (…) like a frame. There could probably have been 25 of those [IEs], but that would have involved too much research on that topic."* Thus, he acknowledges that there is a limit to how much content can appreciably be part of his project.

Expressions such as 'needing' and 'missing' in the following quotes represent under-information of the system:

"I was so immersed in this project (points to all the photos and colour compositions on her board) and then suddenly everybody was drawing, and I was like "shoot, I need shape, where do I get that from?"" (f5, 6, 43)

"I realised that I really needed a platform" (i4, 4, 62). *"(…) you can't just draw a car out of nothing. You need a 'package'. And a package is the platform for your vehicle"* (i4, 4, 44).

"I'm aware that I need to… maybe not set up more rules… but I need something to create the collection [from], because it's very difficult" (f2, 6, 28)

"I'm missing some hardware" (i3, 4, 15).

"I need to find the second phase dogmas" (f7, 2b, 22).

"I need [to talk to] a wheel chair user" (i4, 3, 7).

"You are missing some jersey" (fSupervisor, f5, 7, 48).

"I simply need to do more research" (i8, 1, 28).

Over-information is characterised by information surplus; not all the information assigned to a function can be incorporated simultaneously, or a particular IE becomes redundant. Under-information implies that certain functions are unfilled and that there is not sufficient information available to make progress in the process development.

Between the two is an interval of adequacy – resembling Onarheim and Biskjaer's (2012b) notion of a 'sweet spot'. Adequacy means that the present IEs fit the information needed to produce a move envisioned by the designer. This will be described further in Chapter 11 'Design Syllogisms'.

Under-information of a task should not be confused with the concept of 'under-determination' of a task. Task determination relates to how well-defined the information is about what to work with, how to do it, and by what criteria to assess the outcome of the entire process. The determination of a task develops all the way through the design process, so that any task, regardless of its level of determination at the outset, becomes increasingly determined when approaching the final output. Informedness relates to the instrumentality of the present information to allow progression in the process, possibly towards unknown goals.

An under-determined task is not necessarily under-informed. It can easily be adequately informed to make the progression flow, or even over-informed with loads of information that does not, however, support the designers' ability to move or realisation of where to go.

Information Operationality

As an IE can be any observable piece of data in a design process, naturally IEs can have many different forms. Those forms differ not only in nature, but likewise in level of operationality, i.e. the level of perceived ability of the IE to be transformed in a design move by some action undertaken by the designer. The scale of operationality stretches from the abstract to the concrete level, where the concrete can be handled directly and the abstract cannot. In order to operationalise an abstract IE, it must be converted into a concrete IE. The process of conversion, is one of interpretation. The interpretation process is further described in Chapter 7, Section 7.6.

An example of a concrete IE could be a specific draping technique or a lump of modeling clay, and an abstract IE could be a stack of user surveys or a picture of a Le Corbusier building. However, operationality is not an objective trait of the IE itself. Rather, it is a *potential* subjectively perceived by the designer. One designer might find a specific picture immediately amenable to some design operation. This scenario implies that the designer construes the IE as concrete and specific. Another designer might find the same picture inspirational, but may not be sure how, or what specifically about it, to use in her project. This scenario implies that the designer construes the picture in a more abstract way.

Nonetheless, certain forms of IE manifestations lend themselves more easily to imagined operation: For example, it might be easier for the designer to imagine how she can act towards a piece of physical material than how she can act towards a word or a collection of facts obtained by research.

As shall be expounded in Chapter 10, Section 10.4, we can understand design processes on different 'process levels' ranging from a high, overall process level featuring a high abstraction, low detail, bird's-eye perspective on the process, to a low, operational process level concerning the low abstraction and high detail level of individual process steps. At what level of abstraction an IE is in fact useful to the design process depends on the process level to which it is considered.

An abstract IE can serve to inform the process on a high process level, but might need interpretation in order to be activated in a move at the low, operational process level. The reason for this is that we cannot take intentional action with things of which we are not fully aware, which is the case if designers do not yet know how to construe the role of an IE in their project. Likewise, as physical beings, we cannot take action with things that we cannot, directly or indirectly, touch.

The span of operationality embraced by IEs, from abstract to concrete, corresponds to the span of process levels, in which the IEs can play part. Figuratively, we can say that the nature of IEs can stretch ontically through the different process levels, all the way from the most abstract, overall view on the process, to the lowest level of individual process moves.

Information Urge

When the design system is under-informed it results in a perceived *need* for information. I will call this the information urge. The urge is what prompts designers to source information, whether they seek objective facts relating to some defined situation or self-impose information chosen from more subjective motives. In the present study the realisation of this urge supported the assumption that a degree of structure defines an adequate level of informedness.

Urge implies that the designer realises that the system is inadequately or under-informed. However, as the design system can have a high information density and be under-informed at the same time, it might be difficult for the designer to detect the information insufficiency, unless she is mindful of the different functions needing to be filled. This was expressed clearly in the above quote by Designer f5, when she said *"I was so immersed in this project (points to all the photos and colour compositions on her board) and then suddenly everybody was drawing, and I was like "shoot, I need shape, where do I get that from?"" (f5, 6, 43)* For this reason, processes can suffer and stagnate due to under-informedness, even though they are densily populated in other functions. The topic of stagnation will be addressed in Chapter 9.

7.6 Strategies for Information Sourcing

Since an under-determined design task is characterised by the absence of information, information must be acquired to fill the void. According to Christiaans and Restrepo (2000) the question of how designers select and retrieve contextual information and knowledge *"processed or needed during the design process has been scarcely studied"* (p. 64).

There are, however, some examples from earlier research dealing with ill-defined tasks from an information processing perspective that discuss the matter of how and from what sources such contextual information is retrieved. Contextual information is information that is found outside, and is not directly related to, the task at hand.

According to Eastman (1969) *"The significant difference between well- and ill-defined problem solving is shown to be a specification process similar to information retrieval processes" (p. 669)*, and that ill-defined problems are *"tractable in analysis if they were separated into their information retrieval and search aspects"* (p. 674). Thus, Eastman stresses the significance of processes resembling that of *sourcing* in his account of ill-defined problems. This is a topic that typically belongs in the field of artificial intelligence.

Eastman says that when retrieving *"information from the environment (e.g., from the Experimenter, the original design, or from the problem statement) [it] is related to original information generated by the [subject]. No other source for this new information is possible. (…) pieces of information are generated and related with those that are given before information of specific relevance to the problem is generated".* (p. 672).

Reitman (1964) expresses a similar view on the relationship between constraints. He writes that a feature of ill-defined problems is that "*though they would generally be considered complex they include few constraints as given. (…) All other constraints are in a sense supplementary, generated from one transformation of the problem to the next."* In this sequential process, constraints can occur by transforming the problem into its composite elements. Thus *"as the problem-solving proceeds, the progressively more differentiated problem components themselves become increasingly more important as source of constraints,"* and the 'continuing particularisation' of the problem and its subcomponents entails particularisation of the constraints related to it (p. 297).

Though Reitman thus focusses on the interrelationship between constraints he also notes that there is no fixed limit on the sources of 'transformational equations', i.e. the ways in which or the principles by which a problem can be 'transformed'. Hence the problem solver might consult and refer e.g. to friends, books, existing knowledge, or solutions to related problems to find *"abstract new transformational formulas"* (p. 297).

Thus Reitman, like Eastman, welcomes the idea that information can be sourced from the context 'outside' the task. But where Eastman seems to require that the information retrieved from the context must be coherently related to the information that is already part of the task, Reitman opens up to the possibility that the information gained from the context can be abstract and new in relation to the task. However, at the same time Reitman apparently limits this option to apply to 'transformational formulas' only. Seemingly, constraints are considered generated within the problem by the transformation and its particularisation, whereas only the principles of doing so can be retrived from any source the designer sees fit. In other words, sourcing from the context in this case seems to be an option that applies only to the principles by which a problem is transformed – not to what it is transformed *on* or to the conception of the goal towards which transformations are targeted.

Other contextual information sources mentioned in design theory literature are 'domain knowledge' (Jonassen, 1997, 2000) obtained by 'fact finding' (Basadur, Ellspermann, & Evans, 1994) and previsously acquired knowledge from experience stored in memory (Jonassen, 2000; Polya, 1957, pp. 150-151).

In *The Structure of Ill Structured Problems* Simon (1973) identified three sources of accepting and assimilating information into ill-structured problems: *"information evoked from long-term memory, information contained in problem instructions or additions and modifications to instructions, and information obtained through sensory channels from the external world"* (pp. 197-198). This information processing perspective on problem solving renders the information acquisition sources identical to those possessed by a computer: memory stored on the harddisc, the algorithmic instructions given with a programme, and the input channels such as a microphone or a camera. Though Simon thereby acknowledges the possibility of taking information into the processing system through input from its context, he does not, however, shed much light on how designers do so. A designer is not an information processing system that can turn off input to her sensory input channels or read these sensory inputs in binary, Boolean unambiguity. Rather a designer must employ strategies when assimilating information. Simon does not elaborate on such strategies.

The above examples of contextual information retrieval have some common traits. Very generally one can say that they emphasise two things: One is the assumed relationship and link between the information already given with the task and information subsequently obtained. The other is the factual nature of the information obtained.

I will argue that a more nuanced picture can be sketched of the sources, procedures and strategies for sourcing information into under-determined tasks. In the following I shall supplement the above perspectives with the insights obtained from my empirical studies.

Discovering and Choosing

Though sourcing has hitherto been discribed as one activity, there are, in fact, two compound types of activities involved in sourcing information: discovery and choice. *Discovery* relates to how potential information is found, and *choice* refers to the decision and the arguments with which IEs are adopted to the system from the discovered information. These two activities can range between systematic and spontaneous. The distinction between the two should not be regarded as strictly dichotomous but rather analytically guiding.

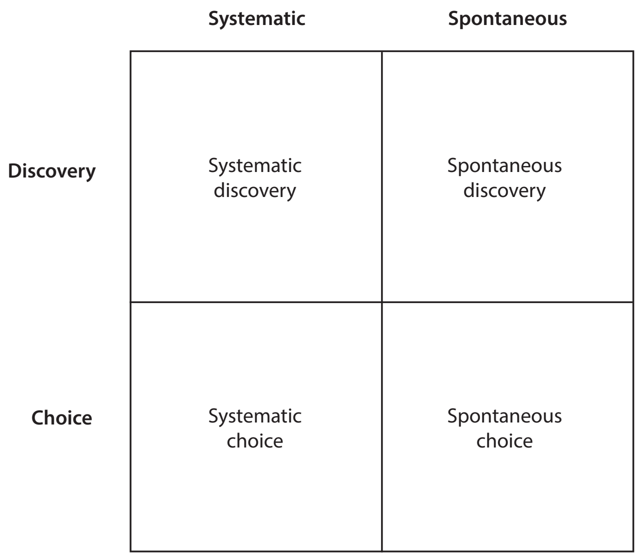


Figure 31: Sourcing activities.

Figure 31 shows a quadrant of sourcing activities. Either of the discovery strategies can be combined with either of the choice strategies. Examples from the data will be given later. Below I shall introduce and exemplify the four quadrants and their sources.

A *systematic discovery* is a search carried out deliberately by actively looking for either specific, or merely some, information with the intention of populating the system or filling a certain function. This can be done in different places. A non-exhaustive list of such places, found in the cases, are:

- Google
- User investigations
- Expert knowledge
- Inspirational places, e.g.
    - Exhibitions
    - Excursions
    - Magazines
    - Blogs
    - Books
    - Shops

A *spontaneous discovery* takes place suddenly, in memory or through experiences. This means that something suddenly jumps to the designer's attention and is either considered related to the task or merely 'too good to let go'. These places can for example be:

- Surroundings in work and everyday life
- Long-term memory, e.g.
    - Past experience
    - Known concepts and theories

A *systematic choice* means that a defined strategy is set up to select from the discovered information to source it to the design process. For example:

- *"I have to choose the first ten pictures from my Google search"*
- *"I will only use information that is mentioned by several respondents"*

A *spontaneous choice* is made from intuition and preference and is thus not characterised by a defined strategy. However, it is still a conscious choice to source the IE to the design process.

Not until a conscious choice is made to source an IE into the design process is it considered part of the design system.

A systematic discovery is not necessarily followed by a systematic choice and vice versa. A systematic discovery could result in numerous search results from which intuitive choices are made. For example, a designer could conduct a systematic Google search and then choose from the search result the pictures that 'talk' to her. On the other hand, a spontaneous discovery might bring several associations to mind to which a systematic selection strategy could be applied.

Examples of discovery and choice in design projects:

Designer f2

In Designer f2's project, we find an example of a systematic discovery and a spontaneous choice.

Designer f2 describes how she arrived at the technique that characterises her entire project. It was her work with the written task that led her to discover the technique. "*I was looking for something that related to the subject [the distorted body], which I could use*", she says (f2, 10, 296). In an earlier interview, she has explained that she chose the technique from among the search results, because *"I really liked him [the designer behind the draping technique], but not so much the rest."* Therefore, she *"picked him [the technique] out"* (f2, 4, 16).

This is an example of a sourcing situation with deliberate and systematic discovery, but a spontaneous choice of strategy.

Designer A
Industrial Designer A has 17 years of professional experience. He reflects on how the sourcing of information in his design processes is carried out. In the interview excerpt he exemplifies a spontaneous discovery. His subsequent choice at first sounds spontaneous, but the spontaneity represents 'reflection in action' (Schön, 1983) and is, as he reveals, really an expertise to see and feel it spontaneously, when the requirements of the task are more systematically met.

Discovery
*"When you sketch you don't have in your head a picture of what it **has to** look like. You just don't. But there are lots and lots of things which you know that you have to comply with when you sketch. It is these requirements about what we can and cannot do that we have to stay within, (…) so you sit and sketch by hand (…) then at some point something shows up… it can be the trajectory of a line… it might be that you are looking at your colleague who sits and draws something, and you see the motif of his drawing upside down, and all of a sudden you get an idea; "we could do it like this.""*

Choice
"When you have worked with design for a lot of years and you have prepared thoroughly for the task you are working on solving, that's when you can suddenly see that one sketch comes across more clearly than the rest. You can just see that here are some things that work in relation to all the parameters we have up in the air, and when you start diving into it then there are some things that are self-evident, and that's when you can feel if it's right or wrong – you can simply see it by going through the different things that need to fit together."

He explains, *"Many times it's a game of chance, but the eyes looking at that game are experienced and can see "where is the chance, that is the right one.."*

Interpreting Information

Discovery and choice of new information can also take place among already sourced information. If IEs are not immediately meaningful or useful to the designer, they must first be interterpreted by her in order to attain a form of perceived adequacy to be actively used in formation. By interpretation the designer elicits new information from existing information.

Interpretation takes place if the designer aims to work with a passive IE or if an urge for information spurs the designer to seek and elicit additional information among already assigned or activated information. In both cases the information in need of interpretation is perceived abstract, relative to the role it will eventually play in the project. Through interpretation abstract IEs can be 'broken down' into more particular or detailed IEs if the designer recognises that it is conducive to the process.

Eastman (1969) describes a similar action by introducing the term ‘decomposition’ of ‘Design Units’ into *primitive* DUs. Eastmans ‘decomposition’ metaphorically divides the ‘design puzzle’ into more pieces that must be recollected. Thus decomposition *“widens the solution space by allowing a greater number of primitive DUs to generate a greater number of design alternatives”* (Eastman, 1969, p. 672).

Interpretation of IEs, on the other hand, can imply not only a division but also a redefinition of the IE, ascribing it a function and potentially a new meaning. Since design is not problem solving, and many elements of the final design are not known in advance, there is no requirement that all information present at one stage of the process remain relevant in the next, or is given a ‘place’ in the final design. The ‘design puzzle’ is constructed, not solved, and therefore new pieces can be added and existing ones discarded.

‘Interpretation’ is a key concept by which an IE becomes instrumental in a design system. It is the designer who perceives and construes the task and the information it comprises. For example, the same picture could be displayed on two different designers’ boards and still be assigned completely different meanings and roles in the two processes dependent on the individual designer’s interpretation. One designer could be inspired by the automatism of a Jackson Pollock painting; another designer could be drawn by his use of colour, and yet a third designer could see Pollocks’s painting as representative of the stylistic context in which another product should fit. As IEs can attain new meanings and functions in the design process, the way an IE is interpreted can change.

Examples of interpretation:

Designer f6

The following example shows Designer f6 discussing with her fSupervisor how to interpret the ‘Balinese Worlds’ IE[15]:

Designer f6: *“I have ‘tribes’, ‘landscape’, ‘culture’, ‘religion’… I have also searched for cultural costumes. Balinese clothes have many layers and techniques.”*

fSupervisor: *“Also, the Balinese dancers [on the pictures] do something with their hands and eyes, these small things.”*

Designer f6: *“Yes. I tried to find books about the culture, costumes, patterns and details. It would be nice to transform some of these to digital prints or funny small details.”*

fSupervisor: *“The Bali things are funny. [they are] Absurd in our context – not in theirs.”*

[15] Conversation is reconstructed from observation notes.

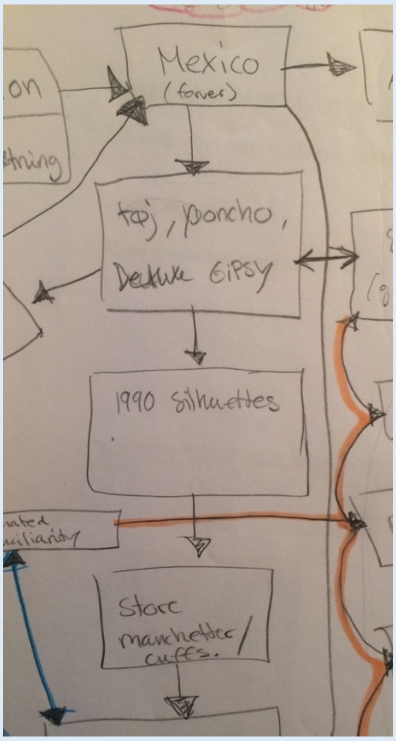
Designer f6: *"The Bali thing is only for the visual part [the practical project], it doesn't have enough depth for the theoretical project. (…) I must figure out which details I like."*

iSupervisor: [agrees] *"You must be more specific: What do you find interesting? How can you translate that into some modern, relevant technique?"*

Designer f5

"I have interpreted my 'shadows' into stripes, rills, plissé, graphical and draped shadows" (f5, 6, 10)

Designer f5
In her project of designing a collection, Fashion Designer f5 has an IE and theme, ‘Mexico’. From a visualisation of her process, Designer f5 explains how ‘Mexico’ has travelled through a ‘funnel’ of interpretation, through ‘Deluxe gypsy’ to ‘1990 silhouettes’, among others.



Asked how ’Mexico’ became ’1990’, Designer f5 answers, *”In that year they wore so many of the things, I had thought of [as related to ‘Mexico’]. Those V-necks, drapings and big cuffs, voluminous sleeves… So it was a way to… [conceptualise] how has that thing (points to ’Mexico’) been interpreted? [However] it (points to ’1990’) is still old, so [I am asking myself] how can I interpret it further? What can I use from it? I have used for example the big cuffs.”* She describes this process as ’driving it through the funnel’. (f5, 5a, 51).

Designer i3
Designer i3 refers to interpretation when he explains how he elicits information from IEs that are already part of his design system: *“In the beginning I just tried to find some different pictures without knowing exactly what they would give me later. (…) And when I start to sketch I sit and look at all of them [the pictures already chosen] a bit more broadly and see what just pops up. And if nothing pops up immediately, I try to focus a bit more on one [particular] picture, [and ask myself] what can that picture give me, if I need some form [inspiration] in one way or another”* (i3, 7a, 108).

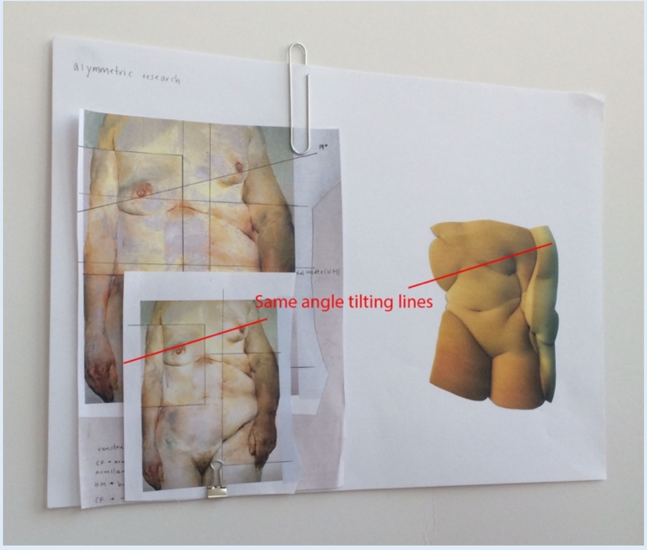
Besides referring to interpretation, the quote describes a shift from a spontaneous to a more systematic discovery process.

Designer f2
Designer f2 works with the main theme 'Distorted Body'. She talks with her fSupervisor about two 'Distorted Body' pictures on her board, and how she interpreted and elicited new information from them. They both portray naked bodies with skin creases:

Designer f2: *"I analysed [the pictures] and realised that these two parts [angle lines of breast position in the two pictures] are tilting at the same angle. I tried to incorporate lines [in the design] that have the same angle."*

fSupervisor: *"So from the inspirational material you made the choice to always do [the] cutting line on [a] 70 or 60 degree angle?"*

Designer f2: *"Yes."*



Interpretation is associated with specification of both *meaning* and *function* of the IE.

In the example of Designer f6, the IEs mentioned already represent her main 'Bali' theme. She is looking for a way to specify both the meaning and the function to them.

In the example of Designer i3, he has not assigned a specific meaning to his pictures but seeks a function (form inspiration) in them.

In the example of Designer f2, the body pictures represent the theme and the meaning of 'Distorted Body'. Designer f2 interprets these IEs into a specific angle that becomes a cutline in her styles, whereby they are given a function.

In Chapter 10, Section 10.3, I will expand on why a maintained connection between meaning and function is desirable, and why a non-existing or weak link between the two can be problematic.

Choice Justification

Sourcing into and activating information in the design system involves and represents a choice. I have already mentioned 'choices' in relation to information sourcing, and that they can be roughly divided into systematic and spontaneous. Yet, in the following, I will nuance the concept of 'choices' and the justification for them. In general, the decision to bring into and use certain information in the design process is perceived by the designer to somehow stand out as superior to alternative decisions. However, designers have different types of reasons for assessing and justifying a certain choice as the better one. As mentioned, designers must employ certain strategies in order to make choices, and these strategies are differentiated by the way in which the designer *justifies* her choices in the design process.

In the data analysis *choices* were identified by tracing actions since, typically, actions in a sense represent choices. When, for example, a designer *uses* a specific material she simultaneously *chooses* that material. Choice *justifications* were found by connecting actions to the explanatory reason given for undertaking those actions. In the data, actions are indicated by action statements involving personal subject pronouns in connection with verb phrases, e.g. *"Right now I am doing shape investigation, but I need to go back and look at some of the old pictures," "I have started to look into materials. I definitely want this one,"* or *"I will have to contact the company on Monday. I need some more information."* Choice justifications represent the types of answers and arguments a designer gives – and which are presumably accepted by others – when she is asked about the reasons why she made specific decisions in her design process. For example, when a designer is asked why she bought certain materials for her collection, the purchase of the materials is the action representing a choice made in the process. When she answers that she bought them because they fit with and supplement the fabrics she already had, she *justifies* the choice.

From the data, six different choice justification types have been identified, which subsume the selection strategies of the case designers. Each justification type represents a specific kind of choice. The six types fall into two main categories: external and internal.

'External' means that the information chosen is not connected to existing information in the design system. This kind of choice is *Elementary* and the justification for it is beyond the scope of the design process.

'Internal' means that the information chosen is already part of the design system or is connected to other information that is. Five kinds of justifications, and choices represented by them, reside under this main type: *Subjective, Pragmatic, Coherent, Objective, and Constrained.*

Table 7 shows the six types of choice justification, which can also be combined.

	Choice	**Justification**	**Example (abbreviated)**
External	Elementary	The information chosen is not linked to other information in the design system. The choice is Elementary, and the justification resides outside the design system.	Designer i4 wants to work with self-driven taxis because: *"I have a great passion for the automotive industry."*
Internal	Subjective	The choice justification is given by the designer's subjective preference or intuition.	Designer i3 picked out some of his sketches *"From what I personally thought were… shapes I think are interesting."*
	Pragmatic	The choice justification is given by the perceived pragmatic preferability of a choice to e.g. generate process movement or minimise undesired effects.	Designer f2 chose to carry on with a specific technique because from that *"you get some fast results, and that was what I needed."*
	Coherent	The choice is justified by reference to and coherence with existing design system elements	Designer f2 sketched her drawn collection "*on the basis of the ones [the styles] I had chosen to realise",* for example *"this one [a top] was converted to a long jacket."*
	Objective	An objective choice justification is sought in external sources e.g. surveys, user studies, disciplinary conventions, etc.	Designer i3 chose to work with a specific idea among some alternatives. The decision *"came out of the feed-back that I have got, both from the doctor and the dentist."*
	Constrained	The choice is forced, and justified with reference to the constraining rule that governs it.	Designer i8 has many wild ideas for his shoe design, but has to pull it in a more classic direction, as *"I have to adapt to my collaboration partner."*

Table 7: Overview of choice and justification types

Elementary Choices

Elementary choices have already been described earlier on in relation to the initiation of a task. Though seemingly dominant in the early stages of design process, elementary choices can be made throughout the design process, when the information already available in the design system does not fit the recognised functions.

Elementary choices can be stipulatively defined as initial or basic choices that bring essentially new information to the design system. Elementary choices need not be defended but merely stated, as the reason for making the choice resides outside the design system and/or precedes the start of the design process. Thus elementary choices differ from other kinds of choices and the justifications for making them. Elementary choices can be grounded in personality or experiences. They are not chosen in relation to or in association with something else already in the design system. If the elementary choices initiate the design process this is a tautology, since there is nothing there to choose in relation to.

An example of an elementary choice comes from Designer f6. She has chosen the theme 'Sport and Dance' for her collection because, as she says, it "*is a big part of my everyday life"* (f6, 0, 27). Questioning why these things are a big part of her life would produce answers far beyond the subject of her design project. What caused Designer f6's interest and talent for design in the first place might, of course, be related or similar to what caused her other interests or talents. However, such causes are rooted outside and precede the design process: the project idea came from the interest – not the other way round.

The same Designer f6 was likewise inspired by the movie *Samsara* to choose 'Bali' as an inspiration. Again, questioning why she watched that movie would produce an answer residing outside the scope and deliberate intent of the design process. People just watch movies – it's an everyday activity. Such causes, beyond the scope and intent of design processes, must be considered unrelated to the reasoning about the design processes. A line must be drawn to avoid a definition of design tasks and choices that regresses indefinitely from the activity of designing. Therefore, the concept of elementary choices is necessary as the analytical dividing 'line' beyond which no further questions are posed and no further justifications are needed.

The concept of elementary choices is reminiscent of other theoretical notions, e.g. Darke's (1979) 'Primary Generator', which has been mentioned earlier. The 'Primary Generator' refers to an initial concept or objective, often in the form of a visual image, appearing early in the process. Yet, *"The term primary generator does not refer to that image but to the ideas that generated it"* (p. 38). The 'Primary Generator' forms *"a starting point for the architect, a way in to the problem"* (p. 38), in other words, similar to elementary choices, it is a designer-imposed*"value judgement rather than the product of rationality"* (p. 36).

The idea of a 'Primary Generator' is different from the elementary choice in that it is related to a particular initial stage in the design process (p. 38). It seems to be construed as a singularly occurring phenomenon in the process. Also, the 'Primary Generator' is affiliated with a *"variety reduction or narrowing down of the range of solutions"* (p. 38). Elementary choices, on the other hand, are seen as providing something to work *with*, rather than removing options.

Other similar concepts that will not be elaborated further here are e.g. 'Alibi' (McDonnell, 2011), and 'First Line' (Beatty & Ball, 2010).

As part of the inception of the concept of 'Elementary Choices', as described above, all data were analysed line by line for Elementary Choices, and perceived instances were coded. The coding was based on a provisional concept definition guided by an orienting concept from theory (see above and on page 167) and observations and notes from the data collection process. Based on this analysis the stipulative definition, set forth above, was coined.

From the analysis, I found that the background for Elementary Choices is often found in the motivation part of project descriptions, because some Elementary Choices are associated with the personal reasons for working with a specific theme or working in a specific way with the project. However, Elementary Choices can also occur later in the design process.

Here are some examples of Elementary Choices and explanations associated with them:

Designer f2

In her project description Designer f2 explains an Elementary Choice for a way of working with draping: *"during my exchange programme I had a whole semester to just 'nerd' with draping. (…) I thought this 3D sketching [i.e. draping] course was much easier to relate to than some drawing (…), maybe also because drawing is not my strongest point. So I got much more volume and 3D understanding by doing it this way. And then I have just used it since (…). So it made complete sense to carry on with it."*

Designer i4
In his project description, Designer i4 explains that he wants to work with the concept of electrical, self-driven taxis and taxi systems because: *"I have a great passion for the automotive industry, design[wise] and technically. And I have been on an exchange programme at UMEÅ University of Design where, among others, I have worked with BMW, AUDI, and VOLVO"* (i4, 0, 22).

Designer f7
Designer f7 is working with a series of surrealist techniques in the design of her collection. The reason for this Elementary Choice is stated in the project description: *"I am a part of the generation-Y, a generation known for being egocentric and (…) only thinking about themselves and only doing things that are beneficial for themselves or people in their inner circle. Things need to have meaning to them before they are performed. (…) In this project I want to break a social norm in society by doing a project that is celebrating the nonsense – the no meaning – of a project that is driven by the process and coincidence rather than by conscious choice. (…) In surrealism there are numerous techniques and games to free the mind (…) I will use the different techniques to liberate the imagination (f7, 0, 10-16).*

Designer i3
When asked where his initial ideas for the project came from Designer i3 answers: *"(…) partly from what I would like to work with, so in principle from what I would like to be able to exhibit in the end and display in my portfolio, and then also from what you can come up with, like a general brainstorm of what problems you meet in your everyday life"* (i3, 7a, 31).
He exemplifies elsewhere that *"one of them was fear related to the health care system, and another one was something about the socket outlets of the future, i.e. electrical supply in private homes"* (i3, 7a, 27).

Designer i4
An example of an Elementary Choice made later in the process is found in the case of Designer i4. At snapshot 4, he realises that he needs to *"sit down and make a profile on what it is I want this design to say. What it should taste of."* He says that *"now starts this emotional 'what is it really that this [design] should say and signal outwardly?' and I have started looking for a name for the project"*(i4, 4, 48-50).

In the following snapshot, Designer i4 has come up with the name 'Ursus' inspired by the polar bear. He says, *"I have looked at the polar bear (…) It has an interesting shape. It is a heavy animal, lumbers along, steady and determined, it wanders. But [it has] a fast [streamlined] shape. Everyone has a relationship to it: We've all had a bear – a teddy bear – it gives people a gut feeling of security deep inside"* (i4, 5, 30).

From the examples of Elementary Choices found in data, they seem to be made on the basis of:

- Availability: Problems or curiosities encountered in everyday life, primed by the surroundings and affected by availability in memory.

  For example, Designer i9 has made the Elementary Choice to work with noise and privacy issues related to phone conversations in public spaces. He writes in his project description: *"The motivation for this project takes its outset in my own experiences with the problem [noise pollution and privacy issues related to increased use of cell phones]. There is a lack of spaces where phone conversations can take place, especially in the public sphere where many people are gathered"* (i9, 3, 49-51).
- Personal interest or skills: Matters of personal experience, skills or general interest to the designer.

  For example, Designer f1 has made the Elementary Choice to work with the architecture of Le Corbusier and Mies van der Rohe. He writes in his project description: *"I am fascinated by the simplicity and clean lines which both Le Corbusier and Mies van der Rohe uses (...) It also fascinates me that even though Mies van der Rohe's buildings are made of heavy materials they still seem very light and fragile. It is this symbiosis between the lightness and the heaviness that fascinates me; an area that I want to translate into fashion"* (f1, 0, 20).
- Perceived future value: For example, ideas about what type of project or product the designer would like to add to her portfolio in order to best 'brand' herself.

  Designer i3 has made the Elementary Choice to work with fright issues in medical settings. He writes in his project description that – inter alia – *"The purpose of this project is to broaden my experience and portfolio into the field of medico design"* (i3, 2, 43-44).

From analysis of the data related to Elementary Choices a tendency is indicated towards a difference between fashion and industrial designers in the distribution of Elementary Choice entries. Figure 32 below shows the distribution of Elementary Choice entries in the cases.

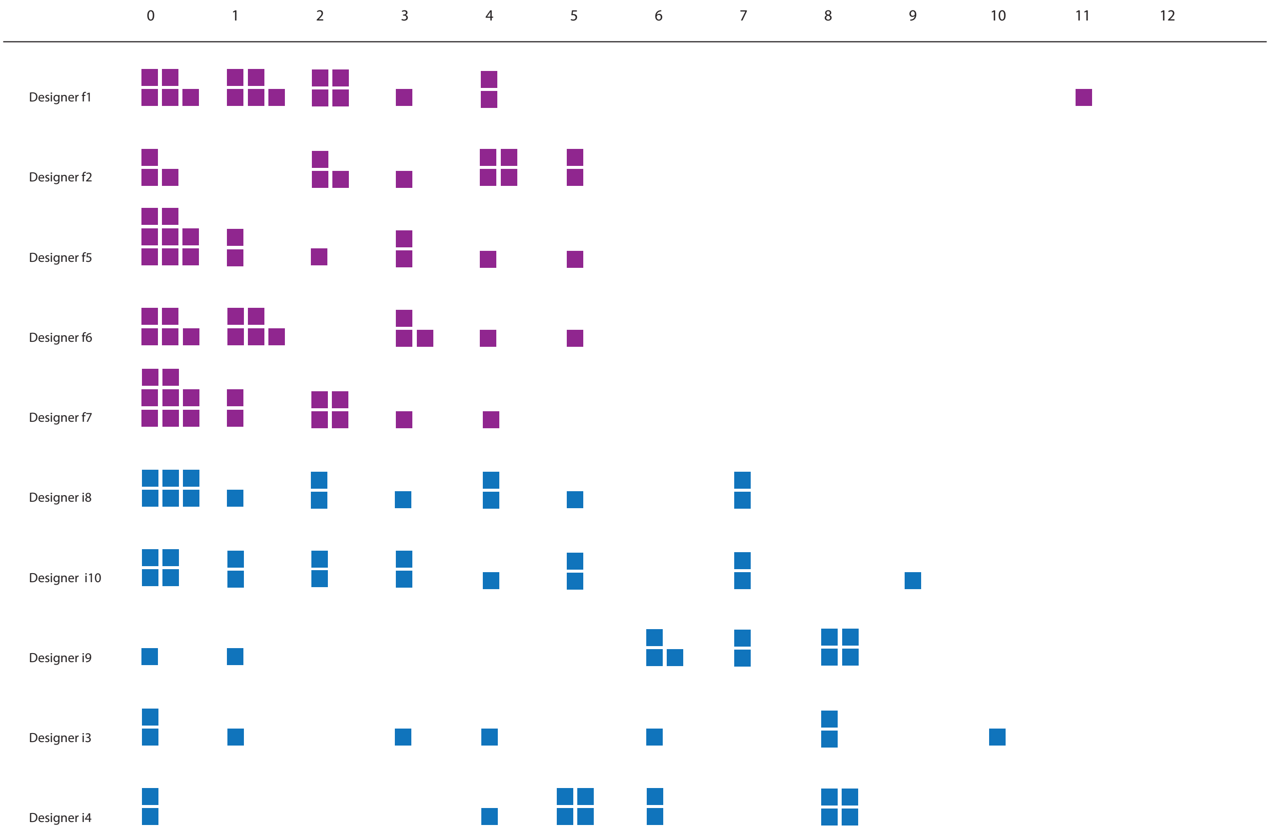


Figure 32: Distribution of Elementary Choices in design cases

Along the vertical line in Figure 32 the design cases are distributed with the Fashion Design cases at the top (purple colour), and the Industrial Design cases at the bottom (blue colour). The horizontal axis represents time, and is divided into the time lapse snapshots (1, 2, 3 ...) through which the cases were studied. The squares displayed in horizontal rows for each case shows the number of *Elementary Choice* entries[16] for each snapshot in time.

As can be seen, there is a tendency of uneven distribution of Elementary Choice (EC) entries which seems to be related to design discipline. The fashion designers seem to introduce many ECs early and to stop making new ECs around midway in the process. The industrial designers, on the other hand, appear to make fewer ECs early in the process compared to the fashion designers, but instead distribute them over a longer period of time relative to the fashion designers and the overall process length.

The two Industrial Design cases displayed above, Designer i8 and i10, seem to differ slightly from the other Industrial Design cases with an EC distribution that is

[16] Each Elementary Choice has only been counted once when it is first mentioned.

reminiscent of the Fashion Design cases. This difference is not only noticeable in the visualisation, but also in the general nature of the task they deal with, as I shall explain in the following. And exactly the nature of the task might be an explanation for the seeming difference between distribution of ECs in the two design disciplines.

It would not be outlandish to assume that in general industrial designers more often than fashion designers engage with demand-driven design and 'structural problems', i.e. an actual problem in the real world serving the needs of someone or something. In the cases studied, this is the case (see Table 8 below).

Discipline	**Case**	**Outset and description of task** cf. the case designer's project description	**Nature of task** Interpreted by means of Eggink (2009) and Verbrugge's (2012) concepts
Fashion	Designer f1	*"Modernism is one of the most influencing periods in modern history (...) In this project I would like to combine the essence of the modernism expressed in Mies van der Rohe and Le Corbusier's architecture and turn it into fashion, focusing on the space, light, materials and structures of the houses"*	Author-driven
	Designer f2	*"Subject: Posture"* *"What does different postures express, and is there something you would rather like to express than others? How do we want to appear in public? What characterises a good/poor posture? Can garments either enhance or cover up a posture?"* *"How can I frame a concept around the topic posture from which I can develop a collection?"*	Author-driven
	Designer f5	*"My inspiration came from Frida Kahlo's childhood home, Casa Azul (...) I want to use this inspiration and mood [from the house] and channel it into a more modern expression. This I found in a series of pictures called Erbgericht by the Berlin-based photographer, Andrea Gruetzner (...) The pictures contain both recognisability and alienation (...) I want to translate this peculiar and familiar feeling into a collection for women."*	Author-driven
	Designer f6	*"Inspired by the documentary movie 'Samsara' I want to explore the culture, traditional clothing and costumes, art and history of Bali, Indonesia. I will create a sports- and dancewear collection for my persona. My persona is a professional dancer who loves to perform and practice."*	Author-driven
	Designer f7	*"[In my generation] things need to have meaning to them before they are performed (...) In this project I want to break a social norm in society by doing a project that is celebrating the nonsense (...) a project that is more driven by the process and coincidence than by conscious choice.*	Author-driven

		(...) In surrealism there are numerous techniques and games to free the mind, I will in my project investigate the different techniques (...) How can I transform these unconscious experiments into a wearable collection?"	
Industrial	Designer i3	*"Within the field of health care, fright or anxiety among patients can lead to bad treatment experiences or even an insufficient or absent treatment. According the Danish Dentist Association approximately 10% of the Danish public suffer from odontophobia (dentist related anxiety) and about 30% are nervous, frightened or has a light anxiety towards receiving dental treatment. (...) This project will aim to find solutions that deal with the negative experience of seeking or receiving medical help."*	Demand-driven
	Designer i4	*"Electrical/self-driving taxi project" "By means of such vehicles we could make traffic safer, reduce tailbacks and give people, who are not able or willing to own their own car, a new and better way to be 'auto-mobile'" "[Want to] see if this [self-driving] technology could be implanted in existing or maybe completely new ways of thinking about taxi service"*	Demand-driven
	Designer i8	*"In the 1970s (...) gay liberation contributed to free men from the everyday hysteria about how to behave and express themselves (...) I want to interpret what the gay liberation has brought men [in general] and their way of expressing themselves style-wise. I want to look at how 'liberation' can otherwise contribute to my project. What is "Material Liberation"? How can I create a shoe collection for men focusing on materials, based on the 70s 'liberation', forms and colours thought in a contemporary perspective?"*	Author-driven
	Designer i9	*"Tele-communicative behaviour (...) wireless connection allows calls to take place anywhere. What are the consequences for having a 'good conversation'? My experience from larger institutions is that they lack areas in which phone conversations can take place without the caller being disturbed or him disturbing others. In this project I want to investigate (...) How can I design a 'space' in which phone conversations can be held with greater pleasure and without inconvenience from and on the surroundings?"*	Demand-driven
	Designer i10	*The list of possible ways to use paper is almost endless. (...) Paper is in many ways an interesting material (...) It is cheap and easily accessible (...) It is at once strong, light and fragile. It has endless modification possibilities and can have many different expressions. Additionally, paper has a potential to be a very sustainable material. (...) I [see] in many ways*	Author-driven

		an unexplored potential in the use of paper in design of lifestyle interior products for the home." *"How can paper be used with more relevance and acceptance as a lifestyle material for future European home interior?"*	

Table 8: Task nature

In the ID cases studied, the project is self-defined, which is why the 'structural problem' is, initially, identified and chosen by the designer herself. Though such a choice is indeed also an Elementary Choice in itself, when the project, from the outset, is free and open, 'structural problems' inevitably bring with them a series of constraints that can serve to guide subsequent choices, which, being guided, are no longer considered elementary. The constraints encountered in a structural problem may relate to needs, utility and functionality – all aspects that may occupy the focus of the designer at the start of the design process in this kind of task. This focus may result in a deferral of considerations of 'visual appearance' – what is sometimes referred to as 'soft' or 'emotional' aspects in the data – until later in the process. In the cases studied, the ID designers at some point seem to realise that they need to source additional information to inform this aspect of their design process as well.

Hence, in the Industrial Design cases form seems to follows function (both temporally and conceptually), as Louis Sullivan said, but often only partly. Frequently another source of information is needed in addition to the one that is retrieved from the existing process information. I will return to this issue in Chapter 8, in the section 'Information Familiarity'.

I mentioned two ID cases that stand out in terms of the (chosen) nature of their tasks. They diverge from the other ID cases – and from my experience with and assumptions about ID design projects in a more general sense – because they do not deal with structural problems: they have a lot of visual and conceptual inspiration material, but there is no obvious 'problem' that they try to solve.

Designer i8 states in his project description that he wants to design shoes inspired by the gay liberation of the 1970s and with focus on material exploration (i8, 0, 11-18). In the first supervision session his supervisor advises him to *"over-assert references to Industrial Design. Otherwise people will feel it's a fashion project. It must sound and read as an ID project"* (i8, 1, 6).

Designer i10 wants to work with and explore paper as a material for lifestyle interior in the homes of the future. As this project is not about apparel, the comparison to fashion projects is less obvious. However, the absence of a 'structural problem' and the distribution of EC entries suggest a similarity. Designer i10 is herself aware of the special nature of her project, as she states in a presentation of her project halfway in: *"This is a bottom up project where I start out with the material. Normally you start with the concept"* (i10, 5, 4). Asked what the 'bottom up' approach represents for her, Designer i10 answers: *"a bit like with material-driven design, which is a notion that is being used a lot lately. It's kind of the same. You start with the material instead of the problem solving"* (i10, 11, 125).

In the fashion design cases, most Elementary Choices are made at the beginning of the design process, as seen in Figure 32. None of the fashion design students' work is demand-driven and seldom tries to solve a 'structural problem'. Rather they seem to strive for some unique, subjective expression in an author-driven design approach. This will presumably apply to most fashion designers in general. The early adoption of many different themes (Elementary Choice), as found in the cases studied, suggests that they are (unconsciously) aware of the lack of externally imposed information and the consequent need to immediately source information into their processes. Their challenge may instead lie in understanding how the sourced information can be given a function in their process.

It deserves mention that the seeming difference in EC entry distribution in the two disciplines and the relation to their task type bears some resemblance to a finding made by Goldschmidt and Smolkov (2006) in a study of the impact of visual stimuli on a designer's performance[17]. In Goldschmidt and Smolkov's experiment, a group of design students were given two different tasks; one was (in the researchers' retrospective reflection) considered *"mainly utilitarian, with its operational properties considered of the greatest importance"*, and the other *"aiming primarily at emotional satisfaction and pleasure through its appearance,"* which required 'high aesthetic appeal' and 'uniqueness' (p. 564). The argued distinction between these two tasks is not unlike the difference between a demand-driven and an author-driven design task, or – from a very generalising perspective – between Industrial and Fashion Design. Goldschmidt and Smolkov found that *"better results were obtained with visual stimuli than without them"* (p. 563) in the latter type of task, whereas in the first type of task no such clear correlation was found. In the case of Goldschmidt and Smolkov's study, as well as in

[17] Goldschmidt and Smolkov's experiment differs from my studies in that the visual stimuli of which they study the effects on designers' performance is not chosen or (necessarily) considered part of the task by the designer herself.

mine, the 'author-driven' task requires immediate visually perceptible information to work from, since few (functional) requirements are inherent in the task. If Goldschmidt and Smolkov's experiment had not been conducted as *"'sketch problems' (i.e., solutions are expected at a rough conceptual level only)"* (p. 564), they might at a later process stage have met – like I did – a more pronounced need for, and thus a more clear impact of, visual stimuli on the 'demand-driven' processes as well.

Subjective Choices

The Subjective choice justification rests on the individual designer's preference or intuition. In that sense, the Subjective choice justification resembles the Elementary choice. However, a Subjective choice is not linked to the introduction of essentially new information, but is a justification of a choice made between information that already exists or that is produced in the design system.

The Subjective justification is unique in the sense that its source of reason is the designer herself and not some external logic. Oftentimes designers' work, or part of it, is author-driven, stemming from a motivation to express something unique, rather than solving a structural problem of external needs and demands. In those cases, that, which is sought expressed, must to some extent be judged by the subject whose expression it conveys, i.e. the designer herself. In subjective choices designers do not apply objective measures to justify their choices but use themselves – their intuitions and preferences – as the scale by which to weigh their options and make decisions.

As mentioned the author-driven approach to design is prevalent in fashion design. In the following interview excerpts Teacher A, a fashion designer with 20 years of experience in teaching and supervising fashion design students, reflects – in correspondance with the findings from the present data – on the motivation and necessity of including subjectivity in those types of tasks and the decisions made in them.

Teacher A
Teacher A believes that design students should *”work with something that is personally relevant and then say ”what does it mean to me?” and ”what do I find interesting?” and then move to the core of that.”* She suggests that *”maybe it’s specific to fashion [design], realising that ”I have to also take myself as a point of departure, because that’s what has to give input when I don’t seek a problem” (…), you can have a designerly problem situation of some kind, but it’s not the [kind of] ’problem’ you solve. You don’t go out and identify some problem, so it has to come from another place. And for that other place to be relevant, you have to bring yourself into the game. You can’t have it out here (gesticulates an arms lenght from body) and make it extremely abstract.”*

”If, as a fashion designer, it [what you work with] doesn’t have relevance for yourself or has something you are interested in yourself, then it can be hard to create a relevance for others too in your work (…) I think it’s the first precondition.”
Teacher A then starts talking about professional designers and says: *”A recurring starting point (…) is almost always, ”what do I feel like right now? What is my agenda, and what am I interested in?” And then that is added to several other things, but that’s where it starts.”*

The Subjective choice justification likewise aligns with the characteristics of author-driven design as outlined by Verbrugge (2012). He observes that this design approach is dominated by the personal style of the author/designer and by concepts derived from the world of fashion and avant-garde art. It is highly individual and intuitive and aims at making objects ‘special’ and ‘exclusive’. The main driving forces in such a process are ’unrestrained creativity’ and ’spontaneous ideas’ (p. 22).

Verbrugge also points out that *“In the domain of Author Design, while existing technical possibilities are transferred into products, it is not the function as such that is at stake, but the meaning the product radiates”* (p. 25). The aim for this radiation of meaning is analogue to the previously mentioned desire to express that can motivate a design task as well as a structural problem. In bringing this meaning out author designers *“rely more on their intuition”* (p. 27) and make use of *“more individualistic creativity”* (p. 43).
The focus on meaning relates author-driven design to Verganti’s (2014) concept of design-driven innovation, which evolves when things are given ’radical new meaning’.

Subjective choice justification is prevalent in the fashion design cases studied, but it also occurs in the industrial design cases. The following quote, however, captures an element of reluctance that is typical for the industrial design cases studied when it comes to Subjective choice justification, as it seems to aften be considered an insufficient basis for making a choice:

Designer i4
In the last part of his design process, Designer i4 is in a supervision session with the iSupervisor. They are discussing challenges in Designer i4's decision making. The iSupervisor is encouraging Designer i4 to allow himself to make subjective choices.

Designer i4: *"(…) I think my problem is that I feel "there has to be a reason for everything." So I'm putting myself down a bit …"*

iSupervisor: *"Some reasons can also be more emotional reasons: "I think this feels more stable" or "I think it feels faster" or "I think it feels a little more sexy" and so on… It's alright to rationalize or validate things through emotional choices, which are more about expressing something or a kind of good feeling, a taste, if you like, rather than it has to be about price or function or other very rational things. It's what makes us different from each other, it tends to be the emotional side rather than the rational side, you know?"* (i4, 8a, 76-77)

The following examples display the use of Subjective choice justification:

Designer f2
Designer f2 is interviewed on her choices of materials:

Interviewer: "*How have you chosen them?"*

Designer f2: *"Intuition. And then I have just tried to get a wide range of different types. Different properties. And they might need to be supplemented."*

Designer i3
Designer i3 is interviewed about his reasons for decision making in his process:

Designer i3: *"I have made some different hand [drawn] sketches (…) I have tried to pick out some of them and draw a little further"*

Interviewer: *"What characterises what you have chosen, what are the criteria (…)?"*

Designer i3: *"From what I personally thought … shapes I think are interesting. Just shapes I wished to explore further (…)"* (i3, 8c, …)

A bit later in the interview (where we talk about a hand-grip that design i3 is designing):

Interviewer: *"What was the point of the height of the handle (…)?"*

Designer i3 *"(…) It was really… it was because I thought it was an exciting shape"* (i3, 8c, 55-58).

Designer f5
Designer f5 is focussing primarily on three photos out of a whole series which inspires her design process. Asked why she picked exactly those three photos to start with, she says: *"it's purely subjective, this (points to the photos) because it was the first three I put up [on the board] (…) I actually realised that I have hung some of them upside down. But I didn't want to change them, even when I recognised they were upside down. Because there must have been a reason, there was the compositional story that I wanted to tell – even if it gives a lightness or a heaviness. (…) it [the three photos] is in a way my muses that reside with me"* (f5, 5a, 67-77).

Designer i8
Industrial Designer i8 is designing shoes. He explains why he started focussing on the galosh as an inspiration for a boot he is designing.
”I just thought it was an exciting reference relating to the ’season’ and ’the classic man’. (…) It’s like the unspoken detail in the boot” (i8, 12, 149). *”I have always thought that the unspoken detail is an interesting thing to have in your considerations when designing things”* (i8, 12, 103).

Designer f2
In an interview, Designer f2 claims that she works on a design ”*until ‘it’s there’.”* In the following quote she explains how she knows when that is: *“With this one [specific style] it’s about realising when you like the way that the technique works with the fabric, when it seems natural and not tense – that you don’t force the fabric in one direction – so it’s more of a personal opinion about when enough is enough and when to do more”* (f2, 5a, 63-64)

Pragmatic Choices

The Pragmatic choice justification arises in connection with the perceived pragmatic preferability. This preferability can lie either in the capacity of the choice to generate process movement and creativity, or in the capacity of the choice to minimise undesired effects e.g. waste.

The following examples demonstrate Pragmatic choice justification:

Designer f2
In the case of Designer f2 an example of Pragmatic choice justification is the expected capacity of the choice to generate process movement and spur creativity. In the following interview excerpt, Designer f2 talks about her choice of technique:

Designer f2: *“I chose two construction techniques (…) but I have chosen only to focus on [one:] subtraction cutting”*

Interviewer: *“How come?”*

Designer f2: *“Because I think it was more interesting and gave me more to work with (…) one of the reasons is also that with subtraction [cutting] you get some fast results, and that was what I needed”* (f2, 5a, 3-8).

Designer i3
Designer i3 makes a Pragmatic choice justification, in this case the benefit of the choice to ease and frame his design process.

In the design of a patient control and communication device, Designer i3 has chosen to focus on the dentist context. The reason for this choice is that the dental treatment situation is a more stable context to design for, because the patient is always in the same position relative to the practitioner. This stands in contrast to *“for example if you lie on your stomach on the examination table at the doctor’s office to have a verruca removed or something, then there is a big difference in how you are placed in relation to the practitioner.”*

Designer i3 describes that this stability is *"a way to get a defined frame around what my product should be able to do (…) to have something to focus on and not focus in all directions. In that case you can easily make something that is o.k. here and o.k. there, and not perfect for any of the situations. So it's really about being able to make it perfect for one thing."*

Designer f6

In the case of Designer f6, a Pragmatic choice is found that does not relate to any perceived capacity of generating process progression or creativity. Rather, it seems to relate to the preferability of not wasting something valuable.

Designer f6 wants to design a dance wear collection. She says that she has *"a lot of interesting fabrics from her last project – it was also sports wear – they are still relevant for this project. (…) I want this project to be colourful too, so why not try to fit them in"* (f6, 3, 57).

Coherent Choices

A Coherent choice is justified by reference to and coherence with existing elements in the design system. The coherence is a perceived link between steps and elements in the design process, determining and justifying choices.

Examples of Coherent choice justification:

Designer f2

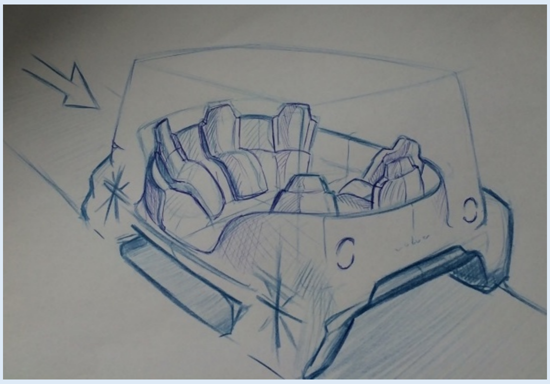
Designer f2 is designing a collection of which eight silhouettes are realised and the rest are only drawn. Designer f2 works from a strategy to first design the eight silhouettes to be realised, and then draw the rest of the collection. In the following quote Designer f2 describes how the design choices of the the rest of the drawn collection are coherently chosen on the basis of the eight silhouettes she has already made and realised by draping. She states that many styles in the drawn collection were *"sketched on the basis of the ones [styles] I had chosen to realise (…)"* (f2, 10, 197). For example, she says, *"this one [top] was converted into a long jacket. (…) with an outset in that draping, but in another material and in a longer version, I mean a narrower version."*

Designer i4

In an interview, Designer i4 explains that he changed the exterior car design and window position after having changed the seat position (for safety reasons) to ensure that *"you could look out the window (…). From here [the original seat position] you would have the view forward (…) you would focus on the landscape outside, so you don't get car-sick, but by changing this [the seat position], you could have had it [the view] to the side. So [I had] to take a step backwards; "how would you then… [solve it]?" Shape-wise you would sit and stare directly into a wall [if the original exterior design had not been changed]."*

Interviewer: *"So you were changing the exterior after having changed the interior due to the safety concern?"*

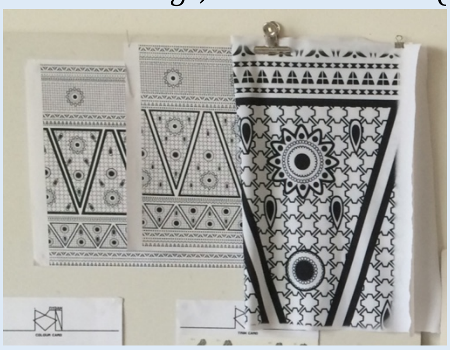
Designer i4: *"Yes"* (i4, 8b, 52-53).



Designer f6
In this quote, Designer f6 accounts for the coherent choice of patterns in her project.

Interviewer: *"These patterns, do you have them from anywhere in particular? I mean your print?"*

Designer f5: *"I have my print from this (points to photo of Balinese pattern) (…) It has been made more graphic and modern and [I have] tuned some things up and down. And this one (points to another print pattern) is also something of what is in here [the Balinese pattern]. And then I have a lot from all kinds of other Balinese ornamented surfaces, both from these costumes and rugs, culture and art"* (f6, 5,98-101).


Designer i10
Designer i10 works with paper in interior design. She talks about a project presentation she has made. In the following she describes that material choices have been derived from her research:

Designer i10: *"Then I told [the audience] about the three most important companies I have visited, telling them about the three materials I had chosen, which I had chosen from [the production of] those companies"* (i10, 11, 135).

Coherence Direction

Coherent choice justification can take two directions: backwards and forwards.

Backward coherence can also be called a top-down process. It requires that features of the final output – some design parameters – are known beforehand. In that case the route towards the output can be envisioned by, as previously mentioned, abducing backwards potential steps that will connect the desired stage to the actual one. In this process, choices can be made and evaluated with reference to their capacity to bring the designer closer to the goal in a kind of informal means-ends analysis (Newell & Simon, 1972, pp. 416-417). The main thread of coherence is thus pulled from the desired goal.

An example of such backward coherence is seen in the case of Designer i3. He knows that he wants to design a *control device* for medical patients. He also knows that he wants his design to be *handheld* and *ergonomic*. It should offer the patient (a feeling of) *control* and *safety*. Thus, he uses these concepts as guidance for his information search. These words, representing features of his design goal, pull him in the direction of his goal, and his choice to apply them is coherent with this goal.

In forward coherence, the current stage of process information is perceived to determine or produce choices. In this case, the course of development is pushed forward from the outset rather than pulled by a goal. This type of coherence is interesting and prevalent in under-determined tasks, where the goal state is unknown. An example of forward coherence is seen in the case of designer Designer f2, when she chooses material for her drapings on the basis of the collages she has developed.

As 'coherence' is found to be a central concept in design processes, it will be further analysed in Chapter 10, Section 10.3.

Objective Choices

An Objective choice justification is sought in external sources e.g. surveys, user studies, professional conventions, etc. It aims to establish an objectively or democratically derived reason for making a choice. The justification is constructed from generally accepted, expressed or enacted norms, opinions, practices and values. One example is *utilitarianism*: What project is perceived to actually help real people? What problem is most urgent and would, if solved, help either the most number of people or people in the most need of help? The project deemed most utilitarian is deemed the one objectively obvious to choose. Another example of Objective justification is *consensus*: which artefact, out of several alternatives, do most people like? Or which gets the highest score in a test among users? This option would be objectively justified.

Below are some examples of Objective choice justification.

Designer i3
In this example Designer i3 objectively justifies his project choice. Among competing ideas *"I wanted to do a project that was not just [meant for/ producing] consumption, but that actually somehow helped some people. So it's definitely a matter of helping in the surrounding world and making life better for somebody. (…) Because this one [the choice picked] has another ethical value… then sustainability can be [allowed to be] weighed a bit lower"* (i3, 7a, 33-37).

Designer f6
In a supervision session, Designer f6 discusses Objective choice justifications with her fSupervisor.

Designer f6: *"I'm thinking of meeting up with a gymnastics or dance team and research what they need. What are important elements in a dance collection? It should not only be my thoughts about it."*

fSupervisor: *"You could also analyse a sports brand, do some user and business research."*

Designer f6: *"Yes, [look at] how do they build up their collection. That would also give me an argument for why I do what I do, then it's not just my own universe."*

Designer i9
Designer i9 has four concept types for the product he is designing, but he does not know which one to go with. He is about to visit some potential users in a company. Designer i9 discusses with his iSupervisor how to choose among the concepts, and the iSupervisor advises him to use the visit to gain insights that can justify objectively the choice to be made.

iSupervisor: "Ask them e.g. which [they find] is most practical, which works best, which is awkward? [ask for] positives and negatives of the four [concept] types. When you actualise it, it's no longer presuming. Then you can say "I know that's the difference"."

Designer f1
Early in his process, Designer f1 is doing studies of men's wardrobes. He asks men to choose the twelve most 'essential' pieces from their wardrobes. (f1, 1, 12). Designer f1 intends to use the results from the user studies to objectively justify design choices in his process. The plan is to *"analyse which types of clothing pieces are most frequently pointed out by the men"* studied. He says that it is a sort of rule or dogma in his project that *"others pick out the clothing pieces"*. However, Designer f1 only wants to *"take the best from the wardrobe studies – things can also be included which were not chosen [by the men], something I pick"* (f1, 2a, 24-34).

Designer i3
Designer i3 explains why, among competing functions of his emerging design, he chose a particular one:
Designer i3: *"It [the decision] came out of the feed-back that I have got, both from the doctor and the dentist whom I have talked to, but also from some peer students and a couple of others I have talked to."*

Just as the Subjective choice justification is prevalent in the fashion design cases studied, Objective choice justification is pervasive in the industrial design cases studied, and rarer, though not absent, in the fashion design cases. This point is articulated well by Designer f1, who finds that it is *"atypical that fashion designers do user studies – usually we just guess what people want*" (f1, 2a, 36). It might be added that designers who do not deploy user studies or other means of objective justification are not necessarily replacing them with arbitrary guesses of what people want. Rather, those designers might want to express and change the meaning of things, as mentioned earlier, and thereby *affect* what people want.

Constrained Choices

A Constrained choice is a choice enforced by circumstances beyond the designer's control, or by rules considered inflexible by the designer at the time the choice is made. Such rules may be imposed by the designer herself or someone else. In a Constrained choice the source of justification is the reference to the rule that governs it.

Examples of constrained choices:

Designer i8

Designer i8 has many ideas and inspirational sources for his shoe design. One of these IEs he calls 'Gay Liberation'. 'Gay Liberation' promotes a funky and avant-garde style, challenging classic conventions. At the same time, Designer i8 has a collaboration partner, a Danish shoe brand, which he thinks is more conventional. He is excited about the collaboration but also realises that it will pull his design in a more classic, more traditional direction than the 'Gay Liberation' theme would.

Designer i8 says: *"I would like to make the ultimative four shoes, but I have to adapt to my collaboration partner"* (i8, 5, 16-17).

Designer f5

Designer f5 has studied Johannes Itten's colour theory for her design project. Here she has found the claim that *"Colours are like tones of music. There's no such thing as a bad tone, it's about harmony. If you want to test [colour harmony in] a composition, you should divide a picture into how many percent of each colour [there is in it], split [it] up, it should be light grey when you mix it."*

Designer f5 has made it a rule in her project to analyse and make sure that each individual silhouette, as well as the entire collection, adheres to the rule that if the colours were extracted from the entity and mixed in liquid paint, the result should be the right tone of light grey.

In a supervision session Designer f5 and the fSupervisor discuss how this rule determines other choices:

fSupervisor: *"(…) you made the colour exercise (…) [ask yourself] if I have to achieve grey, what do I have to change in the [colour] ingredients?"*

Designer f5: *“I would like the entire collection to end up in a light grey [if hypothetically the colours were mixed]. The span of the collection. Then I would need something really creamy light and something fresh and colourful”* (f5, 3, 68-69).

Hence by sticking to the colour theory rule, the need of ‘something really creamy light and something fresh and colourful’ is determined by that rule.

Designer i3

Designer i3 is designing a control and communication device for patients receiving treatment in a medical context. In an interview he talks about creativity in the design process. Yet Designer i3 acknowledges that the medical context restricts some choices and hence creativity due to specific industry-related requirements. He says:

“Creativity is a funny thing, because it’s not like I feel more creative when I generate ideas than when I give shape to things, but it’s different ways of being creative. And of course also things like choosing materials and stuff like that, I feel there’s also a creative phase in that. But in a project like this exact one it’s [choosing materials] actually a bit more analytical, because it’s about equipment for the medical industry and stuff like that. You need to make sure it can be cleaned, and there are many requirements regarding the materials that make it not so creative compared to which materials that could look nice or have special effects.”

The Constrained choice stands out from the other choices, as it is forced. This requires a more nuanced understanding of the concept of *choice*. Since a constraint is a rule dictating what the designer can or cannot do, constraints actually provide the designer with the opposite of a choice. A constrained choice means that the act of determining and activating aspects of design process content – information – is forced into place by the constraining rule.

Activation of information based on a choice demands an argument for the relevance or coherence of the choice to its context, except for Elementary choices for which those arguments reside outside the analytical scope of the design process. In a constrained choice the argument for information activation *is* the constraint itself, since the constraint determines it. Once a rule is introduced the designer does not need to argue further why she obeys it, she can simply refer to it. Thus, in a sense, the constraint takes the place of the argument.

Argument → choice
Constraint → constrained choice

Constrained choices are usually combined with other types of choice, since constraints often leave some options open. In all of the above examples of Constrained justification choices can be discerned despite of the constraints. In these cases, constrained choices will usually be superior to and carry greater weight than subsequent choice arguments.

Though choices and constrained choices are based on different things they have the same effect on the design process: they settle and particularize information in design processes in an approximation towards the ultimate particularity (Nelson & Stolterman, 2003) of the final design.

Combined Choices

Finally, the six types of choices and justification described above can be combined in the decision making.

Examples of combined choice justification:

Designer f2

Designer f2 justifies a choice by a coherent-subjective combination:

"I bought a bunch of materials that relate to my colour scale (…) and they have shown to be very classic… I guess that is because it's part of my DNA [as a designer]" (f2, 5a, 14).

The 'relationship to the colour scale' represents the coherent justification. The 'classic DNA' is a subjective justification.

Designer i10

Designer i10 is designing a modular room divider. She does not know yet exactly what the product will look like in the end. In an interview she talks about a design choice that she has not made yet. She lines up two different, possible justification strategies, Coherent or Subjective, but she does not know yet which one she will eventually apply.

"The colours will come [be chosen] after the shape [in the design process]. [The source of the colours will be] dependent on the product. If [other future choices in the process determine that] the product can only last for a few years, then the colour is going to come from a mood board of trends. In a more durable product it [the colours] will come more from my own intuition. In that case, it's my own decision. I don't have a rational way of arguing for the colour choice yet. If the modular wall becomes playful, that could guide me to a playful choice of colours."

If the colours will come from 'a mood board of trends', they will be coherently justified. If they are going to come from 'my own intuition' they will be subjectively justified.

Designer f2

In the Designer f2's case, a choice justification is found which combines a Pragmatic justification with a justification that could be interpreted as either Subjective or Objective:

In an interview, Designer f2 accounts for the reason why she made a dress in a specific material. She says: *"I thought I needed to bring this colour along. Because otherwise some colour would be missing."*

Interviewer: *"So did you choose that material because it had a certain colour? And why did you need that colour?"*

Designer f2: *"I don't know if I needed to have this [specific] colour, but I needed some colour, and this was the one I had.* (...) *I mean there was no more money left, so in that situation you have to make some compromises"* (f2, 10, 232-242).

The 'need for some colour' in the collection can be interpreted as a Subjective choice, insofar as Designer f2 brings in 'some colour' due to personal preference. It can likewise be interpreted as an Objective one, given that she sees 'bringing in some colour' as an act of adapting to disciplinary conventions and commercial demands.

Yet, choosing 'the one I had' because 'there was no more money left' is unambiguously a Pragmatic choice justification.

Choice justification in process: An example

In Table 9 below an example is shown of the justification types related to a sequential string of choices in Designer f6's design process.

String of choice determination, Designer f6

Action (choice)	Justification	Type
Chose dance theme	I always liked to dance	Elementary
Used old materials	They fit with the theme	Coherent (forwards)
	I think it would be cool with different [untraditional] fabric in dance wear	Subjective
	I already had them	Pragmatic
	I like them	Subjective
Chose and bought new materials	They fit and supplemented the fabrics I already had	Coherent (forwards)
	You have to have stretch and sport fabrics in a dance wear collection	Constrained
	I chose some I liked	Subjective
	Chose non-plain fabrics because I want non-plain look	Coherent (backwards)
	Chose fabrics with colours in accordance with inspirational colours	Coherent (forwards)
Distributed materials in collection parts	Collection is divided in three sub-parts with three different functions. Fabric quality is distributed to fit function	Coherent (backwards) + Constrained
	Distribution on the basis of style/silhouette/collection coherence	Coherence (backwards)
	What I think fit well together	Subjective

Table 9: An analysis of a string of choices in Designer f6's design process

In this chapter, we have seen how the concept of information can be applied to design in a nuanced fashion, as the material *actors* of design. Likewise, it has been demonstrated how this information is sourced into the design system and how choices are justified in relation to existing information. In the next chapter (8), I will address the functional structures of design processes: the *roles* that the material actors can play.

8. ITO – Function Structure in Design Processes

The fact that information can be perceived to be lacking or be redundant in design processes indicates that IEs serve some specific functions, but what are the functional structures of design processes? This issue will be elucidated in the following.

Based on the data, two different structures of functions in design processes have been identified. Though they are both very relevant to design, primarily one is in focus in this dissertation. The difference between the two relates to the distinction between what was previously referred to as the 'directions of coherence': backwards and forwards. As mentioned, forward coherence is the produced links of process steps from a known outset into unknown territory, which is why it is associated with under-determined tasks. Backward coherence is the abduced link between process steps towards a somewhat known result.

Accordingly, there is one functional structure related to the forward orientation and one related to the backward orientation. The former, which I will call ITO, relates to the main theme of the dissertation, namely progression of explorative design processes based on under-determined tasks, and is a key contribution of the dissertation. The latter can be described by concepts already well-known in design theory and it will be briefly described in the section below, with the purpose to position and delimit the ITO function structure. Subsequently the remainder of Chapter 8 is devoted to the concept of ITO.

8.1 Design Parameters

To describe the functional structure related to the backward orientation, I shall deploy a concept borrowed from Suh (1998): 'Design parameters'. 'Design parameters' refers to aspects and features of the expected or required result of the design process, e.g. the parts, assemblies or modules constituting a final design. Hence, if a designer knows the required or desired outcome of a design process, she can infer likely parameters of that output. Reasoning backwards from the output, will guide her process movements; her search, assessment and choices among information with which to populate those specific parameters. This is, as design is often described, an abductive process of inferring the design decisions backwards – a topic that will be further discussed in Chapter 11, 'Design Syllogisms'.

Even in under-determined design tasks certain design parameters will be given at the outset of the process. For example, a fashion designer usually already knows from the beginning that she is going to design a collection of clothing of some sort. This implies that she knows that 'the body' is an essential component; she is going to use some *fabric*, and the final design, given its physical nature, is going to have a *3D shape*, a *tactility* and a *colour* (provided we count black and white as colours, too, in this example). Likewise, an industrial designer will most typically know that she is going to work with *hardware* of some kind, implying *shape* and *colour* as well, and that the design is probably going to serve *specific user needs*. These are some of the design parameters that are conventionally given with the disciplines. However, the designer can depart from them if she wishes to challenge the boundaries of her discipline.

The more well-defined the task, the more specific the design parameters will be, and the easier it will be to imagine and abduce the design path towards fulfilling them. If I asked my reader to build a rectangular massive wooden dining table with four legs it would, in all likelihood, produce a much clearer idea of how to embark on the task than if I merely requested something built out of wood.

Thus, when design parameters serve as functions in design processes it means that the designer needs to fulfil the desires or requirements given. In the case of the wooden table the designer would know immediately that she would need some wood, that she would need to make four legs, and that she would need to research the typical measurements of dining tables.

Design parameters can also be less tangible and obvious but still 'reach back' in the design process to help steer its course. An example of this is found in Designer i3's process. In the interview excerpts below we see how Designer i3 uses aspects of the expected final design to guide his information search:

> Asked how he sources information, Designer i3 answers: *"Well, it just happens in kind of a brainstorm (…) I sit in front of Google Images and then…"*
> Interviewer: *"What search words have you used?"*
> Designer i3: *"I used words such as "grip" among others, and "handheld device" and that kind of things, so typically the headline from my individual…"* (i3, 7a, 100-104)

Below are some examples given by Designer i3 of the search categories he has explored in this way: *control device*, *security/no fear*, *things you hold in your hand*. They reveal, and Designer i3 confirms, that the *"individual…"* means the individual concepts defined from desired traits of the final design.

> *"the first slide is about handheld **control devices**, so it's things like joysticks, and there was a controller for a kind of electronic skateboard and something to control speed (…) things you already control something with by hand"* (i3, 7a, 74)
>
> *"for example there is a (…) pink gun (…) because with a pink one, you tend to think of women who want to protect themselves. (…) I think, actually, I called it "**security**" (…) or "**no fear**"."* (i3, 7a, 76-80)
>
> *"(…) I have a picture of two persons holding each other's hands. Or I have a handle from a sword, and I have a handle from a racket. That kind of more **general things you hold in your hand and that can be nice to hold**"* (i3, 7a, 82).

Thus, Designer i3 has used design parameters to guide his search and steer his process. Progress in processes initiated from under-determined tasks cannot be guided solely by setting the course towards an envisioned, desired or required goal, directed primarily by a vision of design parameters, since, by definition, in such tasks the goal is unclear from the start. Instead the process must be driven from the outset into the unknown by a different logic than fulfilling known parameters of the final design. In other words, progress must be process-oriented, not goal-oriented.

In Simon's (1973) words *"The real problem-solving activity involved with solving ill-structured problems is providing a problem with structure when there is none apparent."* In this chapter, I will describe such a structure which is a finding from this study, and which drives progress in processes based on under-determined tasks. It is a structure of information functions that IEs can take and fulfil in design processes.

8.2 ITO

The functional structure introduced in this chapter is called ITO. ITO stands for Input, Transformation and Output. The basic idea of the ITO framework is that the development of the design process takes place in a triadic interchange between three functions of information: information about *input*, about *transformation* and about *output*. Before expanding on the three information functions, I will describe how they were derived and how the framework was developed.

Developing the ITO Framework[18]

In the Chapter 3, 'Design Problems', I accounted for the discursive convention that design is associated with problems and problem solving. The same chapter featured an overview of problem and solution relations, which, in a simplified form, represents the distinction between paradigms of problem understanding in design. The model (Figure 16) is replicated in Figure 33.

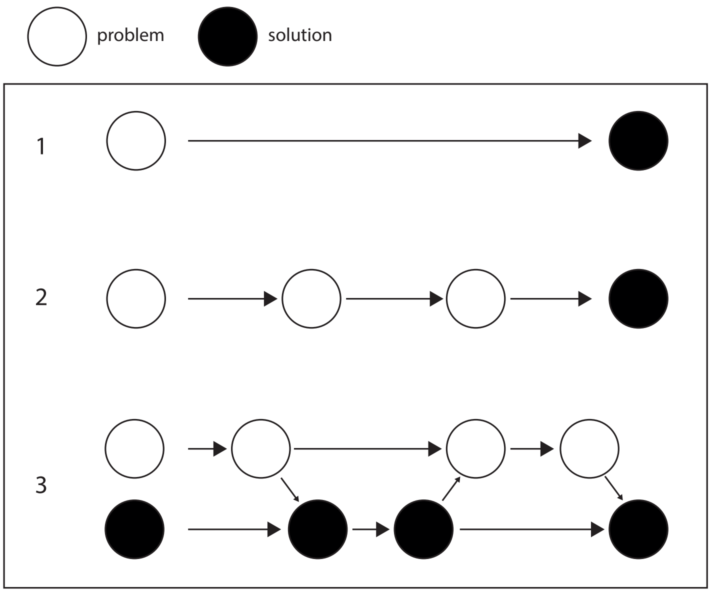


Figure 33: Replication of Figure 16: Three types of problem-solution processes.

To recap, the model shows three different conceptions of problem-solution relationships: Type 1 reflects the linear process of hard systems methodology (Broadbent, 2003), where the problem is given at the outset and the solution is the process destination. Type 2 reflects the iterative process of soft systems methodology (Broadbent, 2003), where the problem changes throughout the process and Type 3 reflects the notion of co-evolution of problem and solution through the process (e.g. Dorst & Cross, 2001; M. L. Maher & Poon, 1996).

The ITO framework was theoretically developed by combining two theories, from type 1 and type 3: Reitman's (1964) problem-solving theory represents type 1. The co-

[18] This section is based in part on material from – as well as valuable peer discussions about – an unpublished paper, ' The Third Space – a hypothetical framework of triadic co-evolution', which I presented at the PhD Colloquium at the IASDR15 Conference on 2. November 2015.

evolution theory (Maher & Poon, 1996; Dorst & Cross, 2001) represents type 3. Likewise, it was supported empirically by the pilot case study analysis.

Pilot case study analysis

As described in the 'method' chapter (2, 2.3), the 23 pilot cases represent early stage excerpts of the design students' Master's projects.

The pilot case study material was analysed for hints of verbal and visual expressions about content, coherence and progression of the design process. For each case, an attempt was made to incorporate the obtained information into a visualised case model (Figure 34). Below are some examples of the illustrations. They are replicated in a reduced size here, but can be found in their true size in Appendix 4. However, the individual words are not necessary to convey the impression of the heterogeneity and complexity encountered in the attempt to visualise the design projects.

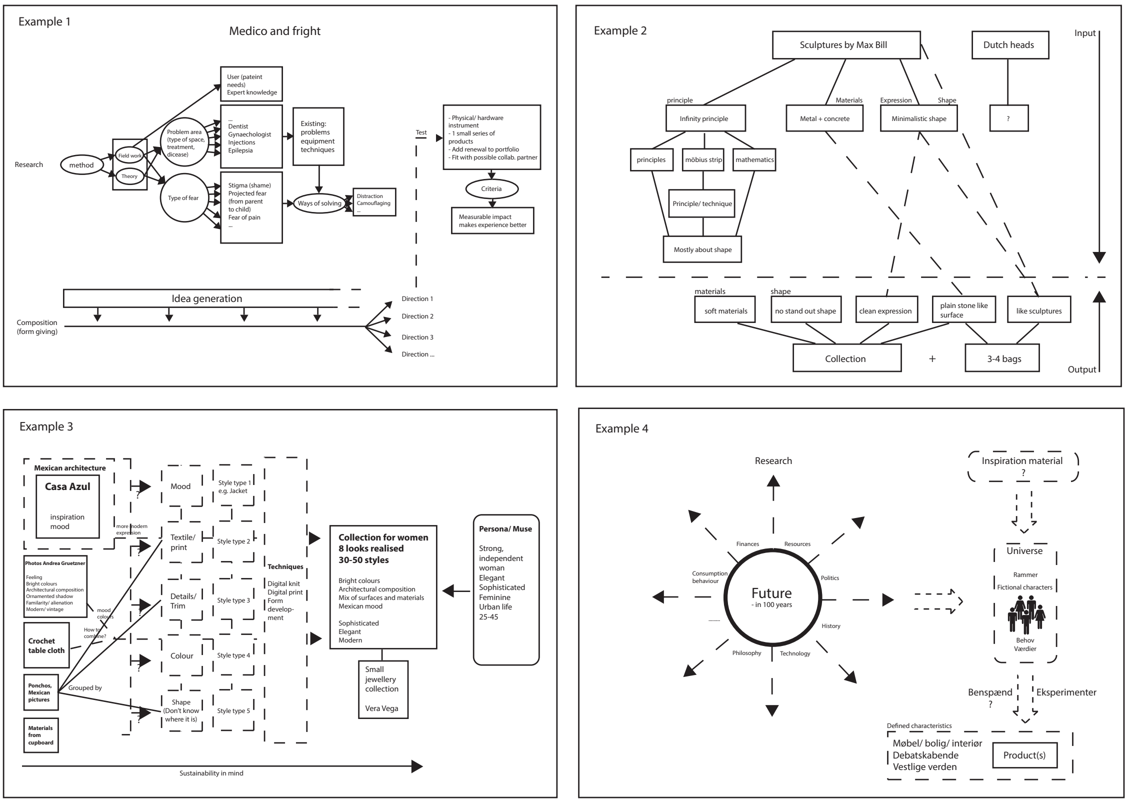


Figure 34: Illustrations of four of the pilot cases.

The visualisations were made because, according to Rozanski & Woods (2012), visualisation can support the analysis of element interrelationships and reveal structures in the situation modelled. However, as it turned out, the attempt to illustrate the cases gave rise to a great deal of confusion and difficulties, which were helpful in the sense that they raised some central questions and challenged my preconceptions toward design processes:

First, I was challenged by the concept of solution. On the one hand, solutions were verbalised as affiliated with process termination. On the other hand, by being mentioned, they were, indeed, present and relevant concepts in the initial process state at which the cases were captured in the pilot case study. If I was to figuratively comprehend the design process, should statements regarding 'the solution' be situated at the end of the temporal process (e.g. a timeline), despite their occurrence and consequently assumed relevance at the early process state? And how can design solutions be conceptualised to comprise the equivocality of being at once a concept informing a state, in which it does not yet exist, as well as being the end result of the process? These difficulties led my theoretical studies to the 'co-evolution theory' of design, in which the concept of 'the solution', at least conceptually, exists and evolves from the beginning of the design process.

Yet, the theory of co-evolution did not adequately explain how to define and distinguish problem and solution. For example, a designer's intent to make a biodegradable shoe collection inspired by a Japanese theme can be regarded simultaneiously as a statement of a problem and a statement of (constraints on) the solution. As has been analysed in Chapter 3, 'The problem of the 'problem', existing theory fails to provide a clear and consistent account of how the concepts of problem and solution are defined and distinguished. And furthermore, not all design project deal with structural problems.

Neither did the co-evolution theory account for the development of all the IEs of heterogeneous nature and function that the designers emphasised and stressed as important based on verbal and visual expressions. Not all process information fits into the intricate concepts of problem and solution that co-evolution theory is built on. For example, methods and 'ways of doing' are vital parts of design processes, but they differ in nature from what they are applied *to* and what they *yield*.

This raised the question of how the various IEs of a design project can be clustered and embraced by a design process conceptualisation.

Theoretical ground

In the following I will account for the theoretical ground from which the ITO-framework sprung.

Reitman's Problem-Solving Theory

Applying the information processing language, IPL-V (Newell & Simon, 1961), Reitman (1964, pp. 288-289) describes problems in terms of generalised three-component vectors of the form [*A, B,* ⇒], of which *A* is an input, *B* is an output, and ⇒ is a process transforming *A* into *B*. Reitman exemplifies this by the 'classic task of converting a sow's ear into a silk purse' by 'a series of operations' (p. 284). In his example, the sow's ear represents *A*, the silk purse *B*, and the series of operations ⇒.

Reitman states that any vector [*A, B,* ⇒] defines a *problem* provided it is associated with a *problem requirement* which specifies that:

> another vector [*A', B',* ⇒'] should be found so that *A'*, *B'*, and ⇒' will be elements of *A*, *B*, ⇒, respectively, and so that the process ⇒' applied to *A'* will yield *B'* uniquely', which we write as *A'* ⇒' *B'*. (Reitman, 1964, p. 288)

Vector components, *A*, *B*, and ⇒ determine sets (p. 288), i.e. quantities, of which *A'*, *B'*, and ⇒' are, hence, elements. If a vector [*A'*, *B'*, ⇒'] is found to satisfy the problem requirement, the problem is *solved* by the *solution* [*A'*, *B'*, ⇒']. The process sequence in moving from [*A*, *B*, ⇒] to [*A'*, *B'*, ⇒'] is called ⇒*.

To ease comprehension this process can be displayed as in Figure 35 (my visualisation).

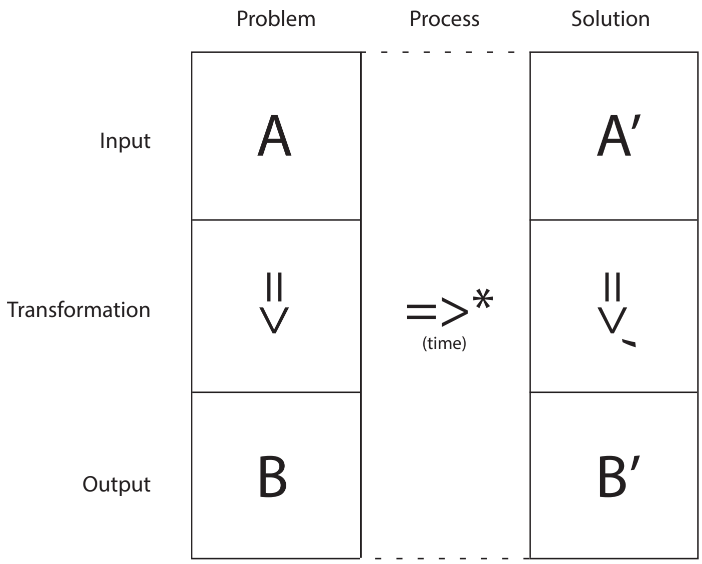


Figure 35: My visualisation of Reitman's problem-solving theory.

Figure 35 depicts how a horizontal process ⇒* leads from problem (*A* ⇒ *B*) to solution (*A'* ⇒' *B'*).

Reitman defines *A* and *B* as initial and terminal/target states or objects, respectively, and the transformation ⇒ as a process, programme or sequence of operations (Reitman, 1964, p. 284 and 289).

Theory of co-evolution of problem and solution

The theory of co-evolution of problem and solution spaces in design processes was developed by Maher (1994) and Maher & Poon (1996) on the basis of 'genetic algorithms'. It has been further developed by e.g. Dorst and Cross (2001) and Wiltschnig et. al. (2013). The theory states that problem and solution spaces co-exist at any state of a process, and co-evolve in a mutual relationship of adaptation through a transforming 'fitness-function' (M. L. Maher & Poon, 1996, p. 7), for each space defined by the current state of the other space (Figure 36).

Co-evolution theory implies that problem and solution should both be considered from the beginning of and throughout the process, rather than being associated with process initiation and termination, respectively.

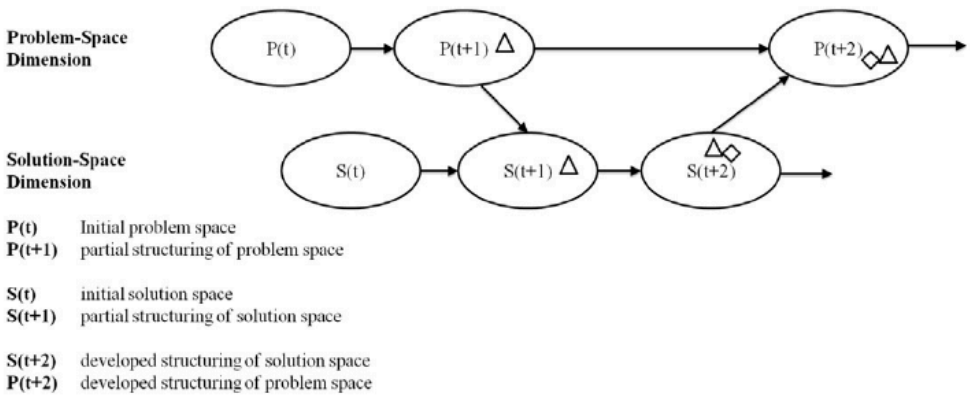


Figure 36: Dorst & Cross's (2001) model of co-evolution, based on Maher & Poon (1996).

Development of the framework

This section describes how the two theories are interpretively combined to form the ITO framework of triadic co-evolution, suggesting an alternative structure through which to understand design process development.

As mentioned in Reitman's theory *A'*, *B'*, and ⇒' are elements of the sets, or quantities, *A*, *B*, and ⇒. Thus these sets can be considered analogous to the notional *spaces (Dorst & Cross, 2001, p. 434)* in the theory of co-evolution. If comparing and projecting the theory of co-evolution onto the present visual interpretation of Reitman's problem-solving theory (Figure 35), we can understand the co-evolution conceptualisation of problem and solution spaces in an extended context, as displayed in Figure 37 below.

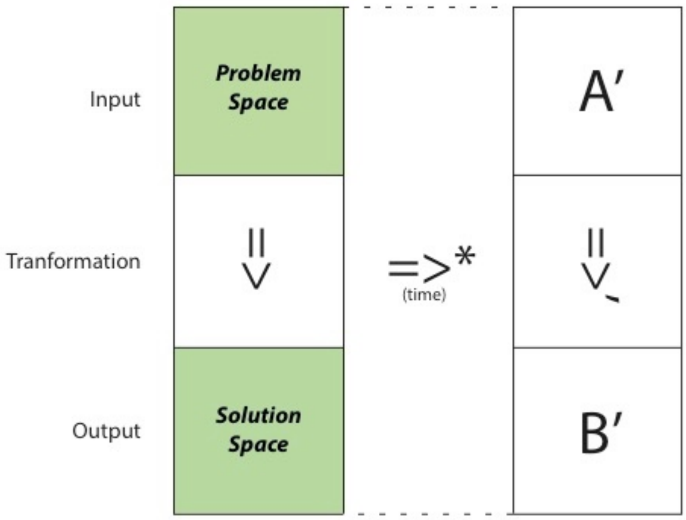


Figure 37: Juxtaposing the theory of co-evolution with Reitman's problem-solution theory.

As visualised in Figure 37 the co-evolution concepts of problem and solution spaces can be juxtaposed with Reitman's vector components, *A* and *B,* respectively.
But as becomes apparent, if following the same line of reasoning, a third component from Reitman's problem vector, that is ⇒, can equally be considered a space in which ⇒' is sought. Reitman defines ⇒ as programmes or operations transforming *A* to *B*. In a design context, this can be compared to methods or 'ways of doing'.

Consequently, a triadic division of design process evolution can be discerned and considered as an alternative to the existing model of co-evolution. The triadic division supposes that all three vector components *A*, *B* and ⇒ are potential spaces of design process evolution. Thus, a key feature of the ITO model is that it provides a framework encompassing 'transformation' – methods and 'ways of doing' – as information equally important as, yet separate from, what they are applied to and what they are intended to yield.

The ITO framework

The three spaces in the ITO model are named:

- *Input space* (corresponding to *A*)
- *Output space* (corresponding to *B*)
- *Transformation space* (corresponding to ⇒)

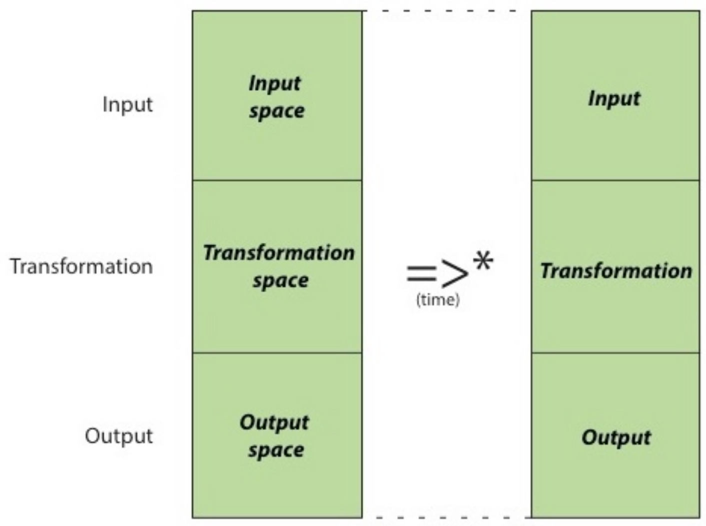


Figure 38: The three conceptual spaces.

As shown in Figure 38, the design process ⇒* will eventually result in an actual solution consisting of input, transformation and output, derived from the three suggested conceptual spaces.

Let me use a metaphor of the mundane activity of cooking a meal (Figure 39) as an example: We all know that in order to serve a nice, tasty dinner (output), we need to buy ingredients for the meal (input). But we also know that we need a recipe to inform us about how much of which ingredient to add in what order to transform the ingredients into a nice dinner (transformation process). These three parts of cooking – or designing – are closely interconnected but still conceptually distinguishable:

Input space: The space in which input, e.g. knowledge and inspiration, is sought to the design process (the potential meal ingredients).

Transformation space: The space in which the tools, e.g. techniques and methods, are sought, which convey transformation from input to output (the cookbook of recipes).

Output space: The space in which ideas and conceptions of potential outputs and solutions of the design process are outlined (the range and character of imagined, potential meals).

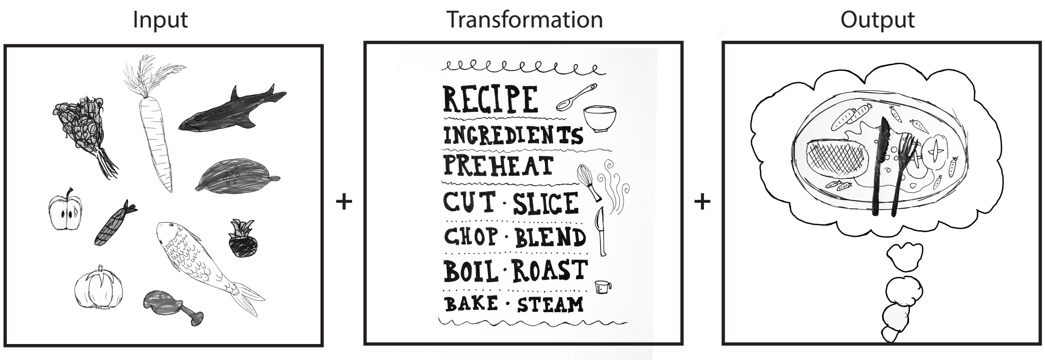


Figure 39: Cooking metaphor of ITO.

What has yet to be addressed, in relation to Reitman's theory, is what the process ⇒* covers. Juxtaposed with the co-evolution theory, the process ⇒* resembles the alternate evolution of problem and solution spaces, as was shown in Figure 36.

If seeing the ITO spaces, and their processual development, as an extended, triadic version of the 'co-evolution' model, then the development of those spaces should feature three parallel tracks between which a pattern of 'triadic co-evolution' can take place, as conceptualised in Figure 40.

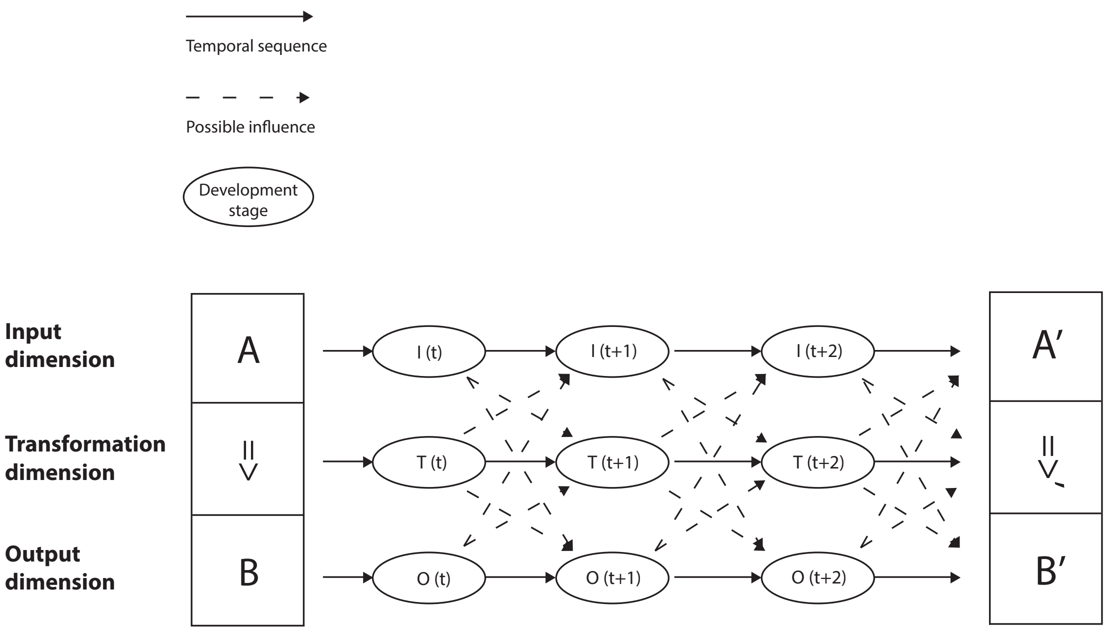


Figure 40: Triadic Co-evolution.

Figure 40 is a merely a conceptual model suggesting that the development of design processes takes place in an interplay between three spatial dimensions, I, T, and O.

The ovals indicate possible stages of development, the full arrows indicate temporal progression, and the dashed arrows indicate possible pathways of cross-space, influence or interplay.

The ITO framework, as visualised in Figure 40, is not representative of the complexity found to characterise design process development and should not be considered a final or individual contribution of this dissertation. Rather it has served a vital role as a stepping stone in the research process. The comparative analysis of the two theories and the development of the framework led to the identification of the ITO distinction of information functions, and the idea that design process development could meaningfully be explained as some kind of interaction between them. Thus, the framework was applied as an analytical tool in the major case study data analysis and helped guide the study to the subsequent findings.

ITO Function Structure

Through the data analysis the categories of ITO have been found to correspond to three different types of information functions identified consistently thoughout the data set. Thus, the ITO structure comprises the function structure linked to process progression on the basis of under-determined tasks.

The ITO structure does not represent an attempt to develop a specific design method but rather constitutes a generic reference model (Gielingh, 2008). Generic reference models provide functional structures in which content need not be predefined, as it is considered data. In this case the content is provided by and is dependent on the individual design project case. Every case contains different information content, yet the ITO structure remains representative independent of these differences.

As mentioned in Chapter 7, pieces of information, if construed as 'constraints', are usually defined as pertaining to either actions or solutions. In the ITO structure this corresponds to the transformation and output functions. The ITO structure proposes three types of information functions, and the bits of information that can assume these functions are conceptualised as IEs.

The remainder of this chapter will describe the characteristics of the ITO structure in relation to design processes. The rest of the dissertation will build on, and expound the merit of, the ITO structure as the foundation for developing an understanding of how design processes progress and 'move' from under-determined outsets.

ITO

The three types of information functions, input, transformation and output denote different functions that can be assumed by information entering design processes. The triadic division is found to be exhaustive in the sense that any IE that is assigned or activated serves as either input, transformation or output at some process abstraction level (see Chapter 10, 10.4).

When an IE is passive in the design system, it has no function and no 'type' – it is like a stem cell of the design system that can potentially assume any function. When an IE is activated in one of the functions, it becomes that 'type' of information: input information, transformation information, or output information.

The three types of information representing the three functions have different characteristics:

Input

Input always refers to something existing. It is the situation or the matter that the designer wishes to transform in the design process – the outset of change.

From a high process level perspective input refers to the sum total of information content present at a given time in the process, *from* which the process moves. Thus, input information can mean the *initial input,* which is the temporally first outset that the designer moves from in the entire process. Or it can be seen as the content present at any stage in the process to which the designer wishes to make further transformative changes.

From a perspective of the low, operational process level, where particular action is taken in order to make a move or a single instance of change, the input information is more concrete. In this case, it does not comprise the collective information at the given stage, but rather particular IEs. For example, the initial input of the process of cooking an entire meal is all the ingredients, whereas the input for the individual process step of peeling a carrot is merely the carrot.

Example of input information:

Designer i3 refers to input information, when he is interviewed about the shape of his medical control/communication device. He explains that to inform his shape he has chosen *"forms that I thought were interesting… Basically just forms I wanted to explore further (…)"* (i3, 8c, 26). Designer i3 mentions that one of those forms were *a half sphere. (…) The half sphere actually came from when I started to be fascinated by the sphere itself, but the half sphere just felt better in the hand"* (i3, 8c, 44). Thus the sphere – and later the half sphere – are input IEs in his process.

In order to activate information – i.e. actually carrying out a process step, for example peeling a carrot – the input information must assume a specific ontic nature (see Chapter 7, 7.5, 'Information operationality'). Since it is not possible to *do* something and direct *action* towards something abstract or intangible, input information capable of activation must have a tangible representation: physical, visual or material.

This nature is not required of information that has merely been assigned an *input* function, since assigned information is not being directly used. For example, Designer i8 intends to use the concept of 'Dandy' as inspirational input information for his shoe design, without knowing at first how exactly to interpret the 'Dandy' IEs and theme and elicit useful, i.e. activatable, information from it. Later he interprets 'Dandy' as the 'galosh', and the abstract theme and IEs of 'Dandy' is given tangible form in the galosh to which Designer i8 associates a *specific* form. At a high process level, without tangible IEs, information cannot be activated – only assigned. The reason is that a process cannot be carried out in its entirety all at once; it has to happen step by step. Thus, input information related to a high process level does not necessarily comply with the requirements that apply to activatable input information.

Transformation

Transformation refers to the way an input is transformed into an output. For an IE to be activated in a *transformative* function it must serve the designer as an operational prescription, or recipe, of what to *do* to the input information in order to transform it. As with the input information this requirement is only necessitated when activating the information. If merely *assigned* to the transformation function, an IE can have any form that evokes in the designer the impression that some operationality, i.e. a way to do something, can be elicted from the IE.

In design, transformation is expressed by methods, techniques and simply ways of *doing*.

Example of transformation information:

Designer f2 has found a specific technique, 'Subtraction Cutting' that she wants to work with. In an interview she explains how 'Subtraction Cutting' can be used transformatively in her project.

'Subtraction Cutting' is a flat construction technique where *"we have something flat [fabric] here, we do something to it and only consider the hip measurement, we sew it together, put it on a body, and see what happens…"* (f2, 4, 11). She explains that when working with the technique *"these kind of tunnels are formed, because you cut out circles and sew them together"* (f2, 4, 59). Designer f2 wants to *"try out the techniques and see if they can be projected onto my project"* (f2, 4, 19).

Output

Output is the result of a transformation. Depending on the process level perspective, output can be the final result of an entire process or merely the result of an individual process step – a move.

Example of output information:

> Designer f1 talks about an IE in his project 'the essential wardrobe'. This IE is linked to a user wardrobe study Designer f1 has conducted of what pieces of clothing men find essential in their wardrobe. Designer f1 explains what function 'the essential wardrobe' will serve in his project:
>
> *"I will not use it to [inform] form and colours, more [rather] the [to investigate and be inspired by the users] use of wardrobe."* (2b, 37-41). Thus, *"It will have great impact on building the collection composition"* (4, 41-42).
>
> The 'collection composition' refers to a certain structure of the desired final output of Designer f1's design process. Thus, 'the essential wardrobe' is assigned the function as output information.

Output information, like the other types of information, assumes a certain nature. Yet in contrast to input and transformation, the nature of an output IE is contingent on what kind of process understanding is applied: As shall be explained in Chapter 10, Section 10.1, 'Three process conceptualisation', the concept of 'design process' can be understood in three different ways. For now, it must suffice to note that the nature of output information depends on whether or not is has been achieved.

If looking ahead in a process or process step, the output has yet to be achieved and will thus be imaginative and conceptual. In the design context, this type of information is expressed in required or desired criteria on the result of a process or process move.

Once the process or process step has been carried through, and the output thus achieved, the output will assume the same form as an input – it will be tangibly particular. The output will add to the existing design system information and form a new and altered state of the content total. Thus, when changing the ontic nature from conceptual to material, output entities become potentially new input entities in the further process progress.

Looking ahead in the process the three types of information have different ontic natures (Table 10):

	Ontic nature	Design example
Input	Material, visual, physical	Inspirational material
Transformation	Operational, functional, prescriptive	Method, technique
Output	Conceptual, imaginary	Required/ desired criteria

Table 10: Ontic nature of the ITO information function types

The three information function types, ITO, assume their relevance in design only in relation to each other in a combination that allows formation and progress in the design process. This combination practice will be discussed in Chapter 11, 'Design Syllogisms'.

Categorisation of design process information has also been suggested by Aurisicchio et al. (2013). They define two information categories: 'design information' and 'domain information'. *"Design information describes the requirements of the problem at hand and proposed solutions, while domain information consists of known facts, concepts, laws and theories in the domain of the problem."*

In this distinction, 'design information' is seemingly corresponding to both input and output information. 'Domain information' refers to conventions of the domain or discipline in which the project is nested and has *"objectives like generation, analysis or evaluation."* In the current representation of design processes domain information resembles objective choice justification types. Hence domain information is not necessarily the content of the design system, i.e. Information Entities from which design is built, but rather a factor potentially justifying or governing that process.

Information Familiarity

The data suggest that on the overall process level in a design process there should be a correspondence between input and output, which is achieved by balancing familiar and unfamiliar information in design processes. This is linked to what Hekkert (2003) refers to as the 'typicality' and the 'novelty' of the design.

To explain this concept, I shall return to the cooking metaphor. Let's say I want to make a new, special type of lasagna. My output criteria would be certain characteristics of the lasagna which I deem essential in order for my guests to recognise that I have, in fact, made a special lasagna and not just a completely different dish. Maybe, in my opinion, what makes lasagna recognisable as such is the layering, the pasta and the gratined cheese on top. Hence, I know that I will have to get cheese and pasta as inputs for my cooking, and that I will have to prepare the ingredients so that they can be layered in a certain way in order to be transformed into my special lasagna. Yet, in order for the lasagna to be special, I will need to add some unfamiliar ingredients that are not usually part of a lasagna, for example celery and tuna fish. I acknowledge that this lasagna sounds a bit strange, but if not for eating, at least it is good as an illustration of the need for the familiar to complement the unfamiliar input to in order to achieve a similar composite result.

'Familiarity' refers to the qualities, possessed by design process information, which by certain conventions are associated and correspond with some (emerging) output criteria. For example, a designer of a physical product will eventually need some three-dimensional input information to work with in order to achieve three-dimensional features in her output.

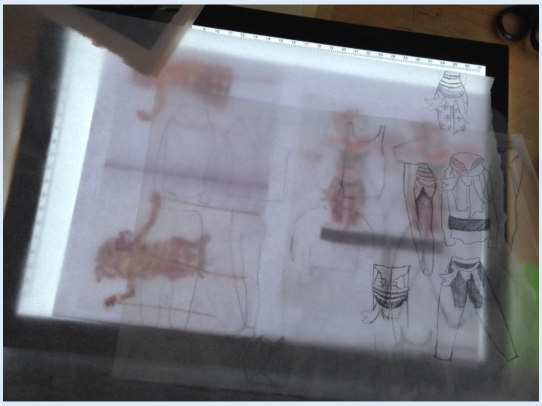
'Unfamiliarity' refers to the absence of a perceived association between the design process information and (emerging) output criteria.

Examples of designers needing or introducing input information corresponding to output criteria:

Designer i3
Half way in his process of designing a handheld control/communication device for medical patients Designer i3 is sketching in 2D. He realises that he needs to introduce shape to be further informed: *"(...) it's also just a [question of], I mean how big should it be before ''it's comfortable to hold, how big should it be to not just look like a big block. (...) And this is also where my sketches do not help me as much, as when I start to work with some modelling"* (i3, 7a, 118).

Designer f6
Designer f6 is designing a dancewear collection inspired by a collection of inspirational materials representing 'Balinese costumes'. A month into her project a new IEs have shown up in her project, 'sportswear', a small collection of pictures of basic sports wear.

She says *"I have done a lot of transformation with the Balinese costume. Drawing with more ornamented stuff and mixed the costumes with sportswear to try to get interesting* *cuts, shapes and forms out of it."*[19] (f6, 3, 2). Thus, the 'Balinese costume' seems to shift from being the main input source to being *"the spice to push it to somewhere new, so it won't just be these basic things, which a lot of dance clothes are."* (f6, 5, 17). And at the same time the 'sportswear' appears to serve as an anchor of familiarity, ensuring a correspondence between input information and the output criteria of a modern, functional dancewear collection. Designer f6 discovers that the 'interesting cuts' emerge out of *"combining these basic sports and training suits with some [Balinese] cuts that I find interesting"* (f6, 5, 17- 19).



Designer f1
In his design of a fashion collection, Designer f1 realises that he needs to introduce 'the body' and the three-dimensionality that revolves around it, in order to inform the form required in the final output. He says, *"I made a lot of collages where I wanted to combine the modernism and the monks and tried to work more into silhouettes and see "how does it look on a body?" Because [when] working with 2D and some surfaces it was diffcult to make it wearable."* (f1, 7, 10)

Likewise, designers can realise that they need to source new, unfamiliar information into the process in order to achieve a novel final output and distinguish their particular design from what already exists. This is for example the case when Designer i4, halfway into his process of designing a self-driving taxi, introduces the 'polar bear' into his shape creation of the car in order to give it a unique expression.

In the beginning of a design process, based on an under-determined task, some or many parameters of the output are unknown or unrealised, which is why the designer might need to source additional information later in the process to ensure correspondance between input information qualities and emerging output information parameters and sustain a desired balance between typicality and novelty.

[19] Quote is reconstructed from observation notes.

During the design process information is sourced and transformed, and choices are made of which information to leave behind and which to 'bring along'. This means that at any stage the content of the design system– and thus the input information for the subsequent moves – gradually assumes a nature corresponding with the design parameters that emerge with increasingly specified output criteria. The final output is the stage in the design process at which the designer chooses – or is forced – not to make any more moves and not to use the state of content she has reached as input for further transformations. Thus, in the end, the (potential) input in a sense corresponds entirely with the final output.

In design, even very under-determined tasks are situated in, and often aimed at, a specific context. The designer is trained and works within a specific discipline and domain that requires certain skills and is associated with norms, practices, traditions, and conventions (see Elster, 2000; Stokes, 2006). If perceived and treated as important by the designer, these represent output criteria that are given at the onset of the project.

Yet, a tendency has been observed in several cases, especially among fashion designers, that such conventions remain implicit output IEs in the design process. Consequently, a lack of immediate (recognition of the need for) correspondence between these output parameters and the required input information is found, which sometimes hampers the flow of progress. For example, several designers do not bring 'the body' into the design system until later in their process. Or they may recognise only later that, in addition to their various, 'unfamiliar' inspirational sources, they should also bring in information that is 'familiar' and conventional, e.g. in relation to the concept of modern or classic clothing, in order for their final output to be recognised as belonging to either of these categories. When familiar information is, eventually, brought in, it is usually done unobtrusively.

Designer f2
Designer f2 acknowledges that an earlier introduction of familiar input information in the form of 'classic clothing' references could have helped her process: *"I think in some way it could have strengthened this project to have some more detail orientation and more references in some way (...)"* (f2, 10, 61). She exemplifies: *"(...) let's say that I had gotten to the shirt and gotten to develop something with this draping principle unto a classic shirt, then there had been a bigger clash, namely between the recognisable and the different"* (f2, 10, 65).

Conversely, a tendency can be traced among some of the industrial design cases studied that a lot of research is done early to establish and source familiar information pertaining to a particular domain, whereas unfamiliar information that can add novelty to e.g. shape creation does not enter the process until later and therefore does not receive the same degree of attention.

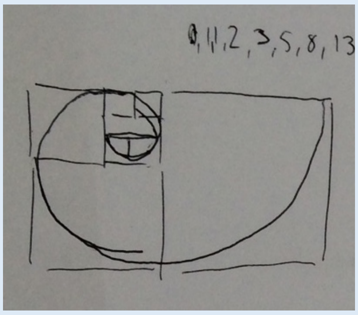
Designer i9
Designer i9 is designing noise-reducing furniture for open office spaces. In an interview towards the end of his design project a new unfamiliar IE, ’Fibonacci’, emerges as he explains his design choices. He uses it to guide choices about the form creation and relationships between measurements in the product.

Interviewer: *”Why did you decide on [the height] 2.10 meters?”*

Designer i9: *”(…) I tried to look at ”okay, it should not reach the ceiling, but it shouldn’t be so low either that I can stand on tiptoe and look over it”. So I had… This one (shows a visualisation of the Fibonacci sequence). So I used some of all these Fibonacci numbers and what you call Fi or…”*

Interviewer: *”The Golden Section?”*

Designer i9: *”Yes, exactly – and see if I could play with some of those relations”.*



In every context and domain, some information will be perceived as familiar and some as unfamiliar. Unfamiliar information has no correspondence to the expected final output of the design process, but serves, on the contrary to ‘alienate’ the familiar information, or as Designer f6 put it earlier it is ”*the spice to push it to somewhere new.”* Some examples of unfamiliar information are modernistic buildings in fashion design (Designer f1), paper as material in design of modern interior (Designer i10), foam matresses in fashion design (Designer f2) and polar bears in car design (Designer i4).

In design, the aim is to create something new. Yet, designers cannot tangibly work with things other than those that already exist. The novelty emerges by literally combining two existing things – something familiar to the domain and something unfamiliar to it – into a new hybrid, or by transforming something existing and familiar in a contextually unfamiliar way.

Because input information must both inform the familiar and the unfamiliar, the most basic, conceptual model possible has two sources of input information.

Consequently, the transformation of a design process, in the most simplified form possible, can be seen as a matter of combining the two (Figure 41(a)). One exception is if the unfamiliar information is used to transform the familiar with, in this case the unfamiliar information serves as transformation information (Figure 41(b)).

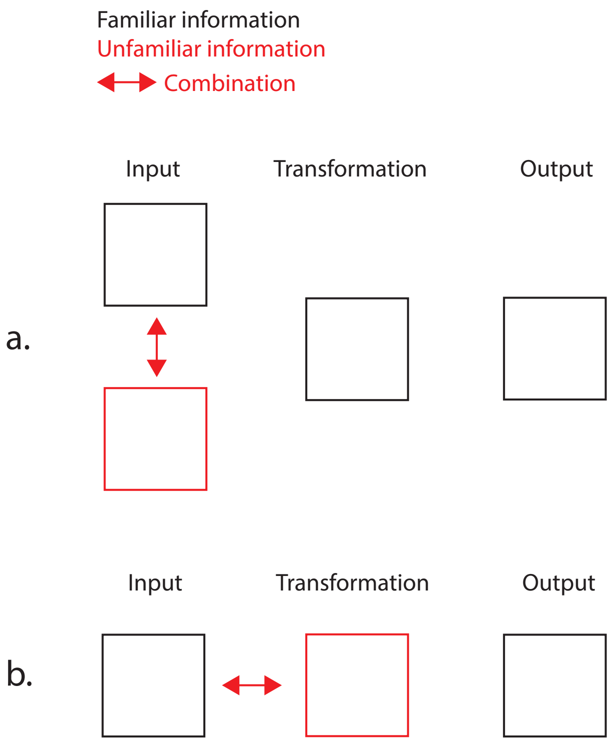


Figure 41: Simplified, conceptual models of familiar and unfamiliar information in design processes.

The balance between familiar and unfamiliar information arguably serves to create a result in which there is a balance between 'typicality' and 'novelty' so that it becomes 'most advanced, yet acceptable' and thereby appeals to the aesthetic preferences (Hekkert, 2003) of the audience addressed.

In a supervision session, Designer f2 shares her considerations with her supervisor about the combination, balance and 'friction' between familiar and unfamiliar information – the most advanced, yet acceptable.

Designer f2 is working with mattres foam as a material in her fashion collection. Since this material is quite unfamiliar to the fashion apparel domain the discussion revolves around its use. The supervisor mentions that the acceptability of the material depends on the doses in which it is applied – presumably relative to the use of more conventional fabric.[20]

Designer f2: *"But people could think "it's foam, I don't want to wear it". (...) It's a balance. It could easily go... not wearable."*

[20] The conversation has been abridged.

fSupervisor: *”You will mix it with those [other materials]?”*
Designer f2: *”Yes, classic materials. Shirt-like fabrics.”*
fSupervisor: *(…)It's [the foam is] a little bit ’disgusting’. It has kind of friction. It's about doses”* (f2, 8, 28-37).

Thus, the balance between the familiar and unfamiliar is in part a commercial consideration taking into account whether the design will appear approachable to users and appeal to them aesthetically. Yet, it is also a matter of the creative capacity to generate ideas and come up with something new.

In creativity theory, the related concept of ’cross-fertilisation’, i.e. combining concepts from two different areas, has been applied by Sternberg (2003) as a way to spur transdisciplinary thinking across domains. Koestler (1964) says that *“The creative act (…) always operates on more than one plane.”* He has coined the concept of ’Bisociation’, which refers to the event by which an idea or situation makes “*two self-consistent but habitually incompatible frames of reference”* intersect and *“vibrate simultaneously on two different wavelengths, as it were. While this unusual situation lasts, [the idea] is not merely linked to one associative context, but bisociated with two” (p. 35)*. In design, this means that designers, according to Woodbury and Burrow (2006, p. 67) *“pull paths of actuality from existing designs and apply them to others in the space.*”

The idea of combining the familiar with the unfamiliar is, however, not exclusive to design. In science, for example, researchers also combine their (empirical) investigations of the object of study, yet to be understood and familiarised, with the study of existing theory. By referring to those known concepts they can contextualise, convey, and make accessible the new insights.

Part IV: Information Processing – Mechanisms of Progress

Part IV is about the mechanisms of progress in design; how the design process moves, and how the design system information is processed, i.e. brought into play by the actions of the designer and used in the process of creation. 'Information processing' thus refers to the handling of information, and the congregation of actions and the Information Entities – the matter – on which those actions are brought to bear. In Part IV I will apply the concepts, which have been developed and presented in Part III, to describe the design process.

Before introducing 'Design Syllogisms' in Chapter 11, which can be seen as the central progress mechanism of design, I will nuance the notion of 'development' in design processes (Chapter 9), and elaborate on how the concept of 'design process' can be differentiated and understood (Chapter 10).

9. Formative Development

In Chapter 7, the concept of *well-informedness* was introduced to describe the condition of the design system in which progress is perceived possible based on the information present in the system. In this chapter I shall give a more nuanced explanation of the concept of *progress* and contextualise it as one of three different states in the *formative development* process.

Formative development relates to the state of development and change in the design system content. Formative development over time is not a monotonic or inexorable process, but can involve the following three situations: *progression*, in which the content changes and develops, *stagnation,* in which there is no change of or development in the content and the designer can feel 'stuck', and *regression*, in which the designer deems one course of development futile and returns to a former state of development to set out a new course (see Figure 42).

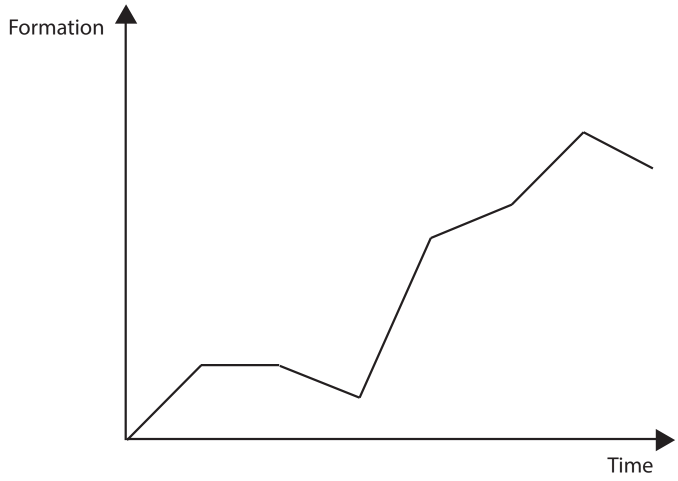


Figure 42: Formative development as a function of time is (likely) non-monotonic.

After defining the general concept of *process*, which should be distinguished from *progression*, I shall explain the concepts of ‘progression’, ‘stagnation’, and ‘regression’.

Process

In general, a *process* is defined in one of two ways. Either as *“a series of things that happen, especially ones that result in natural changes”* or as *“a series of things that are done in order to achieve a particular result”* (Oxfordlearnersdictionary.com, 2017). (In the case of an under-determined outset, ’a particular result’ would simply mean a new state of affairs). When ’process’ is referred to in this section, the latter definition applies. Though some kind of change will undoubtedly occur even if nothing is intentionally done, the change referred to in this section should likewise be understood as the kind of change that is intentionally and purposefully pursued and created by the actions of the designer.

In the design process, as well as in any other process in which change is pursued, change happens in a sequence of moves from one state to another, implicitly as a function of time passing. Yet, whereas time, in an everyday sense, passes, independently of human action, change in the design system is entirely dependent on the actions and abilities of the designer.

Progression

When change occurs, the design process *progresses*. Progression is formative development through which the design system content and the emerging design are altered from one state to an essentially new state. An essentially new state does not mean that the content of the design system is completely new or totally changed. Rather it should be seen as the opposite of regression – a step backwards to a previous and thus already known state.

The term 'progression' only refers to the formative development of the design system, not to the time elapsed in the design process. Formative progression is a product of activity, intentionality and choice.

Through progression the content of the design system is increasingly specified. It would be straightforward to say that through progression the goal – the final design – is approached. However, since a course of formative development can also stagnate and regress, it can only be determined at the conclusion of the process which progressive moves were also goal approximations. Hence, progression does not necessarily imply goal approximation, but merely movement to a new position from a prior position.

Stagnation

When aiming to understand the mechanism of how a process progresses, it is worthwhile to look at a situation in which progression does not occur, i.e. 'process stagnation', and the factors involved. Stagnation is a state in the process in which no or little formative progression is made. A process can stagnate due to perceived obstacles to progress. Yet, a path of development can also be deliberately stopped while the designer works along other paths of development. Thus, depending on the process level, a stagnation can be anything from a small 'open end' to total process development stagnation.

Designers often get frustrated if they feel 'stuck' in a design process. When the clock is ticking while there is no progression, it can be stressful and evoke anxiety that no satisfying goal can be achived within the formal time constraints. To comply with the time constraints and achieve the highest possible formative advancement within the allowed time frame, designers are eager to avoid stagnation. Alas, they do not always know how:

Designer f5

Designer f5 talks about a stagnation in relation to informedness: *"in the beginning, I had found this place with colours in an architectural way – it was in [the house of] Frida Kahlo – but quickly it became clear to me that it was hard for me to move on from there, because it was too ancient, it was missing some modernity and [the capability] to express what I wanted with the colour, so that was where Andrea [Grützner – another inspiration source] came in…"* (f5, 5a, 13)

Designer i10
In an interview, Designer i10 talks about a stagnation in relation to decision-making and the experienced difficulties overcoming it.

Interviewer: *"You said that repeatedly there are places where you are stuck. What kind of places is that?"*

Designer i10: *"It's as soon as I need to make a narrowing decision. And leave something out. It's the worst thing I know. Every time you do it. And obviously you do that many times. Both in choosing a theme, and when starting to sketch. Then you have to leave out some sketches and opt for others."*

Interviewer: *"What do you then do to overcome the challenge? (…) To make the choice?"*

Designer i10: *"I really don't do very much, and I don't know what to do to become better at it. In the end it's often a matter of being pressured by time. And then I make the decisions because I have to. But it would be really great if I could do something to make it easier"* (i10, 11, 112-115).

Designer f2
Designer f2 describes feeling lost and finding that introducing certain information helped her to progress; however, she feels, it is a bit too late. *"At one point I was a bit lost in relation to, well, "okay, how do I move on from here?". And then it worked really well that I took my point of departure in these classical elements. I just think it would have been really nice for me if it had happened a month earlier. Or something like that"* (f2, 10, 73).

Process stagnation relates to several terms in existing theory. For example, Dorst (2004) uses the concept of 'problematic situations', earlier mentioned. He writes: *"[Dreyfus] holds that problematic situations are the results of a 'breakdown' in this normal, fluent problem solving behaviour (…) These 'breakdowns' then are the moments of real choice. It thus becomes very important to distinguish and describe the nature of these breakdowns"* (Dorst, 2004, p. 8). Dorst compares 'breakdowns' to what Frankenberger and Badke-Shaub (1998) call 'critical situations' in design, and which Schön (1983) describes as 'surprises' – the turning points in the designer's reflective conversation with the materials of a situation.

Stagnation can likewise relate to epistemic uncertainty, a concept which, in the application by Ball et al. (2010), is coded using hedge words such as "probably," "sort of," "maybe," "possibly" and "don't know" (p. 576). Similar words can be found to be expressive of situations of process stagnation, along with utterances of feeling 'lost', being 'stuck', and finding it 'hard' to make decisions or move on. Yet, epistemic uncertainty is only an expression of a stagnation insofar as the designer does not immediately know how to respond to the uncertainty.

Having coded for and qualitatively identified stagnation by the use of hedge words like the ones mentioned above, the most representative causes found were difficulties related to:

- Information sourcing
    - Need for information (under-informedness)
    - When to stop
- Information transformation
    - Need to transform (act, move, experiment: get experiential information)
    - When to stop
- Information revision
    - Need for overview (make information and relationships explicit)
    - Need for coherence (link between information)
    - Need for update (make active and passive information fit)

Decision-making in all of the above.

Some examples:

Sourcing

Designer i9 says: *"I should move on to looking at materials, but I feel I need to collect more information about the circumstances of telecommunication in different companies, types, how they behave. Before I look at materials and the properties I need in relation to it"* (i9, 3a, 34).

Designer f2 says she feels "*lost in the concept. I am unsure how to interpret the pictures on the board. (…) Maybe I lack some form of inspiration in the project. I don't know if I should use classic clothing as a reference"* (f2, 2, 16-18).

Designer i4 is unsure when to stop researching in order to be able to *"argue for the project"* before he can start *"creating shapes."*He says, *"I think it's just insecurity on my part that I want to be sure I have all the angles covered"* (i4, 4, 39-40).

Transformation

Designer f1 claims that thinking too much can make his process inert. He says that he feels that *"sometimes I can think too much and then I just need to DO something, because this [draping experiment], I wasn't thinking, I was just looking at some fabric, and then I took it over and said, "wow, nice form""* (f1, 3, 16).

Designer i10 likewise states that she needs to do *"experiments where I don't have to think so much. Just 'do', and see what happens, what comes out of it."* She says that she has *"been a lot in my head"* and that she needs to *"be in the hands"* (i10, 3, 3-4).

In a supervision session, **Designer f2** talks about struggling with when to stop experimenting:

Designer f2: *”At the moment I’m just trying these different things to get a variation, but I’m aware that I need to… maybe not put up more rules… but I need something to create the collection, because it’s very difficult.”*

eSupervisor: *”It’s just to clarify, make the choices.”*

Designer f2: [confirms] *”I cannot keep doing this and waiting for something to show up. (…) I need to figure out how I can do it without making a WHOLE range and then pick out…”* (f2, 6, 28-32)

Information revision

Designer i3 talks about the need to get an overview of and make information explicit: *“Right now I’m (…) [in] a kind of process where I try to, in a way, empty my head. Because along the way I have had some ideas that pop up (…), for what the device could look like. So I have to just get them out on paper before I feel I can focus and say, “what if I’m inspired by a coffee cup, what would it [the design] then look like?”.”* (i3, 7a, 110).

In an interview **Designer f5** talks about information revision in relation to what is displayed on her board. She says,

“I tried to put it [the information] up [on the board]… way back. And I have perhaps left it a bit, so really I ought to take it down. But I think it’s more like a kind of reminder for me (…) I have really been unsure if I should have… if I ought to more consistently have moved on and continuously updated my board, because I have maybe clung a bit to something I liked, but perhaps have not used. Or so…”

Interviewer: *“Do you think that has been a problem?”*

Designer f5: *“No, but maybe it’s more in relation to feeling that it’s hard to make a decision about exactly which way I want to go. I can’t go hundred ways you know. I can maybe go max three . Combined into one.”*

Decision making

Designer i3 explains that he feels stuck in his process. He says, *”There have been a few times where I have been stuck, where I haven’t been able to immediately see what the next step was. But fundamentally ”it’s a lot about trusting your own decisions”* (i3, 11, 73).

In a supervision session, **Designer f5** tells her fSupervisor how she needed to make decisions in her process: *“It was [a piece of] good advice to do the overview: Then I’m forced to make decisions. I need that. (…) I needed that kick in the butt to move on. It’s good you [I] don’t just tell yourself [myself] what to do, but hear it from someone else; “leave this phase, go on””* (f5, 2a, unnumbered).

The identified main types of causes for stagnation show that stagnation can be construed from an information perspective. In the data, the reported causes for stagnation coinside with the obstacles perceived to have been overcome when managing to ‘move on’ from the stagnation. Thus, the concept of progression can likewise be interpreted from an information perspective.

There are two possible outcomes from a process stagnation: either progression is resumed in line with the previous development, when the designer identifies and handles the circumstances causing the stagnation; or the designer deems the course of development a dead end and regresses to a previous stage of development, i.e. a previous stage of design system content from where a new course of progression can take off.

Regression

As mentioned earlier, formative development can involve progression, stagnation, and regression. Regression is the designer's response to experiencing a stagnation as a dead end from which no progression is deemed possible or productive. In this case, the designer abandons the course of development, and the process regresses, i.e. returns to a former state of development from where a new course of progression can take off.

Examples of dead ends, regression and new progression course:

Designer f7

Designer f7 explains how a project can develop in one direction, stray to another, and then go back: *"you can use the mood board and all that to get to one place, but then maybe you have to take off a bit from the main road. (…) I mean, suddenly you can get lost in something, and think that "this [something else] is what it's really about". But then maybe it turns out to be something completely different. And then you have to change the process back again."* (f7, 9, 77)

Designer i3

In an interview, Designer i3 describes his change of course in relation to the material of his emerging handheld control/communication device:

Interviewer: *"What will the surface be like?"*

Designer i3: *"I think, actually, it will be glossy. To start with I had thought more along the lines of a dull, rubber-like surface (…) It will be hard, like my computer mouse or some other plastic product."*

Designer i3 explains why he changed his mind: *"My son has this IKEA night lamp that looks like a ghost made of white rubber (…) that I tried to sit and hold, because it was really a lot like what it [the emerging device] would be like, if it was to be in a rubber-like, soft material. And I didn't like that. (…) It is a night lamp that glows, so you have the rubber, which is kind of pulled over (like a skin), and then inside there's this core that glows and changes colour. It was such an odd feeling of something that was loose and then still pressed against something that was hard. That was just an odd feeling."*

Designer f2
In a project presentation Designer f2 explains that she *"started being focused on body posture, but it became difficult for me to work on it further, so I decided to take it in another direction."* (f2, 6, 2-3)

Designer i8
In an interview Designer i8 reports about a dead end that he encountered, leading him to progression in another direction:

Designer i8: *"(…) I had kind of considered if I could work with 'material liberation' too. To, you know, refer back to that time [the 70es], and then learn how to use it in a contemporary context."*

Interviewer: *"What is material liberation?"*

Designer i8: *"Well, that's the thing… And that's what I tried to work with. But (…) that part of the project stopped, very abruptly, because I realised that it required more time [than I had], and also that I had some more [specialised] collaboration partners like chemists and biochemists, so you could (…) actually develop something completely new and not yet existing (…). So my project had two directions of which one of them stopped very abruptly, because I didn't feel I could move on in an acceptable way. So for that reason, I started doing this other project."* (i8, 12, 59-61)

Designer i4
"Now, I went two ways form-wise, there was this one (points to sketch) that was kind of blocked in the front, and I went back and settled on this kind (points to sketch) of approach, because the interior changed." (i4, 8a, 68). This quote reveals that designer i4 has met a dead end and has regressed to an earlier stage of form development and gone in a new direction.

Designer f2
Designer f2 says: *"(…) I had implemented some of these very curvy lines as cut-lines. (…). Also to give it a bit of a crooked expression from behind. But it became too much. We saw that in the final fitting, we didn't really do justice to the drapes that were already there , because it got too mixed up. (…) So that's how they got discarded, at least in that style (points to picture) and also in the silk dress that was under the foam jacket."* (f2, 10, 175-177). The quote shows how Designer f2 had to reject specific information and the related design development in particular, as it did not contribute value to the design.

It is not always possible to immediately evaluate and determine whether the result of a design process move is useful for the further development or is a dead end from where to regress. If the designer has planned a series of experiments, she might deliberately stop each path of potential development represented by the individual experiments until she is through with the series – arguably to attain a basis for comparison to support her decision-making. Thus, the designer might keep several paths of potential development open and deliberately postpone the assessment of the progress capacity or regress necessity of the result of a move.

The following example shows how a designer expects, but is not yet certain about, the regression from a move due to ongoing related work.

Designer f2
In an interview, Designer f2 refers to an experiment of which the outcome is likely to be deemed a dead end and abandoned:

Interviewer: *"What is the thing up there [on the board] – is that for the project?"*

Designer f2: *"It was an experiment. It is a vacuum tight… of the foam things. They have been laid into this form."*

Interviewer: *"Are you going to use it for something?"*

Designer f2: *"I don't really know yet. Right now I don't think it will be used for anything. I think maybe it was [is] kind of a vague shape… I had hoped for some more creases and stuff…"* (f2, 4, 52-55)

The idea of *regression* is also implied by Schön (1983). Schön introduces the concept of 'conversation with the materials of a situation' as representative of 'reflective practice'. In the conversation with the material, the designer listens to the 'back-talk' of the material (pp. 76-104). This 'back-talk' is, in essence, the designer's appreciation of the unintended outcomes or changes produced by a move, which *"give the situation new meaning"* (p. 131). If a move produces the intended outcome or produces unintended outcomes that the designer likes, then the move is 'affirmed'. In the opposite case, a move is 'disconfirmed', and its outcome 'negated' (p. 146).

Schöns 'negation' implies a *regression*, since, if a move does not produce anything useful, the designer must go back to the outset from where the move was made in order to make another move.

The necessity of the 'unnecessary'

If we imagine that it was, in fact, possible for a designer to have steady, formative progression towards the final design, without fumbling, failures or futile paths leading to dead ends and regresses during the design process, there would be no conflict between progression of formative development and time elapsed in the process; no stagnation or regression. However, such linearity is neither the reality – nor the goal – of the design process. Even though designers strive towards progression flow, stagnation, dead ends, and regression are part of every explorative design process. The seemingly unnecessary detours of the process are practically inevitable products of the experimental chances that must be taken in a creative process, the result of which should be novel and hence unknown to begin with. Which paths turn out to be detours from the ‘direct route’ towards the goal can only be determined after the fact, since the ‘direct route’ from the outset to the final output is a construct that can only be undertood in retrospect.

The follwing examples show the designer’s recognition of the necessity of the ‘unnecessary’:

Designer i3:
Designer i3 describes the necessity of the entire process including periods of non-focussed work: *“(…) there was a time when I had the feeling that the first two months – that is the start-up phase and the research phase – when I worked very broadly, had not yet chosen that I wanted to work with the dentist , and when I hadn’t chosen that it was going to be a communication device – then I kind of had the feeling that those two months were wasted, I mean, I hadn’t’ focussed on one project at that time. But at the same time it was those two months that gave me all the background knowledge I used later, and they were also the reason I ended up in exactly this problem, and that my eyes were opened to it, so you can’t really… I couldn’t have done it without those two months”* (i3, 11, 89).

Designer f2
Designer f2 elaborates on the nature of the design process: *“So many things can happen (…). That is what the processes are good for: You go through a lot of things and realise and abandon a lot of ideas along the way, and some better ones appear, hopefully (…)”* (f2, 4, 88).

The space for fumbling and failure is a vital part of explorative processes. If using natural selection as an analogy to describe creative, explorative development, the vitality of fumbling and failure can be seen in terms of mutation. Mutation can be considered as a built-in ‘failure-mechanism’, a randomisation of nature, allowing for and securing the emergence of variation among organisms, beyond what would result from reproduction of existing genetic material, thus allowing for development of species. Among the genetic alternatives caused by mutation, the fittest survive and lead to new courses of species development, while the weak perish. A similar point is noted by Ranulph Glanville (2009). Construing design as conversation in line with Schön (1983), Glanville says that *“whereas in most models of communication the concern is to reduce error, in design the so-called “error” may be a source of novelty. What is often thought of as error is welcomed as a means of enhancing creativity”* (Glanville, 2009, p. 431).

In explorative development processes the ‘failures’ and ‘futile’ paths prove that the designer has been exploring new and unknown territory, taking ‘mutative’ moves in which she gave up full control of the output and allowed for random surprises. Such moves could potentially lead to something new and interesting beyond what she could imagine based on the concepts already consciously available to her imagination. Yet, potentially they might also lead to process stagnation, dead end and regression. This uncertainty is inevitable in creative, explorative development.

9.1 Nonformation

When a designer encounters a dead end, the recognition of it is linked to the experience of an undesired, unfeasible or otherwise unsatisfying outcome of a move. Thus, a dead end is followed by some negative insight into what does *not* work or what is *not* desired. Such negative information about what *not* to do can also be imposed on to the design system by the requirements of the designer or of others. I shall call this type of information indicating what the designer can or should *not* do 'nonformation'. Just like a piece of design process information is called an *information entity*, a piece of nonformation will be called a *nonformation entity*.

Examples of nonformation:

Designer i3:
Designer i3 designs a handheld control/communication device for a medical context. He explains that in his design he tries to *"avoid those obvious no-go's in the health care system. That is, something with many holes or edges and that kind of thing that cannot be cleaned (…)"*. Noticeably, holes and edges are examples of nonformation in designer i3's design.

Designer f2:
Designer f2 reveals a nonformation entity that she does not initially want in her project; 'classic references'.

"To begin with I was a bit rebellious with regard to it [classic details in the clothing], because I had been kind of put into a box by many of my peers, like "you are the one with the classic references," and I responded, 'no way, that's not me'" (f2, 10, 69).

Designer i4:
Designer i4 is evaluating a user experiment he made, simulating a car experience with tape outline on the floor. He elicits the nonformation that a framework for a workshop cannot be 'loose'.

"I tried. But I realised that putting people into a loose framework – because I had just taped the outline of the car on the floor, I didn't have any screens, I only had some chairs that were just there – it just didn't work, it was way too loose. (…) [A] framework, for a workshop needs to be confined, because people have a hard time relating to something that doesn't exist" (i4, 6, 136-141).

Designer f6:
Designer f6 is designing a dancewear collection. In the following quote she explains a nonformation entity in her project, namely that she will *not* focus on 'functionality': *"In this dance world it's not so much about function, as is the case in for example running clothes. It is not like you can improve your performance by what you're wearing. It's much more about feeling comfortable in the clothes and a lot about what expression you signal outwards (…) and if it matches what your body is expressing. So for that reason, I have chosen not to make very sports-functional apparel, because that's not important for my persona. (…) it won't be highly technical"* (f6, 5, 9).

Designer i3:
Designer i3 talks about the shape he has created for his medical handheld control/communication device *"When you give form to this kind of thing, which has to fit… feel soft inside the hand and that kind of thing, then it's (…) hard not to make it look like a sex toy. And that's not the kind of association I wish to evoke"* (i3, 8c, 30). Sex toy associations constitute a nonformation entity in Designer i3's process.

Converting nonformation to information

Unlike information, nonformation is not an available resource contributing directly to the *formation* of the design. Nonformation brings insight about what to exclude. Even if we hypothetically subscribe to the idea that a design solution can be found from a finite solution space of alternatives, such limited exclusion is of little help – akin to removing a couple of straws from the haystack when looking for the needle. That is, of course, unless the nonformation is dichotomous, i.e. like one of two sides of a coin, in which case it makes no difference whether the in- or the nonformation is given. For example, 'the height of the car must not exceed 1.80 meters' is equivalent to 'the height of the car must be smaller than or equal to 1.80 meters.'

Nonformation is usually not accompanied by *information* about the same design aspect, since, for example, it makes little sense to demand that a car should not be blue, if at the same time it is required that it is purple. For this reason, nonformation will most likely stand alone.

So how can nonformation contribute to the development of explorative design processes? Three strategies have been identified from the data by which designers make use of nonformation in their process:

1) Nonformation can serve as a point of departure from which a gradual formative movement away from the nonformation entity can take off.

Designer A has 17 years of professional experience. He describes how nonformation can be useful in a task with little or no constraining information.

"(…) if everything is possible, then it's harder to start a creative process, because what usually starts a creative process is exactly that you have some obstructions, which means you can't go that way. Because then there is some kind of point of departure for the task, then there is a crack in it. Because then you can start somewhere there, where you are close to what you cannot do. And then move away from it. Because at least it's usually known territory, the place you can't go. (…) it means having a place to start (…) if for example you are told that (…) it cannot be a certain material, or that it cannot be extruded, or… It is a way to get started, and no one says you cannot step into that place, that is not allowed, while you are in the design process. (…) I can step in there and then look from there and in [to the allowed place]."
Designer A exemplifies that he positions himself *"right at the interface. Because that is the known territory, after all. And then you start to move further and further away (…) and it can be quite literally when you sketch. (…) It's like if you have manifold [paper]. The first sketch you draw is the one it cannot be, and then you put a manifold sheet on top, and then you draw something and add a line to it that pulls it away a bit, and after three or four layers you can no longer see the first sketch. And that's when you start to sketch and design away from it."*

Similar examples can be found in the cases with the student designers:

Designer i3: *"The hemisphere actually came from my original fascination with the sphere, but the hemisphere lay sort of better in the hand"* (i3, 8c, 44).
In this example, Designer i3 moves away from the nonformative sphere by discarding some of it – gradually leaving the sphere and arriving at the hemisphere.

2) Nonformation can be reversed provided it has features to which an opposite concept is known.

Designer i3:
If we rearrange one of the previously presented examples of dead end in a chronological sequence, we can find in Designer i3's case an example of inverting features of nonformation to utility of information. The example is from an interview with Designer i3 about the surface of his emerging device:

- *"To start with I had thought more along the lines of a* ***dull, rubber-like*** *surface"*
- *"My son has this IKEA night lamp that looks like a ghost made of white rubber (…) that I tried to sit and hold, because it was really a lot like it* [the device] *would be* [feel] *like, if it was going to be in a* ***rubber-like, soft*** *material. And I didn't like that. (…) It is a night lamp that glows, so you have the rubber, which is kind of pulled over [like a skin], and then inside there is this core that glows and changes colour. It was such an odd feeling of something that was loose and then still pressed against something that was hard. That was just an odd feeling."*
- *"I think, actually, it will be* ***glossy****. It will be* ***hard*** *like my computer mouse or some other plastic product."*

In this example, we can see how an experiment provides experience that elicits nonformation of the undesirability of the initially intended dull, rubber-like, and soft surface and subsequently, how the expectation of the product surface has been reversed to one of opposite features; namely glossy and hard.

3) If the nonformation is the rejected result of an experiment, the process of experimenting itself will most likely have provided the designer with an experience of the material, technique, function or other aspects involved. From these experiences, the designer can draw ideas or hypotheses of how to do things differently and achieve a preferred result. These insights might not have emerged had the designer not conducted the rejected experiment of which the result was nonformative.

Designer i4

Returning to Designer i4's car simulation user experiment an example is found of how some information is elicited in the process of a non-formative experiment. Designer i4 says about the experiment, *"It was a good failed experiment. Because I realised that I really needed a platform – a package – to be able to argue properly for it [the design]."*

Designer i4 conducted the experiment as follows: *"I didn't have very much space, so I had marked an area [on the floor] and said "this is what you've got" and then I had provided chairs, and then I asked "How would you place these to make enough room?" (...) And when they had placed the chairs (…) I asked them to take the ride. Line up and wait for the fictive taxi, get in, but without saying where the door was. One person entered in the back, another in the side. (…). I took them out of the room so they would not influence each other. And it was fun to see what they did individually."*

Designer i4 then explains how the 'failed experiment', which gave him an idea of how not to do expriments, also provided him with useful information: *"[The experiment] gave me the insight that to do this more efficiently, I have to know in advance how big the car should really be (…) seat size and such things. Find the numbers, and what the ergonomic formula for this is. And then try to do it over again. (…) It was too unspecified, but it gave me the direction, I mean the knowledge that I have to be specific/purposive to get some good facts out of it. But it gave me some idea, because I thought [initially] there should be eight seats, but when they [the users] came, (…) they took two of them away to make enough room for a natural flow, so they wouldn't have to tumble over each other. So it went from wishful thinking about eight seats to be six seats"* (i4, 4, 61-78).

Designer f2

Another example is seen in Designer f2's process. She has worked with a draping technique that has been central to her project. She says that she has *"not used it literally everywhere,"* since the original technique has *"sometimes worked and sometimes not worked in relation to having a body inside."* When the technique has not worked, Designer f2 has *"modelled in relation to it. Like, "okay, that does not work, when I do it like this with the pants. What does it take for the leg to actually be able to get in them and walk? Maybe it takes this"".*

In this way she has *"worked further with his [the originator's] technique"* and *"invented my own technique (…) inspired by his thoughts about making new forms quickly, so I have maintained the pace, but then modelled it [the technique] towards a more (…) calm expression."*

She says that *"All the way through [the process] it has been about learning to use his technique. Even though it has been modified from the original idea,"* and she concludes that though she has modified the original technique, *"I have been given a lot of tools"* from working with it (f2, 10, 13-37).

As is evident from the three strategies for making use of nonformation, it is not the nonformation itself that suddenly provides the designer with information, but rather the way the designer interprets or infers from it, or the experiences gained in the process of arriving at it.
The role of nonformation in design processes is related to Alexander's (1964, p. 19) notion of misfit between form and context and the way it obtrudes itself upon our attention. Alexander writes that *"in practice we see good fit only from the negative point of view"* (Alexander, 1964, p. 22). He explains that:

> If a man wears eighteen-century dress today, or wears his hair down to his shoulders, or builds Gothic mansions, we very likely call his behaviour odd; it does not fit our time. These are abnormalities. Yet it is such departures from the norm which stand out in our minds, rather than the norm itself. Their wrongness is somehow more immediate than the rightness of less peculiar behaviour, and therefore more compelling. Thus even in everyday life the concept of good fit, though positive in meaning, seems very largely to feed on negative instances; it is the aspects of our lives which are obsolete, incongruous, or out of tune that catch our attention (Alexander, 1964, p. 22).

Following this line of thought the designer will be more likely to notice and elicit nonformation than information from experience gained through experimentation or obtained prior to the design project. In addition to the likelihood of seeing the negative or the misfitting, Alexander states that the negative also manifests itself in a more specific form that is "*tangible enough to talk about"* in contrast to the good fit that is *"almost impossible to characterise"* (Alexander, 1964, p. 23).

Given this premise, it is obvious that the detours, the dead ends and the regresses of the design projects involving nonformative experience must be recognised for the value they can provide to the explorative process. This value is provided by means of the strategies of conversion exemplified above. Since the final design should ideally be characterised by all-round satisfaction, the design process is in part steered by (divergence from) the non-satisfaction represented by nonformation encountered through the process of formation. Thus, the seemingly unnecessary digressions along futile paths become vital to the progression of design processes.

10. Process Conceptualisation

In this chapter, I will discuss some ways in which the notion of a 'design process' can be differentiated, conceptualised, and understood.

10.1 Three Process Conceptualisations

In Chapter 8, I introduced a visualisation of Reitman's problem-solving theory. My work with this model hinted at a way in which to triadically differentiate the way in which design processes are understood and communicated. Subsequently, this differentiation was established and elaborated by empirical data analysis.

As we shall recall from Reitman's problem-solving model, which was depicted in Figure 35 (and replicated for convenience in Figure 43 below), problem solving involves a *problem vector* in which a quantity of input elements *A* is transformed in a number of ways ⇒ into a quantity of output elements *B* and a *solution vector* in which a single input element *A'* is transformed in a particular way ⇒' into a single output element *B'*. Yet, the entire problem vector [*A, B,* ⇒] is likewise transformed by a process ⇒* into the solution vector [*A'*, *B'*, ⇒'].

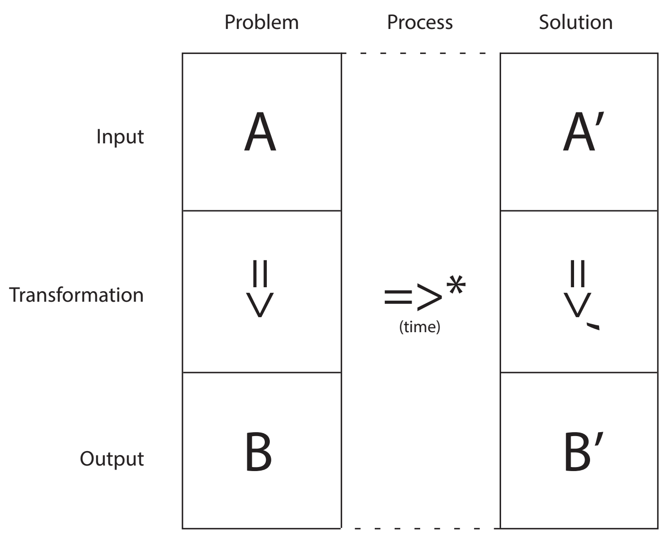


Figure 43: Replication of Figure 35: My visualisation of Reitman's problem-solving model

As apparent from Figure 43, Reitman's model contains three arrows ⇒. Notwithstanding that the process ⇒* is the only arrow representing a temporal extension, Reitman's problem-solving model conveys the impression that there are three different process conceptualisations involved in getting from the input of a problem to the output of a solution. These are represented by the capital H-shape in

Figure 44, which I will call the H-model. Reitman does not himself elaborate on the distinction or nature of these three process conceptualisations.

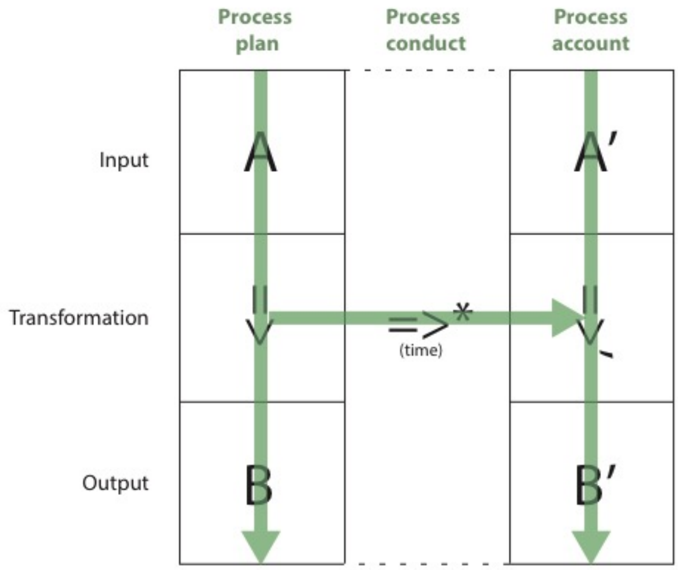


Figure 44: The H-model: Three process conceptualisations found indicated in Reitman's problem-solving model

The three process conceptualisations I have found indicated by Reitman's model and depicted in the H-model can be described as follows:

- The process plan [A ⇒ B] representing the prospective idea that from some quantity of inputs, A, some transformation out of a number, ⇒, will yield some output from the quantity, B. This process conceptualisation is not representative of any time span, as A and B coexist prior to the process conduct ⇒*.
- The process account [A' ⇒ B'] representing the retrospective account that a particular input, A', through a particular transformation, ⇒', yielded a particular output, B'. This process conceptualisation is also not representative of any time span, since only post hoc assessment can determine which particular elements [A' ⇒' B'] turned out to be the solution.
- The process conduct A ⇒* B', in which a specific output, B', through the transformative process ⇒*, is found from a quantity of inputs, A. The process A ⇒* B' or [A ⇒ B] ⇒* [A' ⇒' B'] is the *actual*, chronological process conduct undergone from the temporal starting point [A ⇒ B] to the actual, terminating solution [A' ⇒' B']. The process conduct is the only process conceptualisation that is in fact a process, since it has a temporal extent.

The three process conceptualisations derived from the development and interpretations of Reitman's model have proved to be fruitful to the analysis of design processes, as will be explained in the following.

For instance, the distinction comprises and explains the perceived equivocality of the design process mentioned earlier: A design process is on the one hand a concept that informs the designer, before the process has, in fact, unfolded. This is, for example, the case when the designer talks about her final design that does not yet exist, and about the way to get there. On the other hand, a design process is a chronological process of formation with a temporal extension.

An essential difference must be noted, however: Reitman's model is a problem-solving model, and design is not problem solving. As evident in Reitman's exposition, a *solution* [A' ⇒' B'] is described as particular elements found from quantities of elements provided in the *problem* [A ⇒ B]. This represents a typical search strategy in which all information is provided at the outset, and the solution must be found by searching the solution space and narrowing down alternatives until the optimal solution is found.

In design, on the other hand, the final design may not consist of elements given at the outset of the process. In fact, in a very under-determined task, almost no information might be provided at the outset at all. Yet, as we shall see, design processes can be approached and understood by three process conceptualisations similar to those found in the H-model.

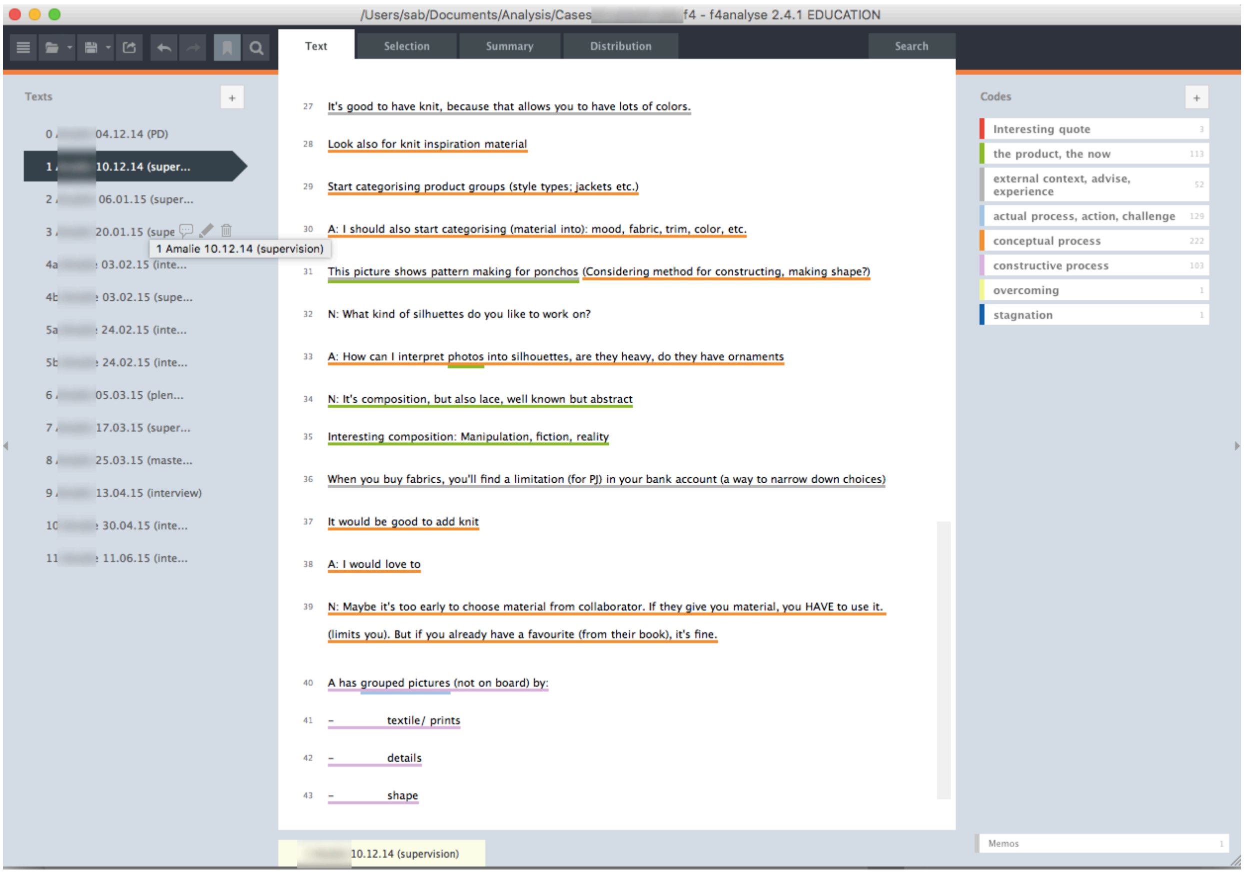
Three Process Conceptualisations in Design

The H-model framework seemed interesting in relation to the present study of design processes since it pointed theoretically at a distinction which converged with casual observations obtained in the data collection process. On the basis of these observations, I provisionally interpreted the *process plan* as the act of conceptually imagining and looking forward in the design process, the *process account* as retrospectively looking back and 'reconstructing' the design process, and the *process conduct* as the actual undertaking of design moves that effected changes in the process.

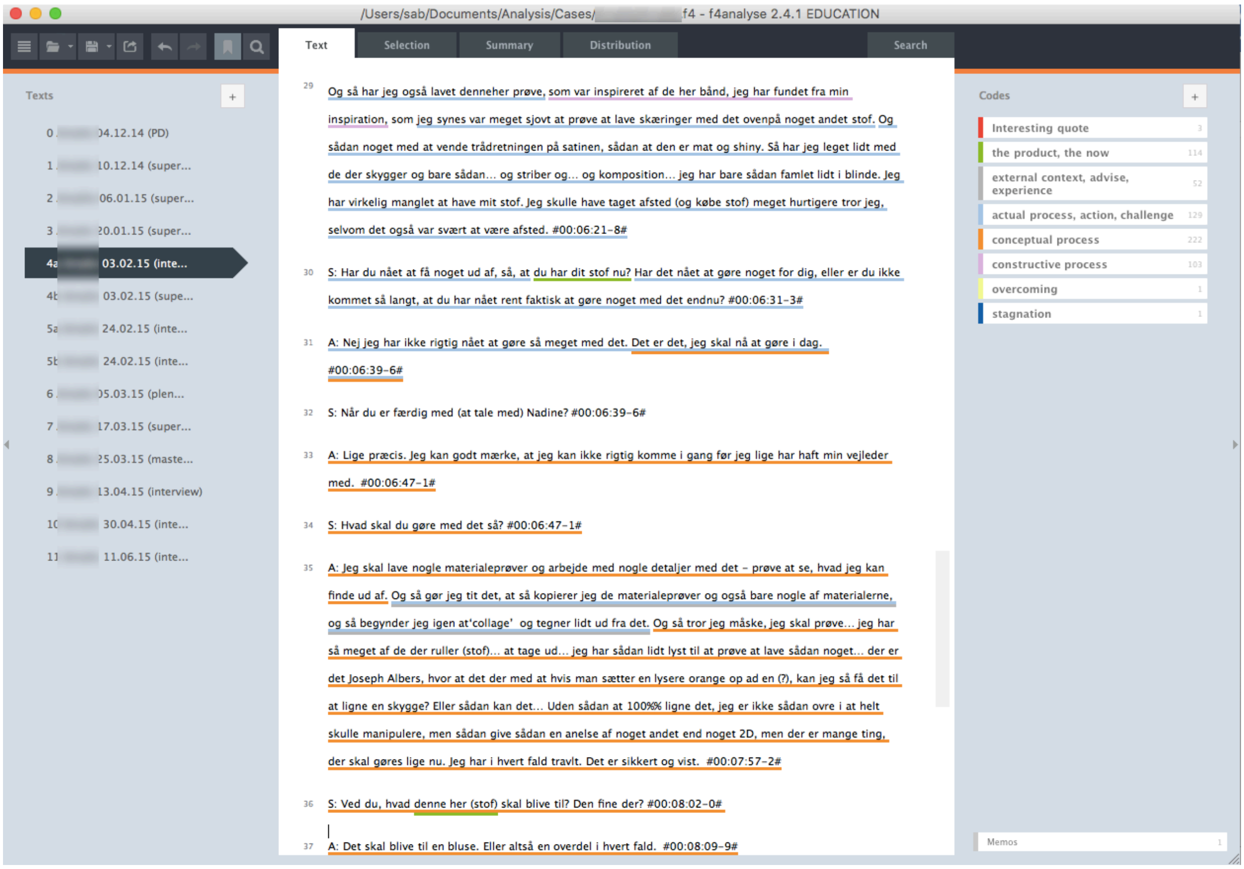
By using this emerging framework as a prototype, I analysed data deductively. I started out by coding through one entire case (Designer f5[21]) 'line by line' using the program f4. For each passage, I assessed whether it appeared to fit into one of the three provisional categories. If it did, it was tagged with the affiliated code. If not, a new

[21] This case was chosen based on the principles mentioned in Chapter 2 and because it had not already been subjected to thorough analysis.

residual code was introduced to describe the nature of the 'misfit'. The residual codes developed throughout the coding procedure in order to embrace and cluster instances of 'misfits' which resembled each other. The coding procedure is exemplified below[22]. The examples feature both Danish and English, since supervisions and presentations were conducted in English, whereas interviews were conducted in Danish.



[22] Sensitive personal information has been veiled in the pictures.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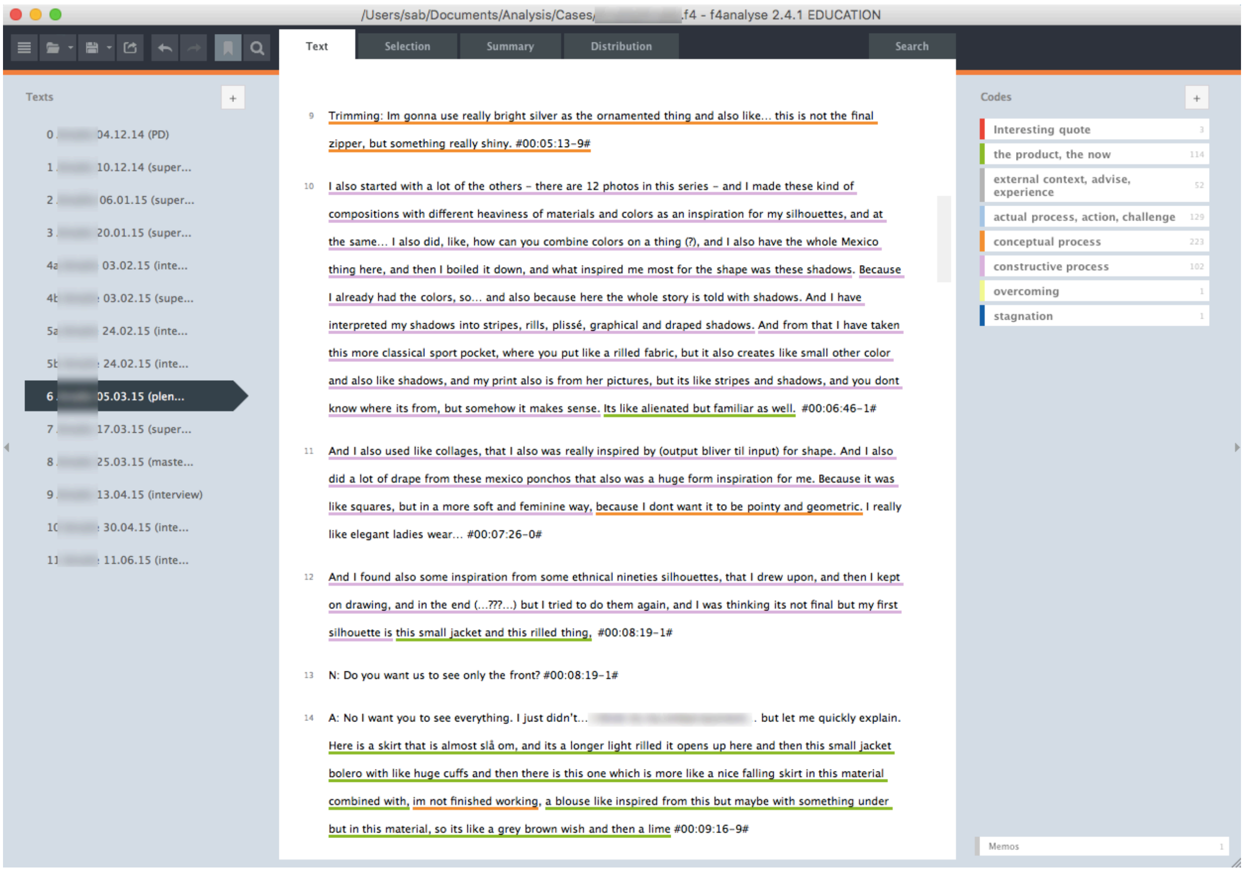
9 13.04.15 (interview)
10 30.04.15 (inte...
11 11.06.15 (inte...
29 Og så har jeg også lavet denneher prøve, som var inspireret af de her bånd, jeg har fundet fra min inspiration, som jeg synes var meget sjovt at prøve at lave skæringer med det ovenpå noget andet stof. Og sådan noget med at vende trådretningen på satinen, sådan at den er mat og shiny. Så har jeg leget lidt med de der skygger og bare sådan… og striber og… og komposition… jeg har bare sådan famlet lidt i blinde. Jeg har virkelig manglet at have mit stof. Jeg skulle have taget afsted (og købe stof) meget hurtigere tror jeg, selvom det også var svært at være afsted. #00:06:21-8#
30 S: Har du nået at få noget ud af, så, at du har dit stof nu? Har det nået at gøre noget for dig, eller er du ikke kommet så langt, at du har nået rent faktisk at gøre noget med det endnu? #00:06:31-3#
31 A: Nej jeg har ikke rigtig nået at gøre så meget med det. Det er det, jeg skal nå at gøre i dag. #00:06:39-6#
32 S: Når du er færdig med (at tale med) Nadine? #00:06:39-6#
33 A: Lige præcis. Jeg kan godt mærke, at jeg kan ikke rigtig komme i gang før jeg lige har haft min vejleder med. #00:06:47-1#
34 S: Hvad skal du gøre med det så? #00:06:47-1#
35 A: Jeg skal lave nogle materialeprøver og arbejde med nogle detaljer med det – prøve at se, hvad jeg kan finde ud af. Og så gør jeg tit det, at så kopierer jeg de materialeprøver og også bare nogle af materialerne, og så begynder jeg igen at'collage' og tegner lidt ud fra det. Og så tror jeg måske, jeg skal prøve… jeg har så meget af de der ruller (stof)… at tage ud… jeg har sådan lidt lyst til at prøve at lave sådan noget… der er det Joseph Albers, hvor at det der med at hvis man sætter en lysere orange op ad en (?), kan jeg så få det til at ligne en skygge? Eller sådan kan det… Uden sådan at 100%% ligne det, jeg er ikke sådan ovre i at helt skulle manipulere, men sådan give sådan en anelse af noget andet end noget 2D, men der er mange ting, der skal gøres lige nu. Jeg har i hvert fald travlt. Det er sikkert og vist. #00:07:57-2#
36 S: Ved du, hvad denne her (stof) skal blive til? Den fine der? #00:08:02-0#
37 A: Det skal blive til en bluse. Eller altså en overdel i hvert fald. #00:08:09-9#
Codes
Interesting quote 3
the product, the now 114
external context, advise, experience 52
actual process, action, challenge 129
conceptual process 222
constructive process 103
overcoming 1
stagnation 1
Memos 1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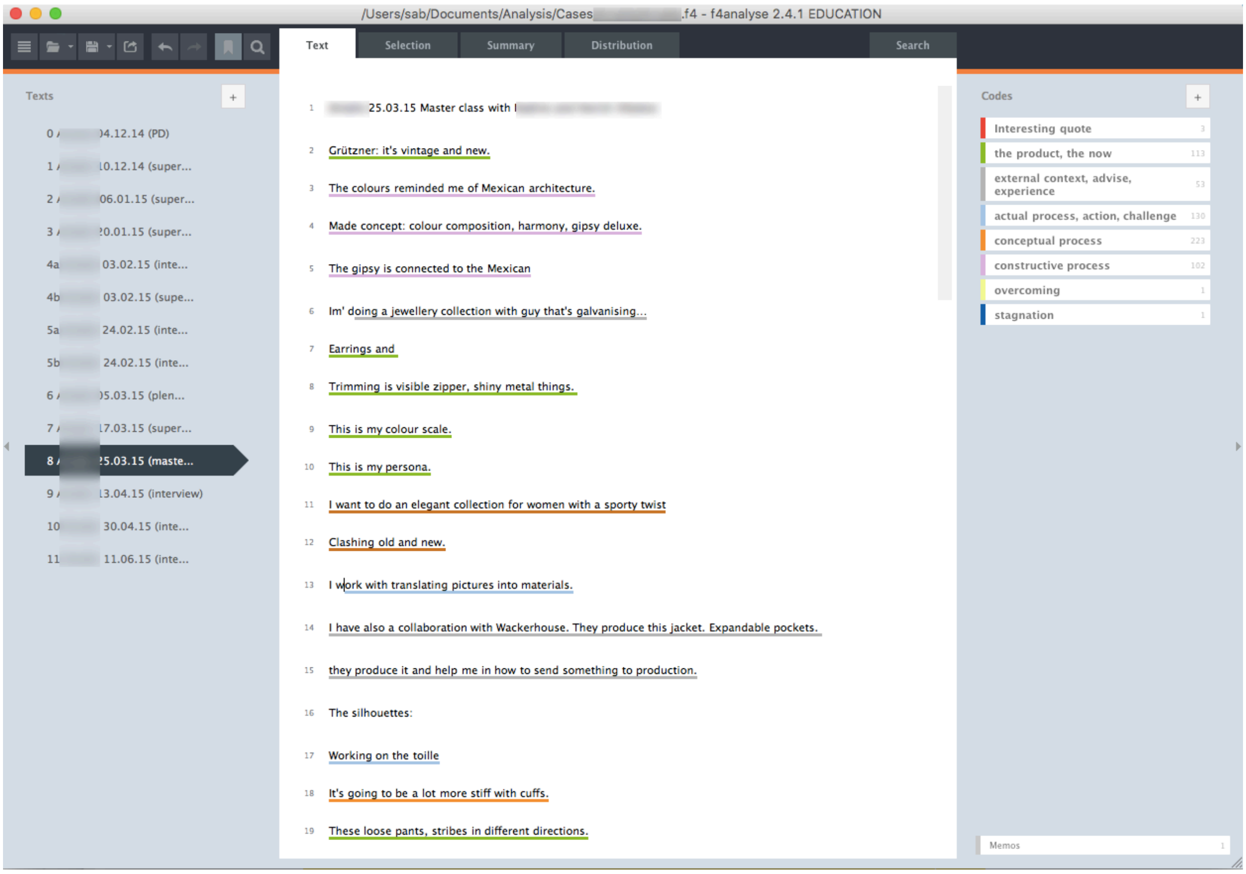
7 17.03.15 (super...
8 25.03.15 (maste...
9 13.04.15 (interview)
10 30.04.15 (inte...
11 11.06.15 (inte...
9 Trimming: Im gonna use really bright silver as the ornamented thing and also like… this is not the final zipper, but something really shiny. #00:05:13-9#
10 I also started with a lot of the others – there are 12 photos in this series – and I made these kind of compositions with different heaviness of materials and colors as an inspiration for my silhouettes, and at the same… I also did, like, how can you combine colors on a thing (?), and I also have the whole Mexico thing here, and then I boiled it down, and what inspired me most for the shape was these shadows. Because I already had the colors, so… and also because here the whole story is told with shadows. And I have interpreted my shadows into stripes, rills, plissé, graphical and draped shadows. And from that I have taken this more classical sport pocket, where you put like a rilled fabric, but it also creates like small other color and also like shadows, and my print also is from her pictures, but its like stripes and shadows, and you dont know where its from, but somehow it makes sense. Its like alienated but familiar as well. #00:06:46-1#
11 And I also used like collages, that I also was really inspired by (output bliver til input) for shape. And I also did a lot of drape from these mexico ponchos that also was a huge form inspiration for me. Because it was like squares, but in a more soft and feminine way, because I dont want it to be pointy and geometric. I really like elegant ladies wear… #00:07:26-0#
12 And I found also some inspiration from some ethnical nineties silhouettes, that I drew upon, and then I kept on drawing, and in the end (…???…) but I tried to do them again, and I was thinking its not final but my first silhouette is this small jacket and this rilled thing. #00:08:19-1#
13 N: Do you want us to see only the front? #00:08:19-1#
14 A: No I want you to see everything. I just didn't… but let me quickly explain. Here is a skirt that is almost slå om, and its a longer light rilled it opens up here and then this small jacket bolero with like huge cuffs and then there is this one which is more like a nice falling skirt in this material combined with, im not finished working, a blouse like inspired from this but maybe with something under but in this material, so its like a grey brown wish and then a lime #00:09:16-9#
Codes
Interesting quote 3
the product, the now 114
external context, advise, experience 52
actual process, action, challenge 129
conceptual process 223
constructive process 102
overcoming 1
stagnation 1
Memos 1



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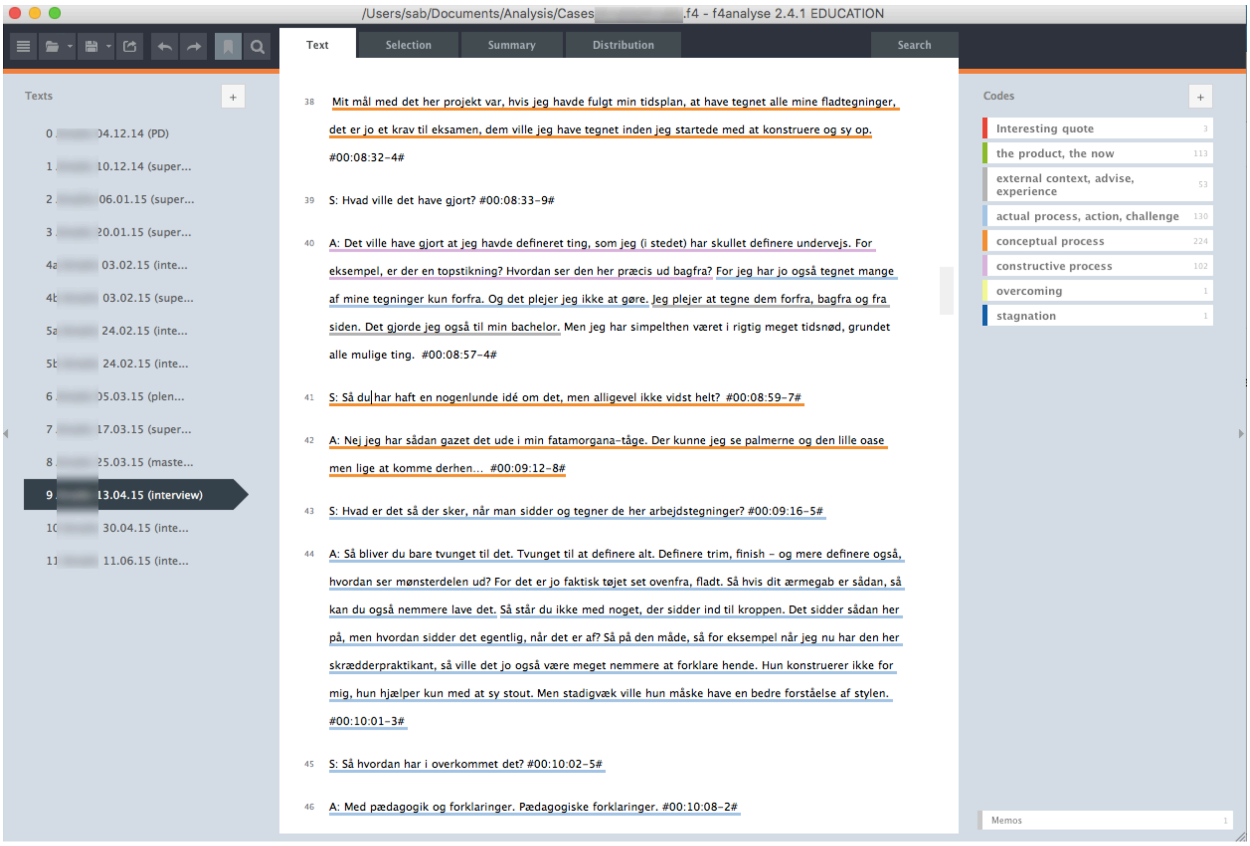
7 17.03.15 (super...
8 25.03.15 (maste...
9 13.04.15 (interview)
10 30.04.15 (inte...
11 11.06.15 (inte...
1 25.03.15 Master class with
2 Grützner: it's vintage and new.
3 The colours reminded me of Mexican architecture.
4 Made concept: colour composition, harmony, gipsy deluxe.
5 The gipsy is connected to the Mexican
6 Im' doing a jewellery collection with guy that's galvanising...
7 Earrings and
8 Trimming is visible zipper, shiny metal things.
9 This is my colour scale.
10 This is my persona.
11 I want to do an elegant collection for women with a sporty twist
12 Clashing old and new.
13 I work with translating pictures into materials.
14 I have also a collaboration with Wackerhouse. They produce this jacket. Expandable pockets.
15 they produce it and help me in how to send something to production.
16 The silhouettes:
17 Working on the toille
18 It's going to be a lot more stiff with cuffs.
19 These loose pants, stribes in different directions.
Codes
Interesting quote
the product, the now
external context, advise, experience
actual process, action, challenge
conceptual process
constructive process
overcoming
stagnation
Memos



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38 Mit mål med det her projekt var, hvis jeg havde fulgt min tidsplan, at have tegnet alle mine fladtegninger, det er jo et krav til eksamen, dem ville jeg have tegnet inden jeg startede med at konstruere og sy op. #00:08:32-4#
39 S: Hvad ville det have gjort? #00:08:33-9#
40 A: Det ville have gjort at jeg havde defineret ting, som jeg (i stedet) har skullet definere undervejs. For eksempel, er der en topstikning? Hvordan ser den her præcis ud bagfra? For jeg har jo også tegnet mange af mine tegninger kun forfra. Og det plejer jeg ikke at gøre. Jeg plejer at tegne dem forfra, bagfra og fra siden. Det gjorde jeg også til min bachelor. Men jeg har simpelthen været i rigtig meget tidsnød, grundet alle mulige ting. #00:08:57-4#
41 S: Så du har haft en nogenlunde idé om det, men alligevel ikke vidst helt? #00:08:59-7#
42 A: Nej jeg har sådan gazet det ude i min fatamorgana-tåge. Der kunne jeg se palmerne og den lille oase men lige at komme derhen… #00:09:12-8#
43 S: Hvad er det så der sker, når man sidder og tegner de her arbejdstegninger? #00:09:16-5#
44 A: Så bliver du bare tvunget til det. Tvunget til at definere alt. Definere trim, finish – og mere definere også, hvordan ser mønsterdelen ud? For det er jo faktisk tøjet set ovenfra, fladt. Så hvis dit ærmegab er sådan, så kan du også nemmere lave det. Så står du ikke med noget, der sidder ind til kroppen. Det sidder sådan her på, men hvordan sidder det egentlig, når det er af? Så på den måde, så for eksempel når jeg nu har den her skrædderpraktikant, så ville det jo også være meget nemmere at forklare hende. Hun konstruerer ikke for mig, hun hjælper kun med at sy stout. Men stadigvæk ville hun måske have en bedre forståelse af stylen. #00:10:01-3#
45 S: Så hvordan har i overkommet det? #00:10:02-5#
46 A: Med pædagogik og forklaringer. Pædagogiske forklaringer. #00:10:08-2#
Codes
Interesting quote
the product, the now
external context, advise, experience
actual process, action, challenge
conceptual process
constructive process
overcoming
stagnation
Memos

The pictures above show how the data was coded for the framework categories. In the analysis process shown, the purple coding mark called 'constructive process' was later conceptualised as *process account*; the orange coding mark called 'conceptual process' was later conceptualised as *process plan*; and the light blue coding mark called 'actual process, action, challenge' was later conceptualised as *process conduct*.

As 'process conduct' refers to actual *action* rather than to verbal accounts of the action, coding for this concept and separating it from the other concepts was tricky. Since, in general, the case designers usually did not actually work on their projects while talking to me or their supervisors, almost everything they report has either happened already or is scheduled to take place after the conversation. However, some pieces of data focus more on considerations of the present moment, on actual, immediate actions and experimentation, and on detours in the process, rather than on a structured retrospective account of the process or on prospective plans and goals. The coding of the 'process conduct' was supported to a great extent by observations from the data collection, which took place at the designers' active working spaces. The coding was also bolstered by the visual data in the form of pictures documenting these situations, and in an interview approach which originated in the material that the designers were presently working with. Yet, the concept of *process conduct* is obviously not merely a product of inductive data analysis, but likewise coined as a logical consequence of the fact that between the data collections the process information changes and something is built. It is this activity that I try to gain insight into by attempting to separate it from retro- and prospective views of the process and to find the instances in which designers describe and show this activity as 'action-near' or as recent as possible.

By coding data as demonstrated above smaller residual categories arose: the external context including advice and prior experiences, e.g. when talking about a previous course; personal or subjective comments, e.g. *"this is very beautiful"* (these were few and scattered and have not been given a code tag); and meta talk, e.g. about the supervision (encountered merely a few times). Finally, a larger residual category arose from data (based on the number of tag entries) which referred to statements about the present process stage and information, e.g. *"I have some different things now."* This was given a code tag called 'the product, the now', and was later conceptualised as the 'position state'. The inclusion of this category allowed me to code the data almost exhaustively by the use of the framework.

After having coded Designer f5's case, I read through the remaining cases focussing on the framework concepts and found that these concepts seemed to correspond with the data from these as well. This formed the basis for searching in a more structured manner for the concepts across the data set by means of concept indicator words, which will be exemplified below.

The purpose of this search was not to count instances, but rather to attain qualitative insights into whether and how these concepts might be useful in shedding new light on the design process and to approximate a definition of this process. Hence, the concepts, which were later termed *process plan*, *process account*, *process conduct*, and *position state*, were not complete in their definition, but rather their characteristics emerged through the study.

For this reason, the indicator words used to search for instances were tentative in order to explore them as explanatory for data. Using the later proposed terms, the concept indicator words for this search were for example:

Process plan: want, will, shall, should, might, maybe, could, plan, intend, going to, my design, product
Process account: did, took, made, relate, inspired, connect, combined, came/come from, defined, categorised, types, scheme, outset, starting point
Process conduct: Now, at the moment, looking into, doing, having, in the middle of, focus, still, working on, continue, stuck
Position state: I have, I've got, this, these, those, here, show, look

The presence of indicator words in a section of data does not guarantee that the meaning expressed in the data relates to, or falls within the emerging borders of, the extent of the concept, which is why encountered instances were assessed qualitatively for their relevance.

Examples of this search will be presented in the following section. Based on the described exploration of the concepts – the *process plan*, the *process account*, and the *process conduct* – this section will characterise and illustrate the concepts and how they serve to conceptualise ways in which designers relate to and work (possibly unconsciously) in their processes.

It might seem trivial to point out that designers refer backwards and forwards in time, as we shall see, since obviously these are the directions which we have at our disposal in general to relate to and talk about time and thus also about process. However, more interesting than the distinction itself is the different purposes these three process conceptualisations seem to serve in the design processes. This will be elaborated and exemplified in the following.

Characterisation and exemplification of process conceptualisations

The three design process conceptualisations must be understood relative to a given position in the process. Let us call this point the *position state*. The *position state* can be anywhere in the design process in terms of formation and time (Figure 45).

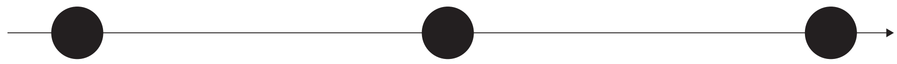


Figure 45: The position state can be anywhere in the design process

From the *position state*, the designer can do three things relating to her process: She can look backwards, she can look and plan forwards and she can make an actual move (Figure 46).

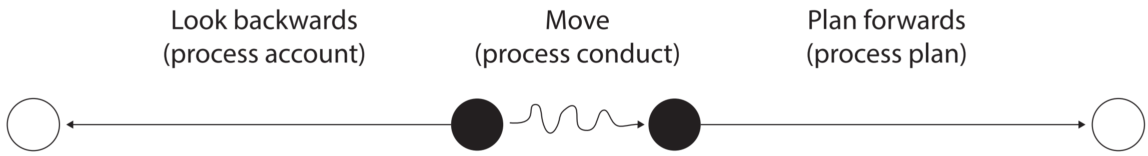


Figure 46: Three things to do from the position state: Look backward, plan forwards and move

Looking and planning forwards corresponds to what I call the design *process plan*; looking backwards corresponds to the design *process account* and 'moving' corresponds to the *process conduct*.

In the following the three different process conceptualisations will be expounded from a design perspective and exemplified based on the cases. As will be demonstrated, they are all, each in their own way, characterised by the ITO function structure.

The Process Plan

The process plan describes a future design process that is *imagined* by the designer, not in every detail, but in an abstract, conceptualised way: how will the process unfold, what will it comprise? What will be the outcome, and how is the current state transformed to the outcome? One can say that the current position state is the input of the process plan.

When at a given position state the designer talks about and plans her process, it is the process plan she talks about and deals with. The process referred to in this case has not yet taken place, and the outcome does not yet exist. Only the point at which the designer is at the given moment is known.

The process plan is not representative of any time span. Input, transformation and output, i.e. the current and future state and way of getting there coexist as *concepts* in the process plan prior to the design process ahead where something is created.

The process plan is represented by expressions pointing ahead in time, about where to go and what to do to get there, e.g. *"How can I…?"* or *"I'm going to..."*. For example, talk of methods, techniques, time schedules, goals, visions, wishes and requirements are indicators of the process plan. Not least, the process plan is expressed in the case designers' research questions[23] that usually contain statements of what situation to do something to (input (I)), what to achieve (output (O)) and how to do it (transformation (T)). All these examples represent talk of something that does not yet exist and how to arrive at it.

Examples of research questions as expressions of the process plan:

[23] At Design School Kolding, the design students are required to submit one or more design research questions to guide their Master's project. The verbatim translation from the Danish word would be 'problem formulation'. However, I find that 'research question' is a more suitable concept, both to describe the actual content and expectation of a 'problem formulation' (which, like a research question, should have the form of a question), but also not to confuse my readers by using the term 'problem' in relation to the design processes. 'Problem formulation' is a conventional term in the general field of education in Denmark, and therefore Design School Kolding's use of it does not represent a specific 'problem' focus at this institution. However, the term hints at a general problem-solving conceptualisation of explorative processes, which – as previously mentioned – is troublesome, but that is a discussion beyond the scope of this dissertation.

Designer f6
*"How can I transform [***T***] my inspiration from 'Samsara' and combine it with sport and dancewear [***I***] and create a collection that consists of cool and functional styles that complete the wardrobe of a professional female dancer with an active and urban lifestyle [***O***]?"*

Designer i9
*How can I design [***T***] a 'space' [***O***] in which telephone conversations [***I***] can be made with greater pleasure and without disturbances from and on the surroundings?*

Designer f5
*How can I combine [***T***] the colours and mood from Andrea Grützner's series of photos with the crochet tablecloths [***I***], as well as induce the feeling of familiarity and Alienation [unassigned] in the design and transform it [***T***] into a new modern collection for women [***O***]?*

Even though the research questions represent under-determined tasks and thus are very open-ended and lack most of the information that will eventually make up the final design, they display a clear functional structure corresponding to ITO.

Even when information is missing in the ITO categories, the process plan indicates the actuality of these categories, of which 'I' is the current state, 'O' is the goal, and 'T' is the way to get there. Conceptualised as a process, the process plan comprises a sequence of (imagined) change. Thus, the categories of ITO differ from those of an individual process move, not in nature, but in the level of abstraction and detail.

However, the process plan is not necessarily expressed in terms of ITO, but can also be a statement about the process merely pointing forwards in time, indicating for example the intention or plan to do something. For example: *"I think I will pull my project in a more minimalist direction"* (f2, 4, 33).

The process plan is not a predictor of how the design process will *actually* unfold. It is very likely that the imagined course of development turns out very differently in practice. Even if this was not the case, the process plan would be very abstract and leave an abundance of possible interpretations and actualisations due to the under-determination of the task in which the output is only – if at all – scarcely or vaguely defined.

Along the process, the designer gains experience and insights that she did not have at the outset of the process and which allow her to imagine other courses, possibly perceived as more satisfactory than the first. For this reason, the course can change.

Designer f1
After finishing his project, Designer f1 reflects how his design evolved differently than he had thought it would in the beginning of the project, and how the course of the process plan changed along the way, as he gained experience:

"I don't think I had 'expected' to see something else [than the actual result], but in the very beginning I had thought it would be something different, and then when you start you find out that "okay, I actually think it would be more interesting to do it in this and that way" (...). But it's not like I think it's a bad thing that it didn't – I don't want to say 'turn out as I expected' – but it is really just the first thoughts you have, and then until it's done [the project] – to me those are really two very different things, but I still feel that it's the same essence or value or within the same area."

So, what role does the process plan play, if the designer does not have to and need to stick to these plans anyway?

From the empirical studies, the process plan seems to serve a vital role as a compass setting a course of action, providing the designer with a concept of a place to go and thus an inducement to move. This is also acknowledged by Woodbury and Burrow (2006, p. 73) who write that *"Construction of design space paths is a main task for design space exploration. At any state along a path, or in design space in general, exploration is largely conditioned by knowledge about both the present state and states reachable from that state by path traversal."*

The course is evaluated when the designers are occassioned to review and reflect upon their processes. This is the case when they must present for their supervisor or class, or when they experience stagnation and have to find the cause and a way to move on. In such evaluation, the process plan provides the designer with a benchmark against which to measure competing courses or paths.

The following are examples of statements illustrating the *process plan* with indications of ITO. On different process levels the statements refer to the future process and how the designers imagine it will unfold:

Designer i3
*"[The] next step is to pick out ideas [**I**], put them together [**T**] into concepts [**O**]"* (i3, 4, 9)

Designer f6[24]
*"The next thing I will do is dig [**T**] more into the Balinese world [**I**] and draw [**T**] from the silhouettes what I find interesting [in the Bali pictures] [**I**]. And also look more into details.* (...) *I want to find out which methods [**T**], shapes and ornaments [**I**] I could use. Without thinking too much, I will explore how I can transform [**T**] these old things [**I**] into [something] modern [**O**]."* (f6, 2, 52-67)

[24] Quote is reconstructed from observation notes

Designer i9
*"[I] have come to a point where I must extract [**T**] some findings [**I**] to work further with. Create focus and make decisions in the project. (...) I have three directions on my project I need to unfold. (...) Maybe the primary [design] solution will be to make something for a work station [**O**]. At this point it is the most relevant [idea], 'cause I can see there are some tendencies. (...) And now I have to try to dive a bit more into [**T**] it to see if it holds water... (...) And then I want to analyse [**T**] what types of conversations [**I**] there are and what I can get information from... (...) I just have to find out how I can segment [**T**] them; for example small talk can cover lots of different types of conversations."* (i9, 4, 6-31)

Designer f1
*"Right now I have to move into investigation [**T**] of clothing [**I**]. I have some inspiration and research [ideas] [**I**] in mind, but now I have to do some experiments [**T**] and test them on my 'own body' [in practice]"* (f1, 2a, 12)

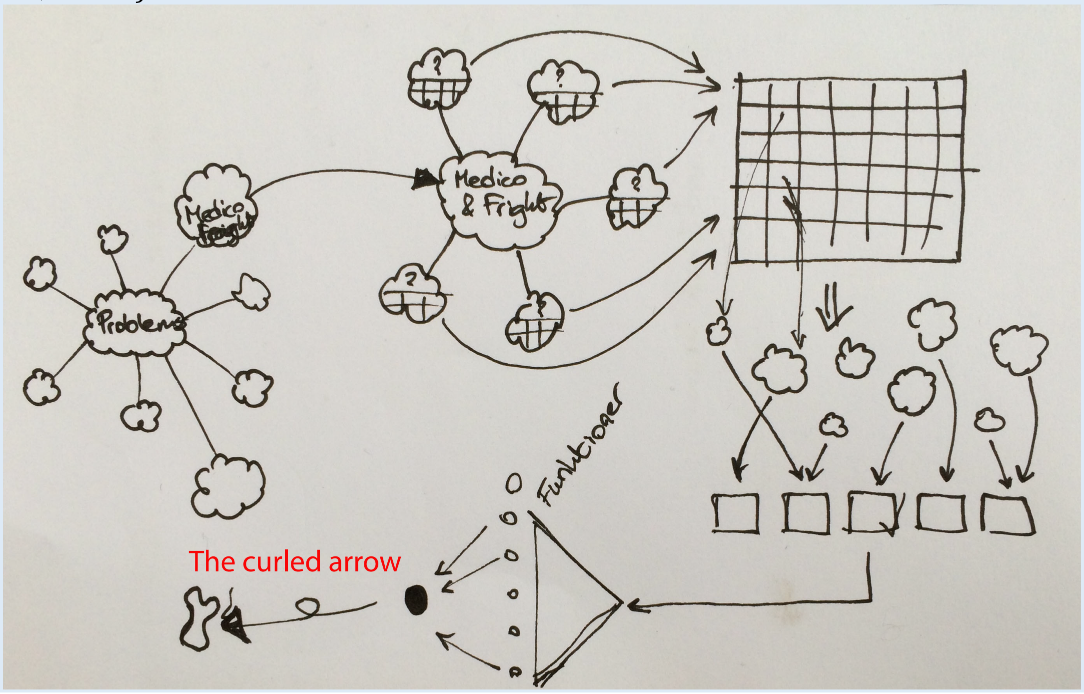
Designer i3
A bit more than halfway in his process, Designer i3 is interviewed about a sketch depicting his process, which I asked him to do as an exercise. The interview excerpt and the sketch illustrate the process account considerations from the current position state:

Interviewer: *"(...) so what happens now?"*

Designer i3: *"Well, now is the time to put form [**O**] to it [**I**]. And that is the reason, really, that I made this curled arrow pointing to something that has another shape [**O**]"*

Interviewer: *"Why is it curled?"*

Designer i3: *"Because I have to work out how to curl it [**T**] into that form [**O**]".* (i3, 7a, 62-66)



Mirage

Distinctive for the process plan is the fact that it points forward in time. For this reason, it includes both the current state of the design system as well as references to actions not yet undertaken and design objects not yet existing. Typical for this process conceptualisation is Designer f5's statement that she works *"both in the beginning and the end at the same time"* (f5, 11, 182).

Through the increasing particularisation throughout the design process, the requirements of the final output and thereby the designer's mental picture of what the final design should be like becomes more well-defined. Designer f5 describes this mental picture as a *'mirage'* and the process of making it clear a *'mirage phase'* (f5, 11, 184). She explains about the mirage that in the beginning of her process *"I can see something, but it is really blurred. But I know what it tastes like; I just need to move closer and closer. So for that reason I already know a little about where it should end up, without being able to really explain it in the beginning"* (f5, 11, 184). She elaborates *"it's not like I know I have to have seven jackets and that all of them should have buttons or something like that. It's more like "what kind of project is it that I want to do. Like there needs to be colour in it, and I want to bring out my inner 'gypsy'"* (f5, 11, 190). Designer f5 narrates that *"everything I put up [on her mood board] bears the imprint of the thing I imagine. But I still don't know what it looks like. So I need to make use of all my ways [of working], which I do with collages and such things, to discover more and more what it looks like. So I can remove more and more of the fog"* (f5, 11, 200). *"I have to make my experiments to find out what it looks like"* (f5, 11, 188).

A similar case is expressed by Designer i9, who states that at the beginning of his project he had the conception of making *"a place that could isolate you when you're making phone calls. But it was still fuzzy."* He describes this project outset as a 'theme' he worked with, and that he *"didn't know how it would end up"* (i9, 10, 96-99).

These examples correspond to Rittel's (1987, p. 2) observation that *"From the beginning, the designer has an idea of the 'whole ' resolution of his problem which changes with increasing understanding of the problem, and the image of its resolution develops from blurry to sharp and back again, frequently being revised, altered, detailed and modified."*

The following conversation excerpts between Designer f2 and the fSupervisor likewise show reflection and conversation about (parts of) the design object without any clear specification:

Designer f2
fSupervisor: *"So is this one [style] more constructed and not so tunnel-ish?"*
Designer f2: *"I don't know yet."* (f2, 7, 35)

Designer f2
fSupervisor: *"Is this a dress or a coat?"*
Designer f2: *"What do you think [it should be]?"* (f2, 7, 63-64)

The concept of a *mirage*, as it was vividly introduced by Designer f5, is reminiscent of Rheinberger's (1997) concept of 'epistemic things', which are – amongst others – material entities or processes *"that constitute the objects of inquiry"* and are characterised by an inevitable vagueness because *"epistemic things embody what we do not know yet"* (p. 28). Epistemic things are thus considered as 'things' or 'entities' although they are not fully understood, like for example the 'dark matter' of particle physics. Likewise, designers regard the outputs of the total process – or parts of it – as well as the procedures of arriving at them, as 'things' which they can reflect on and talk about, although they are neither existing nor well-defined yet.

The concept of *mirage* can be applied to understanding an important turning point in design processes, sometimes referred to as design freeze. This is the point at which the conceptual development process is considered finished, and the designer moves on to realise or construct the design. This point is more conceptual than actual, as even in the realisation phase the design can change.

Designer f6
In her initial time scheme[25], designer f6 had scheduled a certain period for 'realisation' of her collection:

week 48-51: Inspiration research, inspiration visualisation
week 2-5: sketching, development of colours, materials, details, styles, collection
week 6-17: realisation of final product
week 18: Photoshoot and presentation

At the point where Designer f6 is about to realise her collection *"and sew up everything in the final version"*, she says that her drawings of the collection are *"more or less"* finished, but that *"small adjustments happen all the time"*. For example, she is changing a material on a style *"because I don't have enough of it. I mean, I had put it into a bit too many styles [on the sketches] to like… I hadn't really thought about how much of it I had."* (f6, 7, 2-14)

[25] Shortened version

Yet, when the designer's *mirage* has turned into a clear picture of information in the process plan, it indicates a shift from an under-determined to a more well-defined task – from creation to realisation. One can say that the task at this point resembles a task of practical *problem solving*. As designer f7 says, *"It's not like I go around and think about the first things [the concepts and inspiration] now. Now I just have to make it. Now it's more like a craft project"* (f7, 9, 67).

How can a level of information definition be outlined that is sufficiently clear for this shift to take place and for the designer to start the realisation? One option is that when the information is so unambiguous that the designer can no longer *think* of any aspects that are undefined, and she does not *intend* to alter the aspects already defined, this is where the process shifts.

The Process Account

The process account is the conceptualisation of the design process that is post-rationalised by the designer when looking back on what has already happened. Reaching back in time, it stretches the span from the current design process state back to the initial or intermediate outset from which it was attained. One can say that the current position state is the (interim) output of the process account.

Design processes share traits with complex systems that are dynamic, multi-constituent, nonlinear interaction processes of an emergent nature (Snowden & Boone, 2007). According to Snowden and Boone, the causal relationship leading from start to finish in a non-linear process is not immediately apparent but can only be established retrospectively, since *"the way forward is determined based on emerging patterns"* (Snowden & Boone, 2007, p. 4).

The design process account is the conceptualised process of hindsight in which these causal relations are inferred by labeling certain actions and choices as vital for the link between the outset and the current (perhaps finished) state.

The process account can be said to form a constructed and structured narrative of the process that has taken place in which a straight storyline is sought connecting the dots of actions and decisions. This narrative allows for others to gain insight into the design process, and at the same time it expedites the designer's own comprehension and recollection of the process. Søren Kierkegaard said that *"life can only be understood backwards; but it must be lived forwards;"* the same applies to design processes, and the process account is the backwards understanding.

A narrative can be defined as *"a representation of a particular situation or process in such a way as to reflect or conform to an overarching set of aims or values"* (Oxforddictionaries.com, 2016). In the case of the design process, the aim or values refer to those that represent the particular process state in which the process account is undertaken. The process narrative 'representation' is conformed to match the current process state in hindsight, since project progression cannot be predicted, as it arises from circumstances along the process. Therefore, *"though a complex system may, in retrospect, appear to be ordered and predictable, hindsight does not lead to foresight because the external conditions and systems constantly change"* (Snowden & Boone, 2007, p. 3).

Only in relation to the process account can 'digressions' and 'side tracks' be recognised as such, and they are most often left out of the constructed narrative, since outwardly they do not contribute to the story of how the designer got from A to B. This can be illustrated as in Figure 47.

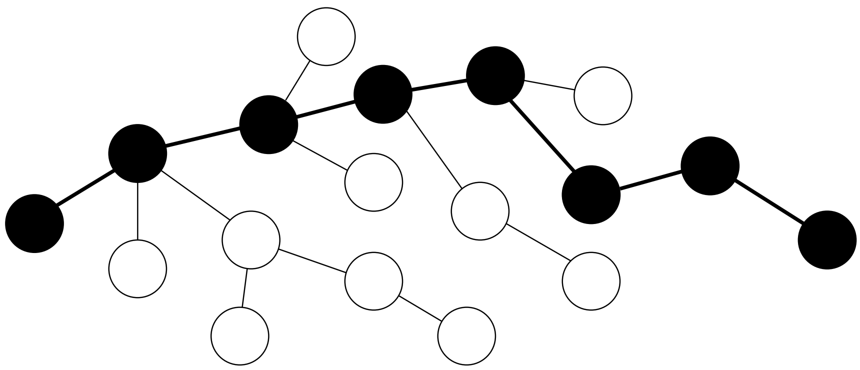


Figure 47: In the process account a straight line of causal connection is inferred from the outset to the current state.

The process account can be seen as the 'beeline' of the design project. Yet, as it refers to the process that has already taken place, it does not represent a temporal extension.

Woodbury and Burrow state that *"Understanding design space paths privileges the easily explainable over the creatively explored."* As process accounts are aimed at creating such understanding, it follows that in them designers *"are permissive in the interpretation of features and create logically coherent design space paths"* (Woodbury & Burrow, 2006, p. 70).

The process account narrative is often encountered in project presentations which, according to the iSupervisor, must show the major stages of the design process and give an overview and explain why the designer ended up where she did (10, 30-31). Likewise, prescriptive design models can be based on the linear account of processes with successful outcomes. However, the process account is not identical to the actual process conduct in which designers do not only design new things, but likewise design and develop their way of acting in order to do so.

The following example shows a process account 'beeline' from a project presentation situation:

In his test examination, Designer i3 draws the linearity of his process account within approximately ten minutes. In essence, it goes as follows:

- *Started out with the broad topic of 'reducing fear in medico'.*
- *Narrowed down to the 'dentist' field by interviewing experts.*
- *Chose to make a control device.*
- *Did research and ideation on different tools for fear reduction.*
- *Did prototyping: Different kinds of communication types and functions.*
- *Chose the device type preferred by both professionals and patients.*
- *Had sparring with expert: Focus on hygiene. Should maybe be tested before real use. The product is not interfering directly with the treatment = low risk medico product.*
- *Did interface design.*
- *Made flowchart to be aware of how the product works.*
- *Found shape inspiration from different handles.*
- *Selected seven different shapes.*
- *Got them 3D-modeled in three sizes.*
- *Tested them on people of different ages and sex.*
- *Moved on with the form generally preferred.*
- *Tried to make it appeal more to men by taking inspiration from modern cars.*
- *Added a 'lip'-shape underneath for better grip.*
- *Did technology research on e.g. light and pressure registration; what should be inside, and found small pressure sensors and a material that can be put between two conductive layers providing resistance depending on how hard you press.*
- *Moving on creating shape, I figured out there should be a split line, and I gave it purpose by using it for LED light signaling.*
- *Designed docking station in the same shape language as the device.*
- *By advice from doctors, I chose circles instead of numbers as communication symbols, as circles don't have to represent a valid scale.*
- *Designed different matching vibrations and sounds: One smooth sound for the first level, two shorter ones for the second and three short ones for the third.*

Since, in the process account, the designer excludes paths and information that do not contribute with clarity and coherence to the narrative about the design process, the process account can be viewed as serving an evaluative function: it summarises how the designer got from A to B and what information of what was available in the design system was activated in and, in hindsight, deemed vital for this process.

By the process account evaluation, the designer therefore seeks to update and clean up the information in the design system, so that information that has remained passive and is not assigned any function in the process plan may be left out. So might information activated only in paths of development of which the outcome, by the designer's assessment, is not significant to the coherence of the process account narrative.

The following examples show conversations and reflections about how to update, clean up in and structure the information involved in the process account narrative. As the examples show, the process account narrative is often represented or supported by visual boards. The structuring undertaken in the process account serves to retrospectively connect the outset with the current (perhaps final) state and to attain a coherence between the process narrative and the current state of the the design system information and thus the current state of the emerging design:

Designer f2

In a post-project interview, Designer f2 talks about the content of the mood board that she displayed at the examination: *"I have taken some things away because they communicated exactly the same. And I have actually put up a picture that was not there [before] (…) I put it up two weeks before [the examination]. It was a picture with (…) those tunnels, and showed that, okay, this is what has been a big part of the project"* (f2, 10, 118-123).

The picture of the tunnels that Designer f2 refers to, represent a technique that has been central to her project.

Designer i10

In a post-project interview, Designer i10 talks about her examination presentation, and what was left out:

Designer i10: *"You only have half an hour [for the examination] (…) When you have worked with it [the project] for five months, there are many things you don't get to say"*

Interviewer: *"Are there commonalities between the things that were not mentioned?"*

Designer i10: *"Yes, they did not have anything to do with my final choice. They were detours. So they were cut out. Because it was about getting them [the examinators] to understand why I had gone this way. So more or less all the detours [were not mentioned]."*

Interviewer: *"Have they been important for your project or your process?"*

Designer i10: *"Actually, I think they have. (…) When you <u>exclude</u> something it's because there's a reason to <u>include</u> something else."*

Designer f6
In a post-process interview, Designer f6 explains that she had made a new mood board. All along the process she had had the same three moodboards representing three distinct parts or 'lines' of her collection. And, she says, *"perhaps they were not that clear [representative] anymore. I was told so too at the test exam. (…) Anyhow, I had left them [the three collection lines], and perhaps they [the three original mood boards] had become a little bit too tame along the way, and I had to spice them up to be able to argue for what I wanted with this collection. They [the original mood boards] were just kind of vague, both the fact that they were separated in that way [into three], and also because the expression was [made in] the very beginning [of the project], and it had changed. And I needed to revise it a bit."* (f6, 9, 56-62)

Designer i3
In an interview, Designer i3 looks back in time and accounts for a post-rationalised structure of his research: *"Since last [supervision] I started on ideation – still on the broad topic of fear and medical. I decided there were four ways to attend to this problem: Distraction, Camouflage, (…) Improvement, and Control (…)"* (i3, 4, 2-7). This quote illustrates how finding patterns and structuring remaining design system information is part of the process account.

Since the process account establishes a rational, congruent narrative between two different process stages, it can be compared to what Goldschmidt (2013) calls 'justifications'. According to Goldschmidt (2013, p. 43) *"it is almost impossible to postpone thinking of justifications until the complete design solution is in place. Rather, designers constantly look for congruence between their candidate partial solutions and corresponding design goals, requirements and constraints."*

I agree with Goldschmidt insofar as throughout the design process justification of congruence is, and must be, repeatedly sought. However, I will contend that these acts of 'justification' are not necessarily or only directed at the relationship between the current state and the end goals and requirements. In an under-determined design task, end goals and their requirements are vague or not determined, especially in the first part of the process. The *process account* adds the point to Goldschmidt's notion of 'justification' that the ongoing act of establishing 'justified congruence' between stages of the design process likewise occurs in the opposite direction, between the outset and the current state. I shall denote the 'congruence' between different stages of the design process – regardless of its direction from a given position state – as the *coherence* of the design process. (See Section 10.3).

Even though perceived process digressions are left out by the process account they are – as mentioned earlier – not redundant. They are very important to the process conduct through which the designer actually moves and through which the formative progression is made (see Chapter 9).

The Process Conduct

The process conduct refers to the actual, chronological design process through which formation progresses. This happens in a series of consecutive action steps – moves (see Section 10.6) – of which the *process conduct* is composed. This conception corresponds to Schön's description of design as taking place in 'strings of moves' (1991 [1983], p. 90). For this reason, the process conduct is related to change and progression of the emerging design. Through the process conduct, by each individual move of which it is compound, the design system information is changed from one state to another.

In the process conduct, chronology links the individual process steps to each other, regardless of how conceptually related they might or might not be. Unlike the process account, the process conduct itself therefore includes all nooks and corners of the path that is sequentially explored by the designer, notwithstanding their eventual impact on or perceivable relation to the final design. This is illustrated in Figure 48.

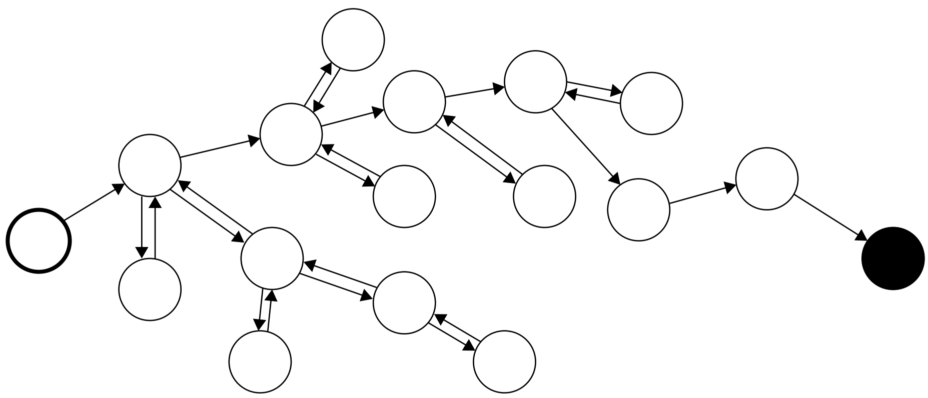


Figure 48: Every path of successive exploration is part of the process conduct.

The following quotes exemplify and express the process conduct:

Designer i3
Designer i3 describes the process conduct, when he says that he *"started very openly and went out on little detours into small, interesting areas"* (i3, 7a, 17).

Designer f2
Designer f2 explains about the nature of the process conduct: *"So many things can happen (…). That is what the process is good for: You go through a lot of things and find out and abandon a lot of ideas along the way, and some better ones appear, hopefully (…)"* (f2, 4, 88).

Designer i10[26]

Talking about her experiments with paper materials, Designer i10 expresses development in her process conduct, characterised by learning by doing as she goes along and not knowing which path of action will eventually lead to the final design:

”I want to sit with the material in my hands, and get a sense of how it works. I learn from the experiments – what the material can do and what techniques work. That's insight you cannot draw your way to. (…) I have experimented most with paper yarn and with egg trays, but they are hard to work with (…) [what I will use] depends on what way I will go [in the project]. I will perhaps return to experimenting [later].” (i10, 4b, 7-10).

Her abundant experiments generate so much material and ideas that she says it *”will be able to lead to other projects in the future”* (i10, 4b, 11). Thereby, she recognises that much of the material generated within the project at hand will not be used in it and the acts of producing it will, in light of her final process account, probably appear as detours. Yet, she acknowledges that experimenting provides her with important learning regardless.

Designer f7

In an interview, Designer f7 tells me how her long process conduct of experiments has contributed to the final designs:

”well… I don't think my process has been wasted (…) Because… it was very free and playful. So in it I was given something, which I could not have thought my way to. Like if I had had to [find a way to] fold a piece of fabric. Then I would have been much more conscious and fixed.” (f7, 8, 86).

The process conduct provides the designer with experience, learning and surprises, and these novel insights benefit the emergent design. The process conduct is the engine of formation through which the position state is moved and changed. The new position state is the output from which the designer can look back through the process account; in addition it is the input from the outset of which the designer can plan the possible further process development ahead.

Typically designers do not consciously distinguish between the process account, the process plan and the process conduct of moving, when referring to ‘the design process'. Thus, their practical understanding of ‘the design process' typically comprises all three process conceptualisations at once. The following example shows how Designer i3 becomes aware of the difference:

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[26] Quote reconstructed from notes.

Designer i3
In a post process interview, Designer i3 explains how, along his design process, he has captured and communicated about his process by having had *"this kind of ongoing document, where I have entered my process, which I then got printed on these boards. These entries, really, were my entire process"* (i3, 11, 31). The way Designer i3 speaks of the boards as *being* his process indicates that he does not distinguish between different process conceptualisations. In this particular instance, he considers the narrative of his process to be his process.

In the same interview, Designer i3 is asked about how he presented his project at his final exam. He talks about some phases of which he perceives his process to be composed, and curiously notices the difference between the process conduct and the process account. This insight is very possibly evoked by being interviewed about the project presentation:

Designer i3: *"(…) actually, it is funny, because in principle, in relation to my time plan, they have – all four phases – lasted one month, but, nonetheless, over half of my presentation was [about] product development"* (i3, 11, 35).

Interviewer: *"How come?"*

Designer i3: *"Well, I think it is simply because (…) what you find in the beginning doesn't give you enough to show in principle (…) Possibly, it has been easier to be effective in the last phase, because in that [phase] you have kind of worked… spelled it out more clearly, whereas in the beginning you maybe waffle a bit more and go more out and look in different places, and maybe you don't want to emphasise all of that [in the presentation] in the same way."*

10.2 The Salami Model of Design

To facilitate comprehension of the design process conceptualisations and the design system in a unified model, I shall introduce the *Salami Model* of the design.

In the Salami Model of design, the design process and the design system are combinedly envisioned as a salami (Figure 49). The length of the salami represents the temporal extent of the design process, and its substance and circumference represent the material content of the design system. We can only look at the content inside the salami if we slice it, but we can slice anywhere along its length and numerous times. The cut will reveal the composition of the salami at the given point. Just as the salami can be thought of as a succession of (potential) slices, the design process can be regarded as a succession of potential snapshots, each revealing a fixed stage of development in the material formation.

The salami has a confined length, the ends of which correspond to the beginning and the end of the design process between which its temporal extent is delimited. Similarly, as represented by the skin enclosing the salami, the scope of the design process has boundaries to its context and thus its information content is limited.

Figure 49: The Design Salami

The cut in the salami leaves us with a chunk of salami on each side. We can look at one and look back at the process account; or we can look at the other, i.e. look forward at the process plan. But we can also look at the cut, the cross section, itself. The salami will look very different depending on where we cut it; the content composition will change. So the cut is a cross-sectional snapshot that will change with every movement of the knife.

Likewise, dependent on where we cut and capture the design process, its immediate state will change. But it can only ever be captured in fixed snapshots since a description of the content of the process would mean looking at a cross section of what was in the design system at a specific state of development in time and in its formation.

The position state is the cut in the salami, i.e. theoretically any state of the process *between* moves. The position state plays a role in all three process conceptualisations, as designers can look back, plan forward and move from any given position. There are two exceptions to this: the beginning when the designer cannot look back, but can only plan and move forward; and the end at which point the designer chooses by satisfaction or is forced by formal constraints to stop acting or moving and can only look back.

The salami model and the implied analytical perspective on design processes as a sequence of snapshots can philosophically be defined by the concept of 'perdurance', implying that *"objects are four-dimensional entities, with temporal parts as well as spatial ones. A spatio-temporal object persists through time by having temporal parts (…) at different times"* (Garrett, 2017, p. 54). According to Garret, temporal parts "are themselves composed of temporal parts" (p. 55). Hawley (2015) says that *"Objects which have any temporal parts are thought to have instantaneous temporal parts ('time-slices'), which do not themselves persist through time."* (p. 6). Yet, in the perdurantist worldview, things *"stretch out four-dimensionally through time"* (p. 5) and thus, despite the thing changing, it also persists. Hawley explains, *"you exchange molecules with the environment, you grow new hairs or lose a tooth to decay. (…) some of your (former) parts lie in the past, and some of your (future) parts lie in the future, but that doesn't mean that you're somehow less than a whole person, right here and now"* (p. 4).

Through the design salami we can analytically view a design system and its information as an 'object' stretching through time, which can be time-sliced to reveal its instantaneous state. Though change occurs and content shifts, the perdurantist perspective on the the design process 'object' embraces both what was (the process account) and what is coming (the process plan) relative to a given position state. Often, the information content of the design system is perceived to stretch out as well, as temporal sub-parts, when they are 'brought along' (see the next section).

It is not my intent to make a general ontological claim for the perdurantist world view of atemporal existence. I do not consider the design process or its result to exist prior to the activity through which it unfolds and emerges. Rather this worldview serves as a metaphor, assisting the theoretical comprehension of design processes.

Bringing Information Along

It is often mentioned in the data that certain information is 'brought along' in the process. Information can be brought along both in the narrative account about and the planning of the design process as well as the actual process conduct, where information is activated in moves.

'Bringing along' information is a metaphor that illustrates the concept of movement in the design process and that the designers can take information with them while moving. They can pick up 'things', bring them along and potentially also let go of them again, and leave them behind on the design journey.

When IEs are brought along, it means that they remain an active or assigned part of the design process. It likewise implies an unaltered or only moderately altered transfer of the IE from one process step to the next. If transformation of the IE, and thus the associative leap it would require to follow and recognise it over a series of process steps, becomes extensive, we can say that the previous IE fades away along with the meaning it carries. In the subsequent section (10.3) ”Information Management and Coherence”, I shall discuss the need to manage this process to attain and retain coherence.

Some information is not ‘brought along’. For example, Designer f7 initially made a series of experiments with liquid stearin, to explore form. Though she did use the resulting shapes, the stearin itself did not play a role in her ongoing process or the narrative. Such information can be characterised as an ’armature’ – a notion introduced by McDonnell (2011) – which refers to pieces of information *”that may be discarded once they have served as ‘a way in’”* to the task or some function of it. Armatures represent *”a supporting framework that plays a critical role in forming a work or making it possible to proceed with creating it. But it may not necessarily be present, literally as image or otherwise e.g. as narrative, in the (new) finished work. The idea of an armature is (…), ‘about something that stands in and then falls away’.”* Though the concept of ’armature’ is helpful in characterising certain IEs, I would like to give a more nuanced explanation of the notion of ’falling away’. The content of a design system usually changes gradually in the course of the process through small steps of transformative actions directed at parts of the information content. Thus, in many cases, an IE will not ‘fall away’ instantly, but rather be transformed over several moves. At some point in this transformation process it may no longer be identifiably associated with its original form. If that happens we can say that it has ‘fallen away’, or that it has reverted to a passive state. If the progress it induced when it was actively used is discarded due to a dead end of the process, it may leave the system altogether.

Themes themselves cannot be activated in or assigned to functions, but they remain ‘active’ meanings in the design process, by proxy of the IEs that represent them and which are activated or assigned throughout the design process. As themes can be represented by various IEs, themes can remain relevant though IEs change. Unless those IEs are given a new meaning, or discarded altogether, we can say that themes are ‘brought along’ throughout the process.

Bringing themes along implies an unaltered or only slightly altered transfer of meaning from one stage of process development to the next. Themes brought along become cornerstones in the narrative development of the process and the choices made during that process.

Examples of information 'brought along':

Designer f2 brings along an IE
Designer f2 talks about her work with a draping technique and how she has brought some of it along. She explains that the main technique, the IE 'Subtraction Cutting', consists of three techniques. She primarily used one, the 'tunnel technique'. She says: *"It is primarily that one I have brought along, and then I have simplified it significantly (...) Such a simplified version of what he [the originator of the technique] tries to explain was mainly what I brought along. Because I find those big, voluminous drapings much more interesting than these (shows more ornamented samples)."*
She makes two choices of bringing along here: she brings one technique out of three, and she brings a simplified version of that one technique.

Designer f2 brings along a theme
Designer f2 is designing a collection, and her key theme is the 'distorted body'. In the following quote, she talks about it as a 'core' of the design project that is present 'all the way'. This core is represented by the 'distorted body' IEs.

Designer f2 says that what makes the design project exciting is *"that there is room for changes, and slowly I can tune into the form language. There is a core that is there all the way, but you can build things up around it."* Asked what the core is, she says *"the core is the body and the distortion."* (f2, 3, 39-42)

10.3 Information Management and Coherence

When designers make a 'cut' in the design process, it means that they stop movement, and instead seek to create an overview of the current content, allow for sourcing and discharge of system information, and that they account for and plan the process in compliance with the system information. This happens for example if the process stagnates or when designers present their projects along the way. Making cuts enables the designer to reflect on action (Schön 1991 [1983], p. 276) and adapt the process narrative, shift the course of development and hence act and move accordingly. Using Schön's terms, we can say that the 'local experiments' (p. 94) and the larger 'problem setting' (p. 40-41) are both adapted to each other in an act of 'reframing' based on the 'back-talk' (p. 79) of the situation.

From the information perspective, cutting the process is an act of *managing information*. The purpose of this act is to attain a coherence between information characterising the current state of the design system and information involved in the process account and the process plan: between actively applied information, passive stock information (often represented by material on a board) and assigned information. This coherence implies that meanings (themes) and functions of information are connected so that any IE activated is thematically anchored, and that any conceived theme is represented by activated or assigned information. Thus, themes play a vital role in establishing the coherence in the process.

Coherence is pursued by suspending and sourcing information from and to the design system, which is what takes place when the designer updates or cleans up e.g. the material on the board as exemplified in the ’process account’ section, and when the designer sources new information required for further planned development.

Within the constraint terminology, this can be compared to the process of constraint management (Onarheim, 2012b; Stacey & Eckert, 2010), which implies pursuing the adequate amount of constraints to secure developmental and creative flow.

Let us use a grocer as an explanatory analogy. The grocer aims to manage the flow in his stock and adapt his supplies to demands. To avoid profit losses, he aims to avoid keeping items in stock that he cannot sell, and at the same time he must plan the sourcing of new items to be able to accommodate expected future demand. Similarly, the designer seeks to manage information to avoid ending up with excess or a shortage of IEs. However, the designer does not suffer losses by suspending unused information. In fact, unused information is practically unavoidable in an explorative process where the designer does not at first know where the process is heading. What the designer does risk losing, if she fails to manage and adapt information as the process progresses, is *coherence* in the process account narrative.

As we have seen earlier, design process information can be assigned *meaning* with the affiliation to a theme represented by IEs. Likewise, it can be assigned *function* in the ITO structure.

When information is activated in a function as part of a process move, it tangibly and perceptibly becomes part of the emerging design. In the most literal, practical sense it is used to design with, and therefore the design is comprised of that information, which – through the perception of spectators – can be ‘read’ in the design. If information is assigned function without being assigned meaning, or if in the process of interpreting information it loses the perceivable link to the theme with which it was originally affiliated, the process can lose coherence.

Besides being part of the tangible formation, IEs and the meaning they carry are part of the narrative account of how the design process unfolded, and how the design was brought about. For example, moodboard information often initially serves as inspiration – especially for the fashion designers. Later on, the designers use the moodboards to support the process account narrative – as a visualised argument for how they arrived at the the current state. Therefore, when the course of the formative development changes throughout the process, the moodboard (displaying IEs that represent themes) must be adapted to reflect what currently *is* to avoid such loss of coherence.

When a designer manages and updates the system information throughout the process, then all the information contained at the 'final cut' of the design system – at the termination of the task – will play a role in the conceptual or physical configuration of the final design product. This means that all necessary information to finalise the design has entered the system and that all information no longer used has been left out.

The design cases show that coherence is important to designers. The following are examples of the perceived need for coherence:

Designer f1

Designer f1 says that his *"biggest problem is, does mood board and collection connect?"* (…) *"Does my mood board and collection go in two [different] directions? I tried to get some functionality from sportswear references [put new pictures on the mood board of men in sportswear]."* (…)

Supervisor: *"You have new men on your mood board…?"*

Designer f1: *"That is to get [some] sporty urban references. It's still not street, but in a classical menswear tradition way"* (f1, 9, 15-37).

Designer i4

In an interview shortly after Designer i4's examination, he tells me about his presentation 'mood board'. He says that before the examination he *"replaced some things, and made it [the mood board] more clear."* Designer i4 mentions several features and criteria of his design, which, he says, he *"wanted it [the mood board] to symbolise"*, which was why he *"sharpened it up"* and *"made a 2.0 edition. In order to take [display] the sharpest values"* (i4, 10, 29-51).

Designer f5

"I have been very unsure whether I ought to have (…) more consistently moved on and continuously updated my board, because maybe I have been a bit stuck on some things that I liked, but which I haven't used" (f5, 4a, 5).

Designer i9[27]

In an interview, Designer i9 says that he had been very busy before the supervision, which was to take place after the interview: He says *"I had to redo my board. I was*

[27] Quote is reconstructed from notes.

lacking overview. It is very important to get everything up, 'cause it helps me to zoom in on the findings I have got and make an overview of them and draw some directions out from that" (i9, 4, 2).

Designer f1
In a plenum presentation, the eSupervisor comments on the coherence between Designer f1's process account and his current design: *"The way you argue for your style is "I have taken these (points at board) and put it here (points at a drawing), and these here and put it like this. But it needs translation processes. You might lose the overview of what you are stating. (…) Maybe you have to adjust what you say as intro. The collection might not in everyone's opinion reflect this (points to the boards) anymore. There are maybe other elements here (points to the drawings) that are stronger. Or maybe draw out some of this stuff (from boards) and maybe less [reference to] Le Corbusier (…)"* (f1, 7, 46-48).

Designer i8
At his test exam, Designer i8 is advised by his iSupervisor, who says that the presentation is *"abstract. Links are missing. You should refer to your concepts in the products. Make an overview of process phases. Inspiration, models, and so on….*
Show the link between the style of each [shoe] collection [part] and the concept behind it." (i8, 11, 17-20).

Designer f5
In an interview, designer f5 talks about the material on her board and that she removed some things from it:

Designer f5: *"They [some pictures] were a part [of the project] in the beginning (…) I have taken them down now, because that is passé. (…)"*

Interviewer: *"Why did you remove them?"*

Designer f5: *"Because they are part of my [departed] process now. They [the three remaining pictures] were my core concept. They were what described my entire concept. It was too much, because the others told other stories too"* (f5, 5a, 61-65).

Designer f1
Designer f1 had made a user study about the theme 'essential' wardrobe or collection in the beginning of his design process, which remained part of his narrative about his design process, even though it did not inform his actual design much. In a post-project interview, Designer f1 talks about the discrepancy between the concept 'essential collection' and the actual collection that were both part of his examination presentation.

Designer f1*: "I wanted to do an essential collection. (…) When looking back at it now, I should just have made these user studies and said "that's fine for the written thesis, I can use it there" (…) And I should have completely avoided talking about it here, at my examination. (…) Because I felt I was criticised for that. I think [the examinators] had expected to see a totally classical mens-wear collection with a plain white shirt and plain black pants with some nice details. (…) this 'essential collection'."* (…) *"I do see now that it's perhaps two different things I have made… that when speaking about essential* *collections, there are just some rules that I think are boring and wrong (…) Which cause people to think about this [classical] kind of style, if you mention it"* (f1, 12, 124-130).

This is an example that information presented along with the collection is perceived to tell a different story than the collection itself. It becomes a 'standard' that the collection is measured against.

Nuancing Coherence

The research data and existing theory suggest that 'coherence' is arguably a central concept and desired property in design processes.

In *The Reflective Practitioner*, Schön (1983) states that the practitioner evaluates his experiments by his ability to *"make an artifact that is coherent and an idea that is understandable"* (1991 [1983], p. 136). Yet, Schön finds that in the design process of the professional designer (examplified by 'Quist'), the sequence of actions *constitute "an internally coherent whole, all moves having been made with fidelity to the implications set up by earlier moves"* (1991 [1983], p. 91). Schön talks not only of coherence of the artifact, but likewise of coherence of the actions in the process of making it. Thereby, he might, arguably, imply that a coherent process can lead to the desirable coherence of the artifact.

In her book *Linkography – Unfolding the Design Process* Goldschmidt (2014a) describes the concept of coherence in terms of 'links'. Goldschmidt studies 'links' through protocol analysis of design process excerpts, and she characterises these links as associative relations between what she calls design 'moves'. I shall use the term 'coherence' a bit differently from Goldschmidt's 'links'; however, the concepts of coherence and links are related.

According to Goldschmidt (2014a, p. 73), *"the quality and creativity of a design process depend on the designer's ability to synthesize a solution that exhibits a good fit among all its components."* Likewise, she states that links among ideas (moves and decisions) are important in the search for successful solutions to design problems (p. 78). In summary, Goldschmidt finds coherence vital to the quality and creativity of the design process and consequently to a succesfull final design. Though I interpret coherence somewhat differently, I agree with the importance of coherence.

Designer f7 equates the 'main thread' of coherence to the *strength* of her process:

Designer f7

"I haven't [changed the narrative about my process] (…) because the process has been so strong, I don't feel that it has really changed that much. So I think there is a main thread from the things I started out with [to what I have now]" (f7, 9, 73).

Coherence in relation to design in general can be understood in many ways, including for example visual and aestetic coherence between elements comprising a design artefact (in the making). However, I shall devote my attention to coherence related particularly to the design process. Here, we can distinguish between *chronological* coherence and *logical* coherence.

A process is by default chronologically coherent; change in a process always takes place in a sequential order over time. This does not mean that every step of the design process addresses the same content. A designer can work with one idea at one moment and another one the next. Still, if the two instances follow each other in temporal succession, they are chronologically coherent. Chronological coherence can seem a rather trivial concept, but it must be mentioned in order to distinguish it from the concept of *logical* coherence.

Logical coherence, on the other hand, does not occur automatically, but must be attained. Logical coherence denotes the perceived meaningful connection or 'congruence', in Goldschmidt's (2013) terms, between design system information and between the steps of development that represent it. Logical coherence determines and justifies the development in the design process, and it allows the designer to answer the question "why?" when asked about the decisions and the development of her process. When mentioning coherence in the following, I am referring to *logical coherence.*

As shown in the examples from the data in the previous section, coherence is expressed in the meaningful connection between the information represented in the current position state of the process, the process account, and the process plan; between passive, assigned, and activated information; and across levels of abstraction.

Since *themes* are the meanings assigned to data (IEs), the link between IEs and themes is central to establishing meaningful connections: coherence.

Coherence can be obtained in two ways, depending on how IEs are connected to themes; it can be *derived* (top-down) or *constructed* (bottom-up). As mentioned earlier, a theme can be derived by ascribing meaning to IEs that are already found and are part of the design system, or IEs can be obtained by their perceived association to a given theme. Often, information is derived from themes, but the relationship can also be inverse, whereby themes are established and constructed from IEs in order to give them meaning and justify their presence in the design process. In design, derived and constructed coherence alternately supplement each other.

Derived coherence means that decisions of IEs and the actions applied to them are derived from and justified in relation to some theme which can be said to associatively produce them. In analogy, it can be compared to wanting to lose weight and therefore being on a diet, eating from a certain set of diet principles. In this case, what you eat is derived from and coheres with that diet concept.

Constructed coherence implies that a (transpired) wish to bring some new information into the design process entails the need of a 'reason' or justification to do so in order to ensure coherence. To serve this need, a theme is created with which the information is perceived to cohere and from which it can be justified in the process account. Back in the diet analogy, this act can be compared to stumbling upon an ice cream that you just *have* to have, which your previous diet principles do not allow. Therefore (if you are a bit neurotic), you start to look for an excuse or a 'reason' that justifies that you can have it anyway without going off your diet. You realise that the concept of cheat days, which is part of some diets, could be a valid reason to have the ice cream. So evoked from your encounter with the ice cream, you devise the concept of cheat days into your diet to justify having the ice cream, and maybe have other things as well that are allowed in – or coherent with – this new concept.

Constructed coherence is a central property in explorative processes based on ill-defined tasks, in which essentially new information must be sourced and adopted into the design system.

Derived logical coherence implies that coherence is established in accordance with the chronology, because the justification for a certain decision was established prior to making the decision. Constructed logical coherence implies that coherence is established after the fact, i.e. justification for some decision is established after the decision was made.

Examples of derived and constructed coherence:

Derived coherence

Designer f2 has a theme represented by IEs 'Distorted Body' that is a central to her project from the very beginning. It was introduced, represented by its IE, to the design system as an Elementary choice. From this theme, Designer f2 derives further IEs carrying meanings as sub-themes, for example 'foam ladies', represented by a photo of mattress foam shaped as voluminous and quirked female bodies, and 'subtraction cutting', a draping technique that distorts conventional sewing patterns, and which later becomes a theme of its own in her process.

Constructed coherence

Designer f2 has some different IEs in her project that are not chosen by justifications coherent with any other information in the design system.

For example, Designer f2 realised that she would have to pick out a number of sewing patterns as input for her 'subtraction cutting' technique, but *"so far I have just used a dress and an undefined t-shirt. That's it. (…) I lack that in my research."* She explains that she is looking for something that has to *"frame a rule"* for the selection of these sewing pattern inputs, so that it is not merely a random selection. (f2, 5b, 31-33).

Likewise, Designer f2 has chosen her fabrics from *"intuition, and then I have just tried to buy a palette of different types and qualities. And possibly I will have to supplement them"* (f2, 4, 66).

Furthermore, from the beginning of her project Designer f2 has been *"unsure about whether to implement references [details] from classical [menswear] clothing"*[28] in her 'distorted body' clothing (f2, 2, 18).

These three uncertainties seem to all be resolved by establishing – constructing – the theme 'classical clothing' to supplement and contrast her theme 'distorted body'. From the 'classical clothing' theme the three 'loose ends' are, consequently, all coherently justified:

Designer f2 can choose the sewing patterns from the classical clothing, so they are no longer randomly selected. She can justify the material choice, since the materials are *"very classic. Just wool, silk and stuff like that."* (f2, 6, 36). Realising this, it seems that Designer f2 finds it more obvious to in fact implement the classical details in the collection, which she had previously been uncertain about. At a supervision session, she says *"That was maybe also why we came to talk about using [classical] menswear [details] in the references, because the materials are so classic"* (f6, 6, 39).

By altering the premise on which subsequent choices are made, constructed coherence can be compared to the pervasively used concept in design literature of 'reframing' design problems. In design, a frame is a comprehensive and global way of looking at and approach the problem, proposing a particular pattern of relationships between elements of the design problem (see Dorst, 2015; Schön, 1983). Reframing refers to the act of *"questioning the established patterns of relationships in a problem situation"* to gain *"a new way of looking at the problem situation."* It is about proposing another approach to the problem by broadening the context or delving deeper into the problem and its causes. Constructed coherence is a similar process of stepping 'backwards' to find a cause from which subsequent information and development will follow. However, unlike the act of reframing, constructed coherence need not apply globally and comprehensively to the task, but can also apply to more local and lower process level aspects of the design task.

A more global instance of constructed coherence, which could arguably fall under the concept of 'reframing', is found in Designer i3's project:

Designer i3

Designer i3 speaks of how he came up with the idea for working with the theme of fear in medical settings:

[28] Quote is reconstructed from notes

"It started out with a thought of ebola patients and patients in isolation, and their meeting with hooded healthcare staff, that there was some fear to work with there. And then I basically just switched to investigate more broadly what kinds of fear there were" (i3, 7a, 33).
In this example, Designer i3 steps back from and broadens a specific situation to a more general one, recognising the abstract and generalisable factor.

In Appendix 2, a visualisation of Designer f2's design process shows how the process information coheres, including derived and constructed logical coherence.

As mentioned in Chapter 8, coherence can generally assume two overall directions: backwards and forwards. *Forwards direction* is related to under-determined tasks (or more precisely under-determined states of tasks). As the goal is not known, the development is propelled, by the capability of one step leading to the next. Thus, the connection between steps is pointing forward. *Backwards direction* is related to task states in which the goal is more specified; where steps of development are inferred backwards as perceived prerequisites to approximate the goal. As the definition of task changes through the process, the coherence direction can change as well. These concepts should not be confused with Goldschmidt's (2014a) terms 'backlinks' and 'forelinks', which have to do with the nature of the interrelations between moves as either ideative (producing subsequent associable moves) or evaluative (resuming to and summing up previous moves) (p. 50). The notion of forelinks and backlinks can thus be compared to the previously mentioned concepts of divergence and convergence in design.

Goldschmidt (2014a) considers 'links' as the *"primary indicator of the quality of the process"* (p. 58) and assumes that a high number of links between moves are *"especially significant in the design process"* (p. 73). Hence, Goldschmidt says it is a hallmark of expertise that *"no time or effort is wasted on ideas that cannot be followed"* (p. 94).

However, it could be objected that a high number of links between all process components could indicate a less thorough and divergent exploration of what Goldschmidt calls the 'design space'. In my studies, processual detours and nonformative insights seem to play vital roles in the synthesis of explorative design processes. Even though, from a chronological perspective, one process step gives rise to the next, it does not guarantee that the outputs of move experiments cohere logically and conceptually with each other. Thus, the logical coherence must sometimes be *constructed* and adapted post hoc to the surprises of explorative, experimental development. The designer must manage (e.g. source and discard) information to achieve a *"good fit among all of its components"* (p. 73): not in the entire chronological process conduct as a whole, but at its given position state. I will argue that the quality and creativity of the process depends largely on the designers' ability to experiment exploratively, to leave and learn from dead ends, and to adapt the coherence of the process narrative according to the process components at any given state.

Some factors that could account for the disagreement between Goldschmidt and myself are the differences in the studied designers' level of expertise (Goldschmidt studies experienced designers, I study Master's design students), and the differences in the 'constrainedness' of the tasks they handle. Furthermore, Goldschmidt studies design processes by protocol analysis, a methodology limited to *"short stretches of time – not more than a few hours"* (Goldschmidt, 2014a, p. 37), whereas I study entire processes in less detail. The short span of the excerpts studied by Goldschmidt might account for the findings that many links are a central quality. If Goldschmidt had studied the designers throughout an entire creative process, she might have found a different relationship between process quality and replacement of process 'components' in the course of this development. Additionally, the link between failed experiments/nonformative insights and the progress they occasioned are not necessarily traceable by protocol analyses.

Once established, coherence is not a stable quality of a design process. As the information content of the design system is bound to change in the process towards an unknown result, the basis for coherence changes as well. Therefore, along the process, coherence can be retained by 'cutting' the process to manage information, negotiate themes, and update the process account and the plan.

10.4 Process Levels

Throughout the dissertation, I have referred to the concept of 'process levels'. The design system can be said to contain a continuum of process levels. By these process levels, the meaning of 'process' can be further differentiated.

As we have seen, design processes contain three different information functions: Input, Transformation, and Output. The three functions are exhaustive in the sense that any IE that plays a role in the design process does so in either of those functions at some process level. The concept of 'process level' must be understood in relation to ITO.

The design process can be considered and understood at any level between the highest overall process level and the lowest operational process level.

The overall process level is that in which the entire design process, from the initial Input to the final Output, is considered in one triadic ITO ensemble. This level has a high level of abstraction and a low level of detail.

The operational process level is that in which a triadic ITO ensemble is comprised of a single move of action. This level can be defined as the one at which the designer perceives an ITO structure to be practically operational and directs concrete action. The lowest process level has a low level of abstraction and a high level of detail.

Examples:

Overall process level
Designer f1 wants to *”combine [**T**] Mies van der Rohe’s architecture and Le Corbusier’s ’La Torette’ monastery [**I**] into a modern clothing collection [**O**]”* (f1, 0, 26)

Operational process level
Designer i3 has *”brought some clay [**I**] in order to rapidly try to make [**T**] a model (...) of the hand sketches or drawings I have made [**O**].”*

Thus, we can see the overall process as originating from an input (I) that is transformed (T) into some new output (O). At the same time, we can perceive every individual move subsidiary to this process as having a similar structure. Schön describes the relations of this structure by saying that local move experiment of various sorts are *”Nested within the larger problem-setting experiment”* (Schön, 1983, p. 141).

In an analogy from cooking, the overall process level corresponds to saying “I will take some ingredients and follow a recipe to cook a meal,” and the operational process level corresponds to saying, ”I will take this carrot, and chop it with my knife into approximately five-millimeter slices.”

In principle, the levels are spanning a continuum of process levels, at any point varying on two factors: (1) The process segment or phase spanned and (2) the level of abstraction/detail. Theoretically, any process level can be viewed in terms of a triadic ITO ensemble.

Figure 50 below shows a diagram of the design system process levels in terms of triadic ITO ensembles. As visualised, the lower the process level, the shorter the process span.

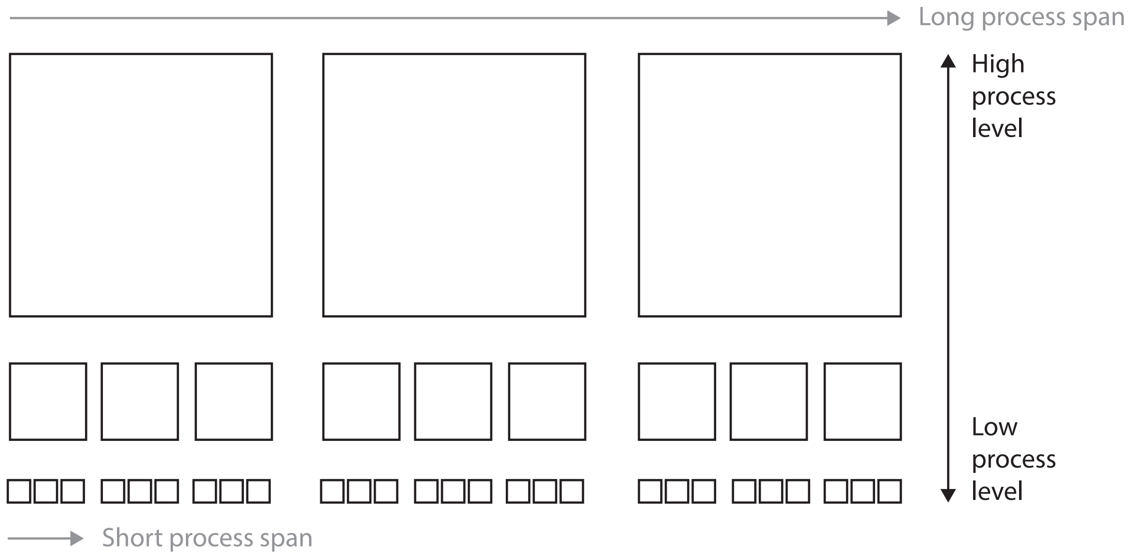

Figure 50: Conceptual visualisation of process levels in the design system

Process levels relate to the three process conceptualisations: the process plan, the process account and the process conduct. On all process levels that are higher than the lowest level of single process moves the design process can only be conceptualised as a process plan or a process account, i.e. not as the actual process conduct. That is because it is impossible to actually *move* or *act out* more than one step at a time – just like we can only walk a long distance moving one foot at a time. Therefore, longer stretches of the process than a single move can only be *imagined*, not carried out.

As the process plan is abstract and long-spanning, it might imply or induce that the designer envisions something very advanced and complex ahead. Yet, since it is not feasible to act in advanced and abstract fashions, the designer often needs to take an abstractional leap from high to low in order to move, thus making the design process progress from the concept of a process plan. That step is taken through *interpretation*. If the designer fails to recognise this, it may cause stagnation.

The single moves are the actions by which the designer *does* something (T) *to* something (I), and thereby conveys a change (O) to the design system. The moves collectively comprise the *process conduct*. The process conduct cannot be expressed in terms of ITO, unless it is broken into its constitutive parts: *moves*. That is because ITO represents *linearity* – a trait that does not apply to the process conduct.

Linearity

It is no coincidence that the same structure is replicated on several process levels, since the ITO structure is a very fundamental one of *linearity*. ITO corresponds to the expression of going '*from A to B*', except the ITO structure also includes the means of the conveyance between the two points. Additionally it acknowledges that I and O are inherently different, since in an ongoing process the not yet attained output is merely conceptual – it is imagined. Any conception of doing something (T) to something (I) to achieve something else (O) builds on a linear rationale, and for this reason linearity is a central concept in design. This may seem both a paradoxical and a controversial statement, since the actual design process is not linear but full of digressions, and since the current and prevalent design methodology discourse (Broadbent, 2003; Bürdek, 2005; Engholm, 2011) is partly grounded in a critique of the simplifications, rationalisations and linearity of the first generation of design methodology.

However, I will argue, linearity plays three central roles in design processes:

- <u>Linearity allows action:</u> The non-linear complexity characterising design processes applies only to the compound of individual moves. Each individual move is, however, a simple linear task. It is not possible to do something complex or steer in more than one direction in a single move. I cannot walk both left and right at the same time; I can only take one step at a time, and that step will move me in one particular direction. However, my steps can, in aggregate, render a curvy path (Figure 51).

Figure 51: The complex design process is composed of a myriad of simple steps

- <u>Linearity spans the process plan:</u> When imagining the process (part) ahead, designers (intuitively) know that it involves some information of what to work with, how to work with it and what to achieve. Thus, designers imagine and conceptualise the process ahead of them by structuring it in linear terms of I, T and O.

- Linearity structures the process account: By analysing and conceptualising the completed process (part) in the process account, the designers identify retrospectively, on an overall process level, the causal relationship between I, T and (current) O, i.e. designers identify what transformation principles transformed a particular input into the present particular output.

Thus, individual process moves differ from process plans and accounts, not in structure, but in the level of detail and abstraction – in the process level.

As visualised in Figure 50, the process level structure in the design system consists, theoretically, of fractal-like iterations of the same ITO figure on different process levels. From a system theoretical perspective, we can see the design system as consisting of wholes and parts, where each whole is made up of parts, and "Each part may on its turn be a whole, consisting of parts" (Gielingh, 2008, p. 423). This structure is therefore, theoretically, indefinite, since parts could be broken into even smaller parts, and wholes could be imagined parts of even greater wholes. However, the design process levels are delimited by the lowest and the uppermost process levels.

In theory, design processes have an infinite number of levels within the span between highest and lowest. Yet, in practice, there is one level in between the highest and the lowest which stands out as distinct. Designers refer to design process 'phases'. A phase can be understood in an abstract way as a period of working with the same information, often transformation-information, i.e. a way of working and doing something, for example, 'the research-phase', 'the sketch-phase', and 'the construction-phase'. Yet, 'phase' can also be used and understood in a more specific way relating to explorative processes: as a 'series' of experiments. I will return to this in chapter 11, Section 11.5.

The notion of abstraction levels in design processes, and the idea that designers move between them, has been described by other theorists. Often, the abstraction levels are defined as a matter of problem decomposition on several levels of sub-problem division (see e.g. Ball et al., 2010; Guindon, 1990), or as different levels of solution specification: for example in a design plan (Chandrasekaran, 1990) or schema (Gero, 1990); or as different scales and detail levels of solution representation, e.g. in a design sketch (Cross, 2008, p. 23).

Kokotivich and Dorst (2016) construe abstraction as a continuum between physical variables of a design and the concepts by which the emotional relationship to that design is communicated. This understanding is reminiscent of what I introduced above. Yet, I construe the abstraction levels from a *process* perspective, so that the level differentiation is determined by the process *extent* covered when articulated in terms of ITO. The scale from low to high abstraction expresses the perceived degree of operationality of an IE to be activated in a process move.

10.5 Moves

Having concluded that the actual design process is composed of moves, this concept needs a further elaboration.

Moves are the actions by which designers transform material content in their design processes in order to depart from what already exists and approach a new design. A move is composed of the three information functions, I, T and O. Because moves serve to transform the design process content, the moves must leave space for attaining new information. Therefore, some information about I, T or O must be unspecified.
The mechanism of moving, i.e. attaining the unknown information in the move, corresponds to what is often referred to in the data, and in design in general, as a design experiment.

My understanding of the concept 'move' coincides with part of Goldschmidt's (2014a, p. 42) definition, namely as "a step in the process that changes the situation." However, I diverge from her further definition that "Design moves are brief acts of thinking (…)" (p. 47). Rather, I see design moves as actual *actions* directed at material, not acts of thinking.

Goldschmidt (2013, p. 44) claims that: *"A move is the smallest perceivable and semantically coherent unit of operation that the designer makes,"* which *"consists of between a few words and a few sentences."* In her semantic analysis of design protocols Goldschmidt differentiates between moves and arguments. Yet, as will be expounded in Chapter 11, 'Design Syllogisms', I conceptualise moves, i.e. actions directed at material, as a special kind of arguments themselves. Additionally, I do not relate the concept of a move to the structure of the designer's verbal utterances. A move, as it is understood in the present study, may be described across many and dispersedly uttered sentences. It is not related to the verbalisation itself, but rather to actions imposed on material. Thus, the move is merely described, and not constituted, by words. In the conceptualistion employed in the present analysis, a move has been *described* when the designer has pointed to the ITO structure of Input, Transformation, and Output categories involved in changing – *moving* – the situation.

According to Schön (1991 [1983], 1992) a 'design move' is a local experiment (Schön, 1991 [1983], p. 94) which results in a *"change in configuration"* (Schön, 1992, p. 5) in for example a drawing. This construal of a 'move' is close to the one adopted here.

However, Schön's account of experimental moves is more complex, and I will return to it in the next chapter in which I shall introduce the concept of *Design Syllogisms* to unifyingly conceptualise the nature and types of moves found by this study.

11. Design Syllogisms – Reasoning with Things

As mentioned my research focusses on what designners act with (information) and how they do it (actions). In the previous chapters, I have examined the concept of 'information' and proposed a functional structure, ITO, that information can fill.
In this chapter I will turn to how designers *act* with information, and how the ITO functions manifest themselves in the design moves, when information is activated in these functions.

Analysing how designers act, I have coded four of my cases for *action statements,* defined as any uttered statement expressing – by the use of a verb in connection with an implicit or explicit personal pronoun – that some kind of action related to the design process *had been*, *was*, or *would* intentionally be undertaken by the designer. Among the many different action statements (which have not been exhaustively categorised for the present study) are actions related to information management (bringing information into and out of the system), accounting for and planning the process, as well as actions of carrying out well-defined sub-tasks (e.g. making a phone call, buying fabric, refining a sketch). However, one specific category of action was found to stand out − what designers often refer to as an *experiment*.

Defined ostensively from the data an experiment is an action in which the material of the design situation is reconfigured and transformed, i.e. the action is applied directly to the material. The reconfiguration is either sought in its own right as a result of the experiment, or as a means to produce further experience that can inform choices. An experiment involves a perceived degree of uncertainty – something that is unknown or needs to be tested by the action. For this reason, the experiments leave room for something new to emerge.

An experiment is represented by a directly *operational* action statement, i.e. something that directs concrete action to specific things. For example, Designer f2 says: *"[T]he idea was to **take** his technique and **try** it on a totally different object. And [then] **place** it on the body afterwards to **see**…"* (Designer f2, 6, 7). This is not always the case in other action statements that do not necessarily describe the means from which and by which the action should be carried out, and which can abstractly span one or more sub-actions. This is the case when, for example, Designer f2 says that she needs to *"**go out** and **make** some decisions about some of these things"* (f2, 4, 66).

As experiments transform the information in the design system and thus formatively *move* the process content to a new place, an experiment can also be referred to as a design *move*. As an experiment directs concrete action to specific things, the structure of the experiment epitomises ITO in the design practice: some input is transformed by some principle, resulting in some output. The specific information that assumes the functions in the experiment determines the nature and conclusion of the experiment.

In this chapter design experiments are conceptualised and differentiated by the concept 'Design Syllogisms'.

I have found that the functional structure of ITO closely resembles the functional structure that we find in syllogistic inferences. Inferences are the ways we reach conclusions when we reason, make arguments and generate new knowledge. In the general understanding, there are three different ways an inference can be made, and thus three different types of reasoning; deduction, induction, or abduction. These three inference types are all considered acceptable to account for conclusions in knowledge generation, even though they are not all resistant to the necessity of pure logic.

In existing design theory, these inference forms have been used to describe different aspects of designing. By introducing Design Syllogisms, I will propose an alternative relationship between inferential reasoning and design related to the designer's experimental moves.

To build the case of Design Syllogisms, I will first account for the three inference forms from a general perspective. Thereafter, I will describe the positions in existing design theory. Subsequently, I will introduce the concept of Design Syllogisms and discuss this concept in relation to existing theory. Lastly, I will give some examples from the data of how Design Syllogisms form part of the design processual context.

11.1 Inferences

Inferences are the acts or processes by which we can legitimately derive conclusions and hence new knowledge, on the basis of premises already known or assumed to be true from a priori and/or a posteriori sources. To infer is what we do, when we reason and propose arguments, and thus the laws of inference pertain to the fields of logic and rhetoric, as grounded by Plato and Aristotle (Rieke & Sillars, 1975; Smith, 2015) and more recently expounded by e.g. Toulmin (1958) and Peirce (1992).

A simple three-part inference form is called a syllogism, for example:

Socrates is a man
All men are mortal
So Socrates is mortal
(Toulmin, 1958, p. 108)

The three parts of a syllogism comprise two given premises (existing knowledge) from which a conclusion (new knowledge) is derived.

Premise + Premise = Conclusion

The three parts of the syllogism can be considered loci that can be occupied by three different functions in the inference. These functions are denominated differently across different theoretical sources, as displayed in Table 11 below.

Peirce (Fann, 1970)	**Toulmin** (1958)	**Galle** (2013)	**Example** (Togeby, 1986)
Case	Datum	Cause	It's raining
Rule	Warrant	Principle	When it's raining, the street is wet
Result	Claim	Effect	The street is wet

Table 11: Denomination of functions in arguments, partly based on Galle (2013)

For consistency purposes, I shall apply Peirce's terms Case, Rule, and Result in this section. A Case is a fact that serves as the foundation for the result, for example *Socrates is a man*. The Result is a conclusion which we are seeking to establish (the soundness of), for example *Socrates is mortal*. The Rule is a principle, which legitimises the link between the Case and the Result, and thus leads from the Case to the Result, for example: *All men are mortal*.

There are three major types of inferences, namely deduction, induction, and abduction. Depending on which functions occupy which loci in the syllogism, the inference is deductive, inductive or abductive (Table 12).

	Deduction	**Induction**	**Abduction**
Premise	Rule	Case	Result
Premise	Case	Result	Rule
Conclusion	Result	Rule	Case

Table 12: Distribution of functions on loci in the three different inference types

A very illustrative example of the relational difference between the three inference types (as in Table 12) is presented by Peirce (Walton, 2004, pp. 10-11) (Table 13):

	Deduction	**Induction**	**Abduction**
Premise	All the beans from this bag are white	These beans are from this bag	These beans are white
Premise	These beans are from this bag	These beans are white	All the beans from this bag are white
Conclusion	These beans are white	All the beans from this bag are white	These beans are from this bag

Table 13: Example of distribution of functions on loci in the three different inference types

In a *deductive* inference the Result is what is concluded from the given premises Case and Rule. This conclusion is, given the truth of the premises, true by necessity.

In an *inductive* inference, the Rule is conjectured from the given premises Case and Result. This conclusion is right by probability.

In an *abductive* inference, the Case is conjectured from the given premises of Rule and Result. This conclusion is right by plausibility.

An inference can be understood as both an act of reasoning, i.e. the process of obtaining the conclusion from the premises, or as a retrospective argument to justify the validity of a conclusion already obtained, i.e. the product of an act of reasoning. For the purpose at hand, the following account will focus on inferences as an act of obtaining conclusions and new knowledge.

Before the reasoning process is brought to an end and the conclusion is obtained, the conclusion is missing. As the conclusion can be the Case, the Rule and also the Result, it means that either of these is unknown. Arguably, the fact that information is missing in the inference is the prerequisite for obtaining new information.

The inference types can helpfully be illustrated with a metaphor often used to describe elementary mathematical functions; the machine.

Something (*X*) is put into the machine, and another processed product (*Y*) comes out in the other end. The machine has a function (*f*) which works on *X* to transform it into *Y* (Figure 52).

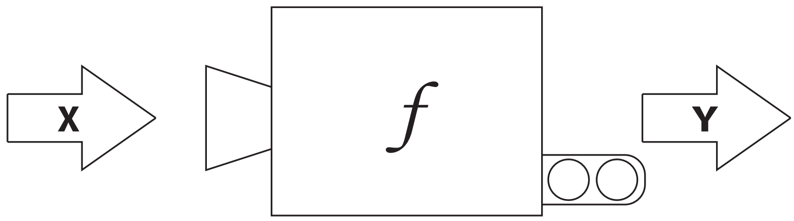

Figure 52: Inference illustrated as a machine

In the machine metaphor there are three potential unknowns:

- *X* (Case)
- *f* (Rule)
- *Y* (Result)

In a *deductive* inference, the known entities will be *X* (Case) and *f* (Rule) (Figure 53).

When a certain input (*X*) and a principle of what to do with it (*f*) is given, the concluding output (*Y*) will necessarily follow from the inference – no conjecture is needed. By this fact, the deductive inference form differs from the two other inference forms.

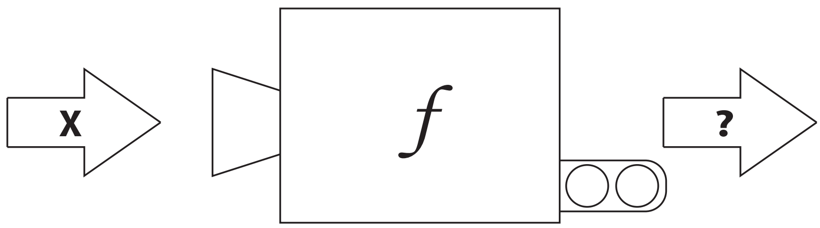

Figure 53: Deductive inference

In an *inductive* inference, the known entities will be *X* (Case) and *Y* (Result) (Figure 54).

If a certain input and output is given, a conjecture must be made of which information must probably be placed on the locus *f* in order to transform the input (*X*) to the output (*Y*). Hence, the conclusion will be based on the conjecture and testing of *f*.

In contrast to the deductive inference, which is necessarily true, the inductive inference is merely probably true (Fann, 1970, p. 10).

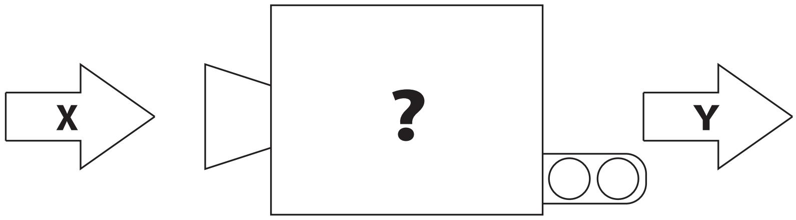

Figure 54: Inductive inference

In an *abductive* inference, the known entities will be *f* (Rule) and *Y* (Result) (Figure 55). If it is known what principle of transformation is to be applied and what output must follow from it, a conjecture must be made as to which information can plausibly fill the locus *X* as input. Hence, the conclusion will be based on the conjecture and testing of *X*. In contrast to the deductive inference, which is necessarily true, the abductive inference is merely plausibly true (Fann, 1970).

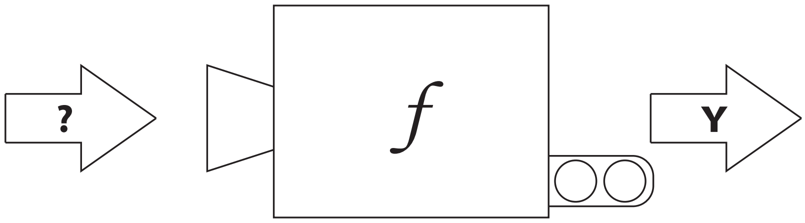

Figure 55: Abductive inference

As is obvious from the machine metaphor, it is not possible to get an output from the machine without an input and some transformational principle for which reason at least two pieces of information are imperative in order to derive the output. That is why a conjecture must stand in for the missing input (*X*) – or Case – in abduction, and the missing principle (*f*) – or Rule –in induction. In these cases, the information represented by the conjecture is also the information that is tested and from which conclusions are drawn.

11.2 Inferential Reasoning in Existing Design Theory

The general theory on logic and reasoning is abundant, and any in-depth discussion of the topic is far beyond the scope of this dissertation. Hence, I will limit my focus to discussing the subject of inferential reasoning as it is applied in existing design theory, with the purpose of positioning my own contribution.

The contributions of existing theory fall within some common conceptions:

Abduction

Many theorists describe the primary logic of design as *abductive* (Cross, 1990; Roozenburg, 1993) based on Peirce's theory of abduction or 'hypothesis' as *"the only logical operation which introduces new ideas"* (Peirce, in Fann, 1970, p. 10), suggesting *"that something may be"* (Peirce, in March, 1976, p. 17). The idea that design is abductive in nature typically implies viewing design on an *overall process level*.

March (1976) is well-known for suggesting that design is abductive, or, as he calls it, 'productive reasoning'. March argues that logic, science and design are different in that *"Logic has interests in abstract form. Science investigates extant forms. Design initiates novel form."* He holds that *"Both science and design require deduction for analytic purposes. Yet science must employ inductive reasoning in order to generalise, and design must use productive inference so as to particularise,"* since *"the prime objective of designing is to realise a particular case or design"* (p. 18).

Cross (1982) also describes abduction as a *"kind of thinking that is peculiar to design."* Though using the term 'constructive' thinking, he distinguishes it from *"the more commonly acknowledged inductive and deductive kinds of reasoning."* Cross refers to the fact that *"March [(1976)] has related it [constructive thinking] to what C. S. Peirce called 'abductive' reasoning"* (Cross, 1982, p. 225). However, March (1976) in fact uses the term 'productive' thinking, as stated above.

Coyne et al. (in Roozenburg, 1993, p. 6) state that *"In design we do not usually start with an artefact description, but with some ideas about performance. We then endeavour to arrive at a description in terms of geometry and material attributes. This is entirely analogous to the abductive process."*

Likewise, Kolko (2010) defines design synthesis as an abductive sensemaking process, and Verganti (2014) accentuates abductive reasoning as a crucial tool for designers when solving 'wicked' problems.

Dorst (2011, 2015), Aurisicchio et al. (2013), Roozenburg (1993), and Eekels (2000) likewise point to abduction as the primary mode of reasoning in design and innovative processes. However, they all distinguish 'normal' abduction from a 'special' kind of abduction, which they assert characterises design and creative processes. Dorst distinguishes between abduction-1 and abduction-2 (Dorst, 2011) or (normal) abduction and design abduction (Dorst, 2015). Aurisicchio differentiates between non-creative and creative abduction, Roozenburg between explanatory and innovative abduction, and Eekels between abduction and innoduction. All these abduction pairs resemble each other. In the 'normal' abductive inference, the Case is abduced from a known Rule and Result ($?+f=Y$). In what I shall call a 'special' abductive inference, only one premise is given or known, namely the desired or required result ($?+?=Y$), while Case and Rule are inferred.

Phases

It is a common conception that different forms of inference pertain to distinct *phases* in a process of design and implementation. For example, March (March, 1976) rephrases Peirce from a design perspective, saying that *"we conceive of rational designing as having three tasks – (1) the creation of a novel composition, which is accomplished by productive reasoning; (2) the prediction of performance characteristics, which is accomplished by deduction; and (3) the accumulation of habitual notions and established values, an evolving typology, which is accomplished by induction."* In this process *"production creates, deduction predicts, and induction evaluates"* (March, 1976, p. 18).

Implicitly regarding design as problem solving, Cramer-Petersen and Ahmed-Kristensen (2015) suggest that *"the process of reasoning in problem solving can be interpreted as a three stage process involving; 1) an abduction that leads to a certain framing, explicitly or implicitly from mental models, followed by 2) deductions that concretise and predict a solution or effect under the conjectured framing, and finally 3) an inductive reference to principles or accepted facts (possibly 'outside' the framing) that evaluates and tests, leading to a new iteration if the result is not satisfactory"* (Cramer-Petersen & Ahmed-Kristensen, 2015, p. 6). This model is likewise based directly on Peirce.

In a similar manner, Aurisicchio et al. (2013) couple different types of reasoning to different roles in the process, stating that *"In design, [deductive] reasoning supports, for example, analysis, a move from form to predicted behaviour."* Aurisicchio et al. refer to Roozenburg (Roozenburg, 1993), stating that *"Reduction has three different forms: (1) induction, (2) abduction and (3) innoduction. These are all forms of plausible, non-demonstrative reasoning that have important roles in problem-solving in science and technology"* (Aurisicchio et al., 2013, p. 46).

Roozenburg (1993) assigns reasoning types to certain parts of the process. For example he says that *"Deduction plays an important role in design (...). Before actually realizing a design, or making important decisions as to the continuation of an unfinished design process, designers have to determine to what extent the designed artefact possesses the desired performance characteristics"* (Roozenburg, 1993, pp. 5-6).

Arguments

Another perspective on inferential reasoning in design is the focus on *arguments*, which relate to the value and persuasiveness of specific ideas or solutions.

According to Pinto (2001) arguments, like inferences, consist of premises and conclusion (p. 36), but where 'inference' refers to *"the mental act or event in which a person draws a conclusion from premises,"* 'argument' refers to *"statements or propositions that one person offers to another in the attempt to induce that other person to accept some conclusion"* (p. 32). Thus, arguments serve as instruments of persuasion (p. 36).

Buchanan (see e.g. 1985, 2001) is well-known for his accounts of 'design arguments'. He describes design as an art of communication (Buchanan, 1985, p. 10). He says that *"[c]ommunication is usually considered to be the way a speaker discovers arguments and presents them in suitable words and gestures to persuade an audience,"* providing it with *"the reasons for adopting a new attitude or taking a new course of action. In this sense, rhetoric is an art of shaping society, changing the course of individuals and communities, and setting patterns for new action"* (Buchanan, 1985, pp. 5-6). Thus, *"In approaching design from a rhetorical perspective, our hypothesis should be that all products – digital and analog, tangible and intangible – are vivid arguments about how we should lead our lives"* (Buchanan, 2001, p. 194).

Though not focussing on the persuasiveness of the design product itself, Rittel (1987) has also described a model of design as argumentation. He states that *"[t]he designer's reasoning appears as a process of argumentation. He debates with himself or with others; issues come up, competing positions are developed in response to them, and a search is made for their respective pros and cons; ultimately he makes up his mind in favor of some position, frequently after thorough modification of the positions. (…) He finds himself in a field of positions with competing arguments which he must assess in arder to assume his own position"* (p. 3).

Building on Buchanan, Halstrøm (2017) equally focuses on rhetorical means, in specific the concept of topoi, for designers to invent and amplify *"persuasive arguments both in the form of situational design solutions and when expressing their choices in the process of making such designs."* (p. 30). Halstrøm argues that topoi can, inter alia, be understood at an argumentative level; as 'inferential topoi' (pp. 48-49). Resembling Toulmin's argumentative model (the 'warrants' in particular), inferential topoi are *"useful tools for analyzing arguments and for reflecting on how valid an argument is"* (p. 49). Inferential topoi *"aim to explain the underlying structure of an argument"* and *"are concerned with the ground that an argument is founded on"* (p. 48). However, says

Halstrøm, *"[the argumentative] understanding (...) is not as much about developing subject matter"* (p. 48), and is, *"arguably, (...) less useful for generating ideas"* (p. 49).

Non-deduction

Though deductive inference has been mentioned as playing a role in certain phases of design processes, there seems, however, to be a widespread belief that deduction is somehow antithetical to the *actual* or *creative* part of design. Arguably, deduction has been 'stigmatised' as the reasoning behind rigid natural science, which, prompted by well-known attempts to establish a 'science of design' – or 'technology' – in its own right (see Cross, 1982; March, 1976; Simon, 1969), is often deemed inherently different from the true nature of design. Hence, though it says more about what design is not, rather than what it is, design reasoning is often characterised as being *non-deductive*.

Cross (1990, p. 132) says that *"Although March, Simon and others have attempted to construct various forms of 'design science', they have been careful to distinguish this from popular conceptions of deductive scientific activity."*

Roozenburg calls the conclusion of a plausible inference 'nondeductive' and states that *"[m]uch of the reasoning in design belongs to the category of plausible reasoning, in particular the reasoning that generates or produces tentative descriptions for solutions to design problems"* (Roozenburg, 1993, p. 4).

Goel and Pirolli (1992, p. 406) hold that *"Because there are very few logical constraints on design problems, deductive inference plays only a minimal role in the problem-solving process. Most decisions are a result of memory retrieval and nondeductive inference."*

Dorst (2004) states that:

> "Design activities can be seen as the reasoning from a set of needs, requirements and intentions to a new bit of reality, consisting of a (physical) structure and an intended use. This process of reasoning is non-deductive: there is no closed pattern of reasoning to connect the needs, requirements and intentions with a form of an artifact and a mode of use. This 'openness' of a design problem is called the underdetermination of design problems." (Dorst, 2004, p. 2)

Hence, Dorst says that deductive reasoning is incompatible with under-determined tasks.

Though not explicitly limiting the following statement to deduction, Dorst (2011, p. 525) likewise states that the 'designing professions' are *"reasoning in ways fundamentally different from the reasoning in fields predominantly based on analysis (deduction, induction)."*

Eekels (2000, p. 384) claims that *”reasoning is considered sound*[29] *if, and only if, it strictly follows the rules of deductive logic (…) in technology, the rules of deductive logic have at crucial points to be transgressed in order to make progress.”*

Buchanan (1985) says that technological reasoning is *”an element of rhetorical art for communication with specific audiences rather than a deductive science concerned only with universal principles”* (p. 10). He hypothesises:

> ”If technology or technological reasoning is regarded merely as a deduction from scientific principles, there is no significant sense in which it can be seen as persuasive. Technological development would be regarded as an inevitable process growing out of scientific advance, and questions of value and social consequence would be regarded as irrelevant to the essence of design, more properly left to politicians and the public than included as a consideration for designers” (Buchanan, 1985, p. 19).

Thinking Rather than Acting

Finally, a prevalent viewpoint is that inferential reasoning in design pertains to the realm of *thinking rather than acting*.

For example, Cramer-Petersen and Ahmed-Kristensen (2015, p. 1) state that *”[r]easoning is a cognitive activity that dictates how humans respond to situations in every aspect of their lives. Design activity relies on the reasoning processes of designers.”*

Rittel (1987) says that *”'Reasoning' pertains to all those mental operations we are aware of, can even communicate to others. It consists of more or less orderly trains of thought, which include deliberating, pondering, arguing, occasional logical inferences. Imagine a designer thinking aloud, arguing and negotiating with himself (or with others), trying to explain or justify what he is proposing, speculating about future consequences of his plan, deciding the appropriate course of action.”*

Yet, the best example is given by the general discourse of design theory in which the concept of ’design *thinking*’ is pervasively used to describe the nature of designing (see e.g. Cross, 2011; Lawson, 2006; Rowe, 1987).

11.3 Design Syllogisms

As mentioned earlier, I have found that the functional structure of the ITO closely resembles the syllogistic functional structure described above.

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[29] Strictly speaking, the correct term here would be ‘valid’, rather than sound. However, this does not affect the point sought conveyed by the passage.

In Peirce's terms, the Case is a fact; a concrete piece of information, a starting point or input (I) to the inference. This Case is subjected to some Rule; a transformative principle (T) in the inference, which serves as a transfer between the Case and the Result. The Result is the output (O) of the inference. This resemblance is shown in Table 14.

Peirce (Fann, 1970)	**Bordal** (My proposal)
Case	Input
Rule	Transformation
Result	Output

Table 14: Comparison between syllogistic functions and the ITO function structure

Experiments build on the ITO structure, where an *input* is transformed by a *transformation* to attain an *output*. Yet, since experiments, by their nature, involve some uncertain aspect – something that must be tested or attained – not all three functions, I, T, and O are initially populated with specified information. For this reason, design experiments share further similitude with the inferential syllogisms, which, as stated, consist of two given premises, from which a conclusion is derived. In other words, in both the syllogistic inference, as well as in the design experiment, two known premises or pieces of information are needed in order to arrive at a new conclusion.
Since, in design, information may be missing (or uncertain) and present in different types of functions, I shall propose and exemplify the term Design Syllogisms, suggesting that there are three forms of experiment, corresponding to the three forms of inference, i.e. Deduction, Induction, and Abduction.

'Design Syllogisms' are the conceptualisation of design experiments as having a syllogistic structure and an inferential nature and variety corresponding to that of conventional inferential reasoning. Yet, Design Syllogisms are not purely mental reasoning, but rather reasoning with 'things'. In traditional reasoning, new knowledge can be derived from already known insights. When reasoning with 'things', new things can emerge from existing ones.

In the following I shall explain and exemplify the three types of Design Syllogisms.

Deductive Design Syllogism

In the *deductive* Design Syllogism (Figure 56), two knowns are needed and (temporarily) fixed: an input, e.g. inspiration, and a method by which to transform it.

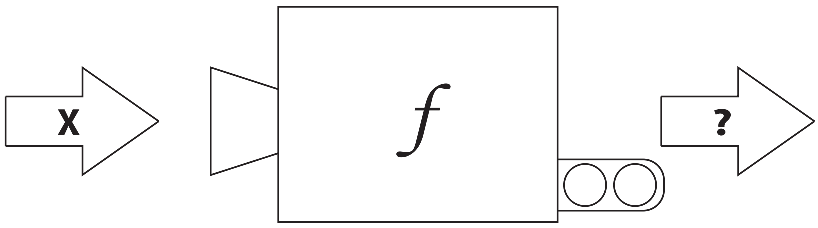


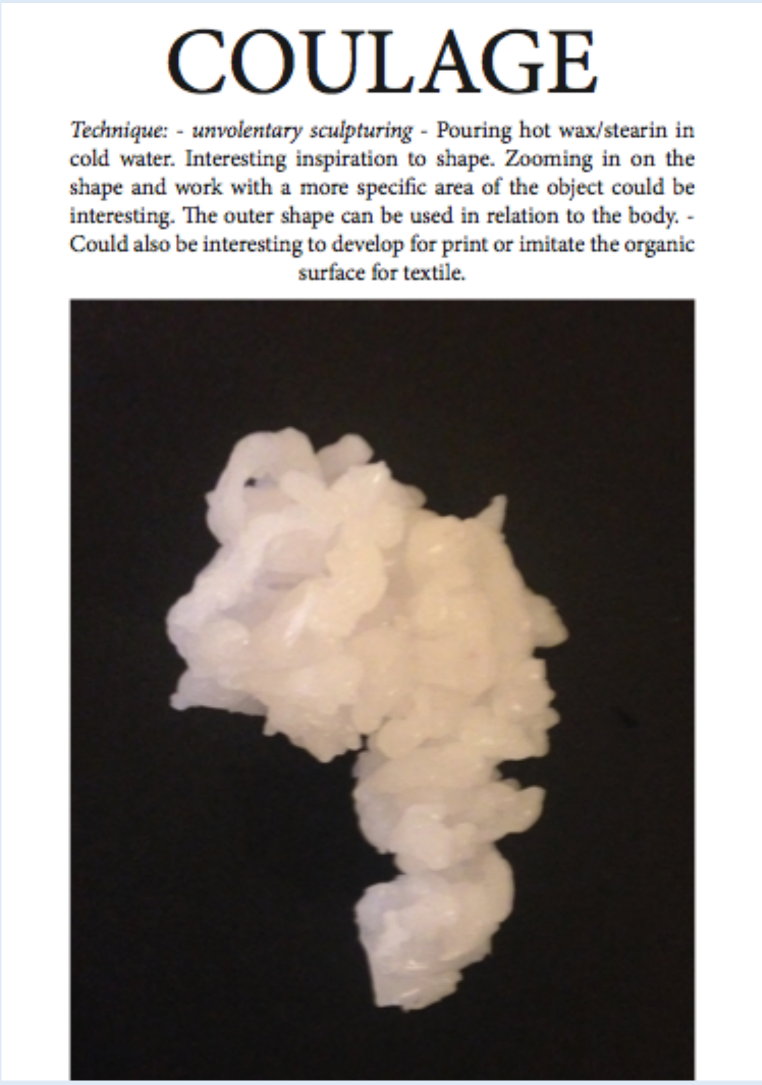
Figure 56: Deductive Design Syllogism

Since the output from this type of experiment follows automatically and inevitably, no information is needed about what the outcome should be. In fact, it would be rather superfluous, since it is impossible to control what result is generated once the premises have been established. The deductive design experiment is reminiscent of the automatism techniques applied in surrealistic art, in the sense that the designer is no longer consciously directing the result, and hence the experiment holds the potential to generate new and unexpected results. As the output is automatically produced, it does not have to be made up by the designer's conscious conjecture, as is the case in induction and abduction. This means that the output of a deductive experiment can transcend the conceptually known and thus consciously activatable world of the designer, since a conscious guess will depart from what is already present in the mind.

In the deductive experiment, the unknown element is the Output; this is where novelty is discovered. However, what is being tested in this experiment is the generative capacity and potential of the (combination of the) *Input* and the *Transformation* applied in the experiment. If they are flexible, they can be replaced, whereupon more deductive experiments can be carried out in order to test other constellations. If this happens, it is the properties of the unaltered information entity that are tested. The deductive experiment is most frequent – and beneficial – in the early stages of the design process, where the information density is lower and IEs are fewer, and where it is acceptable and desirable that the process evolves exploratively with a low degree of steering.

Examples of Deductive Design Syllogisms

Designer f7



Designer f7 is very early in her process doing a series of deductive experiments based on a collection of techniques from surrealist art. The picture above shows the technique *Coulage* (**T**), in which she pours liquid stearin (**I**) into water. Designer f7 has no evaluation requirements for the output – she is at this stage merely exploring form (**O?**) by (in this case deliberately and explicitly) relinquishing control of the output.

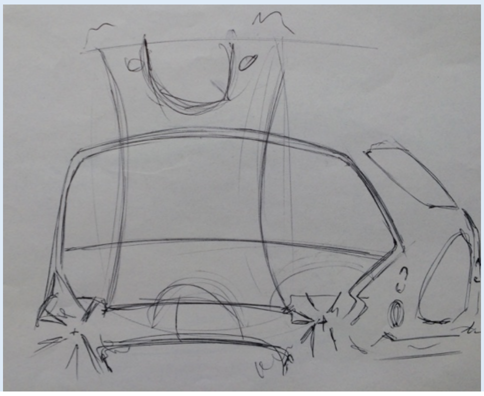
I	T	O
Liquid stearin	Poured into water	Some shape

Designer f2

Designer f2 is designing a collection inspired by body distortion. In snapshot 4 she is working with a specific draping technique, Transformational Reconstruction, developed by a Japanese designer. Designer f2 is planning to carry out a deductive experiment. She wants to drape with fabric (**I**) using the technique – but on another object than the body, for example a sculpture (**T**) to see what kind of distorted result can come out of it (**O?**). She says *"I have to just see what happens. (…) [It's] very unpredictable. So hopefully something emerges that I hadn't predicted."* (f2, 4, 24). In this deductive example, Designer f2 is consciously giving up steering and aiming for the unpredictable result of a specified action.

I	T	O
Fabric	Drape on sculpture	See what happens

Designer i4



Designer i4 is designing a self-driven taxi concept. He has an IE, the polar bear, which he wants to use as an inspiration for the design of his car.

In this example, Designer i4 is a little more than half-way through his project. He initiates a sequence of experimental moves starting and ending with deduction. Describing the first deductive experiment in the sequence, Designer i4 says that he 'dives into' the polar bear. He is wondering: *"What if I deconstruct [**T**] the polar bear [**I**]. What do I get then [**O?**]?"* By splitting the polar bear into its parts, designer i4 acts deductively hoping that the chosen action will yield a valuable insight that he cannot foresee in advance.

While deconstructing the polar bear, Designer i4 realises that an analogy could fruitfully structure and direct the experiment towards goal, which turns it into an abductive experiment. Instead of starting with the bear and splitting it apart, he now starts with the requirement of the output. The constituent parts of the polar bear, in which he is looking for inspiration (**I?**) through the deconstruction (**T**), should represent parallels to the constituents of the car (**O**). He says that he tried to *"deconstruct the car, deconstruct the bear, [and ask himself] 'where are the intersections?': (…) something makes it move (…), then there is a body (…), and then there is like the rest, the skin"* (i4, 8b, 15).

This experiment leads Designer i4 to an idea which produces another deductive experiment. He says that *"suddenly it hit me; what if I take the [polar bear] skin [**I**] and then stretch it over a [car] body [**T**] (…) what would it then look like [**O?**]?"* This led Designer i4 to a series of sketches testing the outcome of the experiment deductively (i4, 8b, 15-21).

I	T	O
Polar bear	Deconstruct bear	Unforeseeable insight
Inspiration of bear part	Deconstruct bear	Similar to car
Polar bear skin	Stretch over car	What would it look like

Inductive Design Syllogism

In the *inductive* Design Syllogism (Figure 57), two knowns are needed and (temporarily) fixed: an input, e.g. inspiration, and a conception of what the output should be like; what requirements it should meet. In addition, a conjecture must be made of a principle of transformation. What is primarily being tested is this conjecture.

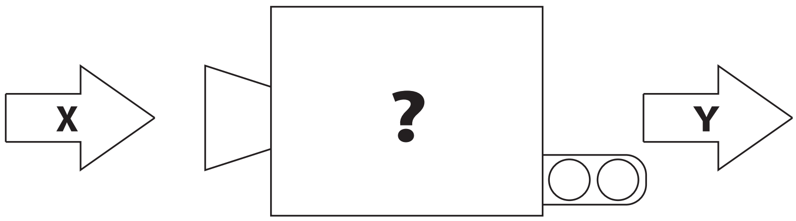
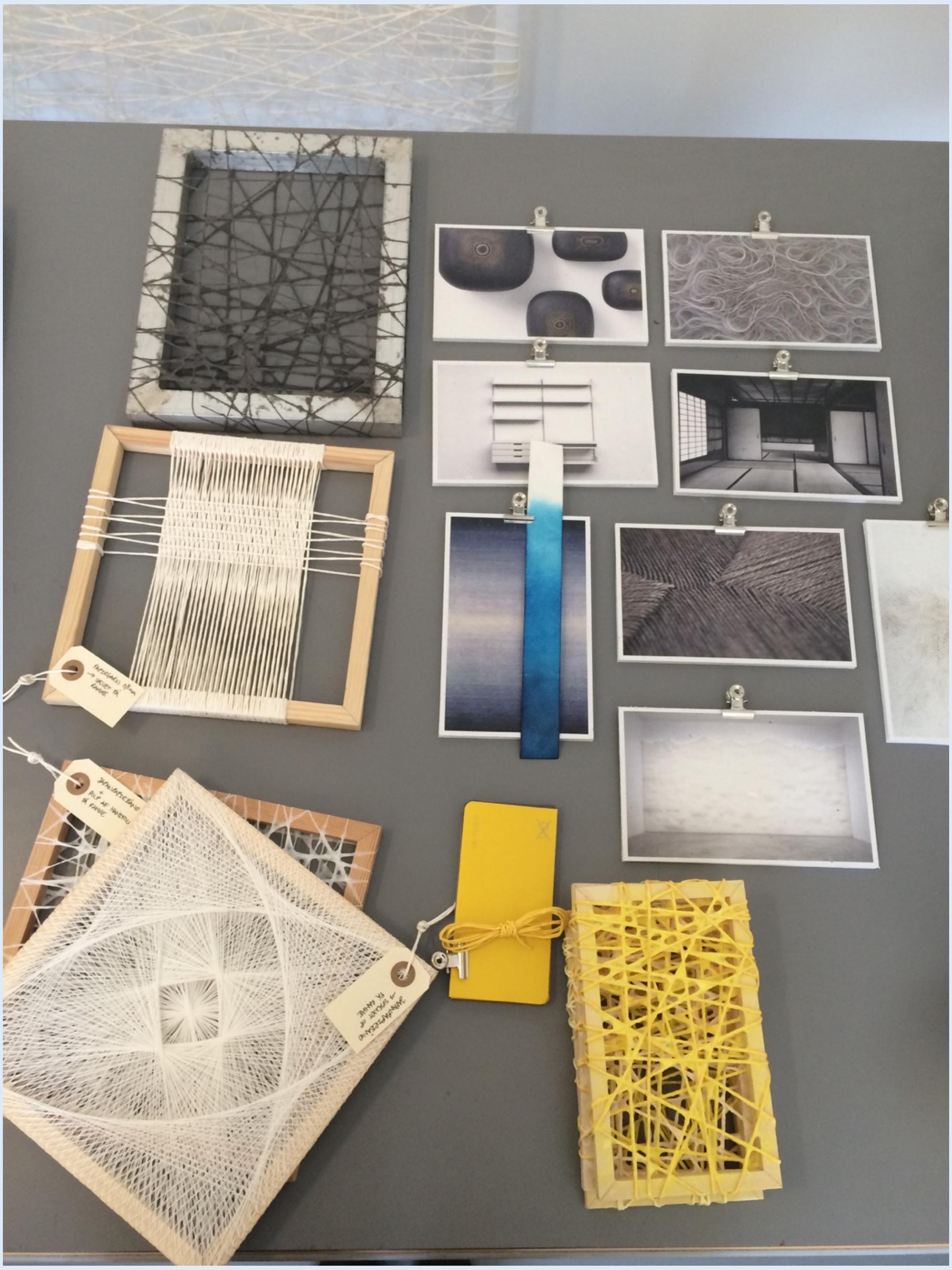


Figure 57: Inductive Design Syllogism

If the input is given, and a conception of the output and its requirements are known, this experimental reasoning process must be initiated by making a conjecture about a principle or a technique that can possibly transform the input into the output. What is tested is whether the chosen conjectured principle or technique does, in fact, generate the desired output from the input. If the technique generates something else than the desired or expected result – in Schön's (1991 [1983], p. 56) terms 'surprises', whether *"pleasing, promising or unwanted"* – it can either be rejected, or the designer can adjust the input or the requirements to the output provided they are flexible. Such unexpected outputs carry potential power to negotiate the experimental situation – resembling what Schön (1991 [1983], p. 78) calls 'conversation with the materials of a situation'.

Since the inductive experiment is contingent on a conjecture, it implies a level of uncertainty, as the conjecture can be unsuccessful in yielding the desired result. This can potentially be an advantage, though, since an unpredicted result can transcend the borders of the designer's imagination and produce constructive novelty. However, this advantage is dependent on flexible criteria for the output. The risk is present that no piece of information solves the equation of the two (temporarily) fixed, known entities.

Designer i10



Designer i10 is halfway through her process. She is working with paper in interior design (**I**), and has decided that she is going to design a room divider (**O**). She is now doing a series of inductive experiments based on the testing of different techniques (**T?**) to evaluate which is more successful in unifying the selected paper material with the type of product to be designed. The picture shows how Designer i10 tries out different techniques with paper yarn and pulp on predetermined frame measures.

I	T	O
Paper	Technique	Room divider

Designer i4

Designing his self-driven taxi, Designer i4 has set up a user experiment[30] to determine the seat position in the car. He has built a simple 1:1 car 'simulator' by putting tape on the floor demarcating the 'car', and providing eight chairs to represent car seats. In the inductive experiment, he asks his test persons: *"How would you set up [**T?**] these chairs [**I**] to make enough space between them [**O**]?"* (i4, 4, 70).

In this inductive experiment, designer i4 is, from the outset of the car simulator, looking for a chair position principle that meets the requirements of the layout of an appropriate and adequately spacious car interior.

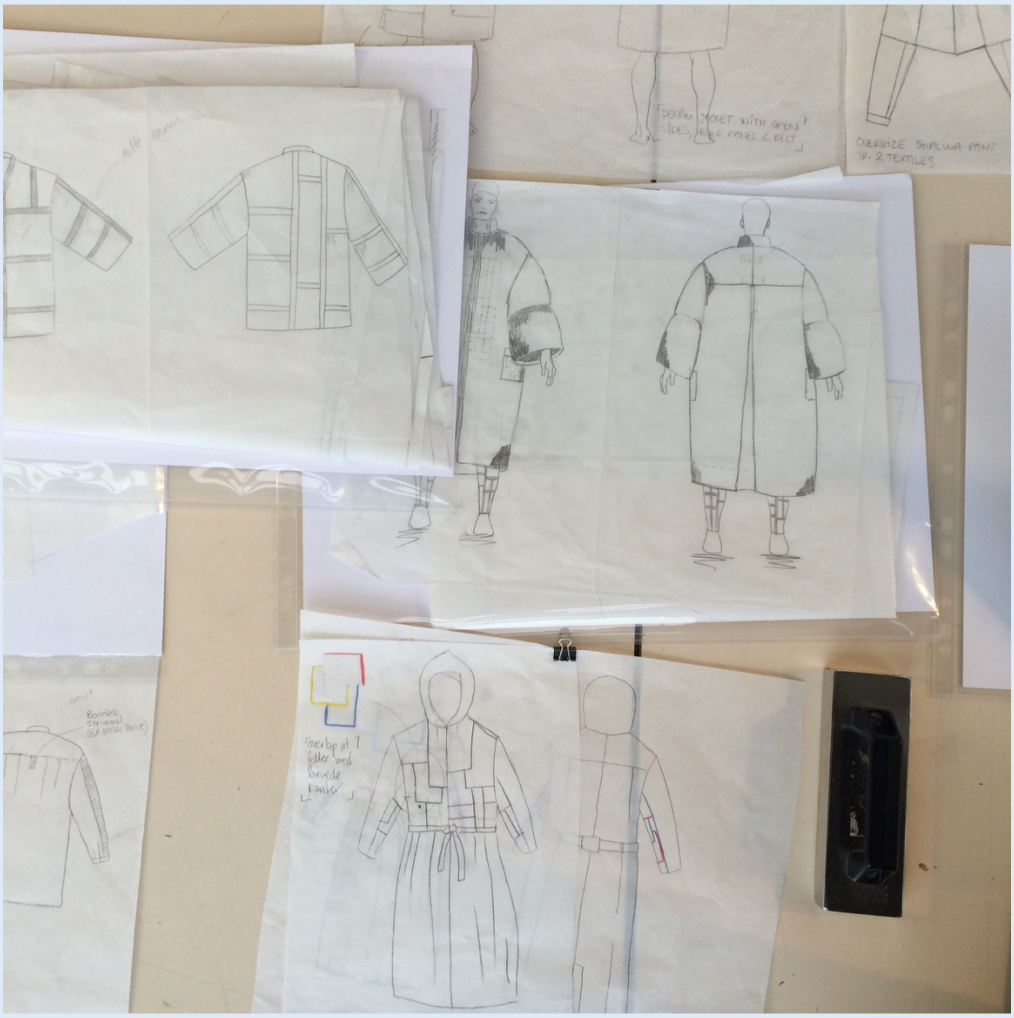
The outcome of the experiment was that the designer realised that eight seats were too many: *"I originally thought there should be eight seats in there, but when they [the test persons] got to six chairs [in the car simulator], they removed the last two chairs [from the experiment] to make room for a natural flow, so that people wouldn't*

[30] The experimental set-up shown on the picture is not the same as the one described in the example above, but a different experimental set-up built by Designer i4.

have to sit on top of each other. So it went from wishful thinking of having eight seats to having six seats" (i4, 4, 68-78).

I	T	O
Car simulator, chairs	Chair position principle	Adequately spacious

Designer f1



Designer f1 is designing a collection, inspired, among other things, by the theme 'modernism'. He finds it a central trait of the modernistic design that everything *"has a function, it's not just pure decoration and embellishment."* Therefore, he says in an interview, since his last supervision he has been working a lot with trying to convert (**T?**) some of the cut lines (**I**) that he has already added to his styles into actual functional features (**O**) in the clothes. Designer f1 says *"I have drawn all these cut lines. I do something to the cut line, so that it gets a function, too. That's what I've tried to get into it"* (f1, 6a, 31). He exemplifies that by saying, *"there was a cut line here, ok, if we move it a bit that could be a zipper or something like that"* (f1, 6a, 35).

Since Designer f1 is looking for ways in which to transform existing cut lines into features of specific functional requirements, this represents an inductive experiment.

I	T	O
Cut-line	Conversion principle	Functional feature

Abductive Design Syllogism

In the *abductive* Design Syllogism (Figure 58), two knowns are needed and (temporarily) fixed: a method of transformation and a conception of what the output should be like – what requirements it should meet. In addition, a conjecture must be made of the input to the process. What is primarily being tested is this conjecture.

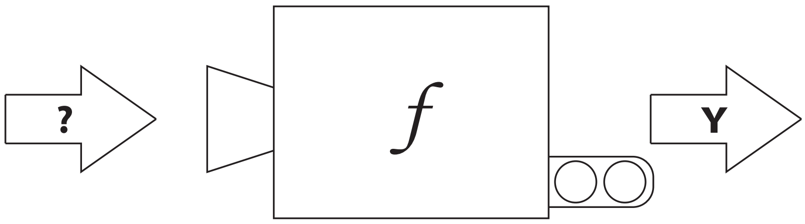
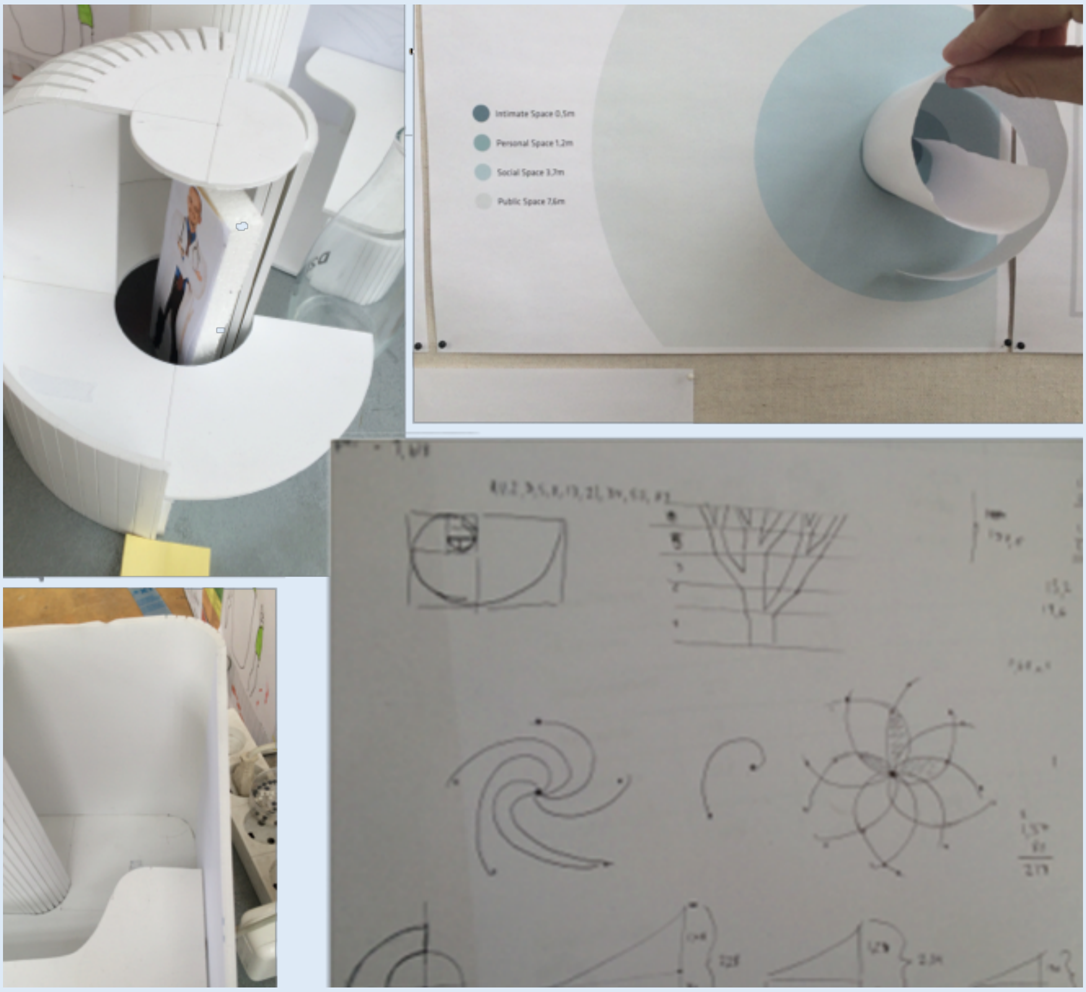


Figure 58: Abductive Design Syllogism

If a principle or technique of transformation is given, and a conception of the output and its requirements are known, this experimental reasoning process must be initiated by conjecturing an input which, subjected to the selected principle or technique, can possibly be transformed into the output. What is being tested is whether the chosen, conjectured input, does, in fact, through the technique, generate the desired output. If the input, subjected to the technique, generates something else than the desired or expected result (a surprise), it can either be rejected, or the designer can adjust the technique or the requirements of the output, provided they are flexible. Like in the inductive experiment, unexpected results are possible, which can potentially be advantageous provided the known entities are adaptable to change.

Examples of Abductive Design Syllogisms

Designer i9



Designer i9 is two thirds into his process. He is working with noise-reducing and privacy-optimising office environment shielding. He wants to create an individual office space solution that gives the individual employee the best working conditions in otherwise open office environments. Designer i9 has done a lot of research and is knowledgeable about several technical and functional aspects that are demanded from the solution (**O**). He has chosen to base his form-giving on the universal principle of the Golden Section (**T**). Now he is experimenting with what kind of input (**I?**), shape- and material-wise, can live up to these criteria. The illustration shows how different figures are contemplated as input. In the upper right-hand picture, Designer i9 is testing a spiral figure.

I	T	O
Shape and material	Golden Section principle	Technical demands

Designer f5

In this example, what starts out as a deductive experiment ends up as abductive ones.

Designer f5 is designing a collection, and in this process she is inspired by Itten's colour theory. She says that Itten *"explains [colour] as tones, like music. There are no false tones, but no ugly colours as well, it's how we combine them, and in the end if all percentual shares of colours in the composition were mixed together like paint you should have a composition that would be light grey"* (f5, 6, 5).

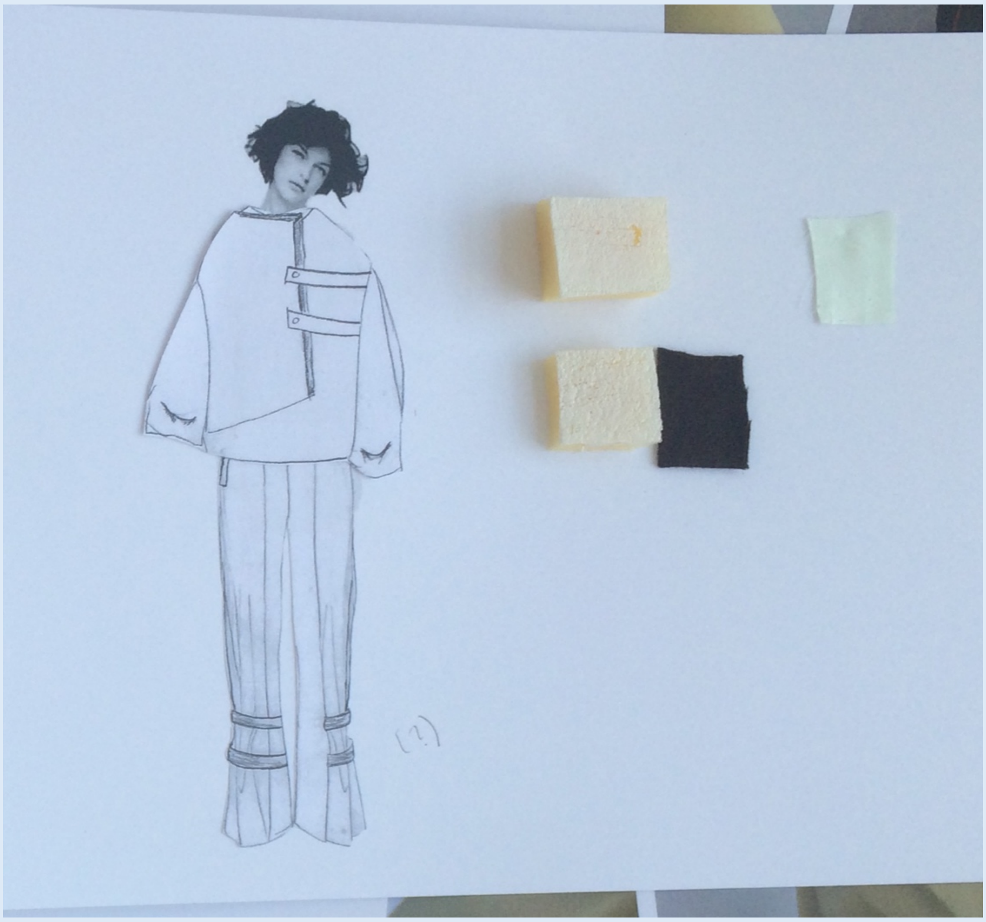
On the basis of this harmony principle, Designer f5 initially tests her three central inspirational pictures, *"and they all match up with Johannes Itten's theory that they harmonize and end up with a light grey"* (f5, 6, 5). This is a deductive experiment, since the colour harmony principle (**T**) is used on the selected pictures (**I**) to test the outcome (**O?**).

Afterwards, however, Designer f5 uses this principle abductively, as she finds and chooses the final colours and their composition in the collection (**I?**) by testing them according to the harmony principle (**T**) and assesses whether they live up to the criteria of constituting, in aggregate, a light grey colour (**O**). The principle thus helps her determine that she would, for ex*ample, “need something really creamy light and something fresh and colourful”* (f5, 3, 69).

I	T	O
Three pictures	Itten’s harmony principle	Test harmony

Find colours	Itten’s harmony principle	Light grey colour

Designer f2



Designing her collection, Designer f2 has decided to include a specific style with a particular shape and expression she wants to achieve. She needs to find the right material (**I?**) that can be put together the way she has planned (**T**) in order to attain the desired result (**O**). Discussing[31] with her supervisor and an external supervisor how to resolve the issue, they point to abductive experiments:

fSupervisor: *"Try with other textures, maybe leather or mesh"*

Designer f2: *"Yes, I need to find the right surface"*

eSupervisor: *"It becomes very 'artsy' if it is all in foam. It depends on how you use it."*

Designer f2: *"This style is maybe not [made of] foam"*

eSupervisor: *"Spend one to two days to see what you can do. And maybe look into other textured textiles, maybe open mesh (...) Try different ways"* (f2, 8, 13-24).

I	T	O
Material	Put together in style	Desired expression

Determining the Inferential Nature of an Experiment

If broken down into small enough steps, every design experiment can be said to be reduced to a deductive inference. The reason is that inductive or abductive experiments involve, and cannot be carried out without, a conjecture. Once the designer has settled on a given conjecture for a given inductive or abductive experiment, the execution of the experiment will rely on the conjecture as 'given' for the duration of the experiment. In other words, Input and Transformation will always be given for the duration of any individual experiment. This is the reason why inductive and abductive experiments can result in unexpected and surprising outcomes: By definition induction, as well as abduction, involve expected or desired outputs ('O' is given). Hence a different, unpredicted unpredicted outcome may surprise the designer. Only when an expectation exists can a different outcome be experienced and judged as 'unexpected' or 'surprising'. In combination with the known premise, the conjecture might thus produce something else. A deductive experiment, on the other hand, cannot (theoretically) produce an unexpected outcome, but merely an outcome, since it is an inherent trait of the deductive experiment that the conclusion is not expected (desired or required) in advance, but simply unknown until it has been produced on the basis of the given premises.

The fact that (in this sense) induction and abduction can be reduced to deduction is not merely an empirical observation of the present study, but likewise described by Peirce. According to Fann (1970, p. 15), Peirce equals the three inference forms with what he

[31] Coversation reconstructed from oberservation notes

calls three ’figures of syllogisms’, stating that *”All arguments in the first figure are really a priori [deduction] (…) All arguments in the second figure are really a posteriori [hypothesis/ abduction]... All arguments in the third figure are really inductive ..."* Fann writes that *”each figure involves an independent principle of inference. For although any syllogism of the second or third figure can be reduced to one of the first, the argument by which this reduction is made must be in the figure from which it is being reduced.”* He quotes Peirce, *"Hence, it is proved that every figure involves the principle of the first figure, but the second and the third figures contain other principles, besides"* (Fann, 1970, p. 15).

So on what terms can the inferential nature of a design experiment be considered inductive or abductive anyway? And how can this nature be determined in practice? The simple answer is that the inferential nature of the individual experiment is determined on the basis of which function (I, T, or O) the designer expresses the need to test. Though a chosen conjecture constitutes a temporarily ‘given’ premise for the duration of an inductive or abductive experiment, it is not considered given (and the experiment thus not deductive) if the designer aims, by the experiment, to test the capacity and adequacy of that conjecture to produce a desired or required result. Therefore, if the conjecture does not produce the desired or required result, it is often discarded, and the experiment is repeated with another conjecture on the same function. (This, of course, depends on the rigidity of the given output and the perceived value of the unexpected output – after all, the explorative strength of the design process is that it can change course due to pleasant surprises providing more promising prospects than the ones imagined.)

In sum, we can say that the function the designer intends to test or explore by the experiment is the one considered missing, unknown or unspecified in the experiment. This determines the inferential nature of the experiment in the conceptualisation of ‘Design Syllogisms’ as described in this section.

11.4 Implications of Design Syllogisms

Having conceptualised design experiments as ‘Design Syllogisms’ and differentiated their nature by the three inference forms, I shall dicuss some of the implications of this proposal in relation to existing theory.

Inferential Oscillation

Throughout the design process there can be many experiments of different kinds. An important point, which has been demonstrated in some of the examples above, is that the designer oscillates between the different inference types. This oscillation is related to the uncertainty and flexibility of design experiments. Let us hypothesise: If designer f7 finds a shape that she likes through her experiment of pouring stearin into water, she could set up her next experiment by looking for a technique that would be successfully applicable to creating the same shape in fabric. Thus, she would shift to inductive experimenting. Or if designer i10 finds a very nice technique using paper string to make her room divider, but realises the paper string is too fragile for the construction, she might want to discard the paper concept in favour of the technique. Her next experiment might then be to test suitable materials to work with, and thus she shifts to an abductive experiment.

Hence, I will argue that design reasoning shifts continuously throughout the design process, and that inductive, deductive, and abductive reasoning are mutually supportive and equally important in design generation. From this perspective, I depart from the idea that design can be described by a single mode of inference. This perspective is at the same time conditioned by and is advocating for a micro-level perspective on design 'reasoning', which leads me to discuss the level of design analysis.

Level of Design Analysis

As described earlier, inferential reasoning in design is often ascribed to an overall process perspective or to distinct phases in the design process. Yet, rather than pertaining to distinct phases of design processes or the entire process, I submit that the inferential nature of design pertains to individual move experiments. The micro-scale operational process level is where we find the mechnisms of actual change; this is where action is directed at the material, and thus where existing material is actually transformed and new material produced.

This notion is supported by Rittel (1987, pp. 2-3), who says that *"[The designer's] focus altenates continually from small component parts, back to the whole problem, and back to other details. This picture defies description in terms of discernable grand phases of task organization. Only at the microlevel we can identify patterns of reasoning conesponding to recurring difficulties of the process."*

From the phasic perspective, deduction is associated with a predictive function and induction is linked to an evaluative function which represent certain supposed process phases. In the proposed Design Syllogistic perspective, however, evaluation (process account) and prediction (process plan) are regarded as management of information and adjustment of coherence that takes place between experimental moves of different inferential natures.

The phasic perspective on design reasoning is tightly bound to the idea that design is phasic in an overall perspective, as was accounted for in Chapter 4, 'Models of Design'. Yet, as I have found that new information can enter the process at different times, that the nature of design inference can change with every move, and that courses of development can be discarded due to new and suprising insights along the way, I will argue that design is primarily phasic if viewed in the prospect of a process plan or in the retrospect of a process account. The actual process conduct, however, is explorative, oscillative and adaptive. And since the process conduct is where development, in fact, happens, I find it the most appropriate place to turn in the description of the nature of design.

We saw in the previous chapter (10, 10.4) that information can be found on several levels, between the procedural and the all-inclusive processual level. ITO structures can likewise be found on every level, whereas Design Syllogisms can only reside on the operational level where information is activated in an actual action resulting in a change.

Design as Tangible Reasoning

Proposing the notion of Design Syllogisms, I will argue in favour of the correspondence between inferential reasoning in logic and experimenting in design. My point is to accentuate that design reasoning is analogous to experiments and that in these experiments designers reason tangibly with things rather than cognitively with propositions.

In the conventional understanding and undertaking of 'reasoning', new knowledge is produced on the basis of some given premises. In design, new things are produced in the same way. The difference is that in Design Syllogisms things have replaced propositions, but the roles these elements play in relation to each other in the reasoning process are the same.

In Goldschmidt's account of a micro-view of design reasoning (2013) she proposes a 'binary reasoning system' to conceptualise the supposed *"high-frequency shifts between embodiment and rationale"* (p. 41). In this system, 'embodiment', which *"is representative of a tangible aspect (or aspects) of the entity that is being Designed,"* is viewed as *"constantly coupled with a validating concept, rationale, or raison d'etre. At the same time every expression of rationale is likewise matched with an instance of embodiment , such as an illustration , instantiation, example , or explicit description of physical properties"* (pp. 42-43). In this binary reasoning system, material embodiment and reasoning are thus considered two analytically distinguished concepts, however closely and frequently coupled.

In the Design Syllogistic perspective, on the other hand, material embodiment is considered integral to reasoning, as every inference is partly constituted by embodied Information Entities. Rather than separating material from rationale, I distinguish between the three inferential ways in which the integrated embodied reasoning can be done.

Goldschmidt and Smolkov (2006) find that *"visual information is prominent in the design process"* due to the *"visual qualities of (…) design products"* (p. 549). They point to a *"debate concerning the mode of such representations: are inner representations, using imagery, the prime generator of visual thinking in designing, or are external representations, in the form of drawings of all sorts and other two- and three-dimensional representations, indispensable to design thinking?"* (p. 549). Tending towards the latter stance, the finding of their study demonstrates that visual stimuli can impact positively on the performance of designers. Yet, in the Design Syllogistic perspective, I presume an even more radical stance; rather than being *indispensable* to design thinking, I find that visual representations, IEs, can be considered *constitutive of* the inferences through which the new is generated.

Not only Abduction

As I have argued for a micro-level perspective on design reasoning as pertaining to the experimental moves of design processes and found that these experiments can be both deductive, inductive, and abductive, at the same time I reject the idea that design is primarily abductive in nature.

Likewise, I depart from the idea of special design abduction. Admittedly, a possible scenario is that more than one function in the Design Syllogism might be negotiable or uncertain in the design process, and for example that only one piece of information is considered 'given' in the syllogism. Yet, firstly, that piece of information is not necessarily residing in the 'output' function of the syllogism, as in special abduction. Secondly, even if designers are uncertain of more than one IE in an experiment undertaken, they tend to *test* just one position at a time and hold steady information on the other positions. For this reason, the syllogistic experiments, when carried out, follow the classical syllogistic structure with two given premises and one conclusion. Information is merely renegotiated *between* experiments.

Dorst (2015) analyses design reasoning by using the 'basic equation' of 'What + How = Outcome'. Since he maintains that the mode of reasoning in design is 'design abductive', the equation to be solved is '? +? = Outcome'. Dorst explains that in the design abductive reasoning *”we **only** know something about the nature of the outcome, the desired value we want to achieve. So the challenge is to find out ”what” new elements to create, while there is no known or chosen ”how”, a ”pattern of relationship” that we can trust to lead to the desired outcome”* (Dorst, 2015, p. 49). This quote reveals some important differences compared to the idea of reasoning proposed by Design Syllogisms. First of all, Dorst’s ’basic equation’ of ’What + How = Outcome’ applies to an overall process level and takes into account the totality of the design task. I have argued that the ITO structure, reminiscent of Dorst’s ’basic equation’, applies to the overall process level as well. However, with the introduction of ’Design Syllogisms’, I advocate for analysing the logic of design on the move level, at which change is, in fact, made.

Secondly, it seems at first glance that Dorst’s equation is at odds with the description of explorative processes of which the outcome is unknown, since Dorst assumes that the outcome is the *only* known aspect of the design equation. However, if we compare the ITO model at an overall process level to Dorst’s equation, we find an underlying difference, accounting for this conondrum: the ’final design object’ is occupying different functions in the two inferential structures. For ease of explanation, I suggest the use of Peirce’s terms Case, Rule and Result for comparison (Table 15).

	Case	**Rule**	**Result**
Dorst (2015)	What (design product)	How	Outcome
Bordal (proposed)	Input	Transformation	Output (design product)

Table 15: Comparison of Dorst and Bordal in Peirce’s terms

In Dorst’s account, the design object is designated as the *Case* (in Dorst’s term the ’What’), whereas, aiming to describe the actual process of designing, I propose that the design object is the *Result* (in my term the ’output’). Thus, the final design object is also unknown in Dorst’s model. Instead the *Result* in Dorst’s equation is the concept of ’desired value’, i.e. the value that a design product will provide to the users upon completion, rather than the design product itself.

In the Design Syllogistic perspective, the concept of value is only regarded as influential to the ITO structure insofar as it can be expressed by tangible IEs informing the *output*. If construed as a fundamental motivation behind the undertaking of design, e.g. to make the world a better place, value is left implicit by the Design Syllogstic account of design, as it focuses instead on matter and action through the combination of which change actually is brought about.

The comparison between Dorst and my own proposal of Design Syllogisms exhibits an example of variance in the assumptions about which function should be filled by which type of information in the syllogistic structure of inferences. This variance might be more widespread than the presented example, but the matter is typically left unanalysed in accounts of design reasoning. Arguably, the theoretical conceptualisations of inferential reasoning in design could, from a general perspective, benefit from a discussion of this matter. If this aspect is left implicit it can confuse the discussion, distort comparison of various theories, and hamper convergence towards a shared understanding.

In Fact also Deduction

However much contested for its scientific rigor and rational logic in the context of design, deductive reasoning is not incompatible with creative and explorative design processes. In fact, deduction is the sole way of reasoning in design that aims to bring out something unforeseen, as in this process the output is the 'unknown'. Yet this happens on a more operational process level than the one addressed by Dorst (2015) when he points to 'intentions', which could incentivise a process, and the 'needs' that will hopefully be fulfilled at the end of the process. Deductive Design Syllogisms promote creativity, as designers use them to self-impose constraints (Biskjaer, 2013; Stokes, 2006) on their conscious actions by relinquishing control and preconceived judgement of the output. Designer f5, who has worked with deductive experiments from Surrealist principles (see example in Section 11.3, 'Deductive Design Syllogism'), describes the benefits of giving up control this way: *"When I am [work] unconscious, I get much more information or material, because I don't think about what works and what doesn't work, and don't sort it too early – and then I can pick out things from that. So in that way, I have more to choose from because I didn't make my pick too early. And then the more conscious [way of working] is more about getting it directed towards fashion"* (f5, 5, 24).

From the Design Syllogistic perspective, deductive inference is key to producing novelty. Thus, design can be simultaneously creative and logical; these concepts need not be contradictory.

Three Types of Experiments – in a 'Schönian' Perspective

Even though the idea of experiments as Design *Syllogisms* with its parallel to syllogistic inferences might be a contribution to the theory of design reasoning, Schön (1983) has, in fact, mentioned an empirically based division of experiments into what I deem to be three functionally similar categories. He calls them *exploratory*, *move-testing*, *and hypothesis testing*.

In Schön's 'exploratory' experiment *"action is undertaken only to see what follows, without accompanying predictions or expectations,"* e.g. *"what an artist does* *when he juxtaposes [***T***] colors [***I***] to see what effect they make [***O?***]" (…) Exploratory experiment is the probing, playful activity by which we get a feel for things. It succeeds when it leads to the discovery of something there"* (Schön, 1983, p. 145). This experiment description is thus reminiscent of the *deductive* Design Syllogism.

In Schön's move-testing experiment, a deliberate action is *"undertaken with an end in mind".* For example, *"A carpenter who wants to make a structure stable [***O***] tries fastening [***T?***] a board [***I***] across the angle of a corner [***T?***]"* (Schön, 1983, p. 146). This experiment description is reminiscent of the *inductive* Design Syllogism. Because induction involves a conjecture, this kind of experiment may not produce the intended result. Yet, *"One can get very good things without intending them, and very bad things may accompany the achievement of intended results"* (p. 146). Because design is an explorative process in which the overall goal is not fixed, the designer is free to change the course of development as she sees fit. Hence the *"logic of move-testing experiments is this: Do you like what you get from the action, taking its consequences as a whole? If you do, then the move is affirmed. If you do not, it is negated"* (p. 146).

In Schön's hypothesis testing experiment the practitioner subjects a hypothesis to experimentation in order to test it. An example of such an experiment is *"If a carpenter asks himself, What [***I?***] makes this structure stable [***O***]? and begins to experiment to find out – trying [***T***] now one device [***I?***], now another [***I?***] – he is basically in the same business as the research scientist. He puts forward hypotheses and, within the limits of the constraining features of the practice context, tries to discriminate among them – taking as disconfirmation of a hypothesis the failure to get the consequences predicted from it"* (p. 147). Yet, *"the practice context is different from the research context*" in that *"The practitioner has an interest in transforming the situation from what it is to something he likes better. He also has an interest in understanding the situation, but it is in the service of his interest in change"* (p. 147).

This experiment resembles the abductive Design Syllogism and Peirce's eponymous concept of 'hypothesis' to denote abductive reasoning, i.e. reasoning *towards* rather than *from* a hypothesis (Fann, 1970, p. 4).

Though I find Schön's account of design generation descriptive of practice and valuable to design theory, his account of the nature of move experiments seems, however, somewhat paradoxical. He holds, one the one hand, that the test of 'moves', in general, follow an instance of 'seeing', involving a judgement of the situation, to which the move is a response (Schön, 1992, p. 5) with intended consequences (see 1991 [1983], p. 79; Schön, 1992, p. 6). However, testing a move in order to obtain an already imagined and intended result, is, on the other hand, only one out of three types of experiment also mentioned by Schön (1991 [1983], pp. 145-146).

Though my Design Syllogistic idea is not based on Schön's contribution, I find that it might be seen as an augmentation of Schön's theory. While Schön mentions a triadic distinction between design moves, which is arguably resemblant of the Design Syllogisms, he has not, however, discussed the reason for emphasising exactly those three types of experiments, how they are related to each other, or the nature of the entities entering these experiments. Therefore, my contribution is not merely to point to the distinction between three types of experiment, but equally to point to underlying structures producing this division, namely ITO and the inferences by which reasoning can be done, as well as the information entering these inferences. Therefore, by Design Syllogisms, design experiments can be considered 'reasoning with things'.

The Sweet Spot of Informedness

In design, both under-constrainedness and over-constrainedness (Stacey & Eckert, 2010) can be hampering the progress of the creative process (Biskjaer, 2013; Biskjaer et al., 2011; Onarheim, 2012b). As we have seen earlier, Onarheim and Biskjaer (2012b, pp. 122-124) suggest the notion of a creative 'sweet spot of constrainedness' in which the (individual's) perceived potential for creativity is a function of the constrainedness at any given point in the creative process, and that *"the perceived potential for creativity decreases in both the direction of 'more' and 'less' constrainedness"* (Onarheim, 2012b, p. 123). But why do designers need a certain level of information to potentially constrain their processes of creation? What kind of exigency does this 'sweet spot' accommodate? This is not elaborated by Onarheim and Biskjaer (Onarheim, 2012b), but I will argue that a possible answer is linked to the concept of Design Syllogisms.

Obviously, designers' raison d'être is to create something new, and to do so by means of what already exists, until the new is created. It was expounded earlier that inferences are the acts or processes by which we can derive a conclusion on the basis of two already known premises, and that this structure applies to design experiments as well. For this reason, two specific pieces of information are needed to advance the process and arrive at the result. This contributes to explaining why neither too little, nor too much information is productive at the operational process level: In order to be in the sweet spot of productive creation, there must be precisely enough information to carry out the experiment (the two premises), but little enough to arrive at a novel conclusion. Likewise, a certain amount of information is necessary in order to devise a process plan that motivates the designer to make the experimental moves.

Since a certain amount of information is necessary in order to propel a creative design process, the designer might need to introduce and temporarily fixate information on certain functions, e.g. at the beginning of the process where the information density is low, or in a design experiment where a conjecture is necessary. Thus, fixating information temporarily can have the function as a process catalyst by which to begin design development. When a piece of information has served its function to move the the state of formative development, it is not necessarily brought along, but might be discarded again as an 'armature' (McDonnell, 2011, p. 563).

In the beginning of a creative, explorative process, a certain degree of uncertainty and flexibility is necessary in order to leave room for experimenting and developing something new. An under-determined task delivers this creative potential.

Explorative Emergence

"An idea is nothing more nor less than a new combination of old elements", James Webb Young (1939, edition 2016, p. 15).

Design Syllogisms are the mechanisms by which design processes move forward – the design *progressor*. Previously, I have introduced information and the functions it can take; I, T, and O. Design Syllogisms are the mechanisms by which these functions are assembled in order to produce something new. When two things become three (two known premises leading to a new conclusion), more information is 'built up' than was there before, i.e. less becomes more.

This conclusion about the capacity of Design Syllogisms to drive explorative emergence stands in contrast to Halstrøm's (2017) account of inferential topoi in design. Halstrøm (2017) appears to consider the inferential structure more valuable as an analytical tool for arguments made about design decisions than for the actual process of design synthesis and development of the subject matter. Halstrøm says that *"the inferential topoi may be used in design but not as much for developing ideas as for the purpose of analyzing the argument that one's solution is proposing"* (Halstrøm, 2017, p. 49). One explanation for this discrepancy is, arguably, that Halstrøm considers the inference rhetorical, while I consider it practical.

Furthermore, Design Syllogisms can help us understand how designers overcome the rift between the conceptual and the concrete. As described in Chapter 8, the nature of an *output* IE is contingent on what kind of process understanding is applied, and thus whether or not it has, in fact, been achieved. Before it has been achieved it is imaginative and conceptual, e.g. expressed in required or desired criteria.

Once the output has been achieved it will be tangibly particular. Thus, in the design process moves the ontic nature of the output changes from conceptual to material. Thereby the concept of Design Syllogisms, explaining design process moves in detail, contribute to the understanding of how we can comprehend the alleged rift between the conceptual and the concrete.

Mechanisms of Progress

In sum, Design Syllogisms can be considered the mechanism of progress in design processes. By Design Syllogistic experiments development is generated as a product of the uncertain or missing information in the syllogism, and new 'things' are produced from the existing ones. If compared to Reitman's problem-solving model (Chapter 8, Section 8.2), Design Syllogisms can be seen as a suggestion for what happens in the process $\Rightarrow^*$ between the static (vertically illustrated) 'states' of the process. Reitman uses a triadic distinction similar to ITO to express static states of a problem-solving process. With Design Syllogisms, I show that such distinctions can be applied in the description of the dynamics of moving, as mechanisms of progress.

11.5 Design Syllogisms in a Processual Context: Examples

Further research still has to study and determine potential patterns of Design Syllogisms and the movement between them in a processual development. However, in the following, I shall give some examples, primarily from Designer f2's process, of the seeming movements between Design Syllogisms. These have not been analysed through all cases, as they merely represent provisional inductive findings, which emerged from the work with analysing on basis of the Design Syllogism 'prototype'. Therefore, the examples of 'movements' described in this section could constitute the onset of future investigations.

Shifts between Types of Inference

"One experiment leads to the next… [After doing one experiment] you think then that you have to try to do the opposite too." (i10, 11, 109)

It is evident from the data, and from some of the examples already provided, that shifts between types of inference take place between design experiments. In the following, some further examples of shifts between types of inference will be provided.

Example 1

Designer f2 has a conversation with her fSupevisor about her work with the chosen technique. In this conversation a shift of experimental inference from deduction to induction is indicated:

fSupervisor: "Do you have some variation – things you want to try out – or is it the same principle? Or is it by accident?"

*Designer f2: It's a bit of both. I'm trying to control it, but I can't, and I'm trying out different things, like for example if I have this classical skirt [***I***] (…) then I'm placing… because it is holes that are sewn together, and that creates tunnels on the inside… like [I am] placing the holes in different places [***T***] and see [***O?***], ok, now it creates a tunnel here, what can I use that tunnel for?"*

I	T	O
Classical skirt	Placing holes	See? (what comes out)

Designer f2 indicates that the inference shifts by saying that she now asks *"what can I use that tunnel for?"* An example could be to ask "if I wanted this tunnel [**I**] to be a pant leg [**O**], how could I manipulate it [**T?**] to serve this function?" Thus, the inference would be inductive:

I	T	O
Skirts with tunnel	Adjustments	Leg

Example 2

Designer f2 talks about her work with her central 'draping' technique that creates tunnels inside the clothes when sewing together holes placed on the sewing patterns. She describes that *"in all those [styles] where I have a tunnel principle integrated, I have done his technique [placed holes on a basic sewing pattern part] as the point of origin, and then sometimes it has worked and not worked in relation to having a body in it (…). And then I have modelled it accordingly. Like, ok, it doesn't work when I do this with these pants, what does it take for the leg to actually get in it and walk in it? Maybe it takes this."*

Here Designer f2 describes a deductive experiment:

I	T	O
Basic sewing pattern part	Holes	Something that works or not

From the deductive experiment, the output becomes input in an inductive experiment, in case it is deemed to not work. Example:

I	T	O
Pants that do not work	Adjustments	Pants in which "the leg can get in and walk"

Designer f2 expounds how she has worked once she perceives that something does not work:
"Then I have draped on (...) And then I have added some fabric, because often (...) [I] ended up making the holes that should create the tunnels, too big, and then there was not enough room for the leg, then I have added some and then discovered, ok now... maybe it is not it. Much back and forth."

Output Becomes Input

When inferences shift, it is often the case that an output from one Design Syllogism becomes the input for the next. Some examples are given in the following:

Designer f1
Designer f1: *"I made some modernism collages [**O**] and some monk collages [**O**]. And then I combined [**T**] these collages [**I**] into something [**O**] that I have used in my collection"* (f1, 7, 11).

In this quote Designer f1 expresses how the modernism and monk collages, which were the output from the move of making them, becomes the input for another move approaching his collection design.

Designer i3
Asked how he works with his inspiration material in his sketching process, Designer i3 says: *"(...) I sit and seek inspiration, and then when you start to draw the first one [sketch], then you can see that... Sometimes it stops after I have drawn one, but sometimes you come to think, really, of the next while drawing the first one"* (i3, 7a, 90).

As indicated, the drawing of one sketch leads to the idea of the next, and hence the first sketch, which is the output of the first move, becomes the input for the next.

Designer f2
Designer f2 describes how she uses the results (output) from her previous work with the draping technique as input for new silhouette experiments:

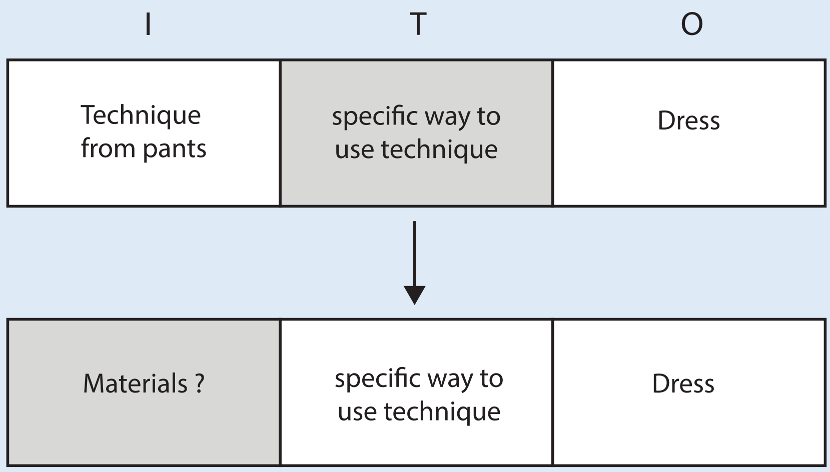
"Then I did a bit, like, silhouette experiments where I just put together some of the drapings or the technique try-outs, tried to see how... or... could I put them together? And then I kind of started to develop a collection..." (f2, 6, 10)

Designer f2
Designer f2 explains how, through experimenting, she produces new inputs for new experiments. She says it's about *"experimenting, experimenting, experimenting. Until*

you have the sense that you are at a place, where you can use something, and then experiment from that." In that way, the output of her experiments becomes the input for new ones.

In a similar manner, a conclusion from one syllogism can become a premise in the next. Though the two scenarios sound similar, they are not. As we may recall, premises denote the two pieces of information which are specified at the outset of the inference, and the conclusion is the unspecified information – that which we test and eventually conclude from. Therefore, the conclusion can be any of the three functions I, T, or O.

An example of a conclusion becoming a premise, once it is established and valued, is seen in Designer f2's case. She sets out with an inductive Design Syllogism trying to find a specific way to use a technique (**T? / conclusion to be obtained**) from a pair of pants (**I / premise**) in a dress (**O / premise**). When she finds a satisfying way to use the technique in the dress (**conclusion)**, she then fixates that information on 'T', so that it becomes a premise in the subsequent abductive Design Syllogism. In this abductive Design Syllogism, Designer f2 tests different materials (**I? / conclusion to be obtained**) which, subjected to the specific use of the technique (**T / premise**), gives the desired expression of the dress (**O / premise**).



Series of Experiments

Often an experiment does not stand alone but is part of a series of connected experiments. A serial setup can be tightly or loosely coupled. A tightly coupled series could be called a 'substitutive' series, since in such series the experiments differ only by the substitution of one particular entity in the entire sequence.

Designer f5

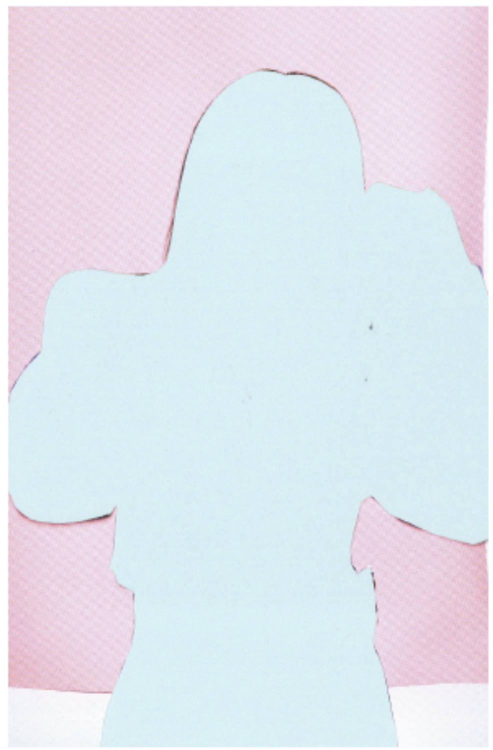
For instance, in the previously introduced example of an abductive experiment, Designer f5 is testing different colour compositions by means of Itten's colour harmony principle. In the substitutive experiment series, Designer f5 then tests different colour compositions until she finds one that, through the harmony principle, produces the desired light grey colour. In this series of experiments, Designer f5 thus fixates **T** and **O** while testing **I**.

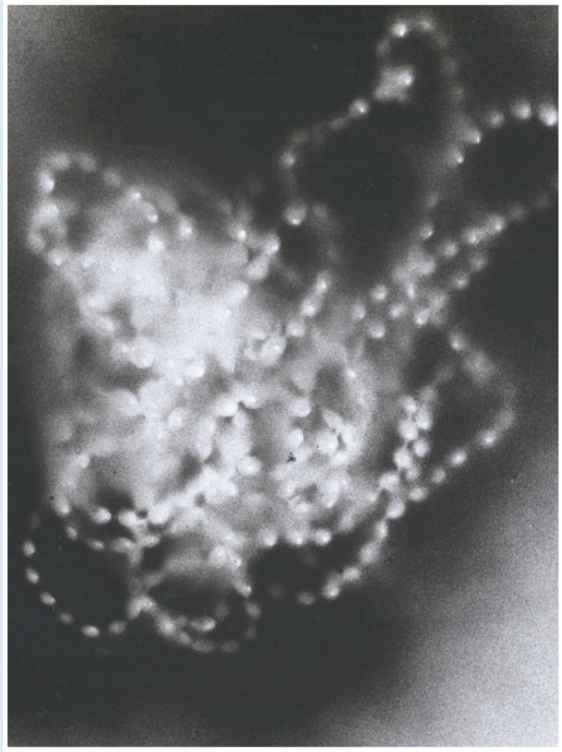
I	T	O
Colour composition 1	Itten's mixing principle	Light grey colour
Colour composition 2	Itten's mixing principle	Light grey colour
Colour composition 3	Itten's mixing principle	Light grey colour
Colour composition *n*	Itten's mixing principle	Light grey colour

In a more loosely coupled series, the connection between experiments is not given by the fixation of premises within the experiment frame, but rather by a shared relation to a common theme. This theme is producing or determining the link connecting the experiments.

Designer f7

For example, Designer f7 started her project with a series of experiments inspired by 10 different Surrealist art techniques. One of her experiments with the technique Coulage was mentioned in the examples of deductive Design Syllogisms. The experiments in this series were not alike in their setup. In one experiment with the technique Autography, the object is cut out (**T**) of a photograph (**I**) to see what shapes are created (**O?**). In another, Aerography, 3D objects (**I**) are used as a stencil for spray paint (**T**) to explore shape (**O?**).





Though very different, the ten different types of experiments based on the ten techniques are connected in a series by their relation to the theme, Surrealist Automatism Techniques, as perceived by Designer f7. Within each of the techniques, designer f7 has carried out a series of more tightly coupled experiments.
Since Designer f7's experiments are inspired by automatism techniques aimed at bringing out the unconscious by reliquishing control of the outcome, they are ipso facto all deductive.

The theme that connects more loosely coupled design experiments can be compared to what Brandt and Binder (2007) call a 'program'. A 'program' is *"an area of exploration setting goals for what is to be achieved by the design, but leaving it open how this is accomplished. The program operates for the designer as the first statement of a design space within which to draft a design"* (p. 4). The designer explores the 'program' by means of design experiments (p. 4). Thus, the 'program' *"frames and contextualizes the designerly experiment by proposing the possible"* (p. 5). According to Brandt and Binder 'programs' are relevant both within the context of design research and design practice (p. 4).

The 'program' itself is framed by the research question, which has a larger scope than the 'program' explored (p. 4). For this reason, the 'program' becomes *"an important intermediary between research question and empirical exploration,"* and design can be characterised by *"on-going interactions between designerly experimentation and programmatic considerations"* (p. 3).

Brandt and Binder's concept of 'program' is repeatedly mentioned in definite singular, the 'program', indicating that the investigation of a project is considered to take place within a single 'program'. This 'program' develops with the design work *"in the sense that what was initially sensed as a relevant context becomes more distinct statements about the design space explored"* (p. 4). However, my studies indicate that, on the operational process level, designers explore many different 'programs' – or frames of serial experimentation – throughout their projects. The number of 'programs' that can be found arguably depends on the process level at which we study the design process.

Series of experiments and their extent can either be planned or unplanned post hoc. If a series is planned beforehand, it can serve to frame a sequence of explorative experimentation, so that a certain path of experimentation is not perceived as potentially endless, but can be recognisably exhausted by predefined parameters. Thus, it helps the designer decide when to stop producing new information.

For example, Designer i3 has decided to test his hand-held control device for fear reduction in the medico industry in three predetermined sizes, supposedly regarded as spanning an adequate sample of human hand sizes. In an interview, he explains that he is about to go *"down to the CNC drilling machine to kind of get out one [model] in my suggested size, and then I did a 10% up and 10% down scale to kind of see how they would fit in my hand and in other hands. But also just to see how the shape will work up in real…"* (i3, 8b, 2). By temporarily limiting an experimental 'space' (in this case the size span between -10% to +10% from Designer i3's initial model), and segmenting this 'space' into conjecture intervals (in this case 10% intervals), Designer i3 has found a way to 'exhaust' the experimentation regarding a certain unknown aspect – the size – of his design.

Designer f2 is similarly looking for a way to predetermine the extent of her experimentation series. In the previously introduced example, Designer f2 is working with her tunnel draping technique, but is unsure what kind of basic sewing pattern to put into the technique. Hitherto, Designer f2 has only used the technique on the upper body, since she has only experimented with the technique on (the upper part of) a dress pattern and a 'random' t-shirt pattern. She says that she wants to *"work downwards on the body"* and that she has yet to do that in her 'research' (f2, 5b, 31). Designer f2 explains that she wants the effect from the technique to *"take place on different places on the body,"* which is why she needs to *"distribute the weight, which at the moment I have only worked with on… [the upper body]."* Asked if she will use some principle for choosing what other sewing patterns to work with (put into the technique) in order to achieve this distribution, she says *"Yes, I think so. But I am still trying to find what exactly is going to create the frame for such a rule."* She is thus missing a distribution principle, which *"is the next thing I have to find out".* Designer f2 then contemplates that a way to distribute weight is to *"test it [the technique] on all body parts. So that could end up as my [distribution] rule."* Segmenting the body into parts could help Designer f2 structure the experiment programme accordingly. Designer f2 arguably perceives certain body parts to relate to specific sewing pattern parts, e.g. arm points to sleeve. Thus, the structure of the series could be 'one experiment per body (pattern) part'. In other words, Designer f2 contemplates using 'the body' as an experimental space. This space could be segmented into 'body parts' representing for Designer f2 exhaustive conjecture intervals of experimentation.

Eventually, Designer f2 chooses 'classical clothing' as her frame, which gives her an experimentation 'space' from which she segments her experimentational conjectures according to what she perceives to be the most basic and classic styles in 'classical clothing'. She elaborates, *"I took six garment types, which were a very classical skirt, classical pants, I looked at the shirt (…), and I also tried with a trench coat (…), and then I had a basic T-shirt as an element [she cannot recall the sixth garment type]"* (f2, 9, 124-132).

Planned and predetermined series can help designers' explorative work by providing a logical and exhaustible structure that specifies how long they should continue down a path of exploration.

The completion of the series can instigate a process stagnation in which the designer is occasioned to evaluate the course of her project rather than losing herself to the (theoretical) eternity of experimental flow.

Examples of designers expressing the need for a predetermined experimental series:

Designer f2
Slightly more than halfway through her process, Designer f2 is working intensively with her draping technique. At a project presentation she talks with the eSupervisor about how long to keep experimenting:

eSupervisor: *"When [do] you say "I want this in the collection, but not that one"?"*

Designer f2: *"Good question! (…) it's not easy (…) At the moment I'm just trying these different things to get a variation, but I'm aware that I need to… maybe not put up more rules… but I need something to create the collection, 'cause it's very difficult (…) I cannot keep doing this and wait for something to show up. (…) I need to figure out how can I do it without making a WHOLE range and then pick out…"* (f2, 6, 25-32).

Designer f5
Designer f5 recognises the potential trap of 'endless' information generating experimentation when she says *"I needed that kick in the ass to move on. (…) "leave this phase, go on"."* (f5, 2, 41).

Designer i3
The same concern is addressed by Designer i3 when he says *"At this point I'm wondering how long to spread out before choosing, picking out"* (i3, 1, 26).

When experiments are carried out in series, often the evaluation of the individual experiment is kept open until the series is completed. After that, some experiments can be deemed dead ends and others can be brought along. Single experiments, on the other hand, are seen as isolated events altering the situation from which it was initiated. Single experiments are evaluated singularly and insights drawn directly from them.

In Appendix 2, Designer f2's process is visualised as a sequence of experiment series.

Transition between Series of Experiment

"I have done silhouette experiments. Afterwards, I need to figure out what to translate them to. I haven't reached an answer" (f2, 3, 10). This quote from Designer f2 indicates an awareness that one series of experiments must be followed by another, even though this series has not been specified yet.

Between series of experiments, as well as between single experiments, inferences can shift and input can become output.

If anything in a design process should be called a phase, I suggest that it is the duration of a series of experiments. Thus, a shift in inferences between these series could, but does not necessarily, indicate a 'phase shift'.

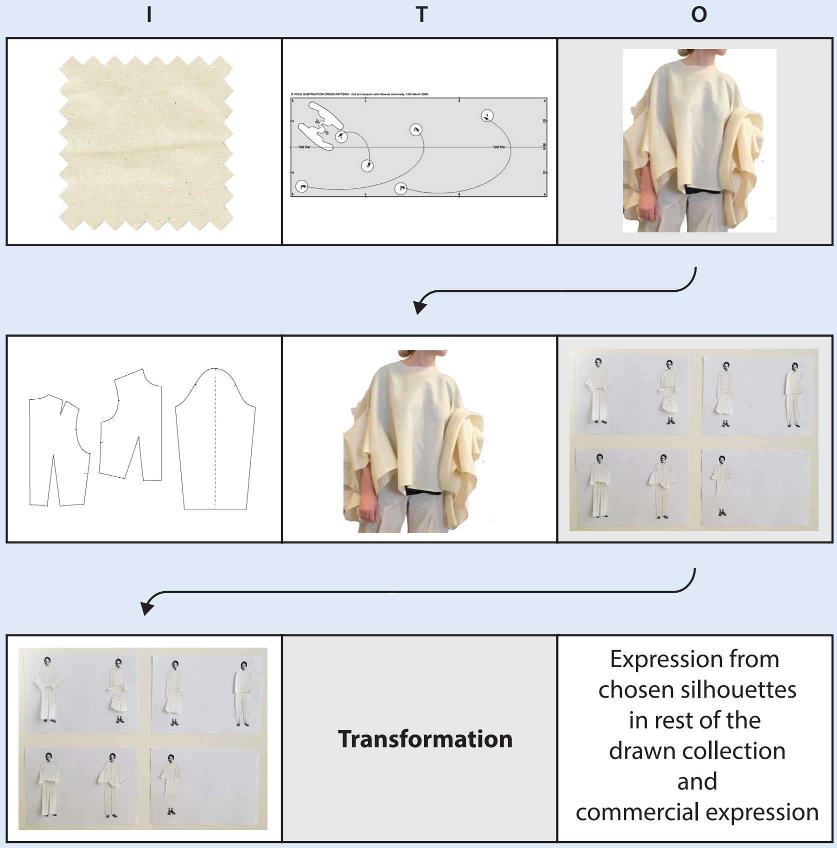
Shift of Inferences between Series

Designer f2 explains that *"At one point I had experimented a lot and found this [top] shape that was funny. And then I had a hard time moving on, because okay what do I do [with the technique] in a pair of pants? What do I do in…? To create some variation"* (f2, 10, 59)

She further explains: *"When I had to find out, ok there's something here that works, how do I then use it in the rest of my collection? And it worked really well that I took these classical elements [basic clothing styles] as the start"* (f2, 10, 73).

Designer f2 had initially experimented deductively with the chosen tunnel drape technique on fabric and had come up with a top that became a central theme in her work with the technique. The way Designer f2 had worked with the technique in the top thus became a guide for her continuous drapings, applied to different pieces of classical clothing, however. Eventually, eight silhouettes were chosen from the result of the draping, and those silhouettes, like the top before them, became the start from which the rest of the drawn collection was developed. However, Designer f2 did not continue draping; instead she tried out other different techniques to achieve the expression from the chosen silhouettes in the rest of the drawn collection.

The development described here can be called shifts of inferences between series of experiments (each row represents a series):



In the first, **deductive**, series of experiments, the draping technique (**T**) is applied to fabric (**I**) to see what comes out of it (**O?**).

From the first series, a certain top represents a specialisation of the technique. This specialised technique (**T**) is brought along to the second, **deductive**, series of experiments in which it is subjected to different sewing patterns parts (**I**), to see what results (**O**) this will yield.

From several of these experiments, the results yielded become the input (**I**) to a series of **inductive** experiments in which transformation principles are tested (**T?**) for their ability to produce an expression resembling, in a commercial way, that of the chosen eight silhouettes in the rest of the collection (**O**).

Input Becomes Output in a Series

As visible from on the illustration of inference shifts in Example 2, we can see that the output becomes input between the second and the third experiment series. Designer f2 says that the collection was *"sketched on the basis of the ones [styles] I had chosen to realise (...)" (f2, 10, 197).* Thus, the output of the work with the eight realised draped styles becomes the input and inspiration for the process and the experimenting by which the rest of the drawn collection is conceived. Designer f2 exemplifies her contemplations of this approach: *""do you [I] need this one in a long-sleeved version?" (...) a more commercial approach to some extent. Like "I need this dress, how does it need to be in relation to the rest?" and so on. "Do I need some more basic stuff now, or do*

I need something wild?" (…) Such considerations." An actual example is a top about which Designer f2 says *"this one was converted to a long jacket. (…) So it started with that draping. But in another material and in a longer version, I mean a narrower version or so"* (f2, 10, 203-213).

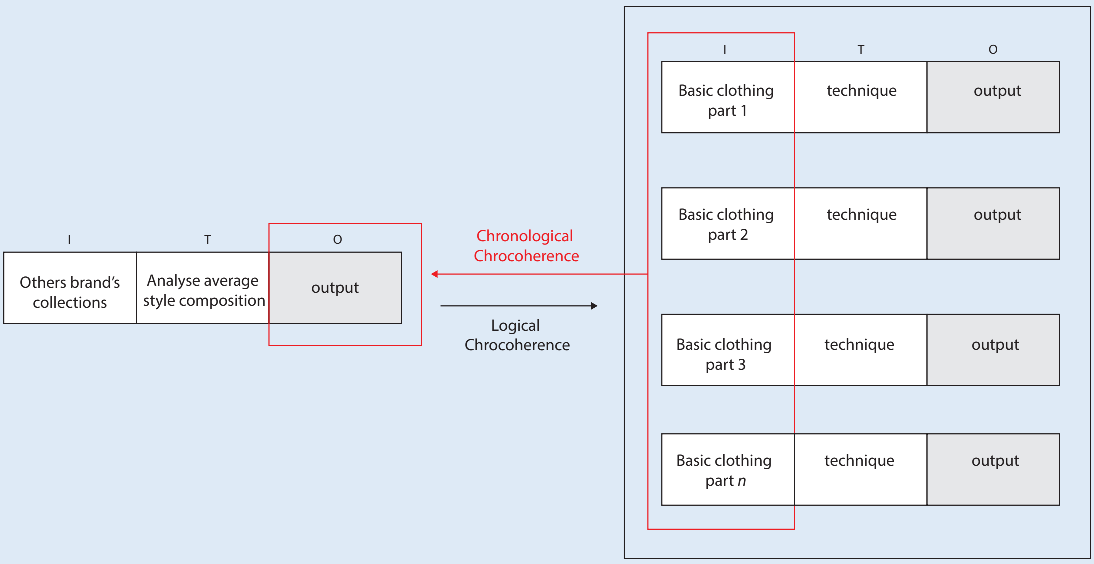
Backward Shifts

A 'backward' shift follows from an instance of constructed coherence, i.e. when the logical coherence between parts of the process do not follow the chronological coherence between their introduction – for example, when the aspiration to carry out an experiment exposes the lack of and the need for the information to precede and enter into this experiment.

In a 'forward' shift, the information obtained from one experiment feeds into the next, so they succesively build on top of each other, like bricks in a wall. In a backward shift, however, the aim to obtain information from an experiment points to the need of establishing precedent information, like realising we cannot build the roof of the house without building the wall first. In a design project we must expect both processes to take place, since in an under-determined design process it is not predetermined what is being built. Thus, it cannot be immediately determined which information should be obtained as the foundation on which to attain subsequent information. There is no 'right' starting point in a yet unknown structure. Rather, the structure of the design emerges along the way, as the information building blocks are put together.

Designer f2

Designer f2 is planning a series of experiments in which she wants to subject different basic clothing parts to her draping technique. Yet, Designer f2 feels that she needs to make a rule for how many and which basic clothing parts to include, *"but what exactly should create the frame for this rule, I think that's what I am kind of looking for."* She reckons that making a collection overview could *"help in terms of framing this thing"* (f2, 5b, 32-35). Therefore, Designer f2 embarks on another experiment to precede the one originally planned. In this experiment, she analyses the collection compositions of other brands that she finds relevant, and uses the outcome – the average of the collection compositions – to guide her own collection composition, so that she can make the overview needed in order to carry on with the initially planned experiment.



Though Designer f2 eventually bases her choice of clothing parts on another 'rule', this example shows how working with one experiment might reveal the need for another experiment to precede it, and thus the shift between experiments is 'reversed'.

12. Conclusion

I shall begin this chapter by restating the research questions of the study and specify how the findings from my research provide answers to these questions. Subsequently, I will recapitulate and elaborate on the central contributions that have emerged from the research. Finally, I will point to reservations about the study and to perspectives for further research.

Research Findings

The research encompasses two intertwined tracks of study focussing on (1) design practice and the mechanisms of progress in design processes and (2) design theory and the concepts by which design can be described and understood in a unifying manner.

Research Questions

The research questions that have guided the study are:

1. Under-determined design tasks are poorly understood in current design theory and practice. What are the progress mechanisms and the underlying structure of design processes initiated from such tasks?
2. Current theoretic design methodology is encumbered with a number of conflicts. What characterises this situation, and how might design methodology be conceptualised in a unifying manner?
3. Questions 1 and 2 are interrelated. How can the answers to these questions illuminate each other?

Research Findings

1. Through a review of existing design theory and models (Part II) I have found that design is pervasively described by an interlinked set of concepts that relate to the fundamental analytical distinction between problem and solution and consequently to the description of design, however under-determined the problem, as an act of problem solving.

   By conducting a critical analysis of the problem term and the problem-solution distinction in general and in relation to design (Chapter 3), I demonstrate that this conceptualisation of design is problematic, as it is hampered by definitional inconstistency and inadequate application. The pervasive use of negating prefixes, e.g. 'ill-defined', to the problem concept in design merely sheds light on what under-determined tasks are *not*. This leaves a poor understanding of the concept of under-determined tasks and how they are handled.

Re-conceptualising design as information processing (Part III), I have introduced the ITO distinction (Chapter 8) as a generic structure of information functions underlying design projects independent of the nature and the heterogeneity of information in those functions. I have shown that the interaction between the ITO functions can adequately and meaningfully explain design process development.

I have argued that progress in design is made when the matter – the information – of the design project is transformed by applying action to it. Actions aimed at transforming information and thereby providing something new and unknown to the design system are identified as Design Syllogisms (Chapter 11): A differentiation of 'design experiments' based on the ITO structure and corresponding to the difference between inferential forms of logic. Thus, Design Syllogisms are proposed as the progress mechanisms of design.

2. In this dissertation, I have characterised the divisions that exists in current design theory: between different paradigmatic positions in design methodology; between different assumptions about the nature of the design task; between different design process accounts expressed in models of design and, not least, between theory and practice. The latter becomes evident through the black boxing of the generative design activities, implying that creative design is inexplicable; through the emphasis on design as *thinking* and through the problem focus, which is first and foremost ambiguous, but also biased towards certain types of design projects and disciplines. Consequently a theoretical incommensurability and disunification exists between diverse design projects and disciplines, implicitly ascribed to the differences that characterise them with regard to their *Information* and *'constrainedness'*.

By conceptualising design tasks as *systems of information*, I have established a unifying theoretical ground which renders the troublesome 'problem' concept superfluous and, as it does not discriminate between the sources of the 'constraints' – or information – in the task, applies to any type of project.

I have proposed a conceptualisation of design in which the diverse Information Entities – the data – of different design projects are subsumed in a generic, underlying functional structure, ITO, which enables the comparison of heterogeneous design tasks and disciplines. The information processing perspective on explorative processes unifyingly brings together the computational approaches of the first generation of design theory and the more recent perspective that design problems are not well-defined.

Based on extensive empirical studies, the dissertation contributes a unifying convergence of theory and practice. The integration, offered by Design Syllogisms, of material and reasoning overarches the schism between 'design thinking' and 'design acting'.

Design Syllogisms constitute a conceptualisation of the black box content of generative design activity creating a unifying perspective on design as simultaneously creative and logical, without any contradiction between these concepts. Accounting for the role of linearity and deduction in creative development, the Design Syllogistic perspective unifies notions that are otherwise incompatible in design methodology.

3. The research has had two tracks of study: an empirical focus on design practice and the mechanisms of progress in design processes; and a theoretical focus on the epistemic and conceptual foundation for understanding design. The two tracks are closely related to one another, since design theory must necessarily reflect the way design is actually undertaken. Research questions 1 and 2 are tightly linked to research tracks 1 and 2 respectively, and the research findings by which they are answered illuminate each other as shown in Figure 59 and elaborated below.

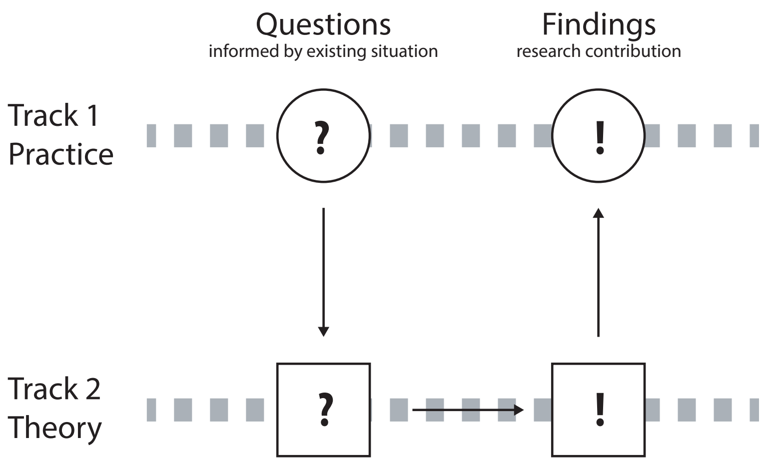


Figure 59: Relationship between research questions and findings

Figure 59 displays horizontally the two tracks of research focussing on practice and theory.

The first circle in Track 1 refers to the encountered lack of understanding of design practice and the progress mechanisms of the design processes that motivated the study and led to research question 1. The first square in Track 2 represents the epistemic and conceptual foundation of prevalent design theory the disparity of which prompted research question 2. The second square in Track 2 represents the answer to research question 2 and the contribution of this study to the epistemic and conceptual foundation of design theory. The second circle in Track 1 represents the answer to research question 1 and the findings of this study concerning the progress mechanisms of design processes.

The black arrows illustrate the course of the research as well as the relationship between research questions and findings: Firstly, a gap was detected in the understanding of design practice, which led to the study of the theoretical premises for this understanding. Revisiting and analysing the existing theoretical foundation led to the development of a new epistemic and conceptual basis for understanding design. That basis, in turn, enabled insights into design practice and the mechanisms by which design processes develop. Thus, research question 1 preceded and prompted research question 2 the answer to which, on the other hand, is a prerequisite for answering research question 1.

Further Research Contributions

Though several findings have already been mentioned in the answers to the research questions, this section will recapitulate and further elaborate on the central contributions of the study.

This dissertation has developed a new theory of design processes as well as a system of terminology on which it is founded. This terminology is summarised in the Nomenclature in Appendix 5.

I have accounted for the development, positions, patterns and prevalent concepts in existing design theory and described the divisions that characterise them. Through a critical analysis, I have exposed the problems related to describing and understanding design in the prevalent terms of problem solving and the associated distinction between ‘problem’ and ‘solution’.

Instead, I have introduced a new system of design terminology to support an *information processing* perspective on explorative design processes. This perspective contributes to bridging the paradigmatic gap in design by combining ideas from early computational models of design with the contemporary understanding of the design task complexity. From this perspective the arena of information processing shifts from a cognitive to a material one.

Based on the information processing perspective design is seen as the sourcing, transformation and management of information. It is based on the conceptualisation of the design task as a system of information. Metaphorically this system can be depicted as a salami which has a length – the temporal process duration – and a circumference that delimits its informational content. The informational content of the system can be expressed as snapshots at any state of the process between changes of its content.

The system view establishes symmetry between the constraint-generating sources and enables comparison between seemingly disparate design tasks to create a unifying design theory.

Information is the matter used in *formation* – the building blocks of design. The smallest perceived unit of analysis is conceptualised as an *Information Entity* (IE). IEs invert the prevalent concept of 'constraints', which denote the limiting *function* of information to a space of options. IEs instead focus on the entities themselves as resources – as building blocks – of which the design is built. This implies that the typical theoretical construal of design processes as a design *space,* which designers narrow down and in which they search for a solution, is also inverted. From the information perspective, design is a building process, and the emerging design is built from building blocks of information.

The *building* perspective rejects the idea that a design 'solution' has a realism-like ontic nature and *exists* in the solution space, waiting to be found by the designer through her search. Instead of picturing the design process as a procedure of search, which narrows down a space from periphery towards the centre in increased particularity, the building perspective contends that designers start at a particular place – with particular information – and build up and expand the emerging design from there.

Information can be sourced and chosen on the basis of different strategies of justification, which are either external or internal to the design system content. Likewise, it can be obtained by conversion of nonformative insights, for example produced by processual detours and regression.

Based on a cross-paradigmatic combination of problem-solving theories, I have developed an analytical framework proposing a design model of 'triadic co-evolution' in which the development of design processes takes place in an interplay between three dimensions: I, T, and O. Thus, the ITO model suggests a foundational distinction in design alternative to that of problem and solution.

The ITO framework has led to the identification of a functional structure of information which meaningfully explains process development as well as the empirical fact that information can be perceived to be lacking or being in excess in the design process. The ITO information function structure does not relate to the final design, but to the process of *moving*. Thus, the ITO framework contributes to explaining the progress mechanisms of explorative processes based on under-determined problems and aimed at unknown goals, as well as the 'sweet spot' notion which implies that a certain amount of information – or 'constraints' – is furthering the creative flow.

Based on analysis of the design processes, the dissertation likewise introduces another system of terminology characterising the design process. This includes a distinction between progression, stagnation and regression in the formative development; between three process conceptualisations found in design: the process plan, the process account, and the process conduct; and between process levels of abstraction in a continuous span between the operational and the overall process level.

Design Syllogisms describe the situations in which action is applied to material – information – in order to transform it, and thus they conceptualise the moving mechanisms of design. Design Syllogisms represent a development of the notion of a design experiment, proposing a triadic experiment distinction based on the ITO structure and similar to that of logical reasoning: deductive, inductive, and abductive. Both in design and in logical resoning something new is derived from known premises. Yet, in mental reasoning we infer new knowledge from propositions, whereas in Design Syllogisms designers derive something new from material Information Entities. Therefore, Design Syllogisms can be considered 'reasoning with things'.

Design Syllogisms defy the prevalent theoretical ideas that inferential reasoning in design is primarily abductive, pertains to distinct *phases* of the process, focusses on *arguments* relating to the persuasiveness of ideas, is *non-deductive* and, finally, pertains to the realm of *thinking rather than acting*.

Conceptualising the moving mechanism of design as Design Syllogisms implies that: the nature of design is best described at the micro-level of operations, where change, in fact, happens; design reasoning oscillates between the three inference forms including deductive inference, which is especially conducive to explorative design processes; evaluation and prediction are not linked to process phases but represent information management between Design Syllogistic moves; and that material embodiment is integral to reasoning, which unifies 'design thinking' and 'design acting'.

By introducing the ITO model and the Design Syllogistic perspective, this dissertation proposes a theory about the 'black box' content of generative and synthesising design activities by which designers make progression and move from the conceptual to the concrete aspect of design. These activities are, in many cases, assumed to be a creative fuzz that cannot be captured by a general, unified or logic description.

This dissertation offers a description of design in which creativity and logic are not considered opposites. Creativity is neither seen as a cognitive process nor as an 'irrational' fuzz that is undefinable across the idiomatic nature of individual projects. Rather creativity is seen in an *applied* perspective, as the patterns that characterise the way matter is subjected to designers' actions, whereby – from an under-determined outset – something new is actually *created*.

A New Model of Design?

The preceding introduction of the research and the findings in this dissertation leaves the question of how the contribution might be positioned in relation to existing theoretical models of design. Answering this question, I want to emphasise that I have had no intention to extract a singular model of design which could embrace and illustrate the entire complexity of design as a whole. Rather, the aim has been to gain and convey a nuanced, in-depth understanding of certain aspects of design processes and their progress mechanisms, especially in relation to the 'fuzzy', creative and (trans)formative facets.

Throughout the dissertation and in this Conclusion, I have elaborated on the particularity and the distinctiveness of the contributions provided by my research and discussed their relationship to existing theory. Table 16 below summarises the contributions of this dissertation in relation to the parameters by which I previously analysed the reviewed models of design (Chapter 4, Table 6).

Type	This dissertation qualifies as basic research embedded in and primarily meant as a contribution to the design academic field. In addition it is based on and discussed in relation to academic theory and methods. Hence the contribution can be considered a design academic model. However, it can also, to a certain extent, be considered an 'analytical' model of design, since it features some conceptual distinctions by which design processes can be analysed.
Disciplinary Domain	Industrial and Fashion Design. The unique feature of the research is that it explores two design disciplines simultaneously, one of them fashion design, which is poorly represented in the prevalent design theoretical contributions.
Theoretical/Empirical (origin)	Based on the two research tracks, the foundation of the research has encompassed both empirical and theoretical studies.

Prescriptive/Descriptive (aim)	The aim of the research has been to describe and explain mechanisms of design processes.
Model Configuration Nature	As the contribution comprises several parts, there is no singular model to describe the nature of the configuration. However, the parts can be characterised individually: The ITO structure is a fundamental **triadic distinction**, as opposed to e.g. a dyadic distinction between problem and solution. The functions of ITO are inherent in the design process dynamic. Yet, the process does not alternate between ITO spaces, as hypothesised in the triadic co-evolution model (Figure 40), but rather it moves by **successive** Design Syllogistic experiments (i.e. composites of ITO). The experimental moves can be viewed as parts of larger process chunks, e.g. series, which can also be viewed as ITO ensembles. The size of the chunk depends on the level at which the process is considered. The process levels can be expressed as an **iterative fractal-like structure** in which ITO recurs in increasingly greater detail the closer to the actual action of the designer the process is analysed. The designer plans and accounts for the process on a higher process level than the one on which she conducts it. Thus, she must take abstractional leaps, or, in Dorst's terms, 'zoom in and out'. Even though there are, theoretically, an infinite number of levels between the highest and the lowest process level, this movement can be seen as a **dyadic alternation** between high and low abstraction. I have described the design process as a salami which comprises the temporal duration and the design system extension. This model is configured as a perdurantist '**four-dimensional' object** with temporal parts that can be divided into 'time slices'. When the designer slices her process, it is an act of information management in which she sources information, accounts for and evaluates her process backwards and plans forwards. The chunks of process between slices are the design moves, i.e. the experiments or series of experiments conducted by the designer. Thus, the process can be seen as a **succession of chunks and slices**. In the slices, the designer manages information. In the chunks, she conducts movement. This portrayal is reminiscent of e.g. Lawson's and Schön's **cyclic** accounts of the design process. Yet, the formative progress happens only in the chunks as small, **experimental steps** in which action is applied to information in a syllogistic experiment, and in which the absence of some information is the generative factor for new information.
Nature of Model Elements	The central analytical distinction of this research is the one between Information (Entities) and Actions. These can be considered 'model elements'. However, the structure of the ITO function can also be said to represent key 'constituents', as in aggregate they make up the dynamics of an experiment and a process.
Problem Nature at Process Outset	Under-determined task in which information is missing or vague.

Table 16: Positioning my research in relation to design model review

Limitations
The contribution and theory of design proposed in this dissertation does not assume to be an infallible 'truth' about design.

First of all, being based on Critical Realism (CR), the study assumes an ontic realism but an epistemic constructivism. This means that despite the acknowledgement that stable and enduring structures shape the mechanisms of the world we can never gain access to any definite truths about them, because knowledge is created and biased by subjects with social and historical affiliations. Furthermore, subscribing to the adaptive approach to theory generation, no research end-product should be considered 'finished', but rather seen as an interim 'latest stage' of a theory (Layder, p. 9) in a collective, general sense. The purpose of research is not to find truths, but to produce ever more adequate knowledge with powerful explanatory power (Layder, p.142). This knowledge is always considered potentially revisable and reformulable "in the light of further argument and evidence" (Layder, 1998, p. 178).

Secondly there are some general and specific limitations to the study:

All theory implies simplifications of the real-world complexity. Otherwise it would be redundant. Thus, the concepts, classifications and typologies offered in this dissertation are inevitably simplifying the complex nature of design. Hopefully, the particular simplifications proposed will serve as meaningful descriptions that ease the comprehension, and thus implicitly the practice, of design.

The simplification is in part a matter of what André Martinet calls 'pertinence' (Barthes, 2013, p. xiii). Pertinence is the point of view and the chosen traits on which an analysis is based *"in other words, each [chosen trait] isolates in the object of study 'a homogenous level of description' dependent on the set of aspects which are of interest to the point of view adopted, which means of course that the rest are wilfully discarded"* (Barthes, 2013, p. 67). Hence, my chosen study – of the micro-level progress mechanisms of Product Design Master's students at Design School Kolding engaged in explorative processes based on under-determined tasks – leaves out alternative, but presumably equally interesting, investigation foci and affiliated findings.

The explorative research process has involved countless iterations and a lot of experimentation and has resulted in an accumulative and compound list of ideas and findings. This is, as mentioned in the method chapter, both the strength and weakness of the method. In the following I will recap some of the limitations of the method: First and foremost, it can be challenging – on an adequate level of detail – to maintain clarity and transparency in the analysis and coding process throughout the entire research process, and this dissertation is no exception to that challenge.

I have sought to compensate for that by having explicated both verbally and visually the patterns by which the process has unfolded and by providing examples of analyses and coding procedures – also seemingly digressive ones – from different stages of the process. Yet, if such explications were to be given for each iteration the dissertation would have been double the length.

This challenge relates to the concepts of process account versus process conduct, which are contributions of this dissertation relating to design processes, but which also seem acutely relevant in an explorative research project. In relation to the explorative research process, the process conduct can be understood as the actual research process, and the process account can be understood as the dissertation itself. Just like in a design process, it would be almost impossible, and excessive, to reproduce in a process description every single step of exploration and insight along the actual process conduct. The process account resumes those process steps of the process conduct, which – in retrospect – are considered essential for the development of the contributions, and which in the end are deemed the most adequate and enlightening within the framework of the study. Though it may seem problematic to leave out process steps and findings, it is necessary to select which of the many insights from the explorative study, in aggregate, comprise the most cohesive contribution and logical process narrative in order to focus on and give substance to the dissertation. This, in itself, represents a challenge when doing explorative research.

However, when some (digressive) steps are left out in the process account there is a risk that the remaining ones convey the (false) impression that findings were anticipated in advance or deliberately sought out from the onset of the research process. Yet, I will argue that quite the opposite characterises the nature of an explorative investigation.

In summary, the explorative research approach faces a methodological challenge of clarity, especially when assessed within more established research paradigms. This represents a dilemma of transparency in explorativity, which is a worthy subject of investigation and discussion in further research within the design research community.

The empirical investigation of this research project is characterised by some specific factors, or *local conditions* (Lincoln & Guba, 1985, p. 123):

It resides within an educational context; it studies Product Design Master's students, and it focusses on explorative processes based on freeform, under-determined tasks. The benefits of this research design are, inter alia, the accessibility to longitudinal in-depth qualitative studies of design processes, the synchronicity and shared conditions of the cases in an in-vivo study, and the under-constrained task environment that allows me to study the handling of this kind of task in particular.

However, these factors and benefits have a 'Janus face' in the form of some limitations:

The choice of design education means that the findings are supposedly not fully generalizable to design as practiced in professional settings.

First of all, several studies have demonstrated that novice and expert designers behave differently (Cross, 2004). As design students are novices compared to professional designers, we can assume that they will sometimes behave differently from more experienced professional designers.

Secondly, as the Master's students' tasks are perceived to represent 'extreme cases' (Brinkmann & Tanggaard, 2010, p. 475) with regard to the level of definition and constrainedness of the task relative to professional design practice, they obviously do not reflect this practice fully. The design students choose their tasks rather freely, whereas the professional setting can be subject to constraints from many sources such as managers, clients, users, legislators etc. Hence the design processes presumably diverge somewhat in these two settings.

The sample focus and the qualitative nature of the study and research design imply that the findings are not statistically generalizable to design in general. Rather the purpose has been to expand theory (Yin, 2014, p. 21) and propose an explanatory framework (Layder, 1998, p. 26). Hence, the transferability of the findings of this dissertation is merely *analytical* (Yin, 2014, p. 21) and determined by the pertinence and *local conditions* (Lincoln & Guba, 1985, p. 123) of the study, mentioned above. This will be elaborated below.

The nature of the conclusion

The nature of the empirical study shapes the nature of the conclusions that can be reached. For example, the longitudinal study has provided an opportunity to see patterns of development in the length of the cases, for example that the function of IEs can change in the course of the process. Another example is in the analysis of the distribution of Elementary Choice Entries. In this case, the longitudinal study allowed me to find a pattern that would not have been visible in a shorter study (see the comparison with Goldschmidt and Smolkov's study of visual stimuli, Chapter 7.6). The longitudinal aspect of data is valuable and could be utilised in further research with a stronger focus on testing and on finding a correlation between concepts along the process, rather than building these concept, which can be seen as a first step undertaken in this dissertation.

The simultaneous study of the two disciplines, Fashion and Industrial Design, has resulted in a rich and diverse data set. It has been the aim of this research to find a way to analyse and conceptualise it in a unifying manner despite the differences. The study of the two disciplines has helped to augment and raise the level of abstraction in the theory building, as it has been necessary to zoom out from the immediate and obvious patterns of each discipline to find the common denominators. For example, the deviation from the problem-solution concepts and the introduction of Information Entities was prompted by the pursuit of a unifying understanding of the two disciplines. Thus the two-discipline study may promote the generalisability of the findings.

The educational setting – within a single university – likewise impacts the nature of the conclusion that can be drawn. As stated earlier, the educational context implies some limitations as to how findings may be generalised. The fact that the empirical study has been conducted within a single university is an additional limiting factor. One might even argue that the empirical study of students within a single university would merely be a study of the teaching methods in the university. In further research this could be investigated by conducting – or comparing with – similar studies in other educational settings. Arguments to the contrary are that the students are affected by many sources in their projects, and at Design School Kolding they receive external supervision from the professional design industry and are required to collaborate with commercial companies about their projects. Another point is – if hypothetically we were to view the student cases as imbedded in a single case: Design School Kolding – that according to Yin (2014) even single cases are generalizable: *"not to populations or universes"* but to *"theoretical propositions"* which refers to the point that the goal of the case study is to expand and generalise (or unify) theory (cf. 'building a new roof over' theory and data), rather than to extrapolate probabilities by means of statistic generalisation (Yin, 2014). Lincoln and Guba hold that the classic, nomic concept of generalisation belongs to a positivist paradigm, and they suggest instead an alternative, based on the naturalistic paradigm, which they call 'the working hypothesis' (Lincoln & Guba, 1985, pp. 110-124). Citing Cronbach (1975), they write that *"when given proper weight to local conditions, any generalization is a working hypothesis, not a conclusion"* (Lincoln & Guba, 1985, p. 123). The working hypothesis implies, in line with the adaptive theory, that research is never finished, but merely a new proposal, on which further research can build. The working hypothesis can be transferred based on *relatedness* between the sending and receiving context, the relation being judged by the similarity of local conditions in the contexts.

Besides, in this way, building working hypotheses for understanding design (in a more general sense), the present study of design students provides insights into their processes including actions, challenges and strategies, and the conceptualisations used to gain insight into these processes may likewise be used to teach novice design students 'context-free rules' (Dreyfus & Dreyfus, 1985, pp. 21-22) of design to support learning and expertise development.

Though a study of students arguably does not generalise fully to the context of the professional design practice, *"the systematic study of the design process since Eastman's work (1969) has partly been based on students as subjects"* (Christiaans & Venselaar, 2005, p. 217). Many studies of design, some of which have contributed considerably to our current understanding of design, are based on studies in an educational context, some from single institutions, others based on single observations, protocols or experimental setups, see for example Eastman (1969), Lawson (1979), Schön (1983), Christiaans & Restrepo (2000), Maher & Tang (2003), Goldschmidt & Smolkov (2006), Dong et al. (2015), Kokotovich & Dorst (2016). Thus, I believe that a study of design students can bring out rich qualitative data and findings which relate sufficiently to design (in a general sense) to serve as relevant working hypotheses and make the further exploration of them in this context worthwhile.

Reflections on the currency of findings outside the empirical context

Though the empirical findings of this study are limited by the specific nature of their context, arguably there are some aspects of the contributions and the way they were derived that may support a broader currency of these findings.

As discussed, the present study might not be directly transferable to professional design practice. However, acknowledging the specificness of the present study, it is possible to generalise *analytically* (Yin, 2014, p. 21) based on the pertinence and *local conditions* (Lincoln & Guba, 1985, p. 123) of the study. According to Lincoln and Guba's empirical perspective of transferring findings from one context to another,

> The degree of *transferability* is a direct function of the *similarity* between the two contexts, what we shall call *"fittingness."* Fittingness is defined as the degree of congruence between sending and receiving contexts. If context A and context B are "sufficiently" congruent, then

> working hypotheses from the sending originating context *may* be applicable in the receiving context (Lincoln & Guba, 1985, p. 124).

Thus, it might be hypothesised that the findings of this study lend themselves to a description of progress mechanisms of explorative processes based on under-determined tasks in general. Yet, it must be assumed that the likelihood of such a hypothesis increases with the number of shared factors between the present study and the situation to which the knowledge is sought transferred.

The findings of this research are not merely empirically derived but also founded solidly on existing theory seeking to expand this theory in order to include the empirical context in question in a manner that is not exclusive of, but rather asserts a new perspective on, existing theory. Contributions such as 'ITO' (Chapter 8) and 'Design Syllogisms' (Chapter11) have roots in theory and have an abstract and general nature. They represent the pursuit of this research, to go deeper than the subjective 'life worlds' of actors – in this case different designers' different design projects – and examine the conditioning underlying structures and system elements (Layder, 1998, pp. 140, 146) (Chapter 2.2). Due to the general nature of these contributions, it could be surmised that they might likewise have a more general applicability than to the specific 'life worlds' by which their emergence has been informed, e.g. that they might expand to other areas in which experimentation is part.

Although design education does not fully resemble practice, the two are indeed related, as professional design practice feeds into the education (professional teachers) and vice versa (design students become professional designers). Therefore we must assume that there are some common traits of the two domains across which a transfer of findings may be reasonable. For example, it is a well-established conception that designers in general work with 'ill-defined' or 'wicked' tasks, though arguably with different degrees of 'ill-ness'. Additionally, as mentioned above, by including ten designers with diverse projects from two different design disciplines in the study, with the aim of finding a shared conceptualisation between them, that conceptualisation lifts itself from the specificness of variables in the individual cases to form a more general picture that is inclusive of those differences. For this reason, the conclusions may have a broader and more general currency than merely enlightening the specific cases that – in combination with theory – led to these conclusions.

The relevance of studying explorative processes based on highly under-determined tasks is the hypothesis that some of the mechanisms that characterise them might transfer into areas in which tasks are less but still somewhat under-determined. How this could be accomplished will be discussed in the following section.

Perspectives for Further Research

In the future, I would like to undertake further studies of how under-determined tasks and their implied uncertainty is handled in other research contexts, both in a professional design context and, not least, in the context of business innovation and change management, where design can play a role as a strategic development tool.

One approach could be to conduct an explorative and relatively grounded study of the handling of uncertainty and under-determined tasks either within a specific (service or manufacturing) company or in collaboration with a consultancy firm. Subsequently findings could be compared to the findings of the present study. If such an investigation were to be conducted in a design company or a design consultancy, a comparative analysis between the two studies could point to discrepancies between design education and practice and potentially point to improvements in design education.

Another, equally interesting, way to approach the study of under-determined tasks outside the present empirical context could be to select specific findings of the present study and conduct more deductive studies, testing different aspects of transferability, frequency and correlations between concepts by the use of mixed analysis methods.

For example, it would be interesting to investigate the potential correlation between Elementary Choice Entries and Formative Progress in the design process.

Different variables of the investigation context could be replaced in future studies, for example, the level of designer expertise, the number and the profession of the task takers, the organisational context of the study and the nature of the product developed. The nature of the product is interesting because the material information perspective is assumed to be closely linked to the physical nature of the outcome of product design. It is relevant to explore to what extent the understanding of explorative design proposed in this dissertation applies to non-physical design, for example service or systems design, and how we might describe and understand explorative processes in this type of setting.

If applying a more normative perspective on the desirability of explorative processes as a driver for creativity and innovation, then an interesting organisational context of study could be business enterprises. They are often caught in a paradox between demands for goal-orientation and process optimisation on the one hand, and the need for creative resources and innovative solutions on the other, which requires explorative processes into unknown territory.

As mentioned, the explorative research process gives rise to a myriad of insights, emerging concepts, and potential research paths, and though only some of them have made it to the final contribution, many of them could favourably have been explored (in more depth). Therefore, some of the 'digressions' of the research process qualify as interesting topics for further research:

Some examples of transitions between individual Design Syllogisms and programmes in the course of a design process were demonstrated. A further study of the strategies and nature of such transitions would contribute to an enhanced understanding of design processes. These transitions could be: Shifts between inference forms; Output becomes Input; experiment series: tightly or loosely coupled; and backwards shifts.

Likewise, it would be interesting to trace back the order of, and the transitions between Design Syllogisms and programmes to explore potential patterns in how they are connected over time in different design processes. If such common patterns of connection could be established of how creative design processes unfold, it could be used in e.g. development of artificial intelligence.

In this dissertation focus has been primarily devoted to the individual move. Yet, both the data and existing theory indicate that experiments are nested in programmes. An in-depth study of these programmes could shed light on the nature of their cohesion and their (framing) role in explorative design processes.

In the data as well as in existing theory, 'coherence' is mentioned as a central concept. Yet, coherence can be understood in different ways, as has been touched upon in this dissertation. An in-depth study of the concept of coherence would be an interesting topic for further study of design processes. This study could focus on the types and roles of coherence in design processes, as well as the relationship between design process coherence and the evaluated quality of the final design product.

One class of coherence found in this study is related to the coherence direction of the overall process, and comprises what I call 'Forwards Coherence' and 'Backwards Coherence'. These concepts do not relate to shifts between individual moves but to the reason by which new process steps are determined on the overall process level: whether they are taken by virtue of their (perceived) capacity to coherently extend the previous step, or whether they are taken by virtue of their (perceived) capacity to lead to a specified end. In other words: whether the progress is 'pushed' from its outset or 'pulled' by its goal. Examples have been found in the data of a seeming shift or turning point in the direction of the coherence in the course of the process. An interesting theme for further research would be the study of the prevalence and the nature of such turning points, for example in relation to the difference between explorative processes and problem solving, and in relation to the concept of 'mirage' presented in this dissertation.

During my research, I have encountered the concept of working 'in parallel' In stead of considering the design process as one long, though iterative, sequence, further studies of the design process might valuably analyse the concept of parallelity of design process paths, and how the development of each of these paths might serve to influence the overall development of the process in a triangulating manner (see Figure 13).

Designers typically use boards to display the project information and, as verbalised by the respondents, to get it 'out' and 'up'. The *board,* therefore, holds a central and facilitating position in the way designers work with information. An extended focus on the board could be relevant in further studies of information management: the board may represent the initial inspiration; the board may be updated to represent the current information situation; or the designer might have several boards that represent different stages or tracks of process development.

The concept of nonformation is introduced in the thesis to describe 'negative' insight about what does *not* work or what is *not* desired. Unlike information, nonformation is not an available resource contributing directly to the *formation* of the design. However, it seems be be convertible into information by different strategies, of which I described the three found in the data. It would be interesting to study the concept of nonformation in depth, and for example explore the sources of nonformation, whether nonformation is always converted into information, and if additional strategies can befound besides the three found in the present study.

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Appendix 1: A Cybernetic Perspective on the Design System

A Cybernetic Perspective on the Design System

Without professing to a general cybernetic worldview, some nuances of the designer's role in relation to the design system can be fruitfully discussed from a cybernetic point of view.

Cybernetics, meaning 'governance', studies the concepts of *"control and communication in the animal and the machine"* (Wiener, 1948). Cybernetics can be considered *"the science of general regularities of control and information transmission processes in different systems (…) It focuses on how a (digital, mechanical or biological) system processes information, responds to it and changes or being changed for better functioning"* (Novikov, 2016, p. 1).

Within cybernetics, a distinction is drawn between cybernetics of the first order and cybernetics of the second order. Von Foerster (1974, edition 1995) distinguishes between the two saying that first order cybernetics is the "cybernetics of observed systems" while second order cybernetics is the "cybernetics of observing systems." Second order cybernetics is defined meta-theoretically in relation to first order cybernetics, as the 'cybernetics of cybernetics' (Mead, 1968).

In cybernetic systems, change and transformation are central concepts (Ashby, 1964, pp. 9-23). An *operator* works, step by step, on some elements (operands) and transforms them into new elements (transforms) (Ashby, 1964, p. 10). If, for example, the operand is the integer 2, and the operator is "add three to it", the transform is 5 (Ashby, 1964, p. 12). In the process of purposeful change, feedback serves as the steering principle by controlling, communicating and regulating the system state. Therefore, *"Cybernetics may succinctly be described as the science of the regulation of systems with "circularity" or "recursiveness" as leading principles and "feedback" as a central concept"* (Drack & Pouvreau, 2015, p. 526).

From a constructivist point of view second order cybernetics rejects the notion that *"observations are independent of the characteristics of the observer"* (Umpleby, 1990). Thus a subject cannot observe or 'stand outside' a system without influencing and interpreting it. From this perspective, the observer is the one distinguishing a system as such (Scott, 2004, p. 1370), and the *"elements and relations, or operations on these elements"* is specified by the observer (von Foerster, 1995, p. 33). Drack and Pouvreau (2015, p. 530) state that *"The main point is that every individual constructs a personal model of the world based on his or her sensing."*

The designer's role in relation to the design system can be seen as belonging to both the 'observed' and the 'observing' system. That does not mean that the designer is both an 'objective' first order observer and a constructivist second order observer. Rather, the role of the designer can be seen both as belonging to the system itself and as constructively observing the system. The reason is that the aim of design is not to study things objectively. What designers study are the things they simultaneously and intentionally aim to change or create. In Simon's words, *"The natural sciences are concerned with how things are. (…) Design, on the other hand, is concerned with how things ought to be"* (1969, pp. 58-59). March (1976, p. 15) expresses a similar idea: *"Science investigates extant forms. Design initiates novel forms."*

On the one hand the designer can be considered more than a constructive observer of the system: She plays an active part in the observed system, intentionally producing the changes in the design system; she controls and imposes operations onto the elements of the system in order to transform the information it contains. She acts and manipulates directly with the material to induce change – without her actions, nothing would happen. This notion of the designer as part of the cybernetic system implies that the designer herself is seen as the *operator* exercising transformation on some elements, which leads to new outcomes. This idea is captured by Glanville's construal of the design as a cybernetic system of communication, where the change is led by the designer's intrapersonal design conversations *"held with the self in a different role"* (Glanville, 2009, p. 431). His account is based on Schön's (1983) characterisation of design as a 'conversation with the material'. In Schön's account we can understand the 'backtalk' of the situation as a communicative feedback mechanism. The appreciation of the outcome of moves (perceived feedback) alternates in processual cycles with moves producing new change (Schön, 1983, p. 102).

On the other hand, from a second order cybernetic perspective, the designer can be considered *outside* the system – as a constructor of the system. The designer *is* neither the operand (that which is changed) nor the transform (the outcome of the transformation), and though she lends and exerts her ability to take effect *to* the system, she *is* not herself the operator (the principle or algorithm) by which the nature of change is determined. This perspective implies that the operating factors of the system are seen as a distinct kind of 'elements' or information that are activated, but not constituted, by the designer. Yet, the designer is the one who construes the system as such, and she is the one who specifies and interprets the elements of the system. Thus, the system is constructed by the perception of the designer.

The 'design system' introduced in this dissertation leans towards the position of second order cybernetics in which the designer is seen as the constructive observer of the system of information. In Chapter 8, I have accounted for the conception of 'operators' – or, as I call it, 'Tranformation' – as distinct elements of the design system.

Though some aspects of cybernetic theory are valuable in the description and discussion of design, there are other aspects whose application seems dubious. For example, Ashby says that cybernetics deals with behaviour that is *"regular, or determinate, or reproducible."* (1964, p. 1), that systems are 'information-tight' (1964, p. 4) (though theorists do not fully agree on the meaning of this concept (e.g. Drack & Pouvreau, 2015)). Additionally, cybernetics is seen as teleologically 'goal-directed' (Drack & Pouvreau, 2015, p. 527). These are arguably aspects that may be or do stand in contrast to the typical characteristics of an explorative design process.

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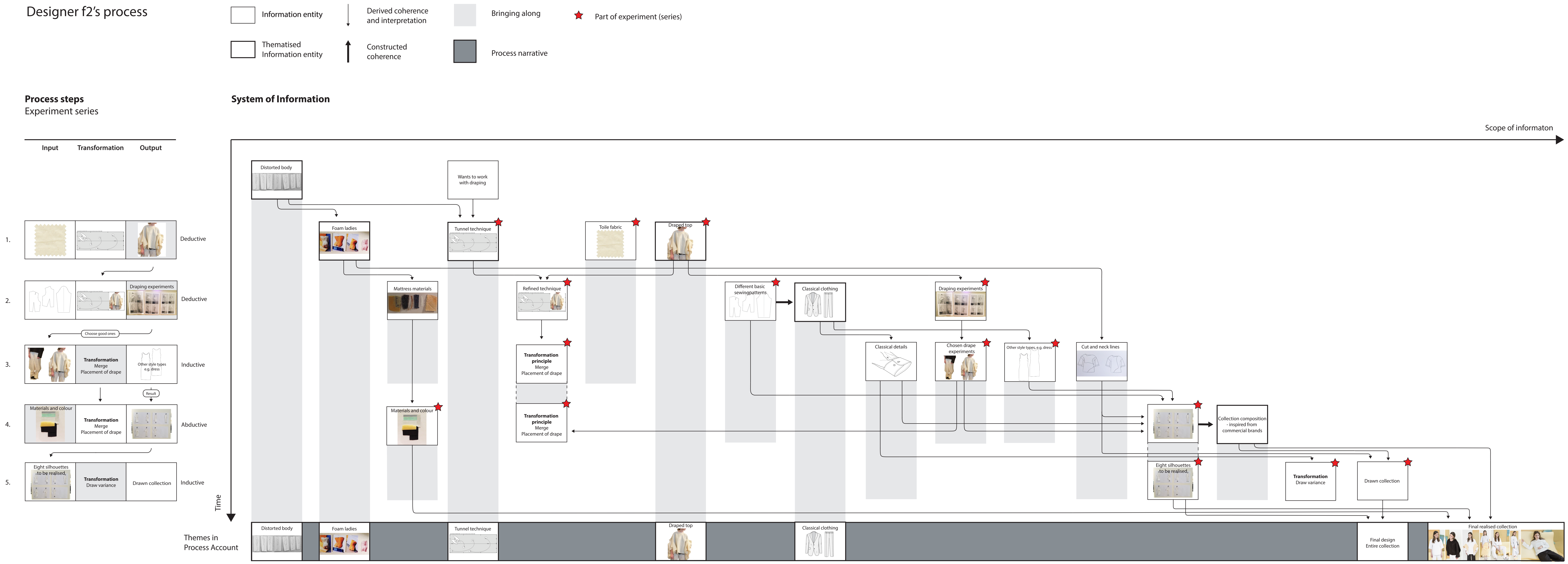
Appendix 2: Designer f2's Process

Designer f2's process



Designer f2's Process

The diagram shows an overview of Designer f2's process.

As described in the dissertation, a design process can be construed on different levels (see Chapter 10, 10.5). In the diagram the process has been depicted on a process level in which the steps are represented as series of experiments (see Chapter 11, 11.6). Hence, every series has been illustrated as an ITO ensemble.

Because the process is depicted on a process level represented by series of experiments, the diagram does not show every single move of the process.

The left-hand side column 'Process steps, experiment series' illustrates the experiment series in which information is transformed and through which the formative development progresses over time, represented by the vertical axis.

The area to the right of this column represents the design system of information (on a corresponding process level). In this area the upper horizontal arrow represents the scope of introduced information in the design system. The light grey fields show how information is 'brought along' (Chapter 10, 10.2) in the design process and how themes thereby become cornerstones in the process account narrative. These narrative cornerstones are depicted in the dark grey horizontal field at the bottom of the area.

In the diagram, the system of information is populated by information boxes. The thin boxes represent Information Entities (IEs) (Chapter 7, 7.1), and the bold boxes represent Information Entities that are thematised, i.e. they have a material manifestation as data but are likewise representative of core themes in the process (Chapter 7, 7.1). The arrows between the information boxes show the logical coherence between them. The thin arrows symbolise how Information Entities are derived from themes ('Derived Coherence', Chapter 10, 10.4) and how information is subsequently interpreted (Chapter 7, 7.6). The bold arrows symbolise constructed coherence (Chapter 10, 10.4) where themes are introduced to justify and give meaning to an IE.

A red stars in the corner of a box indicate links between the left and the right side of the diagram, as they symbolise information in the system that is activated in the series of experiments in the same horizontal row.

The left-hand side column 'Process steps, experiment series' depicts how the process progresses formatively through a sequence of experiment series. The arrows between the series shows how they build on each other and how one series leads to the next.

Explanation of the Experiment Series:

Experiment Series 1
Designer f2 applies the 'Tunnel' draping technique to a piece of toile fabric in order to explore what emerges. One of the outputs in this experiment series is a draped top that Designer f2 is very pleased with.

Experiment Series 2
The draped top comes to represent a specialisation of the technique. Designer f2 applies this specialised technique to six selected sewing patterns to see what results this will yield. This leaves Designer f2 with a series of different draped styles.

Experiment Series 3
Designer f2 chooses the best styles among those from the previous experiment and sets out to create other kinds of styles, for example a dress, by trying to merge the draping principles and the placements used in the chosen styles.

Experiment Series 4
On the basis of the technique applied and the results obtained from experiments series 3, Designer f2 tests different materials and how they will affect the expression. Thus Designer f2 achieves the final design of the eight silhouettes to be realised.

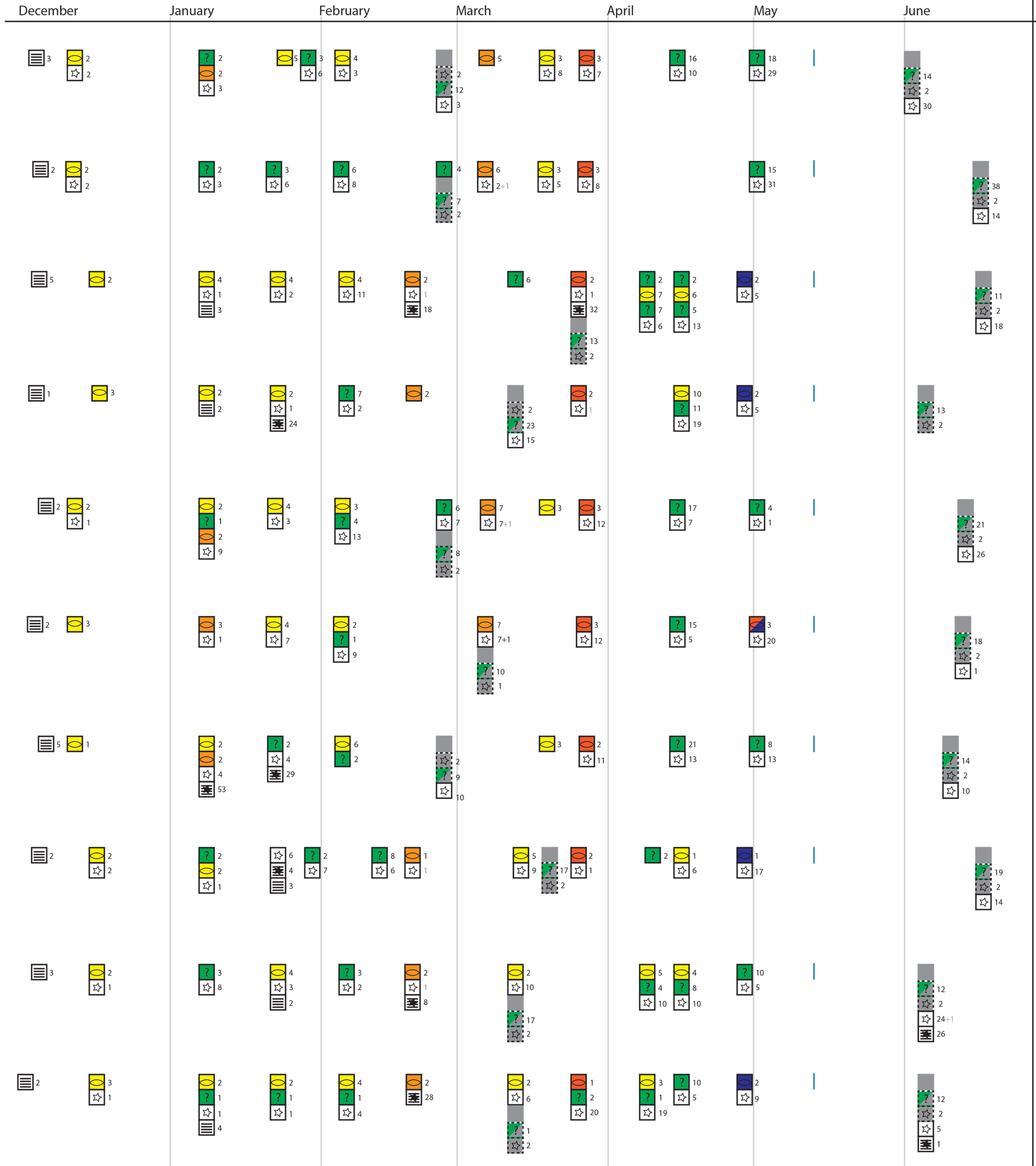
Experiment Series 5
Designer f2 needs to design a larger collection than the eight silhouettes she has already designed. She does not have time for further draping experiments, so instead she takes the styles she has already developed by draping as a point of departure and transforms them by drawing from a principle of variance, for example "do I need this one in a long-sleeved version?" inspired by collection overviews from commercial brands.

Appendix 3: Data overview

Data overview

- Written project description
- Photos of project material
- Other project material: Slideshow/ book/ research/ survey/ other
- Observation
- Supervision
- Plenum Presentation
- Masterclass
- Test Exam
- Interview
- General process
- Exercise (intervention)
- Meta data
- 123 Number of text pages or photos
- +1 Video
- Final exam

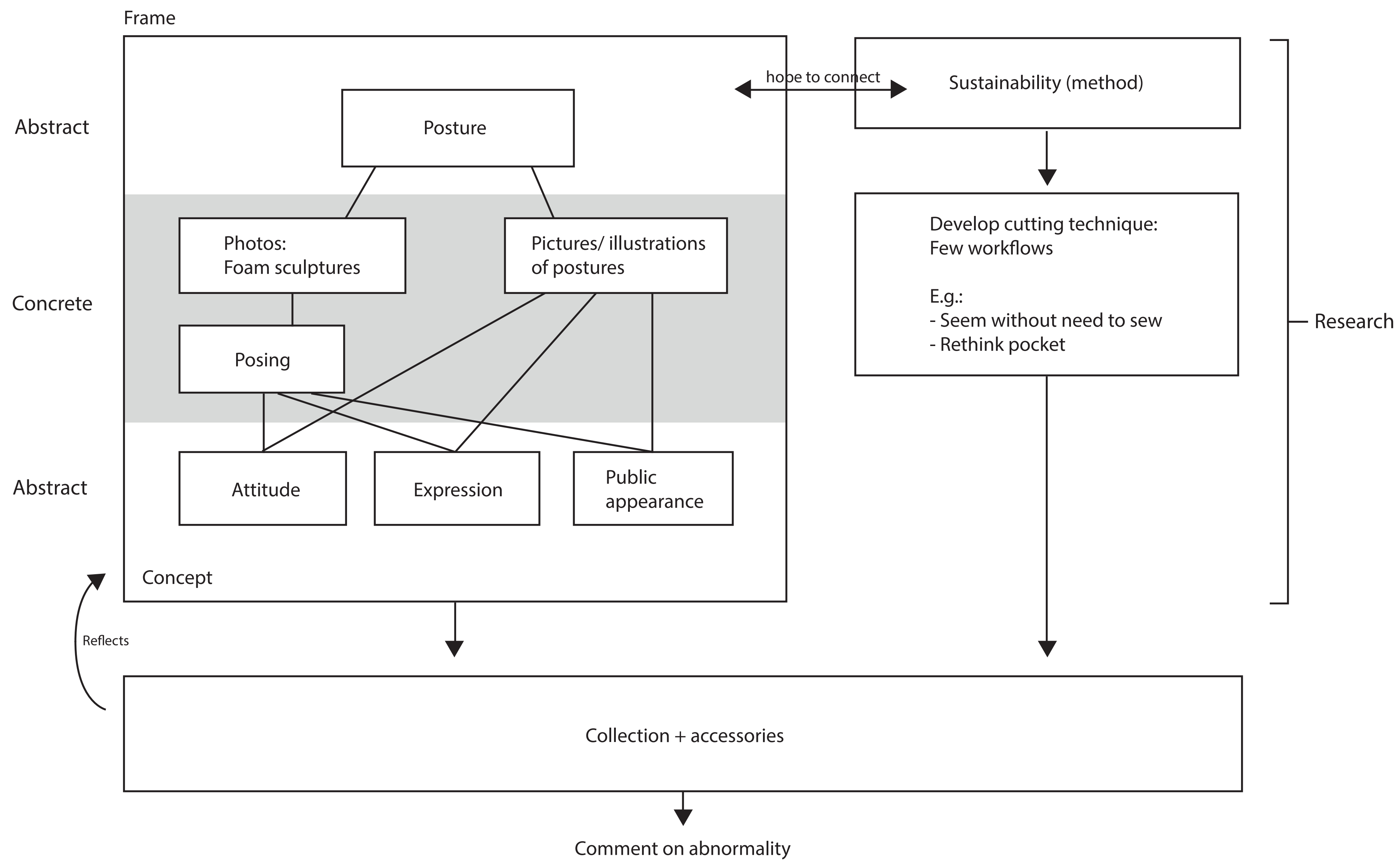
Designer f1
Designer f2
Designer i3
Designer i4
Designer f5
Designer f6
Designer f7
Designer i8
Designer i9
Designer i10



	Interview: General process	Interview: Exercise	Obsevation: Supervision	Obsevation: Plenum Presentation	Obsevation: Masterclass	Obsevation: Test Exam	Written project description	Total text pages	Photos	Meta data	Total visual units	Other project material	Exercise
Designer f1	4 (39)	2 (26)	4 (14)	2 (7)	1 (3)	0	1 (3)	**92**	101	2	**103**	0	2
Designer f2	5 (30)	2 (45)	2 (5)	1 (6)	1 (3)	0	1 (2)	**91**	80	2	**82**	0	2
Designer i3	5 (22)	2 (24)	6 (27)	1 (2)	1 (2)	1 (2)	2 (8)	**87**	58	2	**60**	2 (50)	2
Designer i4	2 (18)	2 (36)	4 (17)	1 (2)	1 (2)	1 (2)	2 (3)	**80**	43	2	**45**	2 (26)	2
Designer f5	5 (32)	2 (29)	5 (14)	2 (9)	1 (3)	0	1 (2)	**89**	114	2	**122**	0	2
Designer f6	2 (16)	2 (28)	3 (9)	2 (3+?)	1 (3)	1 (3)	1 (2)	**64+?**	63	2	**65**	0	2
Designer f7	5 (42)	2 (23)	4 (12)	1 (2)	1 (2)	0	1 (5)	**104**	65	2	**149**	2 (82)	2
Designer i8	4 (14)	2 (36)	4 (10)	1 (1)	1 (2)	1 (1)	2 (5)	**69**	70	22	**72**	1 (4)	2
Designer i9	5 (28)	2 (29)	5 (17)	1 (2)	0	0	2 (5)	**81**	75	2	**77**	2 (34)	2
Designer i10	6 (16)	2 (13)	6 (16)	1 (2)	1 (1)	1 (2)	2 (6)	**56**	66	2	**68**	2 (29)	2

Appendix 4: Visualisation of pilot study cases

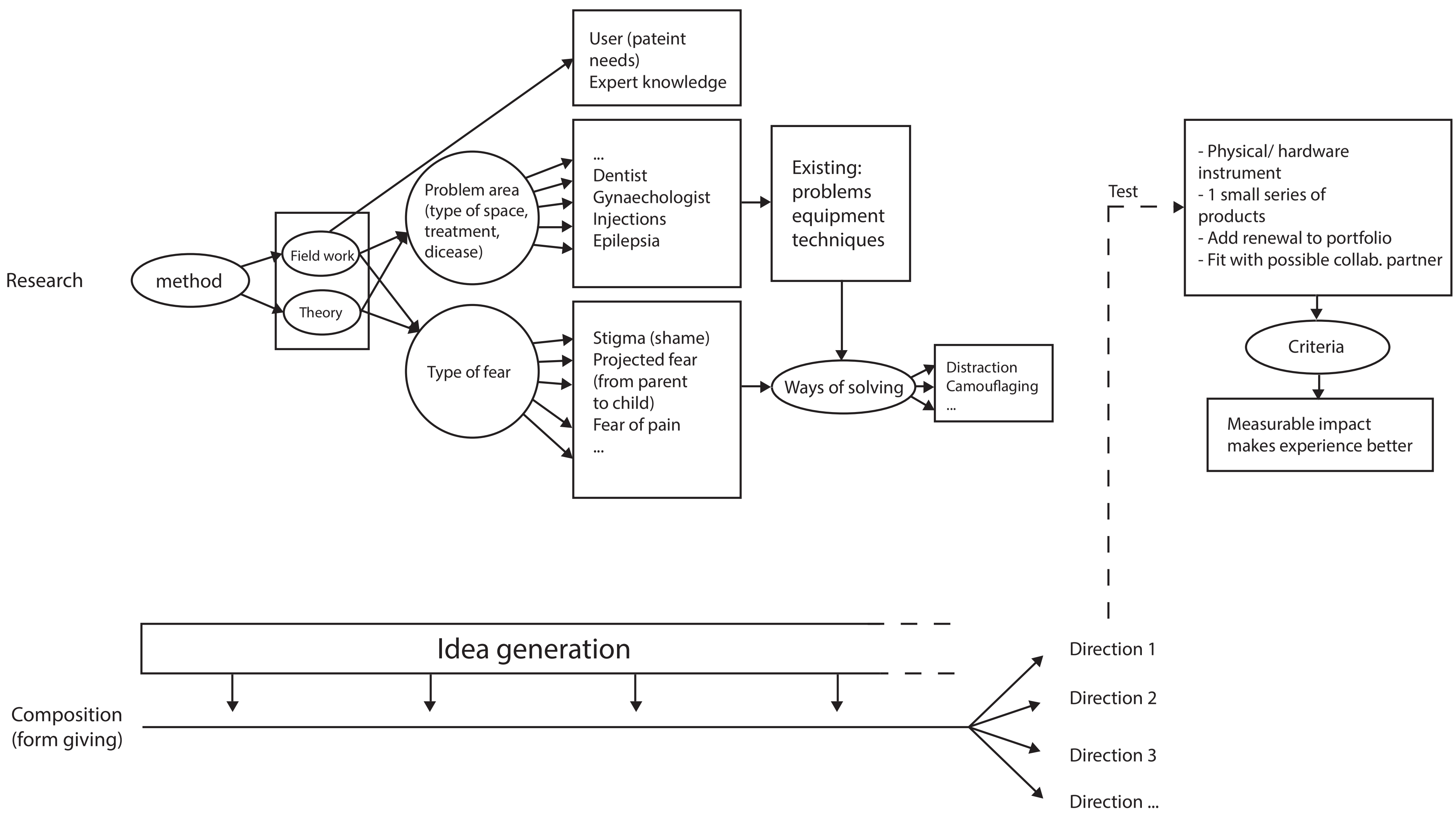
Designer f2



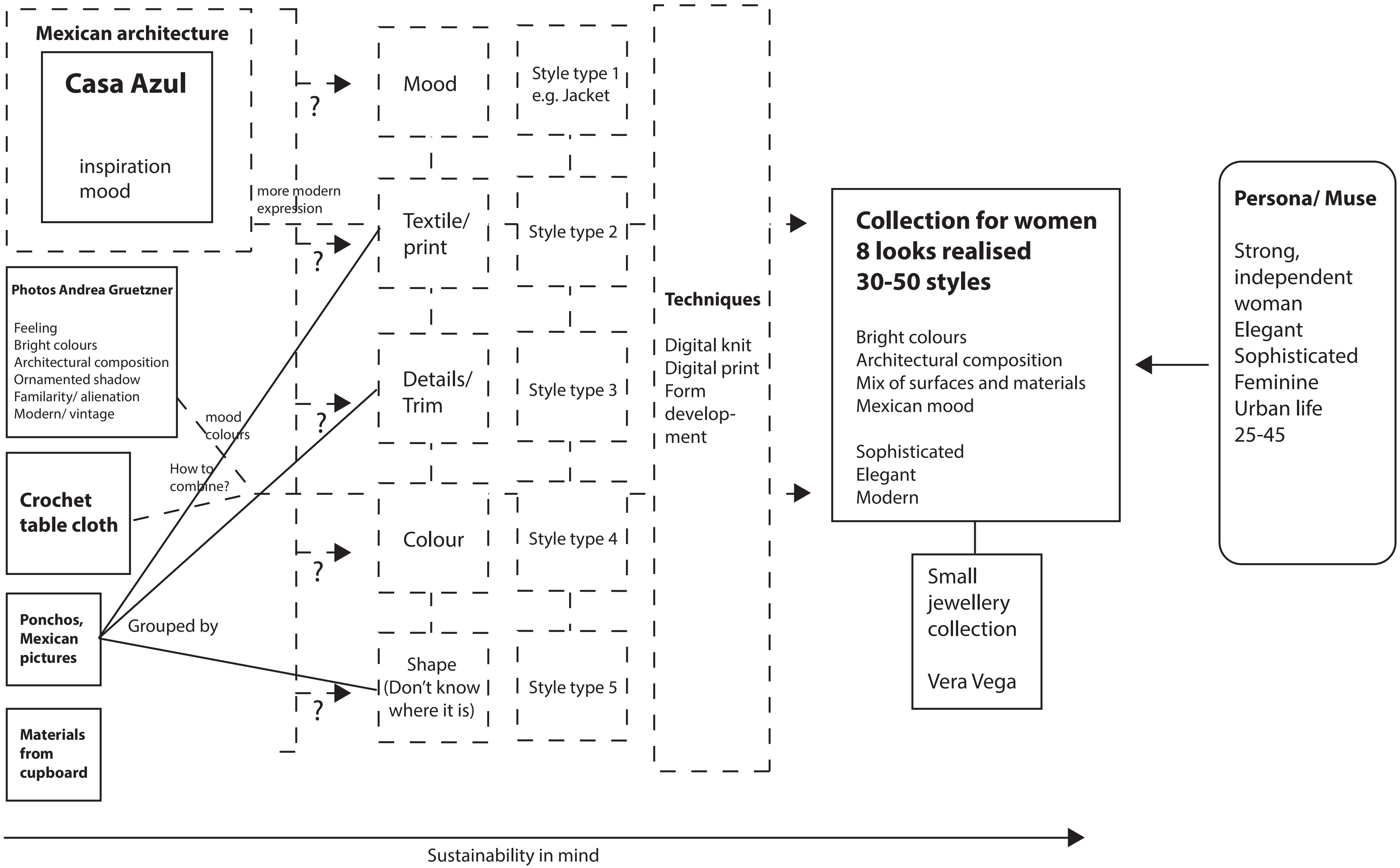
Frame
Abstract
Concrete
Abstract
Posture
Photos:
Foam sculptures
Pictures/ illustrations
of postures
Posing
Attitude
Expression
Public
appearance
Concept
hope to connect
Sustainability (method)
Develop cutting technique:
Few workflows
E.g.:
- Seem without need to sew
- Rethink pocket
Research
Reflects
Collection + accessories
Comment on abnormality

Designer i3

Medico and fright

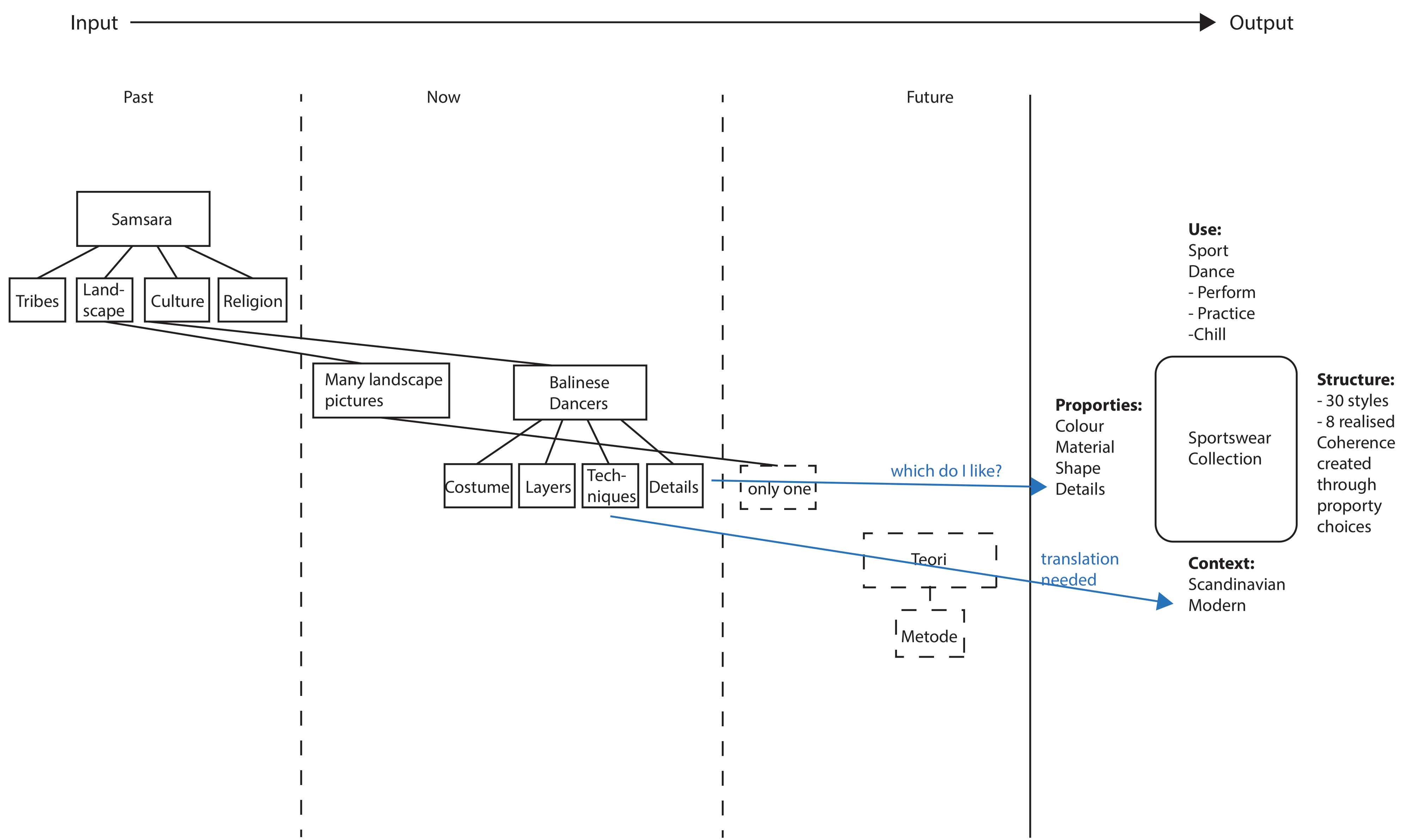


Designer f5

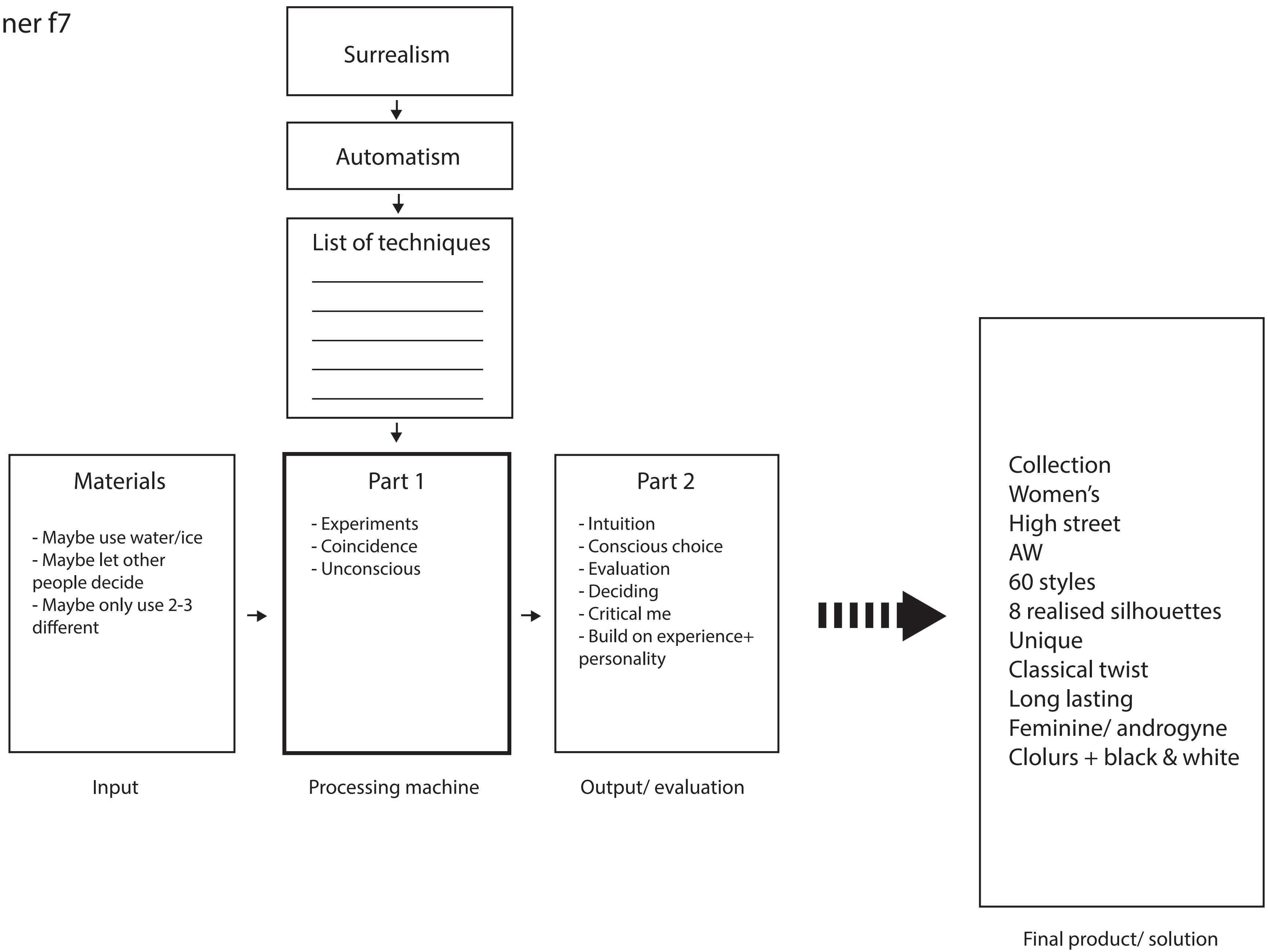


Mexican architecture
Casa Azul
inspiration
mood
more modern expression
Photos Andrea Gruetzner
Feeling
Bright colours
Architectural composition
Ornamented shadow
Familarity/ alienation
Modern/ vintage
mood
colours
How to combine?
Crochet table cloth
Ponchos, Mexican pictures
Grouped by
Materials from cupboard
?
?
?
?
?
Mood
Textile/ print
Details/ Trim
Colour
Shape (Don't know where it is)
Style type 1 e.g. Jacket
Style type 2
Style type 3
Style type 4
Style type 5
Techniques
Digital knit
Digital print
Form develop-ment
Collection for women
8 looks realised
30-50 styles
Bright colours
Architectural composition
Mix of surfaces and materials
Mexican mood
Sophisticated
Elegant
Modern
Small jewellery collection
Vera Vega
Persona/ Muse
Strong, independent woman
Elegant
Sophisticated
Feminine
Urban life
25-45
Sustainability in mind

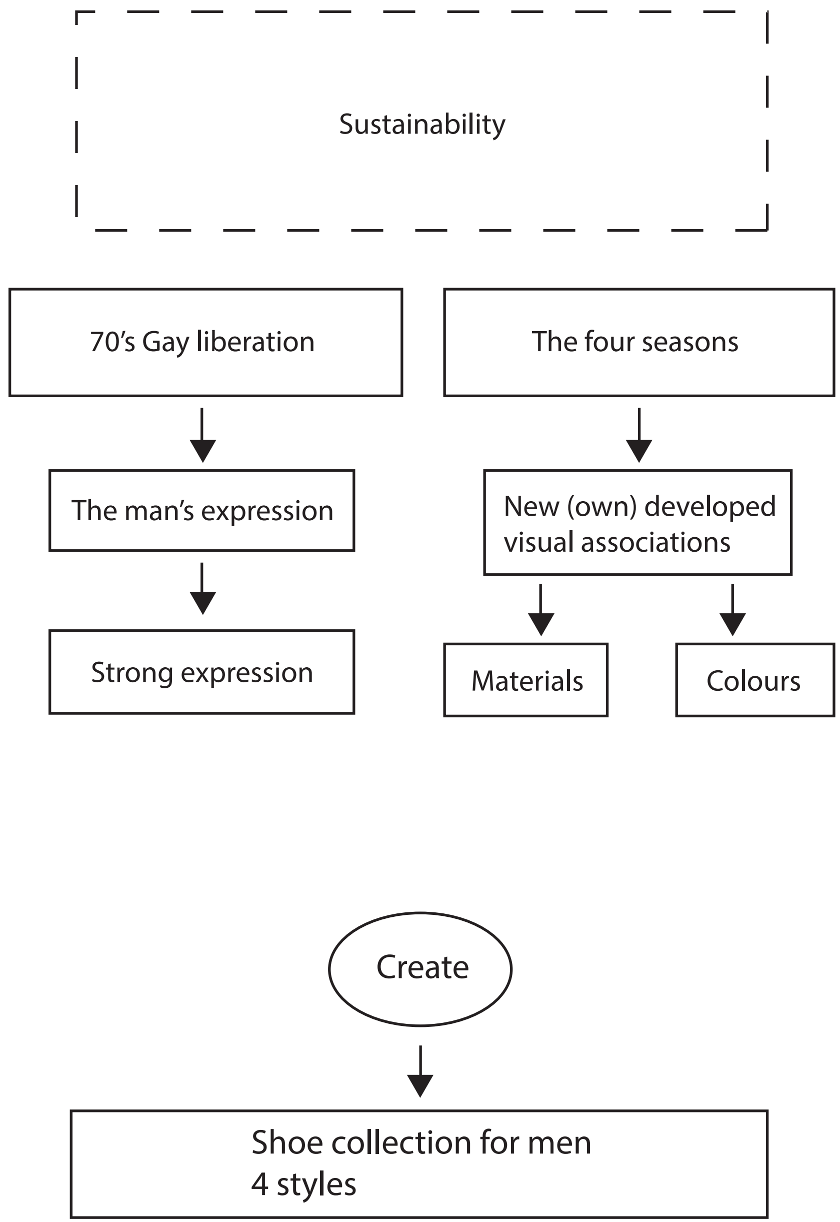
Designer f6


Input
Output
Past
Now
Future
Samsara
Tribes
Land-scape
Culture
Religion
Many landscape pictures
Balinese Dancers
Costume
Layers
Tech-niques
Details
only one
which do I like?
Teori
Metode
translation needed
Proporties:
Colour
Material
Shape
Details
Use:
Sport
Dance
- Perform
- Practice
-Chill
Sportswear Collection
Structure:
- 30 styles
- 8 realised
Coherence created through proporty choices
Context:
Scandinavian
Modern

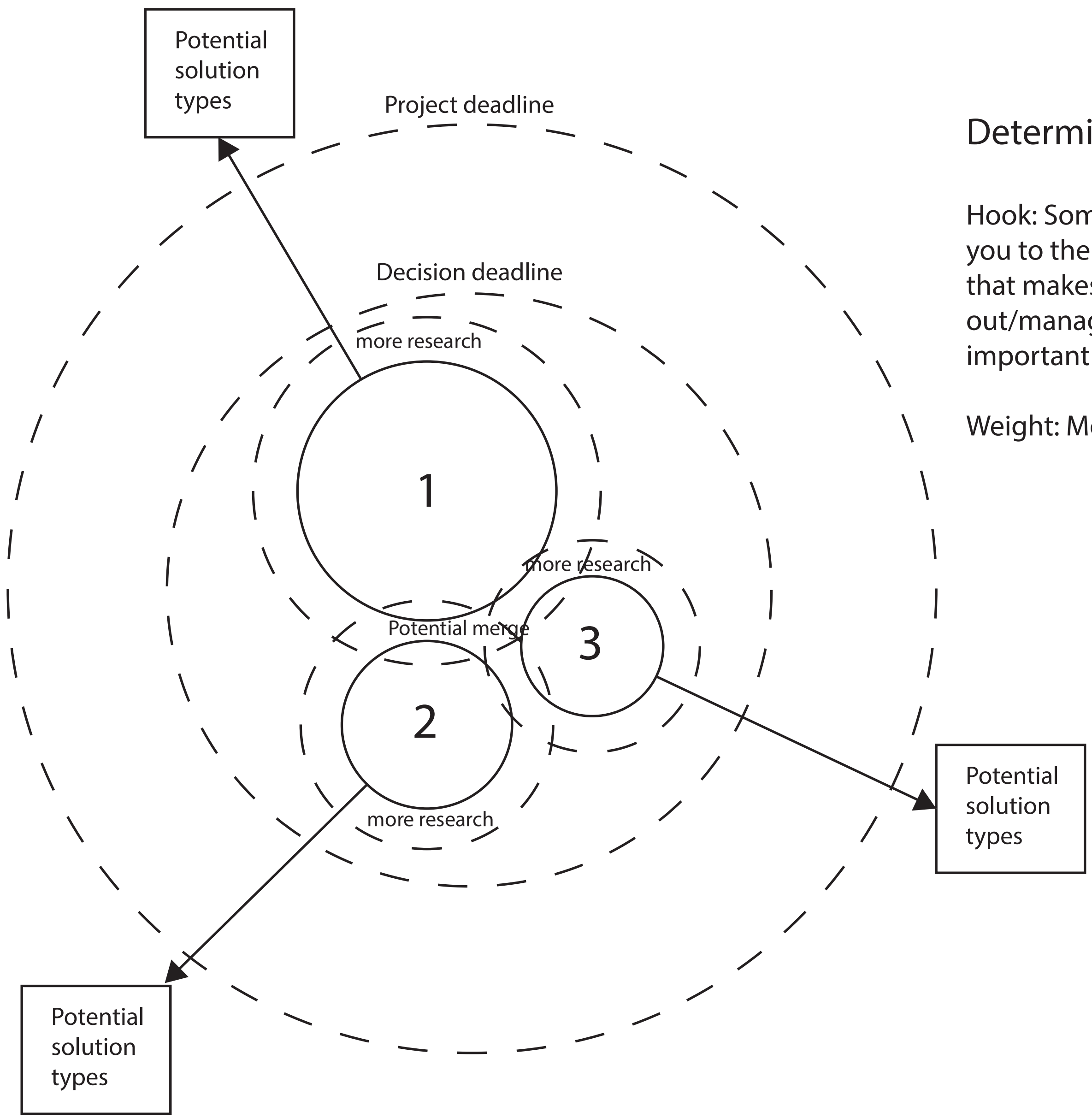
Designer f7


Surrealism
Automatism
List of techniques
Materials
- Maybe use water/ice
- Maybe let other people decide
- Maybe only use 2-3 different
Input
Part 1
- Experiments
- Coincidence
- Unconscious
Processing machine
Part 2
- Intuition
- Conscious choice
- Evaluation
- Deciding
- Critical me
- Build on experience+ personality
Output/ evaluation
Collection
Women's
High street
AW
60 styles
8 realised silhouettes
Unique
Classical twist
Long lasting
Feminine/ androgyne
Clolurs + black & white
Final product/ solution

Designer i8


Sustainability
70's Gay liberation
The four seasons
The man's expression
New (own) developed
visual associations
Strong expression
Materials
Colours
Create
Shoe collection for men
4 styles

Designer i9

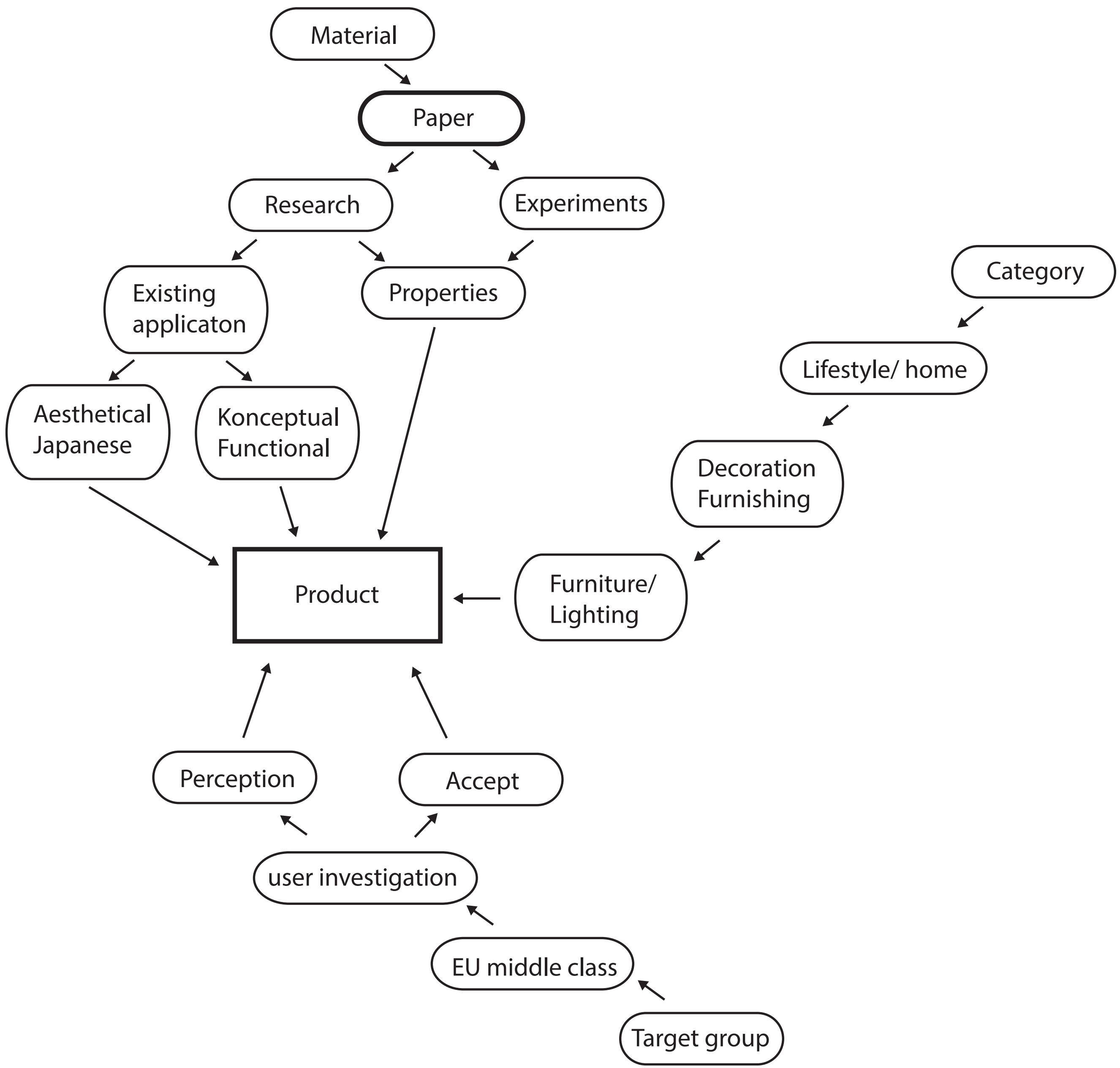


Determinators:

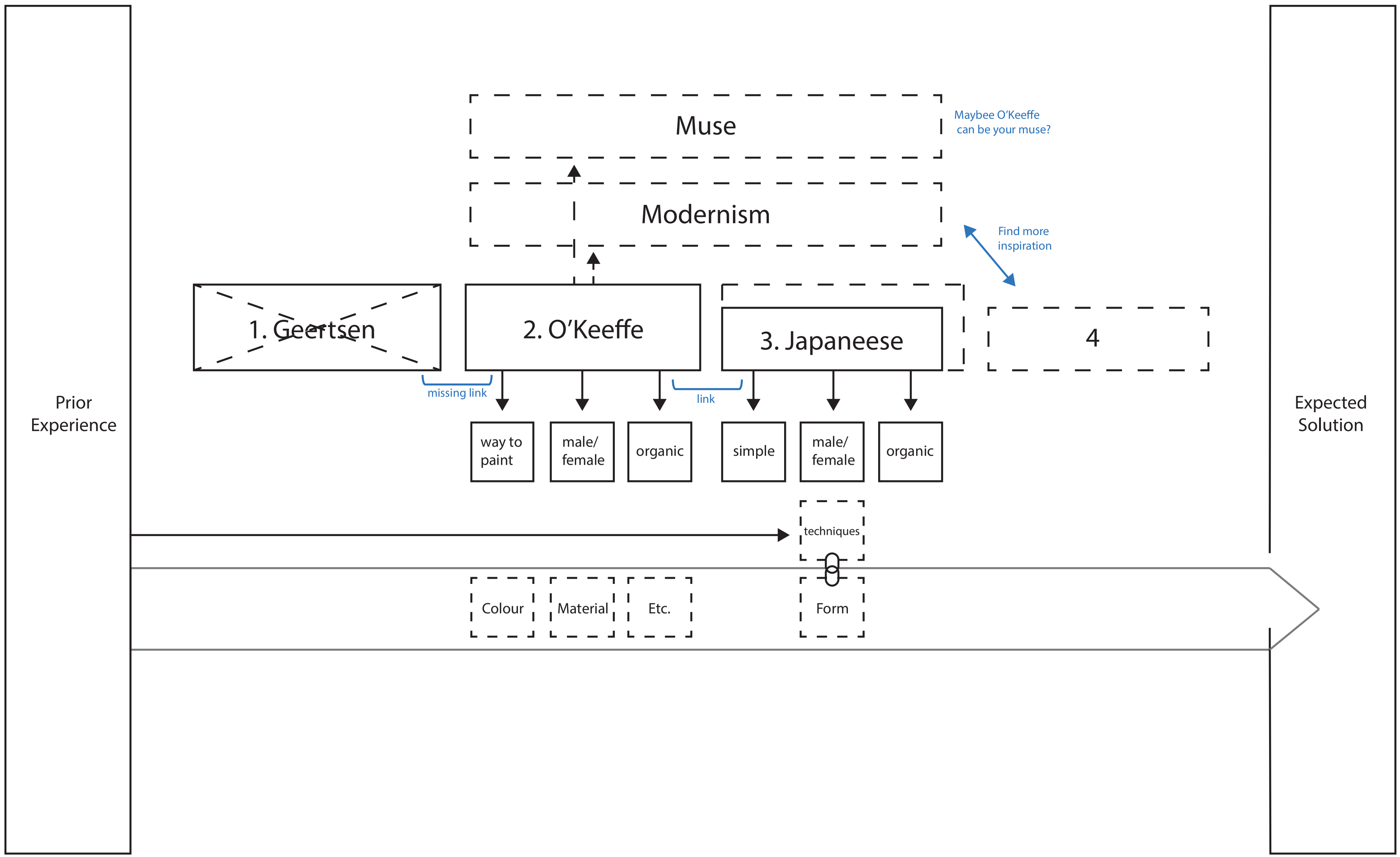
Hook: Something that hooks you to the project. Something that makes the project stand out/manageable/relevant/ important

Weight: Most interesting/ relevant

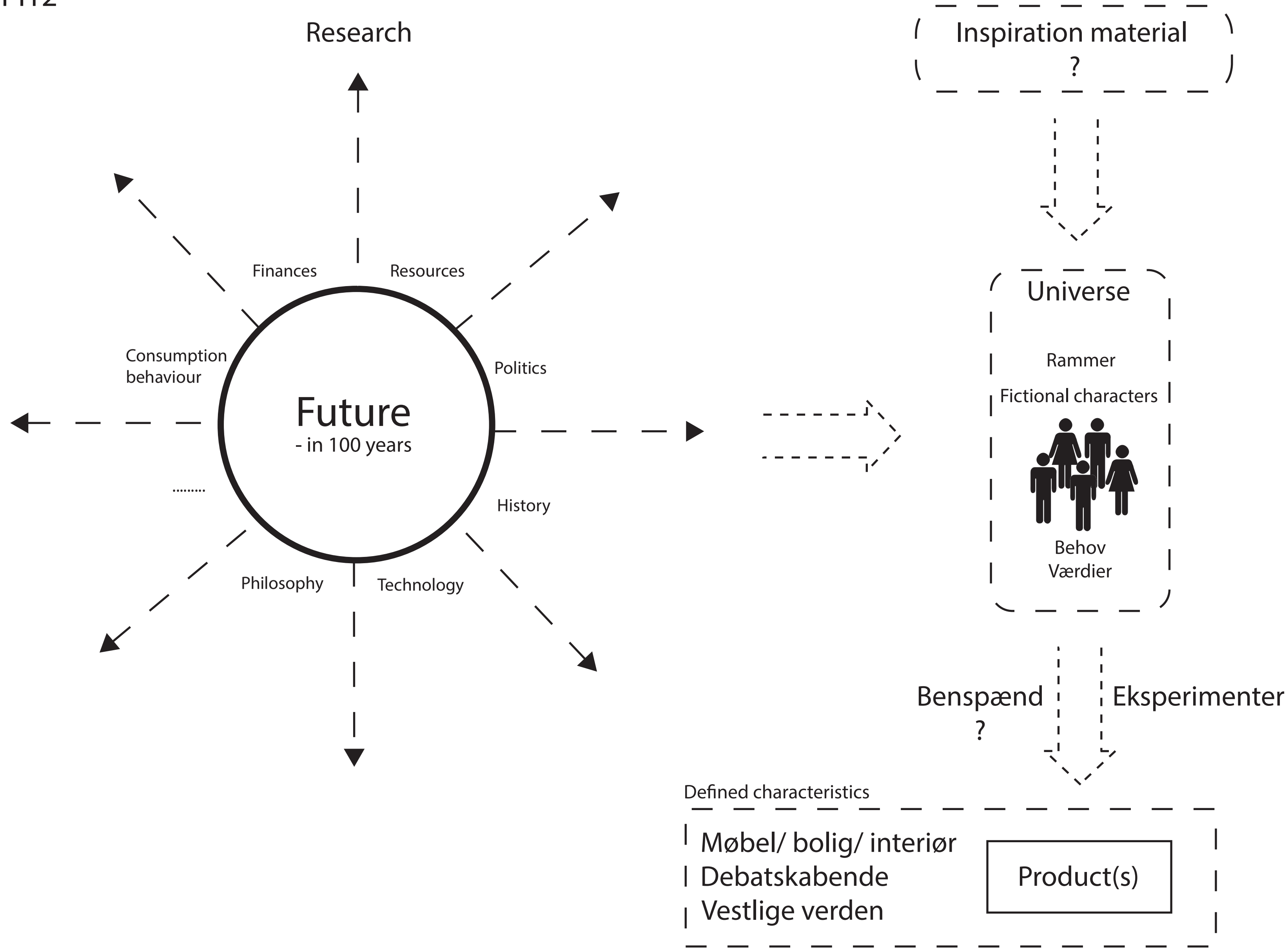
Designer i10

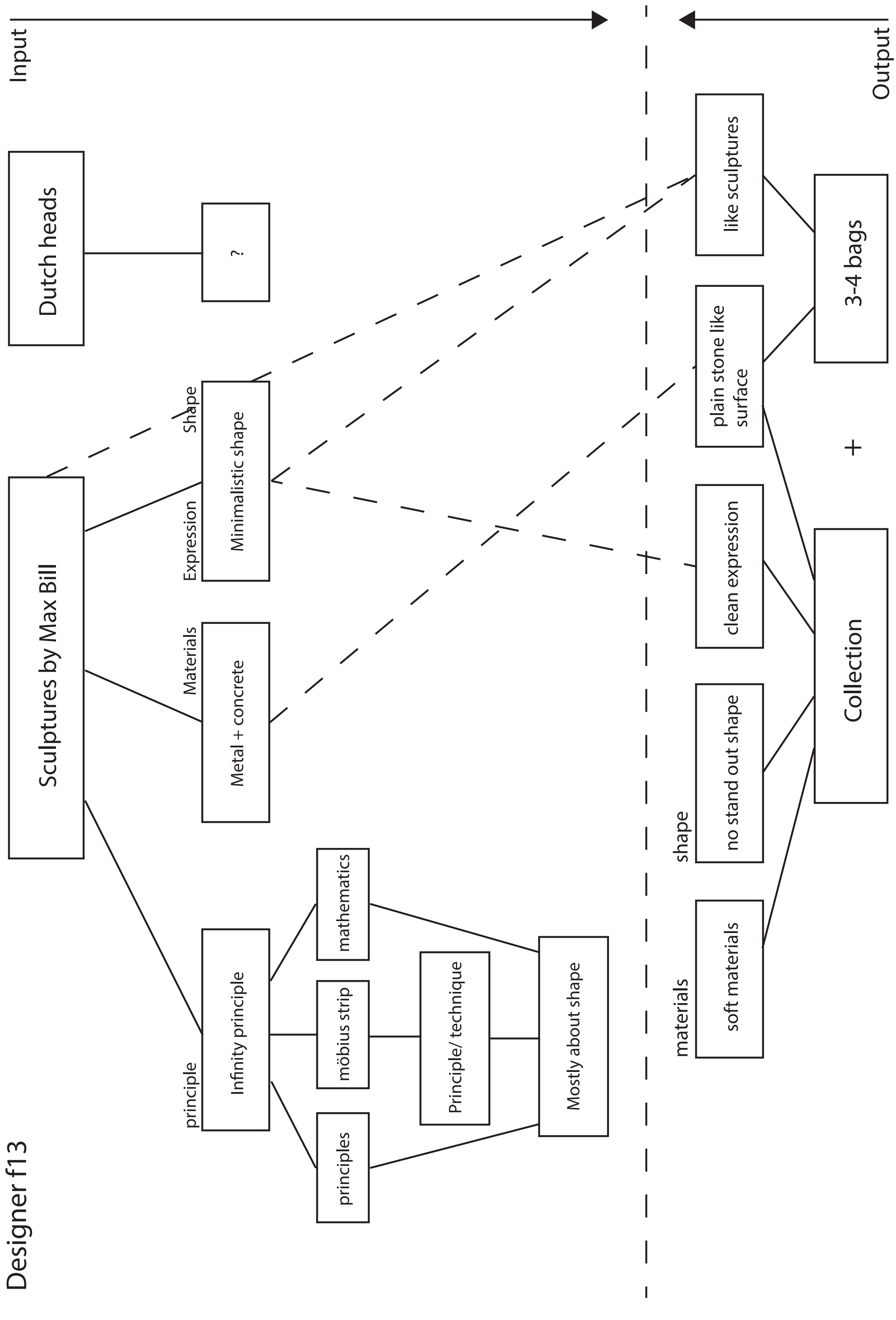


Designer f11

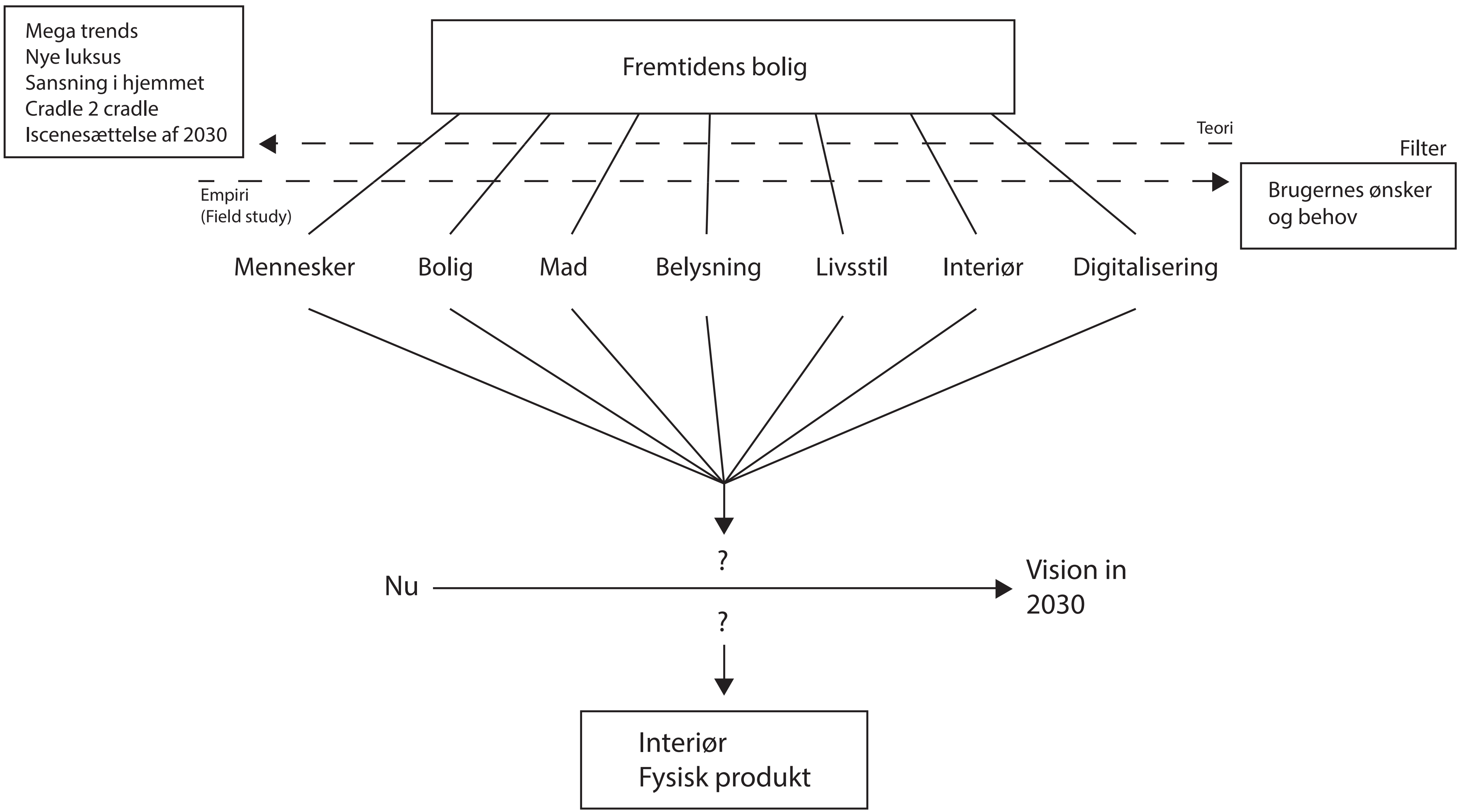


Designer i12

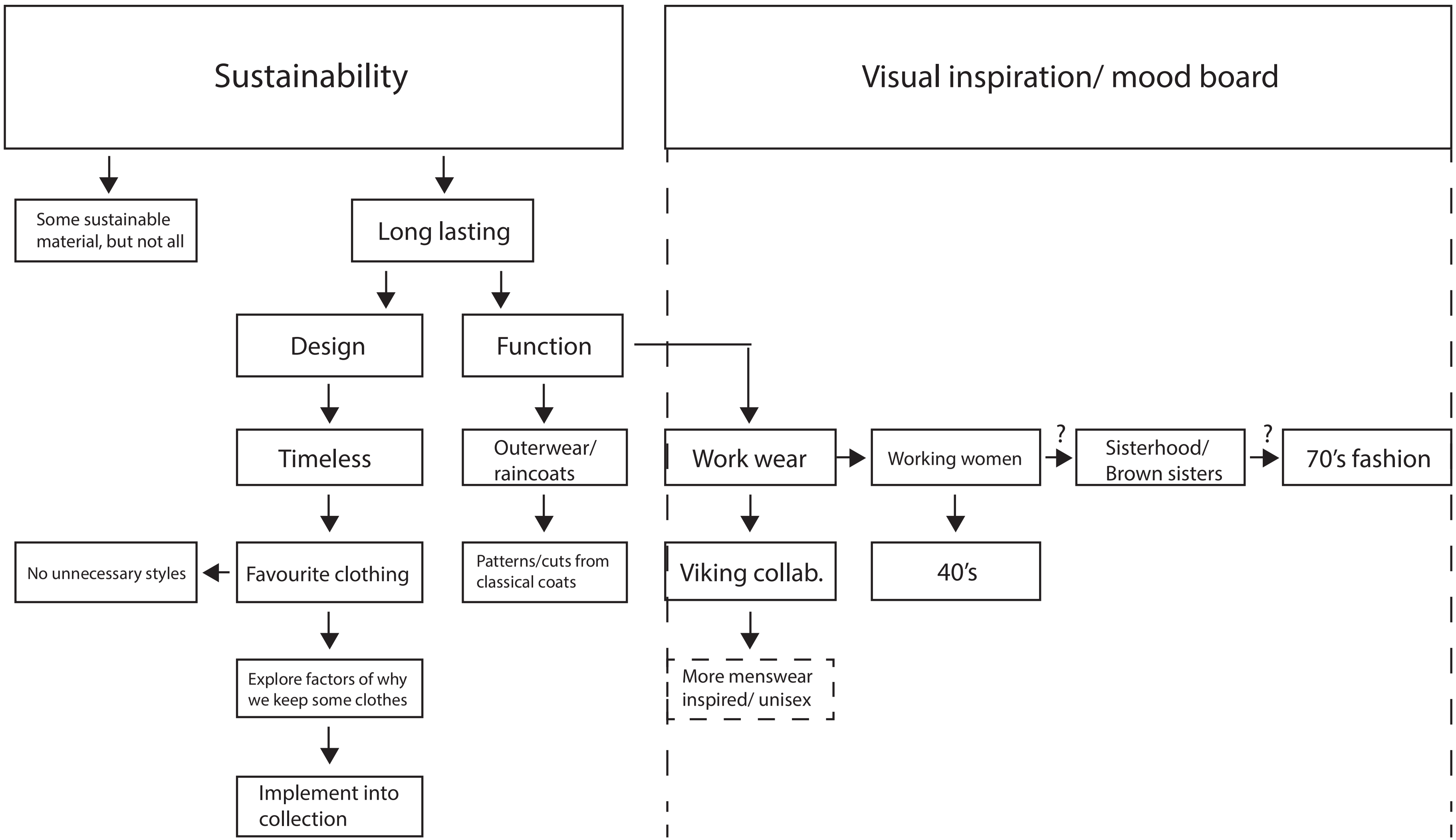



Designer f13
Input
Output
Dutch heads
?
Sculptures by Max Bill
Shape
Expression
Minimalistic shape
Materials
Metal + concrete
principle
Infinity principle
mathematics
möbius strip
principles
Principle/ technique
Mostly about shape
like sculptures
plain stone like surface
clean expression
shape
no stand out shape
materials
soft materials
3-4 bags
+
Collection

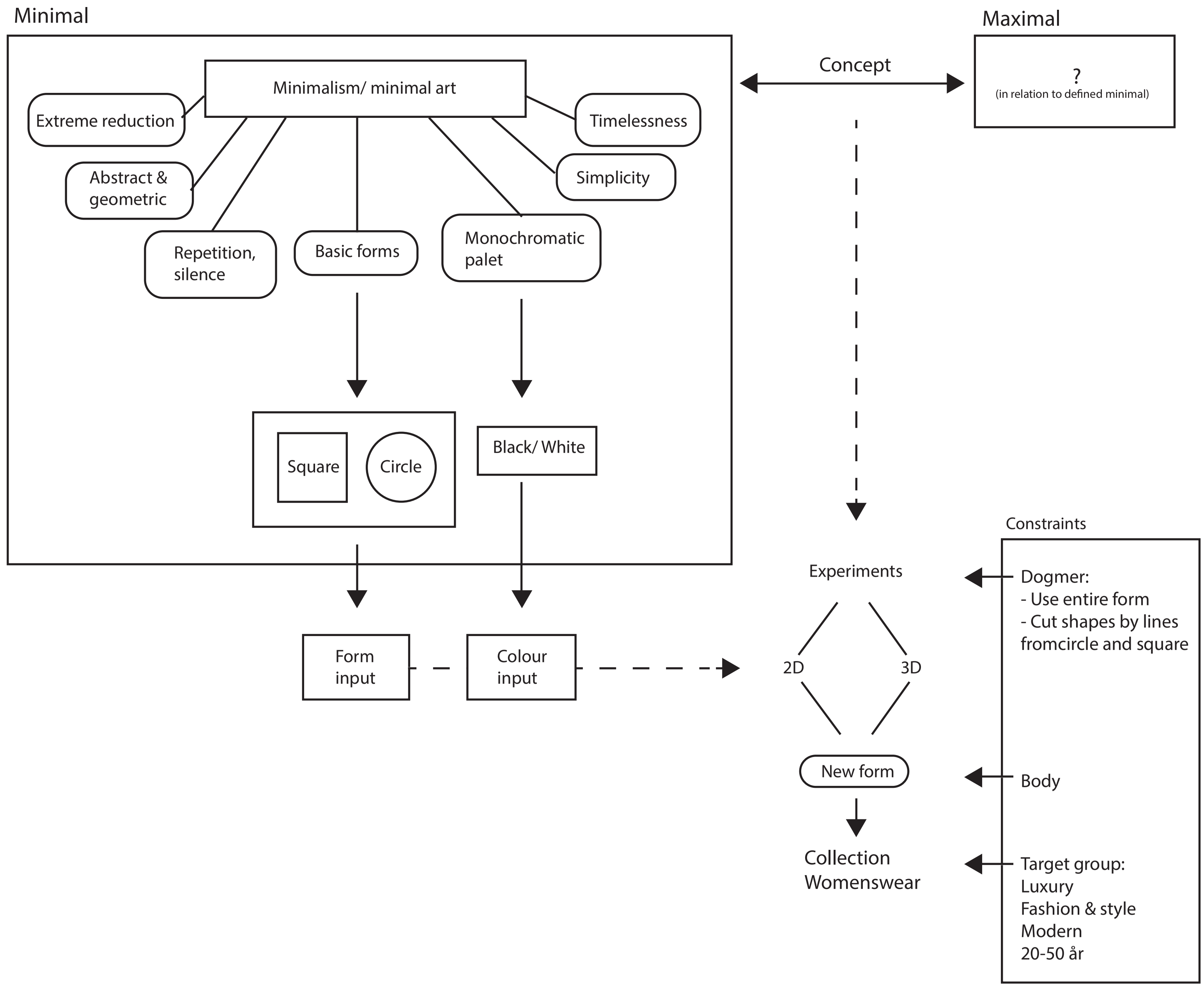
Designer i14



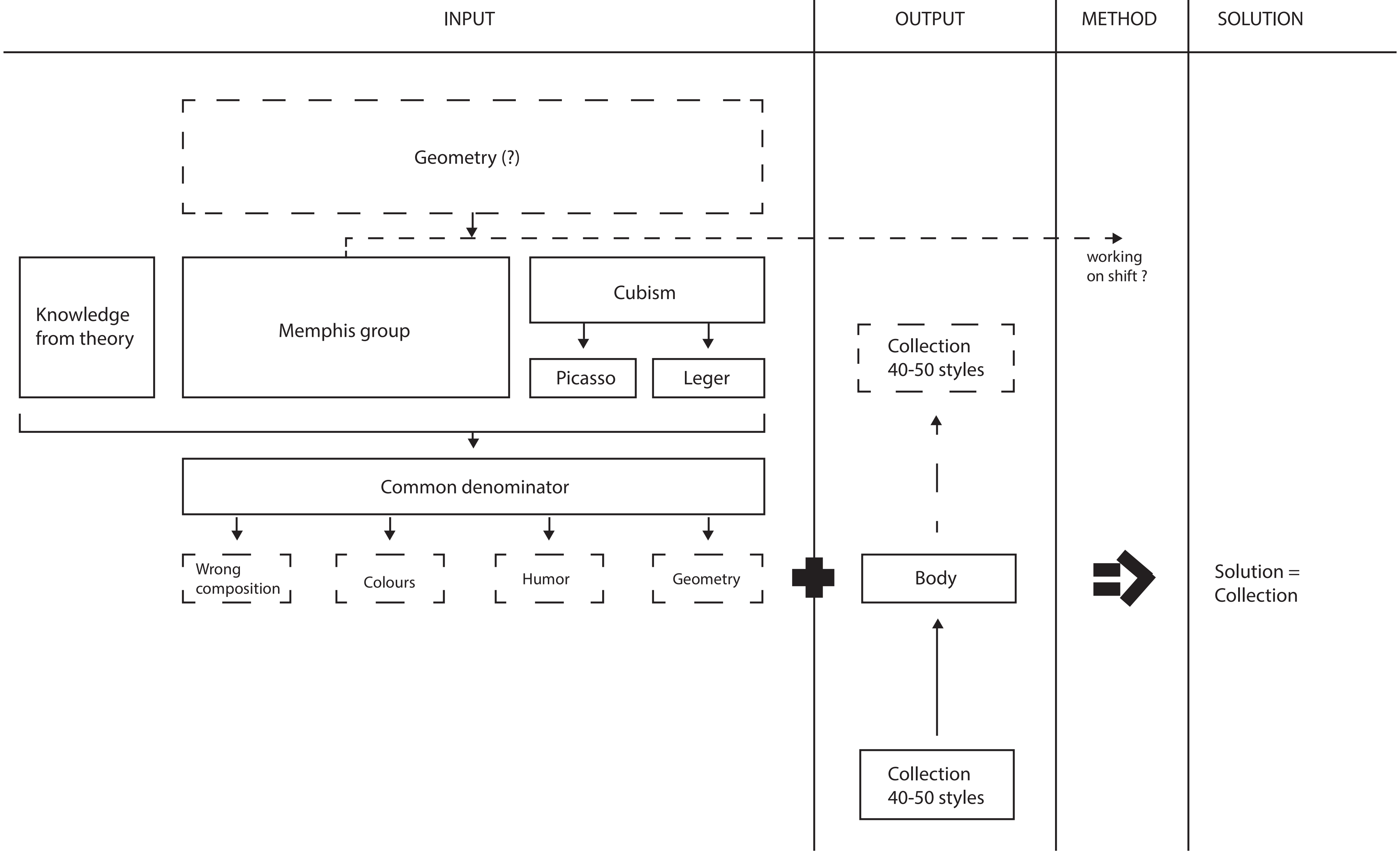
Designer f15



Designer f16



Designer f17



Appendix 5: Nomenclature

Nomenclature

This section features an overview and brief account of the concepts developed and introduced in this dissertation. As the dissertation text itself provides the best explanation of the concepts, the present account should be regarded as an abridged summary rather than a lexicon of concise definitions.

Chapter 6

Design System	A dynamic, conceptual system, the content of which is the information that constitutes the design task. The boundary of the system is the designer's perception of what information belongs to the task.
Task Taker	The person or 'equal group' (the members of which have equal task mandates) to whom a task is given or by whom a task is assumed. A task and its extent cannot be defined independently of the task taker's perception of the task.

Chapter 7

Information Entities	The 'things' that designers act and build with when designing. IEs can have different physical manifestations. IEs are the pieces of data that carry and represent meaning in the design process.
Themes	Themes are the meanings that designers ascribe to IEs (data).
Information Fluctuation	The fact that the information situation, as well as individual IEs, fluctuate throughout the design process.
Information States of Engagement	Information can assume, and shift between, three different states of engagement throughout the design process. These states relate to the designer's degree of resolution about how the information should be used in the design process.
Passive	The state of engagement state of IEs that have been sourced into the design system without any immediate, specific purpose or function of use. Passive IEs can be seen as a 'stock' of information, saved for potential later use.
Assigned	The state of engagement state of IEs that have been given a purpose or function in the design process. The concept of 'assignment' merely implies the intent or plan of use.
Activated	The state of engagement state of IEs when they are actually being used and activated in a function. 'Use' is understood in the sense that some action is imposed upon the IE to transform the content of the design system.

Information Density	The general load or quantity of information in the design system of passive, assigned and active information. The information density does not address the experienced quality or operationality of the information to spur process movement.
Informedness	The adequacy of the design system information (density and nature) to spur formative progress in the design process, as perceived by the designer. The design process can be well-, under- and over-informed.
Information Operationality	The level of perceived ability of a specific IE to be transformed in a design move by some action undertaken by the designer. The scale of operationality stretches from abstract to concrete, where the concrete can be handled directly and the abstract cannot.
Information Urge	The perceived *need* for information that occurs when the design system is under-informed. Information urge is what prompts designers to source information.
Information Sourcing	The act of bringing information into the design system. Sourcing involves two types of activities: discovering and choosing.
Discovering	The ways in which potential task information is found.
Choosing	The decision and the arguments by which IEs are adopted into the system from the discovered information.
Interpreting Information	The act of giving passive or assigned information an operationalisable form of perceived adequacy to be actively used in formation. This is done by subjective interpretation of the meaning and the function of an IE. Through interpretation abstract IEs can be 'broken down' into more particular or detailed IEs.

Chapter 8

ITO	An underlying structure of information functions needed to transform the design system content and 'move forward'. The functions are: Input, Transformation and Output.
Input	The existing situation or matter that the designer wishes to transform in the design process – the onset of change.
Transformation	The way an input is transformed into an output.
Output	The result of a transformation.
Information Familiarity	The qualities possessed by design process information, which by convention correspond to certain (emerging) output criteria. The degree of familiarity of the design process information determines the degree of 'typicality' or 'novelty' of the final design.

Chapter 9

Formative Development	The development and change in the design system content (information). Over time, formative development can involve the following three situations: Progression, Stagnation, Regression.
Progression	Progression is formative development through which the design system content and the emerging design changes from one state to a new state.
Stagnation	A state in which no or little formative progression is made. If the designer abandons further work along a course of development, a situation of stagnation can be deemed a 'dead end'.
Regression	The abandonment of a course of development and return to a former state of development from where a new course of progression can take off. Regression is the designer's response to experiencing a stagnation as a dead end from which no progression is deemed possible or productive.
Nonformation	A insight about what does *not* work or what is *not* desired. Nonformation cannot be used directly as building blocks *in* formation, but can be converted to information. A piece of nonformation is a 'nonformation entity'.

Chapter 10

Process Plan	Describes a future design process (chunk) that is imagined and planned by the designer, not in every detail, but in an abstract, conceptualised fashion.
Process Account	The conceptualisation of the design process that is post-rationalised by the designer when looking back at what has already happened.
Process Conduct	The actual, chronological design process in which formation progresses, stagnates and regresses, and through which the emerging design is developed. This happens in a series of consecutive action steps or 'moves' in which the designer applies action to matter.
Mirage	The designer's increasingly particularised mental picture of what the final design should look like.
The Design Salami	A model of design which combines a representation of the temporal extent of the design process (salami length) with the conceptual extent of the design system information (salami circumference). The information content of the design system can be expressed as a snapshot (salami slice) at any stage of the process.
Bringing Along	When information remains active along the process, either as an activated or an assigned IE, or as an active theme in the process account. 'Bringing along' implies an unaltered or only moderately altered transfer of information from one process step to the next.

Information Management	Information management means creating an overview of information, sourcing and discarding information, as well as accounting for and planning the process. This is done between moves in the process conduct. The purpose is to attain a coherence.
Coherence	Coherence is the perceived connection in the design process: between steps of development, and between information. Coherence between information can relate to the fit between information in the position state and the process account and plan, between different abstraction levels, and between activated, passive, and assigned information. Themes play a central role in establishing coherence.
Forwards Coherence	The process development is propelled, by the capacity of one process step to lead to the next. Thus, the connection between steps is pointing forwards. Forwards coherence is relevant to under-determined tasks, as the goal is not, or only vaguely, defined.
Backwards Coherence	The steps in the process development are inferred backwards from a defined goal, as perceived prerequisites for approximating this goal.
Derived Coherence	Relates to the direction of the link between an IE and a theme. In Derived Coherence, an IE is derived from or justified by a theme already perceived as part of the task.
Constructed Coherence	Relates to the direction of the link between an IE and a theme. In Constructed Coherence a theme is constructed in order to give meaning to and justify the sourcing or use of an IE.
Process Levels	The design process can be considered and understood on several levels representing a continuum of abstraction/concreteness. The highest level is the overall process level that spans the entire process. The lowest level is the operational level of individual moves.

Chapter 11

Design Syllogisms	The situations in which action is applied to matter (information) in order to transform it. Design Syllogisms conceptualise the moving mechanisms of design. The concept of Design Syllogisms comprises three types of experiments based on ITO: deductive, inductive, and abductive.
Experiment Series	The connection between a sequence of experiments. Experiment series can be tightly or loosely coupled. In a tightly coupled series the experiments differ only by the substitution of one particular IE in the entire sequence. In a more loosely coupled series, the connection between experiments is given by a shared relationship to a common theme.

Appendix 6: Models of design – full overview scheme

Appendix 6 is a digital file and can be accessed on:

- USB Stick
- https://www.designskolenkolding.dk/sites/default/files/download/appendix_6_design_model_review_full_overview.pdf

Appendix 7: My Iterative Research Process

My Iterative Research Process

In the research process I have worked iteratively between data studies, orienting concepts and theory generation. The rough sketch below shows how these iterations have unfolded in my actual research process.

Blue: Theory/ orienting concepts
Green: Empirical data studies
Red: Theory building activities
Black: Data collection

- From my previous experience I had learnt that design processes can be hard to grasp, and I discovered that the existing problem-focussed theory did not fit all design processes. Likewise, I had seen that designers impose constraints on their tasks.
- I wanted to study the design process and the role of constraints in this process.
- I hypothesised that the lack of constraints in a ’free’ task was actualising the constraint-imposing behaviour of designers aimed at changing the situation. I assumed that there was some kind of structure characterising this pursued situation.
- I conducted an explorative pilot study in which I interviewed a number of students, design professionals and design teachers.
- The explorative pilot study supported the idea and stressed the significance of investigating the handling of under-determined tasks in a transdisciplinary study of design.
- I conducted the pilot case study with 23 design students at the start of their Master’s graduate projects.
- With the concepts of problem and solution in mind,
- I analysed the data and
- visualised the cases in order to be able to understand and compare them. Some challenges and equivocalities were revealed as to how to understand the cases in these terms (See Chapter 9, section 9.2). I wanted to create an understanding of how design processes could be conceptualised in a manner that would embrace the seeming conflicts.
- The challenges encountered led to the study of the co-evolution theory.
- I analysed data with this theory in mind, but new problems arose: Statements can simultaneously be regarded as a part of the problem and (constraints on) the solution.
- A substantial amount of data/themes from a design process did not fit into the concepts of problem and solution, for example methods differ from what they are applied to and what they yield.

- This led to the questions: How can the actual data from design processes be clustered/categorised (inductively) in a non-paradoxical way? How does this relate to existing ways of analysing design processes?
- I started to pre-code data inductively.
- I chose ten students for further study during their Master's project design process; this data collection period lasted a total of six months.
- At the same time, I engaged in further studies of theory about problems and problem-solving in order to better understand these concepts. Among others, I studied Reitman and his vector-based problem exposition.
- I visualised Reitman's problem-solving theory and noticed some points of coincidence with the co-evolution theory. Likewise, I identified three different potential process conceptualisations (the H-model) but put them aside. I developed the provisional triadic co-evolution framework on the basis of the ITO distinction. Assuming that the design process would develop in some sort of interchange between the
- ITO categories
- I reverted to data analysis. It turned out to be difficult to code the data in that fashion – the categories could not encompass all the data.
- I learnt that there is passive and active information and that action and matter must be separated. Likewise I discovered that processes start out with different types of information corresponding to ITO, and that not all types are present simultaneously at all times.
- These new distinctions formed part of my further understanding of data, and from the concepts of action and matter to which action is applied,
- I started coding the data.
- I realised that if the matter of design processes should be divided into ITO categories, then this matter must be 'broken down' into smaller entities that could be segmented into these categories. Thus, I developed the concept of Information Entities (IEs) (replacing the term 'constraints') and the understanding that design processes are building rather than search processes.
- I found many examples in the data of designers' perceived lack of or 'overload' of IEs.
- I found that these perceptions revealed a structure of functions that IEs should fill, and that the ITO distinctions represented these functions.
- Meanwhile I had also engaged in studies of science theory and forms of inference,
- and I identified the similarity between the ITO functions of IEs and the functions in a syllogism.
- From the data, I noticed a special type of design action in which matter was put together to create something new and that this resembles what is often called an experiment.
- Schön's three types of experiments came to mind,

- And I recognised that they corresponded to the three forms of inference – deduction, induction and abduction.
- On the basis of the three types of inference
- I identified experiments in the data and analysed them.
- I developed the concept of Design Syllogisms to denote three types of experiments, based on the presence of ITO functions in the experiment.
- I worked further with the H-model of three process conceptualisations
- And analysed data on the basis of these concepts.
- I found that the three process conceptualisations (plan, process, and account) signify different understandings and functions of the design process pervasively represented in the data. I also discovered that the process consists of many syllogistic moves (experiments) and that the process can be conceptualised as the design process 'salami'. This led to the systemic view of the design process. Furthermore I learnt that the process must be differentiated at different levels of abstraction.

Appendix 8: Case Overview

Case Overview

The table below gives an overview of the cases in the primary study. The overview does not serve any analytical purpose, but is merely meant to provide the reader with an idea of the nature of the cases studied.

Designer[1]	Research Question[2]	Halfway Key Words[3]	Final Design Description[4]	Final Grade[5]
f1	How can I combine Mies van der Rohe's architecture and Le Corbusier's La Tourette Monastery into a modern clothing context?	• Le Corbusier • Monks • Material structure • Voluminous silhouettes • Grid & Patchwork effect • Slow fashion • Simple surfaces • 'Solitude' • La Tourette (monastery) • Repetition • Draping	Men's collection inspired by the contrast between modernistic architecture and the monk's dress. The collection is likewise centred on the concepts of the 'essential wardrobe' and 'sustainability' interpreted from a longevity perspective.	7

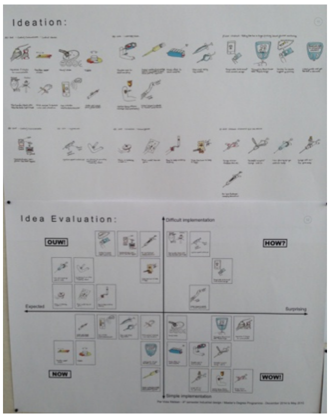


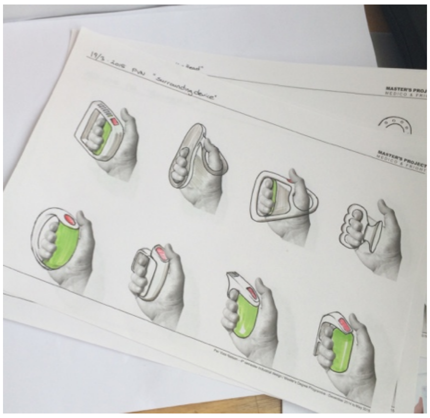
[1] The 10 case designers are assigned numbers between 1 and 10. The prefixes *f* and *i* stand for *fashion* and *industrial* design, respectively.
[2] The research questions, formulated by the designers themselves, are formed within the first month of the project, but can be modified throughout the process. As evident, the degree of specification and conciseness in the research questions varies.
[3] The designers were asked to write a list of key words that best characterised their project.
[4] My description of the design projects after their completion.
[5] On the official 7-point grading scale used in all state-regulated education in Denmark. The grades are shown only to convey the point that the projects all passed and were merited in the higher end of the grading scale.

f2	How can I frame a concept around the topic posture from which I can develop a collection? How can I develop cutting techniques from a sustainability thought? Which cutting techniques are both sustainable and complimenting for the concept of the collection?	• Distorted body • Another point of origin • Test of construction techniques • Julian Roberts (subtraction cutting) – focus on this • Shingo Sato (transformational reconstruction) • Possibly a concept within the concept about material choice: Classical men's wear references • Solely 3D-sketching • From 3D to 2D	Avant-garde women's fashion collection inspired by body posture and distorted body images. The design is centred on a draping technique, subtraction cutting, creating tunnels in the fabric. Specific to the expression is the use of foam as fabric.	7



i3	In what way can a medical instrument help reduce the fear of treatment and/or prevent new patients from developing new fears?	• Problem • Medico • Fright • Functions	A handheld communication device for dental patients. The device allows patients to communicate pain or fear to the doctor while in treatment.	12






i4

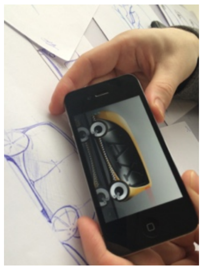
These days where an increased interest in self-driving cars is created by the car industry, businesses and leading countries , it is interesting to see whether the world is ready for this control stealing technology.
Are we ready to let AI take over and drive us around (…)? There is still an insecurity involved in letting go.
I believe that by implanting this technology into an automobile [experience] that is already 'self-driven' (taxis) it would be possible to accustom people to the fact that cars drive themselves and additionally get rid of the current problems associated with the taxi system (CO2, consumption, cheating, etc.)

- Form-giving of vehicle
- Scandinavia
- Polar bear
- Make the simple feel cosy
- Self-driving: the next big thing
- Electrical car: The school has worked a lot with it
- Taxi: The grand version of a shared car
- Volvo: big brand value, they have both self-driven and electrical programmes
- Collaboration: Hope to find a company so I can continue to work on this concept
- Products:
- App: Investigation of the system, how to, external help, now
- Interior: Experiments with users
- Exterior: Form investigation
- How to make models
- Build own 3D milling machine
- Connection with theory
- How to explain choices of form

Design of a car as well as a service system for self-driving taxis.

4





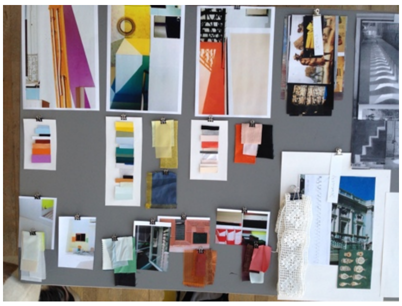
f5

How can I combine the colours and mood from Andrea Grützner's series of photos with the crochet tablecloths and also implement the feeling of familiarity and alienation in the design and transform it into a new modern collection for women?

- Colour
- Colour composition
- Mexico: clothes, poncho, architecture, colours, atmosphere
- Shadows (lines, creases, drills, stripes, pleats)
- Alienated familiarity
- Itten's [concept of] colour harmony
- Joseph Albers' colour combinations
- Big cuffs
- V-neck
- Contrasts
- Modern ornamentation
- Graphical shadows/ draped shadows
- 1990s silhouettes/ Mexico
- Ethnical twist/ sporty reference/ elegant

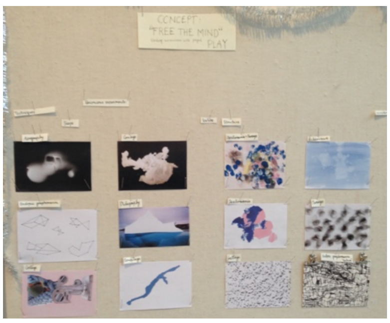
Women's fashion collection inspired by a photo series by Andrea Grützner and Mexico for strong, sophisticated, feminine urban women. The collection has a 'modern gypsy' style, and is centred on colour composition.

10



f6	How can I transform my inspiration from 'Samsara' and combine it with sport and dancewear and create a collection that consists of cool and functional styles that complete the wardrobe of a professional female dancer with an active and urban lifestyle?	• Sportswear/ Dancewear • Function, practical • Cool, feminine • Performance >< lifestyle • Balinese world • Ornament patterns >< modern/ sporty • Streetwear • Practice • Active lifestyle • Sports/ dancewear with a twist • Futuristic/ funky • Colourful/ playful	A women's collection at the frontier between functional dance wear and avant-garde fashion, inspired by Bali and Balinese dancers.	N/A (passed)


f7	How can I shape and create a process that is controlled by coincidence and unconsciousness? In what way will my intuition and consciousness play a role in the final outcome of the project? How can I transform these unconscious experiments into a wearable collection?	• Automatism, Surrealism (Theme/concept) • Constraints (method) • Conscious/ unconscious decisions (method) • Experiment based (method) • Abstract form (findings) • Ready-to-wear (result) • Symmetry/ asymmetry (findings) • Convert the abstract to wearable (findings – the 'problem as such') • Shape/colour/ textile, material (findings) • Childish approach (method) • Embrace chaos and irrationality (method) • 'Mood books': division of project (method)	Women's wear collection inspired by a visual universe, which has been explored and developed by means of Surrealist art automatism techniques aimed at setting aside conscious choice.	10



i8

I want to interpret the consequences of the [1970s] gay liberation and look at what it has given the man and his personal expression in terms of style. Furthermore, I want to explore how the concept 'liberation' can be involved in other ways in my graduate project. What is 'material liberation'?
How can I create a shoe collection for men with focus on materials that has its starting point in the 1970s 'liberation', forms and colours, interpreted in a contemporary/ future perspective?
I want to focus my shoe collection on associations (metaphors) of the four seasons of the year and on the basis of this create a modest, sustainable collection, in which every shoe, material-wise, is adapted to the individual season.

- Gay liberation
- 1970s
- Four seasons
- Modest
- Sustainable
- Metropole
- Men
- Style
- Dandy culture
- Li Edelkoort
- Else Skjold: *The Daily Selection*
- Individualism

A men's shoe collection, the design of which explores and employs various sustainability approaches. The shoes are inspired by the classic dandy style and the four seasons.

10

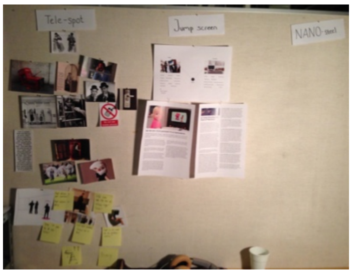
i9

How can telephone calls be isolated from the surroundings so that their impact on them and from them can be reduced as much as possible?

- Start: Tele-spot, Nano steel, Jump screen
- Research
- Gut feeling
- External input
- Idea about end product
- Motivation
- Acoustics
- Development in office environment
- Telephone conversations
- Confirmation, verification
- Idea generation, test
- Decision, define concept
- Form:
- Meaning
- Auditive world
- Nature reference
- Final product, present, test

A piece of modular shielding furniture for open office environments aimed at accommodating both the need for privacy and interaction. The furniture is inspired shape-wise by the golden section and the spiral.

7



i10

How can paper be used with greater relevance and be accepted as a life style material for the future European house decoration?

- Paper as material
- Perception
- Living, home – new function
- Production techniques
- Craft
- Denmark
- Japan
- Paper yarn
- Moulded paper
- Massive cardboard
- Experiments

A room divider, the design of which explores paper as material in the context of house decoration. The room divider is made of paper yarn and pulp stiffly entangling an 'invisible frame'.

12

Appendix 9: Analysis and Coding Examples

Analysis and Coding Examples

In the following I will provide elaborated examples representing excerpts of the analysis and coding procedures of the research process. The examples are presented as a series of research iterations which succeed and feed into each other in chronological order (on a given level of abstraction and detail). Yet, not all themes and concepts, found in each round of analysis, do necessarily feed directly into the next round – some are stored in and added to the accumulated stock of 'information' in the research process, and (potentially) resumed later.

Just as a design process can be viewed on different process levels (Chapter 10.4), so can an explorative research process. The iterations shown here go more in depth and have a lower level of abstraction and a higher level of detail than the more general pattern of data analysis illustrated in the method chapter, Chapter 2.

The exemplified analysis and coding procedures were carried out from June 2015 to March 2016 and thus span only a fraction of the entire research process, which, in line with the adaptive approach, involved analysis and theory building all the way through.

The examples of research iterations shown in this appendix focus on theory emergence from data and thus leave out most accounts of how extant theory has influenced the development of the research contribution.

The coding schemes and notes rendered in the following examples are in a combination of Danish and English.

Theory emergence/prototyping

In Chapter 8, section 8.2, I account for the development of the 'Triadic Co-evolution', which consists of the concepts: I (information), T (transformation), and O (output).

The Input space comprises input for the design process, e.g. knowledge and inspiration material. These are the things in the design process that will be subjected to transformation (in a cooking analogy, the potential meal ingredients).

The Transformation space comprises the tools, e.g. the techniques and methods with which to transform the material (in a cooking analogy, the cookbook of recipes).

The Output space comprises the requirements, ideas and conceptions about the nature of the design output and the solution (in a cooking analogy, the character of the imagined meal).

Likewise, the 'Triadic Co-evolution' framework involves the idea that ITO represents three 'spaces' that 'run in parallel' along the design process and characterise its development.

The framework emerged from the conceptual combination of Reitman's problem-solving theory and the theory of co-evolution in design (Maher, Dorst & Cross). This framework served as a tool to catalyse the analysis process.

One of the reasons why the framework was deemed interesting as a prototype for the data analysis was that the ITO categories seemed to hold the potential to underpin some casual observations that were made while collecting the data.

Deductive analysis/test

Using the 'Triadic Co-evolution' framework as an analytical tool, I started coding one of the ten selected cases, since it was perceived to be rich in data. This case was analysed in depth to test (several iterations of) one analytical model.

The coding categories were: Input (the material that is (to be) transformed); Transformation (the method of transforming) and Output (the desired/required result of the transformation).

By colour coding (yellow for Input, Green for Transformation and Pink for Output) and cutting up the text, I tried to determine which part of the data would reside in which category, and I attempted to place the text pieces accordingly in a tangible ‘Triadic Co-evolution’ map (see Figure 1).

The coding was based on the definitions described above. ‘I’ was assigned to aspects that were interpreted to be inspiration material or other types of research input, for example pictures, costumes and layers. ‘T’ was assigned to comments about techniques, methods or mentioning of (intended) actions such as to “dig in”, “combine” or “focus” – actions that were perceived to relate to some methods or simply ways of doing something. ‘O’ was assigned to statements about desired features of the final design, e.g. that it should be a sportswear collection structured in three parts: Performance, practice/training, and chilling.

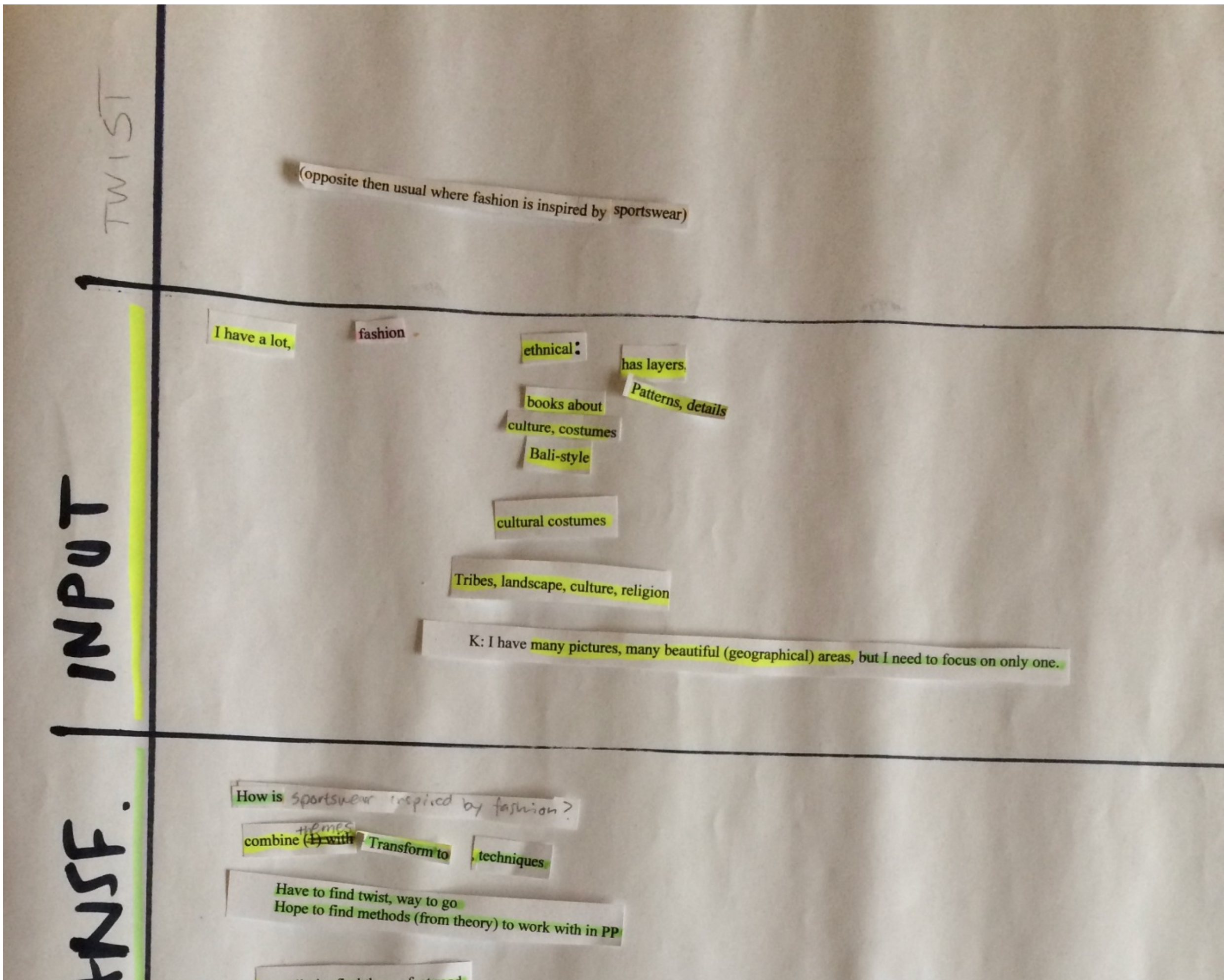


Figure 1: Coding data transcripts deductively by colouring, cutting, and placing text bits in orienting categories

Inductive analysis/insight

During this coding procedure I encountered some issues that challenged the analysis strategy. These challenges consist of insights that arise inductively from the data. They represent the 'back-talk' of the data, as they guide my attention to specific elements of data that stand out or contradict the framework by which I seek to make sense of them.

As shown in Figure 1, many pieces of text did not fit unequivocally into one category. In each of the three tracks we can see colours that belong to another track.

Through the analysis, a specific theme, the 'twist', arose inductively and was added to the map. This can be seen on the top of the picture. The 'twist' concept relates to, and has later fed into the emergence of, the concept of 'familiarity', which is described in Chapter 8.

This method of coding did not persist unaltered for very long, as I came to realise that concepts can change character – and hence category – as the design process evolves. This is described in the following section.

Theory emergence/prototyping

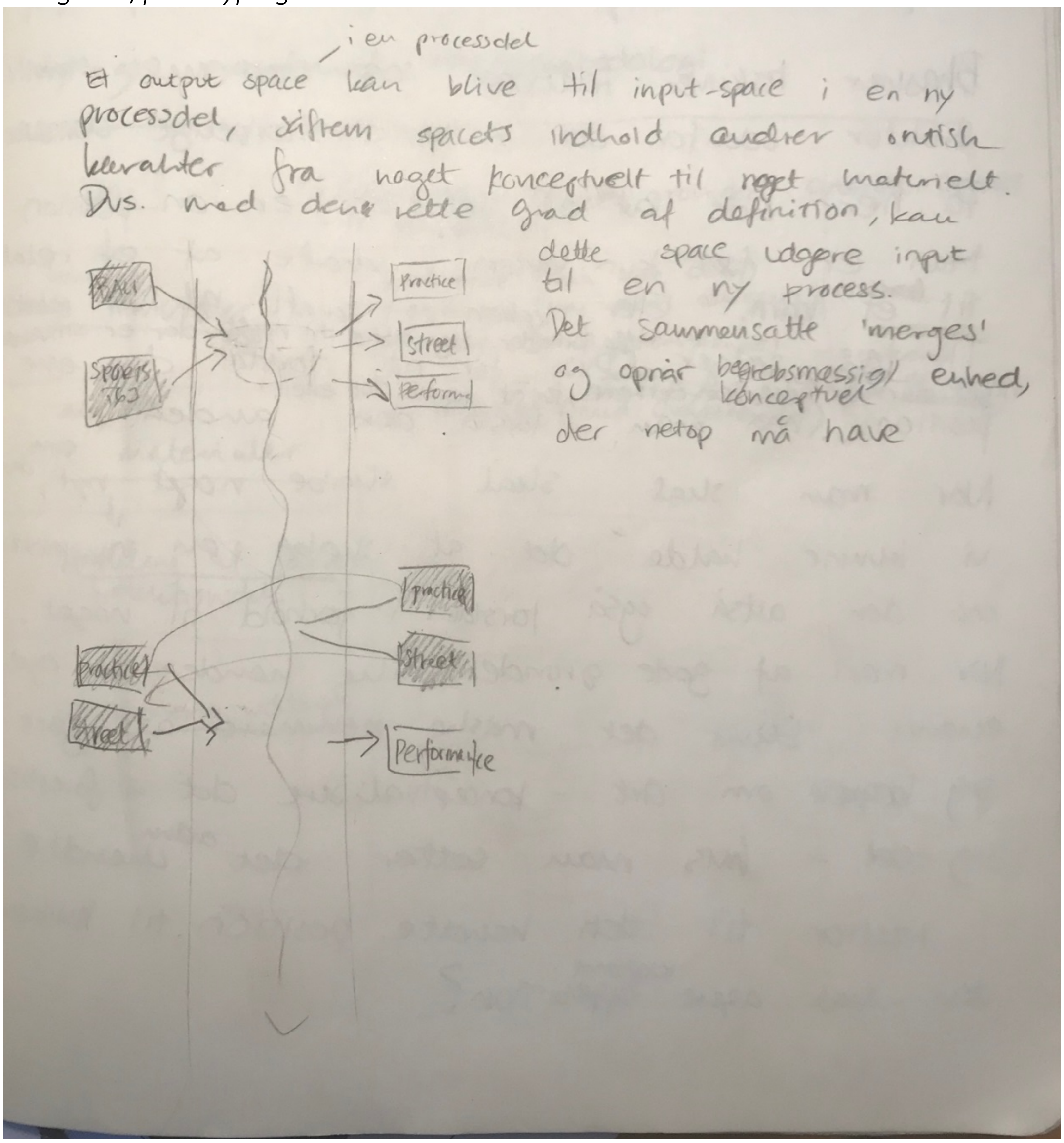


Figure 2: Log book notes

This log book page (Figure 2) shows some of my considerations with regard to the analytical framework. The notes, which are speculative in nature, read that *"An output space in one process part can become an input space in another process part, insofar that the content of the space changes character from something conceptual to something material, i.e. with the correct degree of definition, this space can make up the input of a new process. The combination (of things) is 'merged' and achieves conceptual unity (...)"*

The drawing illustrates my considerations about how certain aspects or elements of the design process can shift character in relation to the ITO concepts. The 'stream' drawn in the middle represents the processual development in which these aspects or elements aggregate, and out of which the design consequently emerges.

In light of subsequent realisations, this drawing implicitly points to a couple of issues and emerging insights: There is a 'stream' of development that is distinguished from the concepts of ITO; and there is (a need for) some yet undefined conceptual framing of those aspects or elements that are perceived to be able to shift between I, T and O (what I shall later define as Information Entities).

To accommodate the observation that aspects or elements can shift between the I,T and O categories, I altered my way of mapping the data, using post-it notes instead in order to gain more flexibility.

Deductive analysis/test

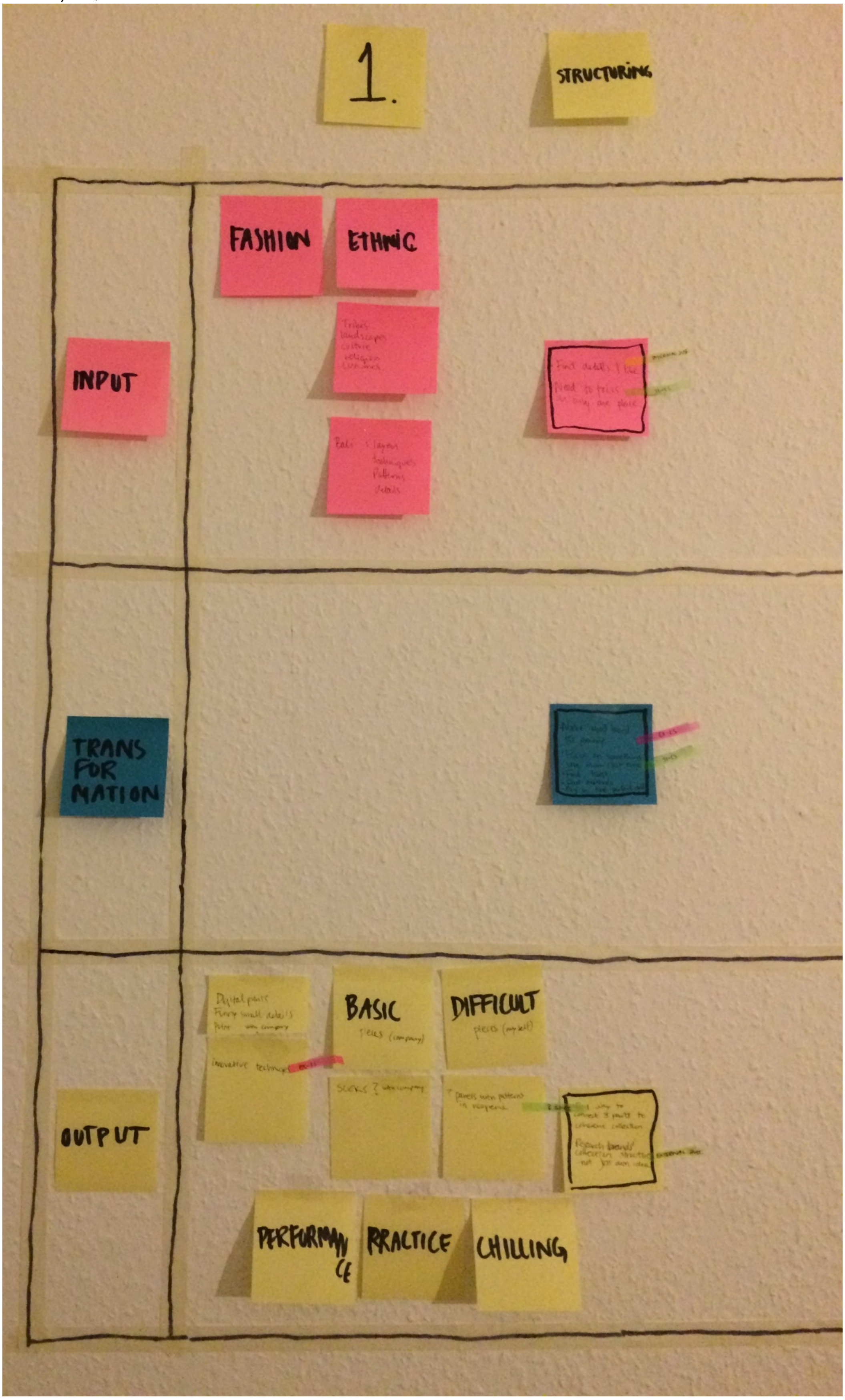


Figure 3: Coding data elements in the Triadic Co-evolution framework

This part of the analysis was carried out on the same segment of data as the previous one and was basically structured like the previous analysis. Also, the way of assigning data to the categories, I, T and O was similar to the previous approach. However, as the photo in Figure 3 shows, I try to identify and condense some elements or aspects of data, as compared to the previous analysis map. The identification of these elements is based partly on the inductive pilot case study analysis, in which I started to notice specific distinctive concepts.

Each element has been given its own post-it note. Some core elements of the design process, perceived to stand out in the data, are marked with bold text on individual post-it notes. Below some of them are other post-it notes representing perceived sub-elements of the core ones.

Inductive analysis/insight

In this round of analysis, as shown in Figure 3, the framework has been extended in several directions. A number of analytical elements have been added, as prompted by the data.

By identifying core and sub-elements in the coding procedure, the conception of some hierarchy is tentatively proposed (which could be seen as a preliminary state of the proposed conceptual distinction between themes and data).

An example of added codes, which falls somewhere in between deductive and inductive analysis, is the thin stickers that have been attached to some post-it notes. These indicate identified imposition of constraints: self-imposed (green) and externally imposed (pink). As the research was initiated with the aim to study the role of constraints in (under-determined) design processes, the concept of constraints is fundamentally orienting for the analysis – at least in the earlier stages of the research process. The yellow stickers indicate that some constraining principle is mentioned in relation to how decisions should be made or choices justified: From a subjective preference or an objective argument (which sows the seed for the Choice Justification types in Chapter 7.6). In relation to the green and the pink stickers, the yellow stickers represent an early step towards zooming out from the constraint perspective towards a fuller picture of the context in which they play a role.

The yellow post-it notes above the frame introduce the numbering of ‘phases’ and ‘structuring’ along the horizontal process line. This division came from the emerging observation that the data have different characteristics: some relate to elements that seem to already be ‘part’ of the design process, e.g. ‘ethnic’, ‘Bali’, digital prints’ and ‘collection’. Others relate to what is not yet there – what is missing – and what should be done. The statements that are clustered under the ‘structuring’ headline on the out-lined post-it notes are for example *“need focus”*, *“find details I like”*, *“find methods”* and *“do research on brand.”* They are called ‘structuring’ because they seem to revolve around some sort of existing ‘content elements’. The statements indicate that designers can perceive that elements are missing in the design process (this is described and exemplified in Chapter 7.2).

The division and shift between a part of the process relating to existing elements and to a ‘structuring’ part in which some elements may need to be supplied, draw the initial contours of the dynamics of the design process (these are later described as the shift between moving and managing information (Chapter 10).

In parallel with obtaining these insights from the testing of the framework, I coded the data inductively by noting and extracting concepts and themes that are immediately apparent when reading through the data transcript, for example, themes that are found to be recurring or that are perceived to have the potential to bring qualitative insights to – or otherwise relate to – the research topic.

The following excerpt (Figure 4) shows a list of these concepts and themes (in a combination of Danish and English) that I made while reading though the data.

Analysis themes
(bracketed or red = my comments)
blue = from theory

Themes

1. **Finding twist/gaps: way to do something new:**
    - Sportswear inspired by fashion as opposed to (normally) fashion inspired by sportswear
    - Need to find twist (missing twist information?)
    - Maybe Problem has an implicit ideal. And Creativity has an implicit discrepancy/anti-ideal (providing discrepancy to create problem)
    - Is it related to the concept of the project?
2. **Concept:**
    - main argument for all other choices
    - overordnet koncept = main goal ((at lave) sports Wear/dance Wear)
3. **Looking for way to interpret visual (input) material into method (transformation):**
    - Bali style has layers – could use some of the techniques
4. **Looking for way to interpret visual material (input) into output information:**
    - (Supervisor) The Bali styles are funny, absurd in their context (expression)
5. **Criteria for choice/narrowing down/evaluation = preference:**
    - ”I must figure out which details I like”
6. **Combining input/transformation/output (problem statements)**:
    - ”How is sportswear inspired by fashion?”
    - ”How can I transform my inspiration from *Samsara* and combine it with sports- and dancewear to make a coherent collection?”
7. **Structuring of single tracks: Local input-transformation-output in single track. Maybe it is structuring of problems, like small problem statements:**
    - I want to dig into every detail of my universe and explore and visualise my inspiration into mood boards, colours, material (Input track)
8. **Looking for internal justification for choice:**
    - I must figure out which details I like.
    - Will draw/sketch from the silhouettes I find interesting
9. **Looking for external justification for choice:**
    - Supervision conversation:
        - K: I'm thinking of meeting up with gymnastics/dance team *(input)* and research (*transformation)* what they need. What are important elements in a dance collection *(output)*?
          It should not only be my thoughts about it *(external*

argument/criteria)

  - N: You could also analyse a sports brand (input), do some user/business research (*transformation*)
  - K: Yes, how do they build up their collection?
    That would also give me an argument for why I do what I do – then it's not just my own universe. *(Looking for justification of choices, external argument/criteria)*.

- Is this the same as providing arguments?
- I-T-O is (maybe) like the structure of arguments?
- Is it (6) like I-T-O or is it like inferences? Is that the same? (Is design process like one big inference?)
- Link between argument and constraint. SI-CS can be justified by both internal sources (preference) and external sources (associations/relations/parallels – e.g. how other brands build collections?) Some specific kind of choices might (by convention?) have to be justified by external sources
- Maybe it's analogising: when a designer referred to another base of knowledge to explain, create, modify or evaluate a design (Wiltschnig et al. 2013)

10. Forming links between *specific* space elements of the process I-T-O:

- Look at *patterns and details* and transform to *digital prints or funny small details* (transformation is missing. Link between I & O)
- Bali dance costumes is where I will find inspiration for silhouettes (transformation is missing. Link between I & O)

11. Constraint themes (self-imposed):

- Make up a Muse/Persona to find information for output
- Do something different from last time (correct/learn from earlier mistakes)
- Do something in a certain way to make it easier (so it can be done by the designer herself instead of others)
- Do something similar to a previous project (to repeat success): "In my last PJ I drew a lot of different stuff, then afterwards I divided it into groups and tried to develop (the collection) from that. I will do that now (in this PJ) too."
- Not thinking too much (automate/make unconscious choices) How do designers set aside thinking?
- Use material I have already
- Making choices that determine other, later choices. Level up choice in hierarchy.

12. Constraints outside process:

- Time frame, budget

13. Primary/Elementary choices: Initial/basic choices that need not be defended. Like philosophical standpoints in science. Grounded in personality, experiences. Finding reasons for these choices goes beyond the scope of the design process. (Like elementary processes in Newell & Simon (1972). "Elementary means that they are not further analyzed in the theory into still simpler processes" p. 29.)

- Have chosen the theme sports and dance, which is a big part of me (I do not ask: Why is it a big part of you. Because that has nothing to do with the project. The project idea came from the interest – not the other way around).
- Was inspired by the movie *Samsara* to choose Bali as an inspiration. (I do not ask: *why did you watch "Samsara"*? Because people just watch movies. It's an everyday activity to watch a movie. There is no underlying intention with regard to the project (probably).)

14. General remarks about input space:

- ...

15. **Words for transformation (what terminology do they use):**
    - Dig, create, transform, combine, explore, experiment, study, do, find, research, dig, mix, play, get closer to (narrow down), emerge, things happen, skrue op, filtrere, krydse, skalere
    - To *find/emerge* and to *create* reveal two different understandings of what is being done. A realist contra a constructivist position.
    - Is transforming the same as narrowing down?

16. **What is transformation?/what do they actually do?**
    - Tingene (de tegninger, der "fungerer") kommer tilfældigt og så skal de bagefter specificeres og tænkes igennem.
    - Work in parallel: on both shape and detail (e.g. pattern/print)
    - Mixing: Combining two themes from input space by cutting things out from pictures, putting them on top of each other and transferring selected details of the mix to transfer paper
    - Jeg kan ikke beskrive 'transformation space' uden at nævne info fra de andre spaces.
    - Et vellykket forsøg danner regel for strukturering af det næste: Fx. detaljer ved hals i tøjet: så gentages det, at der skal være detaljer ved halsen
    - FILTRERE DET KENDTE (SPORTSTØJ) GENNEM DET NYE (BALI-SNIT)
    - Skalere mønstre op og ned for (sammenhængende) variation
    - KRYDSE KARAKTERISTIKA (FX. TEKNIKKER ANVENDT) FOR DE TO MERE DEFINEREDE SUB-KOLLEKTIONER (STREET OG PRACTICE) FOR AT FINDE FREM TIL PERFORMANCE

17. **Bridging principles. Bygger bro mellem et koncept og det konkrete – eller retfærdiggør valg:**

18. **General remarks about input space:**
    - Input space must contain themes representing both input and output (for example a dance collection inspired by Bali must in the input part contain visual material about both dance and Bali.
    - Input space must have at least two conceptually different parts of info in order to be mixed (in transformation) to something (in output).
    - Inspirationen kan være "i hovedet"
    - Et element fra output kan blive til input igen, hvis det er veldefineret. Hvis det skifter ontisk karakter fra sammensat idé/koncept til materiel enhed, der kan sættes ét begreb på.

19. **General remarks about output space?**

20. **Concepts covering specific features/themes (are these constraints?):**
    - Complete wardrobe (means that it must have a certain variance)
    - Persona (fictional target group that has specific needs that must be covered)
    - "Me" (covering the intangible notion of the designer's personality and preferences)
    - Dancewear (certain requirements are inherent in this concept)

21. **Change of space information** (inspired from Wiltschnig (2013) et al. and Onarheim (2012) – ways of reframing mental models/managing constraints)
    a) new
    b) revised
    c) bracketed
    d) deleted

22. **MO vejlederen beskriver design som adskilt fra funktionen:**

- ”It's partly design, partly function”

23. **Kriterium for når noget fungerer:**
    - ”Når det ligner tøj, når det siger lidt sig selv”. (Når input er i tilnærmelsesvis overensstemmelse med output?)

24. **Et ustruktureret problem/frihed til at udtrykke sig (som designer) frem for at løse funktionelle problemer:**
    - ”i den her danseverden handler det ikke lige så meget om funktion, som det gør i fx. løbetøj. Det er ikke sådan, at man ved hjælp af tøjet kan yde et bedre resultat. Det handler bare meget om at føle sig godt tilpas i tøjet, men det handler også bare rigtig meget om, hvad det er for et udtryk, man signalerer (…)”

Figure 4: Inductive analysis document (primarily)

The themes listed here were kept in the finding 'stock' of the research project. Down below, they are referred to in the analysis schemes.

Theory emergence/ prototyping – and analysis

Next up, I made yet another prototype from the same framework scaffold, and after this followed a series of framework moderations on the same template, each moderation exposed to a new slice of data from the same case. Each of these moderations imply, in fact, a small iteration themselves between theorising, deductive and inductive analysis. Yet, for the sake of simplicity, I shall introduce them under one heading. In the selection of moderations exemplified here, I shall briefly explain some of the changes and the reasoning behind their development.

Round 1

	Themes	Structuring/argument building / needs/wants
Input	Samsara movie: **Bali**, Indonesia: culture, traditional clothing, costumes Own universe, style	I want to dig into every detail of my universe and explore and visualise my inspiration into mood boards, colours, material
Tranformation	Collage, sketching, technical drawings, experiments, draping, pattern making	I want to dig into every detail of my universe and explore and visualise my inspiration into mood boards, colours, material
Output	Sport & Dancewear Womenswear Persona: professional dancer, performer, practice, hang out, into culture, art, fashion Stand out Comfortable, feel good Flexible, suitable Cool Functional Digital print Own universe and style Inspiring Important elements (?) Coherence **Collection of 30 styles** **Collection parts:** **1 Performance** **2 Practice** **3 street** **8 outfits realised**	
Problem statement **A ⇒B**	How can I transform my inspiration from Samsara and combine it with sport and dance wear to make coherent collection?	
Twist/gap		
Concept		

Supervisor advise	
Intentional statement (opsummering)	
Other material	Sport and dance is a big part of me, my everyday life, and my DNA as designer Collaboration with sport company Knowledge: Own experience. Research. Fictional persona. BA education. Written assignment

Bold: Structuring of track space

Green: Self-imposed constraint

Red: Externally imposed constraint

Figure 5: New 'Triadic Co-evolution' coding scheme, Round 1

This framework (Figure 5) contains some empty boxes that represent orienting concepts obtained from previous analysis, but which were not found to be present in the data slice analysed together with the framework before it was moderated.

Based on previous insights, this framework has made space for a row called 'structuring'.

The framework embraces the realisation that the designer's research question (problem statement) cannot be placed in either of the categories I, T or O, as it encapsulates all of them.

The box 'other material' contains bits of data that seem of interest, but do not immediately fit into the framework. These are worth noting as they may give vital clues to how to revise the conceptualisation of the design processes.

Round 2

	Themes				Structuring/ argument building
Input	General	Fashion	Ethnical	3	I must figure out which details I like. I have many pictures, many beautiful (geographical) areas, but I need to focus on only one. **6d**
	I have a lot		Tribes, landscape, culture, religion, have searched for cultural costumes Bali-style (clothes?) has layers, techniques Books about culture, costumes Patterns, details		
Tranformation	General	1	2	3	- My last project focused mostly on silhouettes. Now I want to focus more on detail, material, and use time on digital print (Do something different from last time) **9a** - Have to find twist, way to go - Hope to find methods (from theory) to work with in PP - I have a lot, must dig in, find the perfect road
	N: Make mood board for January				
Output	General	Performance	Practice	Chilling	- K: I identified 3 different parts in sportswear: 1. Performance – (more wild) 2. Practice training 3. Chilling/ …?...wear K: I need to find a way to connect the 3 parts to make a whole (coherent) collection. Silhouettes have to be (fit) together. - K: I'm thinking of meeting up with gymnastics/ dance team and research what they need. What are important elements in a dance collection? It should not only be my thoughts about it. How do they build up their collection That would also give me an argument for why I do as I do, then it's not just my own universe. **6 d&e**
	Digital prints or funny small details I will make more basic elements, could be produced by company (Fuss and Disturbed). I will make the more difficult pieces myself. Thought about making patterns in neoprene I thought of using a main stretch fabric in the sportwear and then spice it up with panels/ details, e.g. on the neck or arm, so I can do it myself **9b** Print could be collaboration with gymnastic brand I could maybe do socks with company Sportswear have innovative techniques. You have to be innovative in your techniques, if you want to do sportswear You could develop techniques with a company				
Twist/gap	How is sportswear inspired by fashion? (opposite then usual where fashion is inspired by sportswear) **1+2**				
Concept	K: Bali: Only for visual part (PP), not enough depth for TP I need to find a way to connect the 3 parts to make a whole (coherent) collection. Silhouettes have to be (fit) together.				

Supervisor advise	N: Bali-dance: do something with hands + eyes, small things **3** N: The Bali things are funny, absurd in our context, not in theirs **4** N: Good idea to combine with ethnical N: You're busy then due to production times, be super quick You could also do shoes. N: Be more specific, what do you find interesting? How can you translate to modern/ relevant technique? There's so much (inspiration material). Find out what you find fascinating. N: Make mood board for January Look into materials. Start working with techniques. Think about shapes. Maybe make it more about lifestyle. N: Maybe you should look at dance also? N: You can create this (coherence) by material/ color. Normally in fashion, you have (similar): 1. Only for shows 2. Medium price 3. Low price It fits with your idea, makes sense. N: You could also analyse a sports brand, do some user/business research Sportswear have innovative techniques. You have to be innovative in your techniques, if you want to do sportswear You could develop techniques with a company N: And do form studies.
Intentional statement (opsummering)	I will increase inspiration material, make mood boards, dig in, figure out what is important. **6d**
Other material	Theory, fashion thinking, method Swedish professor, interaction…?… in fashion Theory on how to react compared to body (???) Stella McCartney, sustainability, not big part of PJ **(Suggested sources of external argument/ constraint justification)**

Figure 6: New 'Triadic Co-evolution' coding scheme, Round 2

The coloured coding indications (red and green) are similar to the previous framework, i.e. self-imposed constraints and externally imposed constraints. The bracketed, bold text (at the bottom) is my interpretative comment.

In this framework (Figure 6), I have sought to structure the data by the different themes that were revealed through the previous analytical steps.

The statements assigned to the 'structuring' column are, as shown, statements about aspects that are not yet part of the design process but are perceived needed, and in many instances these statements have the character of *actions* that are to be undertaken.

This tentative division between the content – the themes – of the design process on the one hand and the 'structuring' actions on the other, lays the foundation for the analytical strategy that is employed later when coding for *action* and *matter*.

The bold numbers and letters refer to the inductive analysis document (Figure 4): The numbers refer to a theme number in the document. The letters refer to instances and types of changes in the space information and thus in the representation of the situation (these are mentioned at the bottom of Figure 4). The four types are inspired by ways of reframing mental models (Wiltschnig et al., 2013) and ways to manage constraints (Onarheim, 2012). These types are: new, revised, bracketed, and deleted.

Round 3

	Present track information/ Themes	Imagining track development. (Maybe I will)…	Expressions of missing/needed track information/themes	Structuring of single track/ arguments	Cross track relations
Input	***Balinese world*** *Dancers* *Costumes* ***PICTURE: COLOURS (EXTRACTED FROM BALI)*** **Balinese dancers** Beautiful & strong powerful costumes • Interesting form, shapes and layers • Detail, ornamentations, patterns Old techniques		I need to do material research (missing material knowledge) Will look into details (need to draw out elements, narrow down space)	Samsara ⇒ Bali Will look into details Next: Find out which shapes and ornaments I could use	Balinese dancers: That's where I will find inspiration for silhouettes (I ⇒ O) Will transform Bali into something more modern (I ⇒ O) Will draw from the silhouettes I find interesting and look into details (I ⇒ T)
Tranformation	Collaboration with companies: DK gymnastic company for manufactoring of more plain practive suits. Drawing In my last PJ I drew a lot of different stuff, then afterwards I divided it into groups and tried to develop (the collection) from that. I will do that now (in this PJ) too. **11d** Without thinking too much: Find out how I can transform these old things into (something) modern.	Collaboration: maybe a company that can help me make styles in more modern material Collaboration: maybe adidas	Find out which methods I could use (missing methods)	Will dig more into Balinese world Will draw from the silhouettes I find interesting and look into details Next: Find out which methods I could use	
Output	***3 collection parts*** *performance* *practice* *street* **Performance:** Prof. dancer Crazy Extreme colourful Too much Strong Powerful Feminine A show off Showpieces Wow effect Stand out Extreme persona **Training/practice:** Cloth for her practice More basic Still funky Crazy Funny Cool Very colourful Interesting details Stands out but more classical **Street:**	Technical material: Neoprene			

	When she needs to have something to pull over during training Stay warm Chill with friend More urban Outdoor More rough Also casual Twisted funny details Jogging Sweat suits Want collection parts to connect, have same colour scale, material, details Dancewear collection Modern Functional Practical New, technical materials TARGET GROUP: MORE BRAVE PERSONS, NOT NECESSARILY ONLY PROF. DANCERS **16b** Main goal: make a dance line				
Problem statement **A ⇒B**	Find out how I can transform these old things into (something) modern.				
Twist/gap					
Concept					
Supervisor /other's advise	Comment: Maybe H2O is easier to get into. They are eager to collaborate after Goya success Supervisor: Maybe it could help you to translate into/ develop new material It's in you comfort zone right now. Challenge yourself. Comment: You can find technical companies (to collaborate with) who are not good at aesthetics… (gain from their technical expertise and contribute to their aesthetic expression). Comment: You may (benefit from) think more commercial; would normal people wear it? You could go from basic to more wild.				
Intentional statement (opsummering)	Next: Find out which methods, shapes and ornaments I could use. Without thinking too much: Find out how I can transform these old things into (something) modern.				
Other material	Maybe collaborate with company (help me) make (my styles) in the more modern material, maybe neoprene Collaborate with a DK gymnastic company for (manufactoring of more plain practice (training) suits Maybe also adidas Maybe in the end I'll do an event/ performance to show that it's possible to use it, it has to be functional.				

Bold: Structuring of track space

- Substructure
    - Substructure

Green: Self-imposed constraint

Red: Externally imposed constraint

Italics: From visual material

Underlined: Stressed themes

CAPITALS: Change of space information:

a) new
b) revised
c) bracketed
d) deleted

Number/letter: Refers to Analysis Theme Document

Figure 7: New 'Triadic Co-evolution' coding scheme, Round 3

In this framework (Figure 7), I try to establish a nuanced concept of 'structuring' into the tentative sub-categories 'imagining track development', 'expressions of missing/needed track information/themes', 'structuring of single track/arguments', and 'cross track relations'. These relate to the speculation that needed action (imagining track development) might differ from needed information/themes, cf. the emerging division between content and structure introduced in the previous framework. Likewise, they relate to the observation that elements can shift within a single track of I, T or O (structuring of single track), or change across tracks (cross track relations).

There are a series of 'maybe' statements in the data, both in the 'imagining' column, and in the 'other material' category. These were hard to integrate with the rest of the data. Viewed in retrospect, these can be seen as contouring for conceptualisation of an 'information stock' of passive information (Chapter 7.4), as they point to specific aspects or elements of which the designer is consciously aware, but which have not yet been assigned any role in the design process. However, they are acknowledged potential resources in the process.

Round 4

Analysis [redacted] MO 3 (20.01.15)	**Present track information/ Themes**	**Imagining track development. (Maybe I will)...**	**Expressions of missing/needed track information/themes**	**Structuring of single track/ arguments**	**Cross track relations**
Input	*PICTURES OF* ***CLASSICAL SPORTSWEAR*** *STYLES (clothing details)* **Bali** *figures* Costumes ***FABRIC*** *SAMPLES* *PICTURES OF* ***DANCING POSITIONS*** *(body)* Trying to get interesting cuts, shapes forms out of it HAVE LOTS OF INTERESTING FABRICS FROM LAST PJ I WANT TO PUT INTO THIS. BUT I DONT HAVE ENOUGH METERS SO NEED TO FILL IN I have my materials, which I have bought in colours I like 8 And also find in my inspiration material Havent done a colour board, because then it's annoying you cant find the right material in the right colours.	Fur Want to see what company can do Maybe lycra, more shiny Gold I want to use fabrics that you normally don't use in sportswear. But it hasn't affected my project yet.	Need information (to get closer to) silhouettes, mood, style Need to specify details I like Don't have enough meters from last PJ fabric, so need til fill in It's difficult finding innovative materials in a store	Cut out of pictures (space has been narrowed down) I have my materials, which I have bought in colours I like 8 And also find in my inspiration material	Technique experiments (T) are (at the moment) silhouette (I/O) inspiration Cut out (T) the interesting silhouettes in the pictures (I) by hand and put it (T) on the body poses (I). Because of the poses it gives different interesting silhouettes (I/O) I want this PJ to be colourful, so why not try to fit the fabrics from last project in?

Transformation	*MIXING classical sportswear style pictures with Bali /costume pictures and drawing on top* *Putting CUT OUT of Bali figures on top in different positions* Cut out the interesting silhouettes in the pictures by hand and put it on the body poses. Because of the poses it gives different interesting silhouettes	How can I put in a more 3D way? How will it (the inspiration material?) function in real clothes? Next thing: I want to transform ornamented stuff into textile with both embroidery and quilt. Sew in on material with layers underneath. Play with how to put in on materials Maybe do collab with commpany about print and transfer Will visit gymnastic company in herning Will talk with H2O Want to see what company can do Want to continue drawing, see what happens and specify details I like. Will do more complex collages with more than one cut Will do layer illustration on light table. Classical sport styles and Balinese pictures, project elements from one to the other I hope, when analysing my sketching, I can see what parts could be what fabric.	3D way – closer to real clothes (narrowing of space) Need information (to get closer to) silhouettes, mood, style Need to specify details I like	The technique experiments give inspiration of how to transform the Balinese clothes into (modern/my) clothes. (To find out:)Are there specific places on the body it would be nice to put it (the cut outs)?	
Output	Trying to get interesting cuts, shapes forms out of it Innovative materials Embroidery and quilt **Simple styles** (vil fylde mere) **Some more tailored styles** **Performance part:** Will be showpiece-ish Do myself	Fur Maybe lycra, more shiny Gold **Practice part:** Gymnastic brand help **Street:** H2O help	Need information (to get closer to) silhouettes, mood, style Need to calculate cost of styles		

Problem statement **A ⇒ B**	
Twist/gap	
Concept	
Supervisor/other's advise	It's good you experiment with different techniques, but ina way you just lay it on top. Go a bit deeper. What does it do with the body or the movement? Was it (the technique experiments) more (just) inspiration for you, or do you want to use it further? You can bring the expensive things to the company yourself. Maybe then they will be more willing to help Unique pieces for when on tournaments 15th of feb: collaboration agreement finalised Research what is good material for dancewear You need sparkle, it looks a bit dull. Look for something to freshn them up (the materials from last PJ). Its about the combination In next step you need to know: What do my styles look like? How can what you already have be used? In sneakers you also have maybe 15 different materials in one style. Its partly design, partly function
Intentional statement (opsummering)	
Other material	Sewing tests

	Puma havent answered. Adidas dont know. Have to focus on the one's I got now, maybe its enough. It's difficult finding innovative materials in a store Need to calculate cost of styles (collaboration guy wants it)

Coding

Bold: Structuring of track space
- Substructure
  - Substructure

Green: Self-imposed constraint

Red: Externally imposed constraint

Blå: svær at placere

Gul: Meget interessant, men mangler kategori i skema

Italics: From visual material

Underlined: Stressed themes

CAPITALS: Change of space information:
a) new
b) revised
c) bracketed
d) deleted

Number/letter: Refers to Analysis Theme Document

Figure 8: New 'Triadic Co-evolution' coding scheme, Round 4

This framework (Figure 8) is much like its predecessor. The blue and the yellow text bits are coded as hard to place in the scheme. The yellow bits are some that I find very interesting but which have no category in the framework. They revolve around obstacles in the process. The blue bits often relate to needs for something. These two themes are identified as interesting for a subsequent research focus, which is mirrored in the dissertation.

In the 'cross track' structuring column, it is possible to, retrospectively, identify a forerunner for the syllogistic structure of an experiment (Chapter 11). Yet, at this point, I had not identified experiments as an instance of coupling I, T and O.

Round 5

Analysis [redacted] MO 4 (03.02.15)	**Present track information/ Themes**	**Imagining track development. (Maybe I will)…**	**Expressions of missing/needed track information/themes**	**Structuring of single track/ arguments**	**Cross track relations**
Input	*OWN FABRIC SAMPLE OF LASER CUT FABRIC ON NET BABRIC* *SKETCHES OF MIX BALI PATTERNS/SPORTSWEAR ON BODY* *DANCER WITH CUT OUT BALI HEAD ON BODY* *COLLECTION STYLE TYPE AND MIX OVERVIEW WITH PICTURES OF EXISTING SPORTS WEAR STYLES* BOUGHT FABRICS: SPORT MATERIAL *NET FABRIC SAMPLE* There was not so much to choose because I went directly for sports material GLITTER: *GOLD FABRI SAMPLES* *METAL TRIM EDGE SAMPLE* **SPACY** (?)				*SKETCHES OF MIX BALI PATTERNS/SPORTSWEAR ON BODY: It's from here I get my styles (I – O)*
Transformation	WORK IN PARALLEL ON BOTH PATTERN/PRINT AND ON THE SILHOUETTES (SHAPE) Things happen when I start drawing Tingene opstår til fældigt og skal så tænkes igennem. Det, der fungerer, er det, der ligner tøj	I hope the performance pieces will emerge from designing the two other collection parts instead of that I have to define what show pieces will look like Use glitter the right way so it does not become disco like Will do embroidery test Will test if laser cut works in my material Have to make pattern bigger and make it on	In need of randomness – less control.		

		computer (company said it was too small (for laser cutting?)). I will take some of the details out.			
Output	***COLLECTION STYLE TYPE AND MIX OVERVIEW WITH PICTURES OF EXISTING SPORTS WEAR STYLES:*** **HOW MANY JACKETS, HOW MANY STREET OUTFITS, HOW DO SWEATSHIRTS DIFFER** MUST NOT BE DISCO-LIKE MUST NOT BE CARNEVAL **SPACY:** Taler om sidste projekt. Krigere. Gammeldags udgangspunkt, nye materialer. Lidt superhelteagtigt Materialerne gør det meget: - neopren - Mesh Want modern look High Tech Sophisticated Glamorous Trim should be the exotic, glamour part Man skal kunne se kroppen Har talt med gymnaster: de har brug for fx indbyggede			Trim should be the exotic, glamour part	
	knæbeskyttere, god udluftning, ikke for stramt.				

Problem statement A ⇒B	
Twist/gap	
Concept	
Supervisor/other's advise	N: Be specific (with the company) what kind of zipper, colour etc. Be cafeful it doesn't become carneval It's good to have something else (spacy) than the Balinese
Intentional statement (opsummering)	
Other material	Fuss and disturbed were open for collab on both practice and chilling part H2O were interested, but it should fit in with thir style and colours a bit too much. They lack DNA. It doesn't fit my project. Fuss and disturbed asked me to send something right away when I have something (finished drawings?). They will also help with technical drawings. If I do the patterns and send it with the drawings they could make the finished styles. I dans: Tøjet gør ikke én hurtigere eller påvirker resultatet, som fx i løb, det handler mere om udtryk, så jeg kan gå friere til værks. Mit må gerne være mere krydret end det almindelige, klassiske dansetøj.

Coding

Bold: Structuring of track space

- Substructure
    - Substructure

Green: Self-imposed constraint

Red: Externally imposed constraint

Gul: Meget interessant, men mangler kategori i skema

Italics: From visual material

Underlined: Stressed themes

CAPITALS: Change of space information:

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c) bracketed
d) deleted

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Pink background: A choice is established as prior to others in a hierarchy of importance. Becoming constraining to other choices.

Figure 9: New 'Triadic Co-evolution' coding scheme, Round 5

This framework (Figure 9) is much like the previous one. As in Round 4 the blue colour coding refers to bits that are hard to place. As shown, these statements occur at several places in the scheme, as they seem to hold the potential to relate to more categories. This points to the conception that some elements of the design process can be in a state in which it is unassigned, but is potentially assignable, to the categories I, T or O.

The purple marking refers to an action/choice the result of which will determine further actions/choices. In essence, it points to an experiment that the designer has set out to do in order to further her process.

Inductive analysis/ insight

After constructing, testing, and extracting insight from the series of frameworks and the realisation that elements change both within and across the ITO tracks, I encountered a challenge. This challenge is expressed in Figure 10, where, in a log book note, I conjecturally state that *"the information tracks cannot co-evolve since an evolution of any of them means that they are no longer of the nature that characterized their (ontic) being at the outset".* In other words, specific elements of the design process do not necessarily remain in one category throughout the design process. Using a cooking metaphor to refer to the design process in which I distinguish between the ingredients (I), the recipe (T) and conception of the meal (O), on the one hand, and the pot in which everything is mixed and develops, on the other, I ask tentatively: *"When you put ingredients in the pot, is it then more 'ingredients' or more 'meal'?"* I conclude that *"the understanding of information tracks must be separated from 'the pot'."* I have illustrated this below the text in the log book displayed in Figure 10.

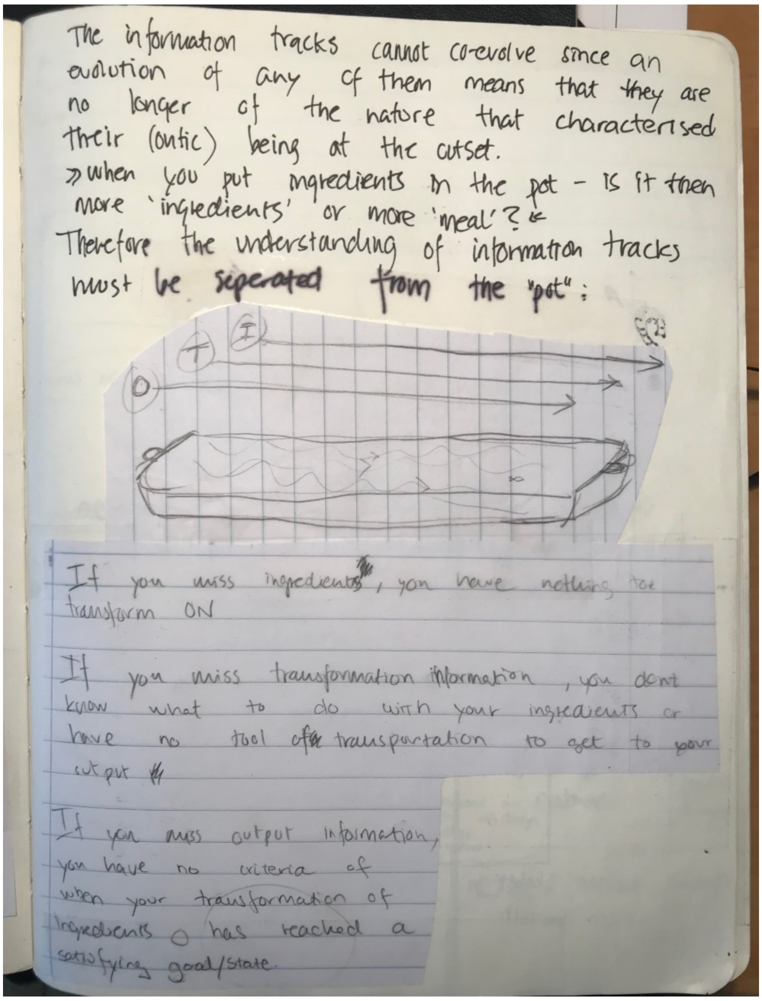

Figure 10: Example from my log book

The log book entry shown in Figure 10 exemplifies how I question and criticise the framework based on the testing, and it reveals the insight that the idea of three parallel tracks of I, T and O stretching throughout the entire process did not satisfactorily match the data.

Theory emergence/prototyping

With the realisation that the framework did not adequately match the data, but without invalidating it entirely, I resorted to a different strategy of analysing and coding data. This strategy was based on the findings gained inductively through the previous sequence of prototyping.

Thus, with a qualitative interest in the parts of the data that were incompatible with the original 'Triadic Co-evolution' prototype, and in the findings that altered, or were deemed residual to, the framework, these data and findings came to guide the next step of analysis.

The new strategy is based on a separation of 'action' from 'matter' or 'information'. The relevance of this separation was suggested by several findings. First of all, the conception that the ITO categories should be distinguished from some 'stream' or tracks of development indicated that the elements assigned to ITO might differ from other aspects of this development and its undertaking. Secondly, the emergence of the 'structuring' category, within the framework, otherwise consisting of the ITO categories, suggested that some division was needed between content and structure: between the elements deemed to fit the ITO categories as opposed to the actions by which these were provided, connected and structured. Furthermore the sub-division of the 'structuring' category introduced in 'Round 3' prompted the speculation that the need for action might differ from the need for information/themes and hence the emerging division between content and structure introduced in the previous framework. This gave further weight to the separation of 'action' and 'matter' or 'content'.

The observation that certain discernible elements of data fit into the ITO categories whereas others do not, and the idea that these elements should analytically be separated from action, occasioned the need for defining those elements as distinct analytical units. Those units were termed 'Information Entities' (IEs) (see Chapter 7). Like Rheinberger's concept of 'epistemic things' (see Chapter 10.1), the concept of IEs was coined before it was fully outlined or 'filled', and hence the concept definition developed during the research process. In the present dissertation, the concept of 'IEs' is presented in a formal definition, dividing 'themes' from 'data'. This definition is analogically framed by the application of a definition of 'information'. However, at the stage in the research process described here, the concept of 'IEs' was merely provisional and ostensively defined by examples from the data. Such examples can be found already in the pilot case study analysis, where design 'themes' start to emerge in the data analysis as central nodes between which links are discussed in the conversations which are corroborated by the pictures of the project material on the designers' boards. Likewise, they were characterised in relation to the concepts of 'constraints' (Chapter 7), which was central to the initiation of the research project.

Deductive analysis/test

In the examples of coding for action and information shown below, the yellow code represents 'action' and the green code represents 'information'.

'Information' was coded in the data guided by the still provisional definition of IEs. This implied the following observations: When verbalised, the IEs are typically captured by adjectives, nouns, and proper nouns, and when visualised, they take the form of (clusters of) e.g. photos, sketches, material samples and written words. Material displayed on the designer's project board or chronicle is IEs. Any word mentioned frequently or with perceived emphasis in conversations about the project may be an IE. If the designer is asked to write a list of key words, which characterise her project, this list will point to IEs (Chapter 7.1).

'Action' was coded in the data, by using *action statements* as indicators. These statements often involved personal subject pronouns in connection with verb phrases, e.g. *"Right now I am doing shape investigation, but I need to go back and look at some of the old pictures," "I have started to look into materials. I definitely want this one,"* or *"I will have to contact the company on Monday. I need some more information."* However, they could also be formulated passively, e.g. *"This needs to be completed today."*

Four cases (330 pages) were coded for these concepts, along with inductive findings, in this iteration round of analysis. The cases were chosen, as described in the method chapter, based on the perceived richness of data they contained and shifting between the two design disciplines.

Example 1

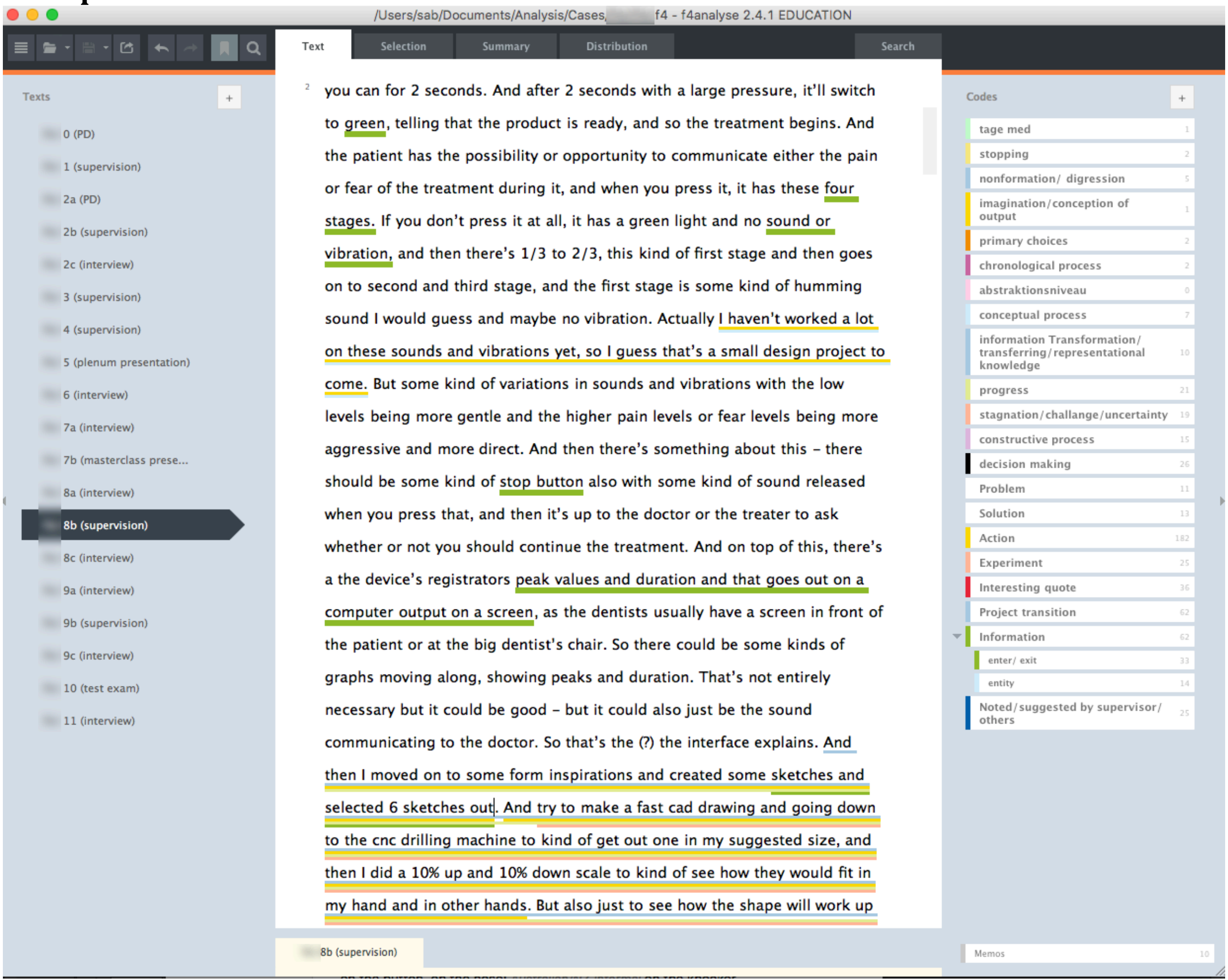

Figure 11: Coding for 'action' and 'information', example 1

Example 2

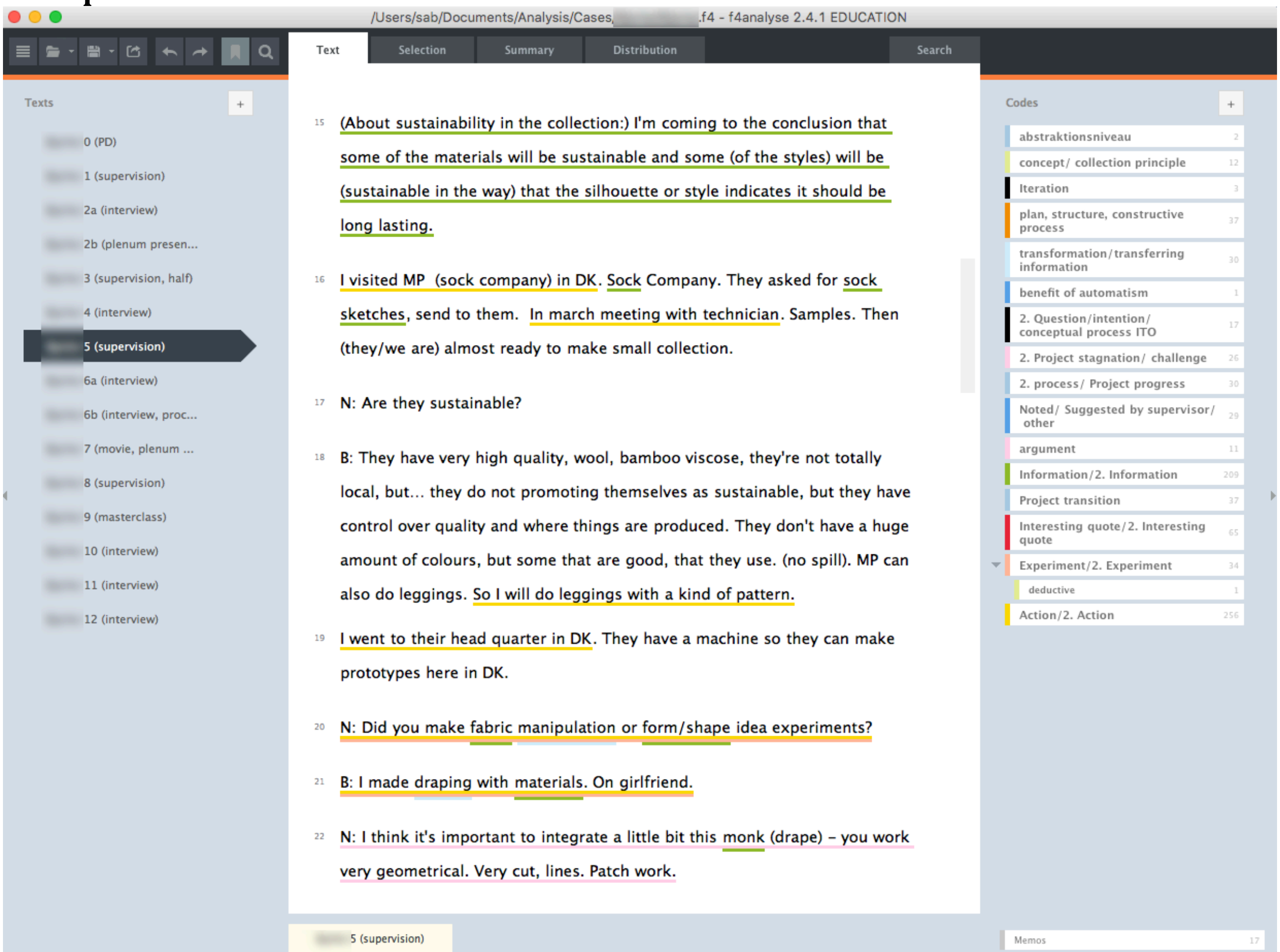

Figure 12: Coding for 'action' and 'information', example 2

Example 3

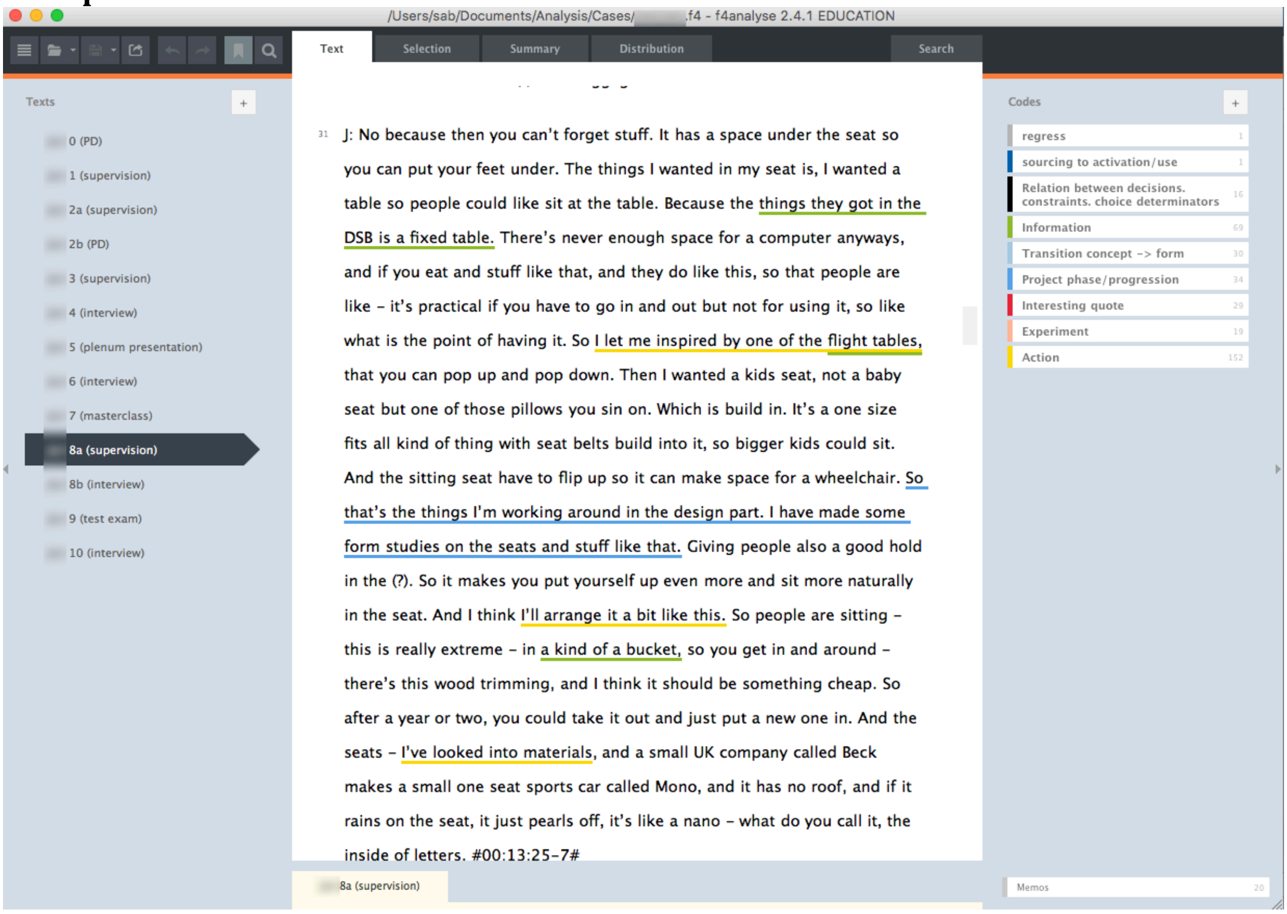

Figure 13: Coding for 'action' and 'information', example 3

As the examples (Figure 11, 12 and 13) show, 'action' and 'information' tags are accompanied by a myriad of other tags (in the right-hand column). These are concepts that have emerged as a result of the ongoing inductive analysis driven by a maintained open attitude towards data and the insights that can be drawn from them, even when the analysis is prompted by a distinct prototype of orienting concepts. Additionally, the codes originate from the comparative approach in which themes found in subsequent analysis of other cases have been brought back to previously analysed data. Because the codes accumulate in the f4 files, all codes assigned to the file documents at any time during the research process are visible at once.

Inductive analysis/insight

From the analytical process initiated by coding for 'action' and 'information', a number of subsidiary findings and coding tags emerged.

When coding for information in the data, I found many examples of designers' perceived lack of or 'overload' of IEs. This observation converged with what I had seen in the pilot case study. It laid the groundwork for the hypothesis that there is a structure of functions that IEs should fill. Later the ITO distinction was reintroduced as representative of these functions (rather than 'spaces' or 'tracks of development', as had originally been suggested).

Some examples of the code tags that emerged are:

Project/ process transition/progression/phase: relating to instances in the data in which some process development was indicated. The data pieces marked by these tags later informed the investigation of 'formative development' of design processes (Chapter 9).

Experiment: A certain type of 'action' in the data was perceived to stand out: experiments. That tag was given when something seemed, with the naked eye, to fit this category. Afterwards, the instances were further analysed to investigate why an action was interpreted this way and to find commonalities. This later contributed to the concept of 'Design Syllogisms'.

Argument/decision making: How choices are made is a central question in relation to design processes. This type of code tag was given to statements regarding decisions in the process. Decisions and actions can be considered closely related, since an action can be seen as expressive of a choice. This code tag subsequently informed the development of the notion of 'Choice Justification' (Chapter 7.6).

Interesting quote: When a statement was encountered which somehow seemed very interesting, but did not fit into any category, or did not immediately resemble previous findings with which it could be clustered, the tag 'interesting quote' was assigned. Noting down interesting quotes throughout all data analysis has, for example, led me to coin the term 'nonformation' (Chapter 9.1).

My further research endeavours were guided by some of the various themes that emerged through analysis some of which ended up constituting vital parts of the collective research contribution.