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“It’s alive, it’s magic, it’s in love with you”

Opportunities, Challenges and Open Questions for Actuated Interfaces

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ABSTRACT

Actuated Interfaces are receiving a great deal of interest from the research community. The field can now present a range of point designs, illustrating the potential design space of Actuated Interfaces. However, despite the increasing interest in Actuated Interfaces, the research carried out is nevertheless primarily preoccupied with the technical challenges and potential application areas, rather than how users actually approach, experience, interpret and understand Actuated Interfaces. Based on three case studies, investigating how people experience Actuated Interfaces, we point to; magic, movement and ambiguity as fruitful perspectives for understanding users’ experiences with Actuated Interfaces. The three perspectives are employed to reflect upon opportunities and challenges, as well as point to open questions and relevant areas for future research for Actuated Interfaces.

Author Keywords

Actuated Interfaces; shape-changing interfaces; user experience; interaction design; mid-air displays.

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

Research into the kinetic properties of physical objects has been conducted under a variety of headings: Actuated Interfaces (Poupyrev et al. 2007), Shape-changing Interfaces (Coelho and Zigelbaum 2010; Rasmussen et al. 2012), Kinetic Interaction (Parkes 2009), Organic User Interfaces (Holman and Vertegaal 2008), and Expressive forms (Vallgårda and Redström 2007), just to mention a few. The present paper investigates how people experience actuated interfaces according to the definition of actuated interfaces by Poupyrev et al. (2007), defining Actuated Interfaces as; “*dynamic, self-reconfigurable devices that can change their physical properties depending on the state of the interfaces, the user, or the environment”*. An increasing amount of work has been conducted on creating new forms of Actuated Interfaces, demonstrating the breadth of the application potential; from displaying ambient information on a mobile phone (Hemmert et al. 2010a), to an interactive advertising billboard that reacts to its environment through bending and rotation (Oosterhuis and Biloria 2008).

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Despite the wide range of visions and conceptual interfaces that have been built and presented within the domain of Actuated Interfaces, the attention has predominantly been focused on technical challenges and potential application areas of Actuated Interfaces, rather than investigating how users experience and make sense out of them. A handful of studies have begun to focus on users experience with Actuated Interfaces, such as; Harrison and Hudson’s (2009) user study of changeable physical buttons on a visual display, Hemmert et al. (2013) evaluation of peoples reaction to different postures of a small prototype or Togler et al. (2009) who explored people’s reactions to a shape-changing water faucet. However as pointed to by Rasmussen et al. (2012), studies of user experiences are relatively scarce, and while the evaluations which has been carried out has provided valuable insights, evaluations are often sketchy and based on small samples of users. Consequently, we argue that it is time for researchers to supplement the existing investigations of technical challenges and application potentials of Actuated Interfaces, with a turn towards user experience. It is a necessity to move beyond the (understandable) technological fascination, towards understanding Actuated Interfaces’ strengths and weaknesses from a human perspective.

We are used to interact with, and handle, static physical artefacts and to manipulate digital dynamic content. Actuated Interfaces challenges this familiar interaction paradigm, given their self-actuation, as artefacts and interfaces suddenly can become dynamic, move and alter their appearance. In this paper we investigate whether such artefacts have inherent experiential qualities, and we hypothesise that their dynamic physical form, promotes active and bodily engagement, invite for curiosity, and for spurring the imagination. In this paper we use three cases of Actuated Interfaces to investigate these issues. The first case explores how non-verbal cues of status can be communicated through rotational movements of a TV (Mortensen et al. 2012). The second case is a mid-air display, allowing users to explore and experiment with an ambient soundscape (Alrøe et al. 2012). The third case is a shape-changing bench, exploring how shape-changing furniture may shape the social space and situation. While the three cases have been built on a diverse set of theoretical backgrounds, for different purposes and utilizing different means of actuation, they all focus on investigating human experiences with Actuated

Interfaces. Through investigating these cases, we point to movement, magic and ambiguity as fruitful perspectives for understanding experienced qualities of Actuated Interfaces. Lastly we discuss and reflect upon challenges and potentials in Actuated Interfaces, based on the three aforementioned perspectives.

RELATED WORK

While a long and rich history of designing physically actuated artefacts exists within machine and robotic science (Togler et al. 2009), its history as a studied output modality within interaction design is significantly shorter. Physical form is often neglected as an output modality, as it lacks the flexibility that is so characteristic of graphical displays (Djajadiningrat et al. 2007). However, current advances in material science such as Nano manipulators, organic actuators and fast, networked embedded microprocessors (Poupyrev et al. 2007; Coelho and Zigelbaum 2010) are paving the way for physical artefacts to become physically malleable.

Although the field of Actuated Interfaces is being explored under different headings and with a variety of foci, four common and related visions seem to be permeating the work.

(a) Providing tangible interfaces with dynamic physical output, enabling the physical to, not merely being coupled to dynamic digital attributes and information, but through changes of their physical properties (e.g. form, position, movement and size) themselves become dynamic and self-reconfigurable (e.g. (Poupyrev et al. 2007; Ishii 2008; Ishii et al. 2012)
(b) Eliminating the physical/virtual divide by blurring the boundaries between material, form, function and computation. In order to enable physical objects or entire environments to be dynamically reshaped or re-configured (e.g. (Parkes et al. 2008; Harrison and Hudson 2009; Bodanzky 2012)).
(c) Physical adaptation to different users, uses, contexts and conditions (Coelho and Zigelbaum 2010), making it possible for objects to ergonomically adapt to their users, use-spaces or conditions (Coelho and Maes 2009; Fabian Hemmert et al. 2010).
(d) Exploiting a range of perceptual qualities of motion. By using physical motion it is possible to stimulate not only visual, but also aural, tactile, and kinaesthetic sensations. Physical motion draws on our innate human response to movement and its ability to both capture and focus our attention (Parkes and Ishii 2010) and our natural instinctive reaction seeing moving objects as "being alive", provoking a significantly deeper and emotional response (Parkes et al. 2008).

The visions permeating the field illustrate the focus on technical possibilities of physical movement and change. And while the fourth (and less articulated vision) focus on the users experiences; it mentions little of the quality in doing so.

CASE STUDIES OF ACTUATED INTERFACES

As the investigations regarding the experienced qualities of Actuated Interfaces are currently at a very early stage, this paper has adopted a cross case-study approach. This way, we may start to identify common phenomena and concepts, with regard to how people experience such interfaces. It is then, the job for subsequent research to further investigate these phenomena and concepts amongst a broader set of cases. Through picking three rather different cases we are able to ensure a certain breadth in the phenomena we observe and identify.

In this paper we present three cases; Turning TV, Aerial Tunes and the coMotion bench. The cases have applied diverse approaches to explore the users' experience; both with regard to design brief, evaluation location and amount of users (see Table 1). The turning TV is the result of an experiment studying how non-verbal communication of status can be transferred to product behaviour and how people experience this. Psychologists were involved in the design and evaluation of the Turning TV. Aerial Tunes is a collaborative instrument for playfully manipulating a soundscape. It was designed for promoting aesthetic experiences through an innovative interface. Finally, the coMotion bench is a bench that changes form as people sit on it. It was designed to investigate how such an interface can trigger encounters between strangers in a semi-public space through changing the atmosphere of the situation. Thus the cases have been designed with rather different agendas and based on different theoretical perspectives.

Case	Eval. type	Users
Turning TV	Lab	15
Arial Tunes	In situ (2 locations)	200+
The coMotion bench	In situ (3 locations)	120+

Table 1. The three cases, test locations and number of users.

In the following sections, we describe each of the three cases, with relation to their design, the three experiments and findings regarding users' experiences of Actuated Interfaces.

Turning TV

Turning TV (Mortensen et al. 2012) is a TV that autonomously turns towards a person in the room with the aim to offer the best viewing angle at all times. When more people are present in the room, the TV only follows one person. In the Turning TV case, we were interested to explore how knowledge of non-verbal human-human communication within the field of psychology can inform the design of product movements. Users often interact with products as though they were social agents, rather than advanced tools (Reeves and Nass 2003). This happens with products ranging from traditional computers to robotic vacuum cleaners (Forlizzi 2007). In the case of Turning TV, we explored whether it is possible for products, through their self-actuated behaviour, to give people an experience of being a high-status person.

Figure 1. Wizard controlling the TV's movement, and an overview with positions where TV can be turned (left). Lab with living room setup. Turning TV in the middle (right).

Design

We "translated" the non-verbal communication cues into movements in such a way that the TV always turned towards one person. The 'attention' from the TV provided the person with the experience that the TV was ready to serve the person in question. The translation from non-verbal human-human communication into human-product communication is of course a matter of interpretation. We experimented with a few other product movements, but turning was the prime movement as this was the movement, which was easiest for the users to comprehend.

Experiment and method

We set up an experiment where we made a TV turn towards a person in the room. We investigated the TV's behaviour in two situations, one where there was one person in the room, and one where there were two persons in the room. In both cases the TV followed only one person. The experiment ran as a Wizard of Oz experiment where the wizard controlled the movement of the TV based on a video signal from a near-by room (See figure 1). The experiment is further described in (Mortensen et al. 2012).

Findings

Based on the results it can be argued that it is possible to nonverbally communicate likeability and status using simple product movements, but only under some circumstances. When two participants interact with the TV simultaneously they interpret the movements of the TV as if it likes one of them more, or rates one of them higher. When participants use the TV alone they rate the TV as polite and that the TV is paying attention to them. The presence of other users was important to the participants' perception of the TV. The TV was perceived as breaking social norms when more than one participant was present. It appears that it might be possible to instigate conflicts between users via product agency and it is important to consider this when designing products, especially with actuated interfaces. Negative emotions and social conflicts are an inherent part of our social relationships and hence becomes an inherent part of our interaction with products that appear to have agency.

Aerial tunes

Aerial Tunes (Alrøe et al. 2012) is a collaborative, tangible interface allowing people to manipulate a soundscape through manipulating balls hovering in mid-air (see Figure 2). Aerial Tunes allow people to physically grasp, manipulate and re-position the balls while exploring and experimenting with a soundscape created based on at what height the balls have in the air. The created soundscape is dynamic, as small repositioning of the hovering balls occurs constantly due to irregularities in the controlling airflow.

Design

Aerial Tunes is a modular, scalable system. Currently, it consists of six cubes, each handling one floating ball. In each cube a radial blower and a corresponding control-circuit is installed that can position and hold the ball at different heights in the air by controlling the strength of the blowers' airstream. In each cube there is also a distance sensor allowing the cube to sense if a ball is repositioned by a user (by grabbing the ball and moving it up or down in the airstream). If the ball's position is manipulated, the blower's strength will hence be adjusted so the ball will remain in its new position. As the ball's height is manipulated, the cube communicates these changes to a computer controlling the soundscape that reacts by making changes in the soundscape. The system is further described in (Alrøe et al. 2012).

Experiment and method

Aerial Tunes was evaluated utilizing a number of techniques (Alrøe et al. 2012). In sum, prime evaluations consisted of workshops with musicians, short-term field evaluations in a cantina and a long term field study (four weeks) in a public city library. During the four weeks field trial, interaction data was logged automatically by the system. In addition we did interviews and observations and provided a guest book for people to note down their impressions and reflections upon their use and experience of Aerial Tunes (see Figure 2, right).

Findings

The hovering balls created a magic-like experience among many of the people that observed and interacted with the system. People found the behaviour of the hovering balls both surprising and peculiar. It was this behaviour that appealed and attracted people to come closer to, and to start interacting with Aerial Tunes.

As there were no perceived 'right' or 'wrong' way of interacting with the system, and the mapping between the balls' position and the soundscape were difficult to

Figure 2. Aerial Tunes (left) and an example of notes written in the guest book (right).

decipher, the system promoted exploration and investigation and a richness in the interpretations of system functionality. The abstract soundscape, and the diffuse coupling between input and output further provided opportunities for exploring the nature of interaction. This, together with the distributed nature of Aerial Tunes opened up for a collaborative exploration and interaction with the system. Indeed, people collaborated, got inspired and learned about Aerial Tunes and what it was through and with each other. The almost magical property of the hovering balls and the visual irregularities in the balls movements invited users to engage with, and explore Aerial Tunes.

The coMotion bench

The coMotion bench (see Figure 3) is a shape-changing bench, designed to explore how height alterations in the horizontal surface can spark encounters between strangers. If the coMotion is unoccupied it appears as a stationary bench. However, when someone sits down on the bench, it will after a short while provide a small vertical push under the person. If more than one person are seated, the bench will tilt or change shape in different ways depending on the number of people seated and their position on the bench. In the case of coMotion we explored how to encourage people to connect with others on the bench and further, how the shape-change affected the atmosphere experienced by its occupants and how this differed according to the contextual setting of the bench.

Design

The coMotion bench is 2.5 meters long, 45 cm high and 40 cm wide and seats six people. Hidden to people, the bench is divided into three subsections and uses two linear actuators on each sub-section side as legs and to change its form. The actuators allow the bench to alter the angle of the different sub-sections or raising/lower the seats' height altogether (see Figure 3). The height of each leg (i.e. section side) can be individually controlled within the range 55-85 cm. The height of each bench-sections' side can be controlled 1) by a wireless remote control or 2) in an autonomous mode where the bench change each individual sections height based on in what configurations people populate the bench. This autonomous mode is controlled by six force-sensors distributed on the seating-area. The sensors detect if and where people are seated and coMotion alters its shape depending on pre-defined 'seating patterns'.

Figure 3. The coMotion bench.

Experiment and method

The coMotion bench has been tested in two configurations. First, coMotion was tested in a concert hall foyer and at the departure hall of an international airport. In these two tests, coMotion was controlled in a Wizard of Oz fashion through a wireless remote controller. This allowed the design team to explore different movements, their effects and to understand how the autonomous movement behavior should be programmed. Second, the bench was tested in a shopping mall. At the mall the bench worked autonomously based on the seat-sensors' input and the programmed 'seating configurations'. All three tests were video-filmed. As people moved away after sitting on the coMotion bench, we approached them and performed semi-structured interviews. All material was analyzed after the conclusion of the experiments.

Findings

People reacted quite strong to the manipulation of what they often believed was a static object. People were often surprised and curious to locate the force that affected them while seated. Many sought confirmation among the other people seated on the bench or in the immediate vicinity. In the interviews they expressed a wide range of emotions ranging from fear to delight to frustration to relaxation. The three diverse locations (concert hall, airport and shopping mall) used for testing also fostered quite different emotional reactions. Indeed, people attributed diverse meaning to coMotion in the three settings. For example, at the airport people talked about 'a sensation of flying' while the amusement appeared more explicit in the concert hall where people referred to for example '*my turn is over'*. Thus the context quite often influenced the attribution of meaning and understanding of what coMotion did and why.

PERSPECTIVES ON ACTUATED INTERFACES IN USE

Despite the different origin, purposes and designs, we observed a number of similarities, with regard to how people experienced the installations in use. In the following sections, we introduce; magic, movement, and ambiguity, as perspectives though which we investigate the experienced qualities of Actuated Interfaces across the three cases. These perspectives emerged through identifying common phenomena across the cases, as well as from reviewing existing literature on Actuated Interfaces. The perspectives in themselves are not novel concepts to the HCI community, as they all have previously been posed as relevant themes. Movement has

been pointed to for example by (Young et al. 2005; Hummels et al. 2006; Ross and Wensveen 2010), magic by (Tognazzini 1993; Landin 2005) and ambiguity by (Gaver et al. 2003; Eppler et al. 2008). The three perspectives obviously does not provide an exhaustive list of perspectives for discussing Actuated Interfaces, but provide a relevant starting point for initiating a reflection upon users experience of and with Actuated Interfaces. The perspectives were chosen as they highlight both some of the qualities and potentials of Actuated Interfaces, as well as the related challenges.

In the following we present the three interconnected perspectives and use them to reflect upon the cases. We seek to point to both opportunities and challenges related to each perspective, as well as open questions for further research. The reflection is primarily based on the three cases, as research on Actuated Interfaces rarely recount the users experience, and when it is included it is often done with few details, and using examples from existing research is thus difficult.

Experiencing Movement

The ability of Actuated Interfaces to physically move and alter form, presents an opportunity for designing expressively rich interfaces and in this way also designing for rich experiences. The application of physical movement within HCI, has received some attention from for example (Young et al. 2005; Hummels et al. 2006; Ross and Wensveen 2010). When seeking to understand movements within products, a rich source of references is found for example within psychology (e.g. (Heider and Simmel 1944; Scholl and Tremoulet 2000)), animation (Vaughan 1997) and dance (Loke et al. 2007).

Having explored the notion of movement in the three cases, we point to a number of elements in the users' experience, which is worth considering when designing Actuated Interfaces; how does the movement relate to the users body? How and in what way do the users interact with the movement? What metaphorical associations arise from the movements? Can movement in itself attract attention?

The three cases relates to the body in different ways and present people with different degrees of control over the movement. In the case of Turning TV, movements are experienced at a distance, allowing the users to explore the movements, though moving about the space and thus coupling their actions to the TV's responding movements. With the Turning TV there is no choice of participation. Presence alone triggers the TV to follow a person. While this pattern of movement can be perceived as limited, it is also easy to decipher and comprehend, and it triggered quite strong emotional reactions. Thus, the complexity arises from the dialogue between two participants attempting to decipher why the movement was only locked to one person. One couple commented on the TV following only one person: "It's still you it's…" to which the other participant responded: "It's in love". But sometimes the extremely simple "communication" with the TV also breaks down: "*...that's maybe where it was a bit provocative. Look at me, I'm here! And then you look; now what?"*.

Aerial Tunes provides, beyond the visual experience of the movements, a more tangible experience. The setup allows hands-on control of the movements and the corresponding soundscape. Opposed to Turning TV the users can, by their actions, control whether or not to interact with the interface. The users however, do not have the full control of the movements or the soundscape, as the balls does not float steadily in the airstream, causing the ball to move unpredictably. Owing to the unpredictability of the balls movements, they were to some extent, perceived by people interacting with the system as having a will of their own. The unexpected movement of the hovering balls had a strong effect in attracting attention as one person commented in the guest book "Attracted my eyes immediately". Moreover, the nature of the movement was subject of exploration of the guests: "I actually think, it is pretty cool, that you can move the ball by waving the hand around it" and also subject for further reflection on how the movement could generalize to other situations: "In back to the future Michael J Fox has a floating board, you have balls which does the same. I wonder if one can create that board then? I think it is funny to watch the floating balls even though my grandma probably won't believe me.".

Opposed to the other two cases, the movements of the coMotion bench was primarily felt rather than seen. The movement of the bench was often attributed by the users as something being "wrong" with them. Indeed, the seated people did not initially consider that the movement could originate from the bench, as this was so unexpected in the environments where the bench was tested, one phrased it as *"I thought, hello am I sick?"* another *"I thought I was dizzy… and I thought - am I that tired"*. Users often looked around the room, seemed to make sure what they sensed before looking down, when they looked down they perceived that it was the bench moving, Employing the haptic sense, thus has a more private effect than e.g. vision and hearing, and evoked strong emotional responses, e.g. *"I was turning around, because I was afraid somebody came up behind me"*.

The three cases draw on different associations for the movements they apply in their design. The movements of the Turning TV (Mortensen et al. 2012) directly seek to utilize our innate willingness to interpret artefacts' movements as exhibiting human traits. Heider and Simmel (1944) as well as Scholl and Tremoulet (2000) has explored this willingness to interpret even simple movements as having human characteristics. In (Scholl and Tremoulet 2000), they found that people, even when not instructed to, attributed personality traits (e.g. shyness, being a bully) and emotions (e.g. frustration, anger) to the movements of geometric figures. Turning TV directly seek to translate familiar human movement patterns, such as; individuals turn their body more towards, and pay more visual attention to, other individuals perceived to be of higher status (Abramovitch 1976; Dovidio et al. 1988). Aerial Tunes on the other hand does not seek to imitate familiar human movement patterns. However, it does provide the sense of something living. Rather than to aim for the balls to float steadily in the airstream, Aerial tunes "come alive" as the balls'

seem to dance in the air, in accordance to fluctuations in the streams of air sustaining the balls floating in mid-air. The movements of the coMotion bench does not draw on a specific frame of reference or seek to imitate familiar life, but rather rely on the effect the transformation have on people and not the motion itself. The movements explore and provoke intimacy among people seated on the bench, as it literally tilts people into each other.

The 'living' soundscape together with the moving, hovering balls in Aerial Tunes attracted the attention of passers-by, through tapping into motions' natural ability to draw our attention. Whereas, the movements of the coMotion bench, were rarely perceived at a distance, or even by people placing bags and personal items on it while it moved. Even when the bench changed shape, sort of waving, it did almost nothing to attract people's attention if they were not seated on it.

Opportunities and Challenges

The ability for Actuated Interfaces to change their physical properties present a wide range of possibilities for tapping into motion's natural ability to draw our attention, convey information through physical change and for products to enter into new relations with both people and environments. Although the movements applied in the three cases are simple, compared with the complex range of human movements that we are used to interpret, they point to the potential of employing physical change as an interaction parameter.

Beyond the potentials that applying movement as an interaction modality, it also constitute some challenges. One challenge is the duality of how people experience and interpret the movements. For although several studies have shown the human capability to recognize emotions in movements (e.g. (Heider and Simmel 1944; Scholl and Tremoulet 2000; Saerbeck and Bartneck 2010)), the emotions experienced based on movements are less consistent. In all of the three cases users expressed a wide range of emotions. The movements of the Turning TV provoked both positive associations, such as the TV being in love, while others while felt uncomfortable with the TV's discrimination and described the experience as a bit uncanny. The surprise of the movements of the coMotion bench caused delight, giddiness, smiles, as well as people becoming alarmed, chocked and annoyed. Other studies have found a similar widespread emotional register, when presenting users with the hidden ability to move, such as in (Burneleit et al. 2009; Togler et al. 2009).The response to Aerial Tunes was less dispersed and extreme, compared with the other two examples, as the movements generally spurred curiosity and engagement. However, the stochastic nature of the movements also provoked discomfort, as this kind of movement could not easily be understood.

Another challenge is how to present the capabilities of Actuated Interfaces to move, whether it is clearly, immediately visible and directly manipulable, as in Aerial Tunes? Or if it should be a hidden quality aiming for surprise with the control concealed, as is the cases of the Tuning TV and the coMotion bench? Another challenge raised by the actions of both the TV and the bench, is what happens when artefacts employ human characteristics, such as using body language or begin to have their own intentions, such as dictating how people should be seated. The above-mentioned behaviour caused the different users to express and interpret these systems as being polite or unfriendly.

Open questions

Existing work on movements in Actuated Interfaces raises a number of questions for further research. While we are able to translate familiar human movements into product behaviour (e.g. (Burneleit et al. 2009; Togler et al. 2009; Mortensen et al. 2012)), the benefit of doing so, from a user perspective remains somewhat unclear. The three cases provide no definite answers to what the quality of adding movement to products is, from the users' perspective, but point to movement's ability to attract, intrigue and provoke.

Furthermore examples of Actuated Interfaces, such as Turning TV, which mimic the movements of living objects potentially face the challenge of determining, *what is the social etiquette for objects*? And how should they then enter into the social dialogue with people, should they just be submissive or would we accept them to have a 'mind of their own'? Another relevant question to explore is the influence of expectations and context on the experience of Actuated Interfaces, as the way the movements are presented and in which context they are presented could potentially influence the experience. The three cases illustrate the importance of exploring this influence, whether to present the ability to physically change openly as in Aerial Tunes, or conceal the ability to move within a familiar form, as the case is with Turning TV and the coMotion bench. What are the qualities of either approach, and how do our reactions change as we begin to expect things in out surroundings to move?

Experiencing Magic

The capacity for self-actuated physical change in Actuated Interfaces makes it possible to create situations, which seemingly do not adhere to the physical causalities that otherwise govern our interactions with everyday objects. Magic has previously received focus from the HCI community from for example Tognazzini (1993) and Landin (2005). With regard to magic then Actuated Interfaces hold the potential to create a sense of magic and wonder in people everyday lives, as they can challenge the expectations we hold of how objects behave. We know that an object placed in mid-air does not stay afloat, but drops to the ground when the hand releases it. We know that household appliances such as the TV or a public bench, do not suddenly acquire a mind of their own. However, in the case of Aerial Tunes (Alrøe et al. 2012), Turning TV (Mortensen et al. 2012) and coMotion these expectations are breached, creating a seemingly magical reality wherein it is possible for objects to float in mid-air and for a TV or a bench to come alive.

Rasmussen (2013) points to Subbotsky's (Subbotsky and Subbotskiĭ 2010) concept of magical causalities as a way to discern magical properties in interaction design. Subbotsky describe the concept of magical realities as

opposed to the physical reality where the physical reality is governed by the natural laws of causality. Magical realities on the other hand are governed by magical causality, which violate our innate expectations of how people, objects and animals behave in the world. Subbotsky (Subbotsky and Subbotskiĭ 2010) point to four types of causal effects, which can be considered magical: 1) *Mind-over-matter magic* (the direct effect of consciousness over matter), 2) *Animation magic* (the sudden acquisition of spontaneity by nonanimate physical objects), 3) *Non-permanence magic* (a violation of the physical laws of object permanence, physical space and time) and 4) *Sympathetic magic* (when certain objects or events affect other objects or events in a non-physical way, through similarity 'the image equals the object' or contagion 'once in contact, always in contact').

The three cases illustrate two different approaches to create a sense of magic, namely non-permanence magic and animation magic. Aerial Tunes provides an example of non-permanence magic. Other examples defying the physical laws can for example be found in ZeroN (Lee et al. 2011) a mid-air display or Kodama's (Kodama 2008) magnetic ferrofluid sculptures. The sense of magic was directly expressed by people interacting with Aerial Tunes (Alrøe et al. 2012). The breach of our familiar 'physical reality' was also more clearly manifested here, by the ball hovering in mid-air seemingly defying gravity. Although science can both create and explain why balls can float in mid air, what is actually experienced point towards a sense of magic. In a diary left for users to express their experience with Aerial Tunes, they responded to the interface with remarks such as *'COOL', WOW', 'SHIT HOW COOL'*, alongside opinions such as *"Marvellous Music Magic"* and observed on-site, a girl asked her friend: "What is this?" to which he answered: "*It is magic*". While the users most likely know that the balls defiance of gravity is not really a violation of the physical laws, but merely an illusion of doing so, the experienced effect is still that of non-permanence magic.

The coMotion bench and Turing TV are both examples of animation magic. Other examples of animation magic can for example be found in the thrifty faucet (Togler et al. 2009) or the impatient toaster (Burneleit et al. 2009). The sense of animation magic was less explicitly stated in the case of both the Turning TV and the coMotion bench. However, the comments expressed about the behavior of the TV, indicate that the TV seemed to come alive, and that it was perceived as an autonomous agent. One of the participants expressed the experience as; "*Since I was the one being followed it became a little uncanny. Devices rarely do this type of thing and following me is something that I attribute to humans and animals for example, but not electronic devices*" ((Mortensen et al. 2012), p.67). Seeing the TV as an autonomous agent points to an experience of a magical reality where the ordinarily physically static TV suddenly acquires spontaneity, a will of its own and even a preference for one person over another. Significant to the experience is that the behavior of the TV is outside the control of the participants, and regardless of what they do the TV will still regard one of them as having the highest status.

The sense of magic was not explicitly stated in the case of the coMotion bench, but the actions and replies to the movements point to that the people experienced the bench to acquire 'a will of its own' as it unexpectedly started to move. When encountering the bench there was a large difference in the response from users experiencing the bench alone, opposed together with others, even if they were strangers. Users who experienced the movements when alone were more prone to leave the bench, than people seated on the bench at the same time as others, as they could seek confirmation from others experiencing the same thing, either by talking about it or trough body language. Realizing that it was the bench moving, they sought to demystify and find answers for its movements, both with regard to its' purpose, for example *"why would it through me off? "...my brother was sure that we were not allowed to sit on it*" and "as well as for how it moves *"Is it air pressure?"* "*Is there anybody inside?"*.

Opportunities and Challenges

The perspective of Magic elucidates a number of opportunities and challenges for Actuated Interfaces. While magic might serve as a fruitful way to pique curiosity, provide a source of immediate attraction and a sense of wonder in the interaction, then it can also cause people to feel uncomfortable or irritated. The perspective of magic also poses a challenge when seeking users' response to an Actuated Interface, as it is difficult to determine if users experience it as magical. The absence of providing magic as an explanation to what they have experienced, could stem from users either not seeing it as magical or an apprehension to provide magic as an explanation for an experience, as magic generally is seen as being irrational and therefore alien to modern society (Bogdan 2012). Exploring the magic of Actuated Interfaces, as well as other types of interfaces, thus poses a challenge, as users might find it challenging to use magic as an explanation for an experience, and to 'on command' put these experiences into words, when confronted by a researcher in an interview.

Open questions

Viewing Actuated Interfaces though the perspective of magic, points to a need for exploring how people experience the breach in physical causalities through mind-over-matter magic, animation magic, non-permanence magic or sympathetic magic.

We also need to identify how we can seek to understand whether or not these experiences, which seemingly defy the natural laws of causalities, are experienced as creating a magic reality or a magical experience. Furthermore the concept of magic, points to a need for exploring how users experience of Actuated Interfaces change over time, especially since most studies of Actuated Interfaces only expose the participants to the interface once. Thereby neglecting the question of what happens to the experience of Actuated Interfaces, beyond the initial experience of surprise, fear, wonder, or delight, when the element of surprise is lost and the experience become familiar.

We might also need to consider the way we conduct the evaluations, as some things might be difficult for users to express in an interview, such as for example giving magic

as an explanation for an experience. The Guest Book used to gather user experiences in Aerial Tunes, provide an example of an approach, where the users were able to communicate feelings and impressions in a more spontaneous manner, than during the interviews. The Guest Book seemed to provide a channel where people was allowed to speak (or rather write) freely. Several people made reference to magic experiences and it appear that the format of a book invite for quite an open-minded narrative description of experiences.

Experiencing Ambiguity

When encountering a new artefact, its affordance and our past experiences form our expectations of the artefact and how to make sense of it (McCarthy and Wright 2004). When encountering Actuated Interfaces, the ability to interpret artefacts is challenged, as their ability to move and physically change form is often imperceptible. Distinguishing for example the Turning TV from its static counterpart is difficult or even impossible. Actuated Interfaces thus challenge our expectations of the artefact, potentially causing surprise as familiar objects suddenly come alive and start moving.

The coMotion bench and Turning TV both rely on familiar form references, whereas Aerial Tunes is a purpose-made form without previously known purpose and interaction modalities. When people interact with Aerial Tunes they do so, to uncover not only one aspect of Aerial Tunes, but its very nature; what is it, what is it for, and what can be done with it? The installation provides no specific way to use it, and there is no right or wrong, which opens up for both individuals and groups to experiment and play. The ambiguity of the coMotion bench arises from both the materials used, as well as the shape change of the bench. The dimensions of the bench and placement in the context, suggest to the user that the object is a bench, while the materials (stretchy fabric and elastics) is unconventional for a bench. This ambiguity was clearly seen in people hesitancy to accept it as a bench, and many approached the furniture by tapping it or poking it, as a way to clarify whether it was ok to sit on it or not. The movement and shape-change of the bench further added to the ambiguity, as when the bench altered form it no longer had the form that indicated that it was a bench.

All three cases also point to ambiguity of people's interpretation of the artefacts. In the case of both the TV and the bench, users speculated as to the intentionality of the objects. The TV gave rise to speculations about why the TV preferred one over the other. People reacted for example by stating, "it's in love with you", speculating that the TV has some notion of preference for certain people (e.g. men). With the bench, people speculated about if it wanting them to get off, as they thought (due to the bench's movement) that they were not allowed to sit on the bench. The ambiguity of people's interpretations of the bench's shape change was evident when the bench was explored in three different contexts. The three contexts people produced radically different interpretations of the same shape-change. In the airport people referred to the movement as a preparation of the flight, whereas in the concert hall it was related more to amusement rides. Similarly we found that the sense making of Aerial Tunes was extremely subjective and seemed to be coupled with people's backgrounds and interests. We saw that musicians related it to live performance, whereas a psychologist experienced Aerial Tunes as having a great meditative effect. One person revisited the installation several times during the exhibition period, viewing Aerial Tunes as a healing instrument through its combination of the visual appearance and soundscape. Some did not consider the music at all, arguing they found the playful nature and magical appearance a perfect match for a toy, where others again were captured by its calming effect like a fireplace or a fountain. One even related Aerial Tunes to hover boards from the movie "Back to the future".

Opportunities and Challenges

Using movement as an output modality presents a challenge to the traditional HCI approach of designing a single correct way to interpret a system (Sengers and Gaver 2006). While we might be able to interpret identical movement patterns in different forms displaying the same emotions (Saerbeck and Bartneck 2010), interpreting movement is often ambiguous rather than straightforward and singular. Sengers and Gaver (2006) argue that it is not necessarily a problem that users interpret a system in diverging ways, even beyond what the designer intended, but that a more nuanced view of interpretation is needed in which multiple, perhaps competing interpretations can exist. Although ambiguity in Actuated Interfaces presents a potential for creating designs that are open for interpretation, engaging and thought provoking, then ambiguity is not a virtue in itself, but should be the outcome of purposeful design, rather than an unanticipated result (Sengers and Gaver 2006).

Open questions

The ambiguous nature of peoples' interpretation of Actuated Interfaces also poses the question of how to evaluate such interfaces. As exemplified with Aerial Tunes and the coMotion bench, people's interpretations can be highly individual and heterogeneous. One approach is to determine whether an authoritative interpretation was successfully communicated, but an alternative approach is to evaluate how an interface embraces the ambiguity and fosters multiple interpretations in practice (Sengers and Gaver 2006).

Furthermore, ambiguity point to exploring the impact of the physical form on peoples experience of an artefact. Saerbeck and Bartneck's (2010) psychological experiments indicate that emotions can be recognized regardless of the form they are exhibited in. Still, reflections on the interpretation and ambiguity of Actuated Interfaces point to a relevance and influence of the form, whether familiar or unfamiliar, on the experiences. The influence of the context on users experience and interpretation of Actuated Interfaces was seen while testing the coMotion bench in three different contexts, which point to considering both the choice of context when testing Actuated Interfaces, as well as its impact on the results.

CONCLUSION

In this paper we have emphasized the necessity of supplementing the existing investigations of technical challenges and application potentials of Actuated Interfaces, with a turn towards studying user experience. Despite the increasing quantity of examples of Actuated Interfaces, there exists only little knowledge on how users encounter, experience and understand this type of interface in use. This paper presents an attempt to further the understanding of how people encounter, interact and live with Actuated Interfaces, as well as the qualities they possess, which set them apart from their physically static counterparts.

Based on three cases, we have presented three perspectives aimed at unfolding different aspects of users' experiences with Actuated Interfaces. Albeit the perspectives do not provide an exhaustive list of perspectives for discussing Actuated Interfaces, they do provide a relevant starting point for initiating a reflection upon how users experience Actuated Interfaces. The perspectives of; experiencing movement, experiencing magic and experiencing ambiguity, take their point of departure in the users' responses to the three cases, while building upon different fields of knowledge already established, in particular those of psychology and design. The perspectives are thus, not in themselves new the community, but by applying them as a tool for reflection on Actuated Interfaces, they provide new insights into how the kinetic physicality of Actuated Interfaces are experienced.

Although this paper only begin to scratch the surface of experiencing Actuated Interfaces, then applying the three perspectives to the three cases, contribute a number of potentials and challenges, as well as topics for future research on Actuated Interfaces. The topics discussed revolve around four common themes: expectations, interpretation and sociality of Actuated interfaces, as well as the approach to evaluating Actuated Interfaces.

Lastly, we would like to point to that Actuated Interfaces hold a potential for active exploration and experimentation, as well as for spurring emotional engagement. Which are qualities that are not normally found nor cherished in classic interaction design, but which are of immense importance and relevance if we are to design for the whole spectrum of human experiences in everyday life.

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