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Published in:
The Design Journal

DOI:
https://doi.org/10.1080/14606925.2020.1810434

Publication date:
2020

Document Version:
Publisher's PDF, also known as Version of record

The Design Journal
An International Journal for All Aspects of Design

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rfdj20

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To cite this article: Myra Thiessen , Sofie Beier & Hannah Keage (2020) A Review of the Cognitive Effects of Disfluent Typography on Functional Reading, The Design Journal, 23:5, 797-815, DOI: 10.1080/14606925.2020.1810434

To link to this article: https://doi.org/10.1080/14606925.2020.1810434

Published online: 03 Sep 2020.

THE DESIGN JOURNAL

A Review of the Cognitive Effects of Disfluent Typography on Functional Reading

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ABSTRACT Recent debate has seen the proposition that difficult to read, or disfluent, typefaces can improve certain learning conditions. This is counterintuitive for typography where it is the aim to support reading acts by creating texts that are as clear and as easy to read as possible. We explore recent literature on the disfluency effect in an effort to contextualize the results for typography research that is grounded in functional readability. What is

The Design Journal DOI: 10.1080/14606925.2020.1810434

Routledge Taylor & Francis Group

evident is that the discussion about whether or not disfluent reading materials support learning is far from resolved. Further research is needed in key areas such as those related to the typographic principles of visual cuing and emphasis as well as other broader areas such as how we may be able to determine threshold for disfluency, benefit over time, and what impact environmental distractions have on the disfluency effect.

KEYWORDS: Typography, functional readability, psychology, cognition, disfluency

Introduction

Recently, a small group of typographic and legibility researchers have begun to call for more collaboration in an effort to generate knowledge that is useful and practical (Beier 2016; Dyson 2013; Thiessen et al. 2015). This is likely due to the recognition that although investigations into many aspects of reading, reading processes, and cognition have been documented over many decades, some basic questions about how findings relate to typographic design for reading remain unanswered. This may be because much of the knowledge generated about reading has been undertaken by psychologists and vision scientists whose research questions tend to be framed around understanding cognition and behaviour broadly; whereas, typographers tend to be more concerned with the reading materials and how these might be designed to better support reading and learning behaviours. Although understanding how readers behave and interact with texts is essential to supporting reading tasks, the knowledge generated by studies that are strictly focused on reading processes is not always easy to translate into typographic outputs.

To discuss this issue, this paper evaluates the disfluency effect, which purports that increasing the perceptual difficulty of reading materials can have a positive effect on a reader's memory. This effect has seen recent debate; however, the academic community is no closer to consensus on how and to what extent disfluency affects cognitive functions such as memory. We postulate that through multidisciplinary collaborations involving psychology and typography, experimental research that draws on both cognitive neuroscience and psychological methodologies data can be generated that is more accurately reflects readers and reading materials.

Functional readability

Guided by tradition, typographers tend to rely on experiential and craft knowledge. This is a rich tradition that is informed by generations of accumulated knowledge of technique and technology and by observing different typographic styles and readers. These tend to

follow cultural preferences and reading requirements over time, along with the aesthetics of the typographer. However, with technological advancements and data collection tools like electroencephalography (EEG), functional Magnetic Resonance Imaging (fMRI), and eye-tracking equipment we have the capacity to understand reading processes in a more detailed way.

It is important to recognize, however, that within an applied practice like typography scientific paradigms cannot provide a complete picture about ideal reading scenarios. This is because they can only speak to a narrow set of defined and controlled criteria at any one time since the isolation of variables is essential to experimental methodologies within science. We see scientifically based investigations as essential to understanding typographic practice, but their usage depends on the nature of the investigation; the criteria tested may not consider aspects of reading in contexts – and texts must perform in a broad range of real-life reading scenarios. In order to test and gather data on reading behaviour and material, artificial reading scenarios must be created, most typically in laboratories or other controlled environments. Regardless of whether or not the materials are realistic, the environment or the task necessary for systematic scientific study will impact the reading action. This means that to create a successful text for the intended action, the typographic practice will combine the science (generated under controlled conditions), the craft, and the reading scenario. We call this evaluation of reading in context *functional readability*.

Our definition builds on a popular understanding of readability, which focuses primarily on craft, and states, 'if the columns of a newspaper or magazine or the pages of a book can be read for many minutes at a time without strain or difficulty, then we can say the type has good readability' (Tracy 1986, 31). However, what is missing from Walter Tracy's definition is clear integration of the knowledge developed about readers and reading behaviour in response to typographic materials and the context or environment in which they are expected to complete the reading action. For functional readability the performance of a text is examined with Tracy's understanding for ease – including how typographic variables such as typeface, size, space (horizontal and vertical), and layout interact – but is expanded to incorporate how external environmental factors and differences across individual readers and their expectations and goals, might impact the reading action. It considers how emphasis, grouping or visual cueing is interpreted (Dyson and Beier 2016) but might also include less traditional typographic applications such as those that signal to readers appropriate vocal expression when reading out loud (Bessemans et al. 2019) or how easily additions like hyperlinks used to enhance text meaning through hidden layering are understood. In short, functional readability evaluates text typography and speaks to how well that text supports comprehension and how appropriate it is for the specific task, context, environment, and

reader. Questions that evaluate functional readability might include: Is the typography to be read at night? Will it be back lit? Is the reader nervous because he or she is visiting a hospital? Do they have a reading difficulty?

The disfluency[1] effect

Central to functional readability are the needs of the reader and how they might respond in the light of varying tasks, typographic genre, and individual preference. In the psychological literature, the spectrum of fluency in the context of written information (from fluent to disfluent) refers to 'the subjective experience of ease or difficulty with which we are able to process information' (Oppenheimer 2008, 237). It is the cognitive effort needed to complete a reading task measured by speed and accuracy and includes judgements about perceived effort by the reader. This is closely linked to functional readability because a reader's impression of texts based on how it looks[2] can influence how difficult or convoluted the content appears, how time consuming it is understood to be, or whether it is trustworthy (Song and Schwarz 2008b, 2010).

The disfluency effect, as observed by Oppenheimer (2008), may impact a range of cognitive processes, including encoding, conceptual understanding and reasoning, spatial attention and processing, and, central to typographic presentations, perceptual fluency. Perceptual fluency is affected by visual aspects of the typography (Dunlosky and Mueller 2016) including features related to how clear and easy to recognize letters and words that comprise a text are. This includes features such as the presentation surface (e.g. screen or print; high or low resolution), the visual complexity of the typeface, or issues related to type size, contrast, and space, such as crowding. These issues may be better understood within typographic literature as describing texts or typefaces that are more or less readable and legible.

Texts that are seen to be challenging in relation to perceived cognitive effort can hence be considered as disfluent. However, these harder to read texts are not always seen to be undesirable in cognitive psychology. Since they elicit more attention, disfluent typefaces can be associated with conditions of desired difficulty (Bjork and Bjork 2011) that act to slow down reading speed and in this way, increase the likelihood that individuals will recognize errors in text and content (Song and Schwarz 2008a) or contribute to an increase in retention for facts (Diemand-Yauman, Oppenheimer, and Vaughan 2011; French et al. 2013; Sungkhasettee, Friedman, and Castel 2011). This rationale is counterintuitive to typography, where the aim is typically to facilitate conditions that support reading with minimal effort.

The 'how' and the 'what'

By its nature, typography practice and research must draw knowledge and theory from a range of disciplinary domains. This agility in practice is a strength and provides a broad understanding of several interacting fields of knowledge. It is an approach that is grounded in collaborations across typography and psychology that aim to produce the most applicable and productive knowledge in legibility research. However, we see two problems central to the discussion: (1) psychological scientists do not tend to generate knowledge that has a clear application to typographic practice primarily because they are more interested in reading behaviour and individual differences rather than the material used to read from; and (2) typographers lack the vocabulary to interpret results generated through psychological experiments into relevant typography application. So, while both psychological scientists and typographers are interested in reading and legibility, they tend to prioritize different aspects of the behaviour. As Dyson (2013) explores, psychologists tend to place more focus on improving our understanding of *how* the brain and the perceptual system processes and understands information; whereas, typographers are more focused on the *what* and are primarily interested in ways reading material can be designed to improve the reading experience, the accessibility of the information, and overall impression of the text. Thus, we attempt to expand on Dyson's effort to reconcile psychologists' and designers' approaches where possible or identify differences that may enrich our understanding of 'how we read and how we may design letters to facilitate reading' (Dyson 2013, 282).

Although *how* we read and *what* we read are difficult to separate in practice, collaborative research teams have been historically rare. In the sixties and seventies, a team led by Herbert Spencer included researchers with background in academic research and researchers who were practising designers (Spencer 1968; Spencer, Reynolds, and Coe 1973). More recently, the value of unique multidisciplinary teams can be seen directly in practice with the work of Microsoft's Advanced Reading Technologies and their collaboration with type designers, first with the ClearType project (Berry 2004; Larson et al. 2007; Larson et al. 2007) and again with the development of the typeface family Sitka (Larson and Carter 2016). Another contemporary example is the Centre for Visibility Design at The Royal Danish Academy of Fine Arts, which includes researchers with backgrounds in graphic design and in psychology (Beier and Oderkerk 2019a, 2019b). Within the research community, several newer experiments employing a paradigm of classic psychophysics[3] are results of collaborations between type designers and vision scientists (Beier, Bernard, and Castet 2018; Beier and Dyson, 2013; Dobres, Reimer, and Chahine 2016; Sawyer et al. 2017; Xiong et al. 2018), and typographers and neuroscientists (Keage et al. 2014; Thiessen et al. 2015). These novel multidisciplinary methodological approaches are

showing that choice of typeface has cognitive and perceptual implications that can impact on behaviours and abilities to sustain reading activities over time.

The differences observed in motivation, priority, and vocabulary may be what makes finding common ground across psychology and typography more difficult, and thus, why collaboration is rare. However, the fact that typography, a traditionally craft-oriented field, can use experimental methods to identify *yes* or *no* answers to questions regarding comprehension or reading ease, is, in our view, a gift to the design community. It is nonetheless important to remember that within the context of typographic practice, knowledge is inconsequential if it cannot be translated into a typographic output. Our aim is to expand this discussion and advocate for greater consideration and integration of cognitive neuroscience and psychological research as a means to inform a typographic practice that prioritizes functional readability.

Making sense of the disfluency effect

The literature has seen debate about the value of the disfluency effect with two studies published in Diemand-Yauman, Oppenheimer, and Vaughan (2011) occupying a central role. In the paper, findings are presented that suggest increasing the visual complexity of learning materials by using difficult to read typefaces improves retention and recall in memorisation tasks. In their first experiment Diemand-Yauman et al. demonstrated the disfluency effect for a short-term task taking place over a few hours and in a lab setting. Participants were asked to learn about three different fictional creatures. They were expected to memorize seven characteristics for each creature for a total of 21 characteristics. The disfluent conditions, examples shown in Figure 1, were Comic Sans Italic and Bodoni Italic both in a 60% tint of black at 12-point. For the fluent condition, Arial Regular at 16-point printed in full black was used.

The first study was followed up by testing the hypothesis under more realistic learning conditions: in high school classrooms with school aged participants over a period that ranged between one and a half weeks for some groups and up to four weeks for others. Teachers were asked to deliver their usual content but for the disfluent condition used materials that were presented in difficult to read typefaces, consisting of either Haettenschweiler, Monotype Corsiva, or Comic Sans Italic (Figure 1), or materials that were visually manipulated through intentionally distorting the type by moving the paper during photocopying. For the control condition, teachers used their normal materials with no visual manipulations. At the end of individual curricular modules, the participants who were exposed to the disfluent conditions performed better when tested compared to the control (fluent) condition. These results may seem relatively straightforward, and they are presented as influential on learning, but they are not a complete picture of the disfluency effect and do not

	Disfluent		Fluent
12 point Comic Sans Italic	*The quick brown fox jumps over the lazy dog.*	16 point Arial	The quick brown fox jumps over the lazy dog.
12 point Bodoni Italic	*The quick brown fox jumps over the lazy dog.*		
12 point Hattenschweller	**The quick brown fox jumps over the lazy dog.**		
12 point Monotype Corsiva	*The quick brown fox jumps over the lazy dog.*		

Figure 1.
Examples of the typeface conditions tested in Diemand-Yauman, Oppenheimer, and Vaughan (2011).
We have attempted to replicate the typeface conditions as they are shown in Diemand-Yauman et al.; however, there is some discrepancy in how the materials are described and it is not entirely clear when italicized Roman versions of Comic Sans and Bodoni are used or whether they were true italics.
When comparing letters across font it is more appropriate to standardize size by equating x-height rather than pointsize.

account for several interacting factors related to cognitive effort and processing, which may also play a role. In short, they only tell half the story.

Measuring brain activity using EEG demonstrates that the visual complexity of a typeface effects the cognitive effort required to identify individual letters (Keage et al. 2014), aligning with cognitive research, which shows that texts set in typefaces that are visually complex are harder to identify by readers than ones that are simpler (Beier, Sand, and Starrfelt 2017; Pelli et al. 2006). This increased attention and cognitive effort is seen at both low-level visual processing (up to 200 milliseconds post-stimulus) and higher-level recognition processing (220–300 milliseconds), suggesting that disfluent typefaces require more processing resources for letter identification and comprehension (Keage et al. 2014). This finding may account for the improved memory related performance seen in some studies exploring the disfluency effect (Diemand-Yauman, Oppenheimer, and Vaughan 2011; French et al. 2013; Sungkhasettee, Friedman, and Castel 2011). However, further analysis of Keage et al.'s finding shows that differences exist in the processing of disfluent (compared to fluent) typefaces beyond extraction of low-level features and recognition of the letter has occurred; that is to say, readers must continue to exert increased cognitive effort to integrate and maintain disfluent stimuli in the working memory (after 350 milliseconds post-stimulus) in comparison to easier to read variations.

Such phenomenon is a concern for typographers who aim to support reading by reducing the cognitive burden on attention and working memory processes (Unger 2007). Working memory (Baddeley 1992, 2002) describes some of the cognitive processes that underly

functional language operations such as attention, visual, and speech-based processing. These processes are central to reading comprehension, but fragile and limited in capacity. In this light, most legibility research projects are driven by the assumption that comprehension and other higher order tasks can be supported by reducing the cognitive load necessary to complete simple low-level tasks, like letter and word identification. However, the disfluency effect suggests the opposite and claims that disfluency creates a level of desired difficulty, that by attracting more attention, acts to promote deeper processing and thus supports learning (Bjork and Bjork 2011). Experimental strategies that remove letters or words to render disfluency, or that invert words (Sungkhasettee, Friedman, and Castel 2011) utilize cognitive domains such as spatial processing, concept formation and reasoning – not usually relied on heavily during expert reading – which appears to facilitate learning. However, this is not necessarily the same as manipulating visual complexity by using difficult to read typefaces, which likely increases attentional load. A difficulty is that in experimental studies disfluency is operationalized through a range of different typographic manipulations, including variations to content or visual/stylistic changes, but these differences are not always made clear.

Although Diemand-Yauman et al. recognized that competing issues such as the novelty (referred to as distinctiveness) of the learning material, individual participant differences followed by the between-subject study design, or how the content was delivered by the teacher may have contributed to better performance, it was nonetheless suggested by the authors that difficult to read typefaces are an easy and cost-effective way to improve students learning results. This statement is counterintuitive for typographers, and for functional readability, and might also be irresponsible before these data had been tested for reliability. Indeed, more recent studies have proven the results reported in Diemand-Yauman et al. difficult to replicate (Dunlosky and Mueller 2016; Taylor et al. 2020) suggesting their importance may have been both inflated and premature.

Further, and suggesting there are still gaps, a meta-analysis of disfluency studies revealed no effect of perceptual disfluency on recall, but did show that the use of difficult to read typefaces does impact an individual's judgements of the time and effort needed to adequately memorize content (Xie, Zhou, and Liu 2018), as well as increasing the actual time needed to learn information (Eitel and Kühl 2016; Sanchez and Jaeger 2015). One exception to this trend, and with a thorough methodology, is the work by Geller et al. (2018), who found an effect on memory in favour of handwritten scripts compared to the font Courier[4]. One very interesting point this study raises is that it suggests there may be a threshold at which point novelty or visual complexity ceases to be beneficial to memory. In Geller et al.'s experiment, readers tended to remember words better when they were presented in an easy compared to hard to read

handwritten variation (Geller et al. 2018) suggesting the possibility of a perceptual disfluent effect that is strongest using only mildly difficult to read typefaces.

Considerations for typographic application

More difficult to read texts tend to impact efficiency by increasing cognitive load at both discriminative and sustained processing (Keage et al. 2014; Thiessen et al. 2015) and increasing reading time (Sanchez and Jaeger 2015), suggesting they take more effort to decipher. This means it is likely that fewer cognitive resources are available for readers to perform any number of parallel and higher order tasks, making it difficult to see how increasing the visual complexity of a text could lead to desirable reading conditions.

Typographers are very interested in typography that is designed for likeability and clarity of content because such focus is closely connected to the motivational aspects related to reading actions (Unger 2018). For this, some of the most relevant topics that have been investigated by the research community are: changes of typeface (Garvey, Eie, and Klenna 2016; Pušnik, Podlesek, and Možina 2016), size of type (Legge and Bigelow 2011), and variations to spacing conditions (Perea et al. 2012). It has also been shown that the visual aspects of a text, such as those related to genre, provide information about the kind of content it contains and thus dictate reader expectation and response (Gonzales Crisp 2012; Moys 2013, 2014; Schriver 1997). Further to this, typographers must also consider the reading environment, with all the inevitable distractions, as well as understanding what the reader aims to achieve by completing the reading task. Although not typically part of studies of disfluency, we think these above-mentioned factors related to functionable readability contribute to a reader's impression of ease and are, therefore, relevant to discussions of disfluency.

Motivation and preference

Importantly, impressions of difficulty like those associated with disfluency are very likely to impact one's motivation to engage with a task (Oppenheimer 2008) and this preference for typography likely develops early in the literacy development process (Walker and Reynolds 2003). Since a reader's motivation plays a large role in whether they will engage with the text and for how long, typographers typically take a position that involves making the reading task look as easy as possible. In an examination of the visual impact of high-quality and poor-quality typography, Larson et al. (2007) explore the importance of aesthetics on reading performance. They assert the way that a text looks, and whether it is visually appealing, can impact on how well it works for a reader, or a specific demographic of readers. Aesthetics perform an important role by capturing a reader's attention and providing cues as to difficulty or genre. Although Larson

et al. did not find any differences in reading performance based on typographic variation, they did determine that participants performed better when in a better mood. This was measured indirectly by observing a reduction in frowning when participants were reading test variations that were more legible, which may indicate less frustration.

An individual's opinion of whether or not they will remember something later, is called *judgment of learning* (JOL). This is based on several factors, among these the impression of perceptual information such as the typographic setting (Luna, Nogueira, and Albuquerque 2018). If we follow the reasoning of most typographers, and the above-mentioned findings on the positive effect of high-quality typography, one would expect a positive influence on JOL in cases where the text stimulus is highly readable. This is also the case. In a series of studies, Yue, Castel, and Bjork (2013) explore and try to replicate results that support desired difficulty for learning. They showed participants a series of words one at a time in groups of 26 words. The word groups were either clear or blurry. For each list participants were asked to rate how confident they felt they were on remembering each word if asked later in the experiment. Yue et al. found that memory for clear words was higher than for blurry words and that this corresponded to the JOLs indicated by each participant. This trend was apparent over short (2 second) as well as or long (5 second) exposure times; however, memory for the blurry words improved with a longer exposure time. Yue et al. suggest that visually distorting words does not create a desired difficulty, later confirmed by Magreehan et al. (2016). Rather, readers are just likely to need more time to complete reading tasks and learn equivalent content when disfluent compared to fluent material is used (Eitel and Kühl 2016; Xie, Zhou, and Liu 2018).

Sanchez and Jaeger (2015) confirm this result demonstrating fixation time is on average longer when participants are reading from texts that use typefaces that are more difficult to read, suggesting that the overall slower reading time is a result of the need for longer fixations. The matter is, however, not completely clear. Strukelj et al. (2016) show different results with eye tracking as they found no disfluency effect for learning outcomes, reading time, fixation time, or time spent reading. The studies do differ in how visual complexity was defined with Sanchez and Jaeger varying typeface across Courier (fluent condition) and Mistral (disfluent condition); whereas, Strukelj et al. manipulated a single typeface, Arial, by using a filtering technique that created a blurring effect, interpreted in Figure 2. This further suggests that there is likely a threshold at which visual complexity impacts reading behaviour and points to a need for more research.

The literature supports the often-voiced hypothesis among practising designers that typefaces can have an inherent connotation. Applying the attribute scaling methodology of semantic differential,

	Disfluent		Fluent
12 point Mistral	The quick brown fox jumps over the lazy dog.	12 point Courier	The quick brown fox jumps over the lazy dog.
12 point Arial (blur filter)	The quick brown fox jumps over the lazy dog.	12 point Arial	The quick brown fox jumps over the lazy dog.

Figure 2.
Examples of typeface variations tested using eye tracking. Sanchez and Jaeger (2015) tested fluency across typeface while Strukelj et al. (2016) manipulated a single typeface with blurring, interpreted here.

developed by Osgood, Suci, and Tannenbaum (1957), it has been demonstrated that when asking participants to rate a typeface's semantic association, participants agree on assigning the same adjectives to typeface styles (Brumberger 2003; Juni and Gross 2008; Tantillo, Lorenzo-Aiss, and Mathisen 1995; Walker, Smith, and Livingston 1986), and associate certain typeface styles with certain products (Doyle and Bottomley 2004). Lewis and Walker (1989) have manage to show similar results by employing a paradigm based on performance, and demonstrated that participants react to the relationship between the meaning of the word and a perceived meaning or character of a typeface in a similar fashion to the Stroop effect[5] (Stroop 1935). After a preliminary study, where participants were asked to rate a range of typefaces on a series of seven point scales with opposite adjectives at the extremes, Lewis and Walker found that when typing the adjective pairs of strong/weak, bright/dull, fast/slow, light/heavy in either the typeface Cooper Black or Palatino Italic, and when the adjective was consistent with what the typeface had been judged as in the preliminary study, the response time was faster than when it was inconsistent. Readers are also more likely to group description words or see them as members of the same category when they appear in the same typeface (Oppenheimer and Frank 2008). This suggestion that readers categorizes concepts based on their visual appearance points to the value of visual cueing. Typographers regularly draw on visual cueing techniques, such as grouping, hierarchy, and emphasis created through visual relationships that are determined by typeface, colour, or placement. What Oppenheimer and Frank (2008) show is that these actions improve fluency and related cognition, suggesting that how visual relationships are interpreted and understood impacts learning as well as motivational aspects related to reading.

Finally, an interesting exploration for typographic application are studies that looked at distinctiveness (Rummer, Schweppe, and Schwede 2016). Distinctiveness can be described as how different or unique a font is and also how different typefaces are from each other when multiple typefaces are used within a single text. Distinctiveness is important for typographic practice in several ways. Typeface designers develop alphabets that share visual

characteristics so the letters sit together in harmony, but that are also different in important ways so each letter can be easily identified (Beier 2012). When mixing typefaces typographers tend to choose families that have distinctive differences so to create enough contrast that the change can be easily seen by the reader (Beier 2012; Gonzales Crisp 2012). Changing typeface is a way to signal the reader to the importance of a word or phrase, determine a hierarchy and structure, and to group related information. Rummer, Schweppe, and Schwede (2016) explored distinctiveness in relation to disfluency since unusual typefaces are known to attract attention, and although they found no effect of distinctiveness, questions remain about whether or not typeface distinctiveness can be useful in typographic application. For example, Rummer et al. did not mix typeface stimuli within a single reading condition, which eliminates the opportunity for direct visual comparison. They also speculate that other moderators could contribute to the strength of an effect of distinctiveness such as learner, material, or task characteristics. Explored in this way, distinctiveness aligns closely with the typographic principle of emphasis and since questions remain about whether learners benefit from its use, we suggest further study is warranted.

Conclusion

Contextual and cultural consideration in reading research is important to inform best practice for functional readability. Conversely, in order to examine, for example, the brain's response to specific stimuli, distractions must be limited and experiments undertaken in laboratory settings. Consequently, our ability to collect data of external validity may be limited by the necessary use of contrived reading scenarios in lab environments. Nonetheless we propose that this is a necessary and important piece of the puzzle that to now has been missing. Used alongside other data collection methods as well as more qualitative analyses that explore preference or individual reader scenarios, a more informed set of principles can be developed. Interdisciplinary collaborations are necessary to produce findings related to a wider range of reading material and requirements, as well as readers, and also likely to improve our knowledge about text and typeface design in a more robust way.

Although it is not clear whether or not disfluent conditions related to visual complexity support learning and memory tasks over the long-term, what the current debate has highlighted is how things can go wrong. It is counter intuitive to typography to suggest that teachers use difficult to read typefaces as a cost-effective way to improve learning results (as it was suggested by Diemand-Yauman, Oppenheimer, and Vaughan 2011). Further still, it is perhaps irresponsible to make this suggestion before the academic community has had adequate opportunity to test the robustness of the claim. We see value in continuing to explore disfluency since questions

related to emphasis (distinctiveness) and visual groupings, threshold for visual complexity of typefaces, extended reading conditions and learning effects over time, and the effect of reading or learning environments remain unanswered. However, we suggest that the best way to further knowledge of reading processes and materials are through collaborative research efforts that involve both psychology and typography. For example, most of the experiments into typeface disfluency have compared typefaces of different families and styles. This approach makes sense when the aim is to investigate the ultimate effect of disfluency, yet it is not effective when investigating the effect of more subtle differences across typefaces such as those a typographic practitioner may draw on to create hierarchies or emphasis. Finally, in most of the cases reported in this paper, issues of typographical fluency relate to scenarios involving the reading of text at an average reading distance of about 40–50 cm. For normal vision adult readers this also means that perceptual difficulties in identifying the letters and words are a minor problem. However, out in the environment, reading can be affected by a range of situational and physical deficits, which can result in great challenges in the perception of the type. Creating new more controlled investigations that focus on intermediate levels of disfluency as stimuli, could contribute with more nuanced answers to the disfluency debate.

NOTES

1. We use the term disfluency/fluency to align with psychology literature and because we discuss issues related to visual aspects of typography but also a reader's impression of a text based on those visual aspects.
2. Typographic genre is related to how texts are categorized by readers base on broad visual features, e.g. newspaper compared to novel. Readers develop expectations that can influence their reading strategy based on how a text looks (Moys, 2013, 2014).
3. Psychophysics describes a branch of psychology that explores the relationship between physical objects or stimuli and mental phenomena.
4. The monospaced nature of Courier may affect its readability, and thus, the results reported in the Geller et al. study. A collaborative approach that includes typography researchers is likely to bring to light such concerns.
5. The phenomenon known as the Stroop effect was first reported by John Ridley Stroop in 1935. It shows that it is easier to name the ink-colour of a word such as 'red', if the colour is red compared to any other colour.

Disclosure statement
No potential conflict of interest was reported by the authors.

Funding

This work of the second author was supported by the Danish Council for Independent Research [grant number DFF – 7013-00039].

References

Baddeley, Alan. 1992. "Working Memory." *Science (New York, N.Y.)* 255 (5044): 556–559. doi:10.1126/science.1736359.

Baddeley, Alan. 2002. "Is Working Memory Still Working?" *European Psychologist* 7 (2): 85–97. doi:10.1027//1016-9040.7.2.85.

Beier, Sofie. 2012. *Reading Letters: designing for Legibility*. Amsterdam: BIS Publishers.

Beier, Sofie. 2016. "Letterform Research: An Academic Orphan." *Visible Language* 50 (2): 64.

Beier, Sofie, Jean-Baptiste Bernard, and Eric Castet. 2018. "Numeral Legibility and Visual Complexity." DRS 2018 Conference Proceedings, Limerick.

Beier, Sofie, and Mary C. Dyson. 2013. "The Influence of Serifs on 'h' and 'l': Useful Knowledge from Design-Led Scientific Research." *Visible Language* 47 (3): 74–95.

Beier, Sofie, and Chiron Oderkerk. 2019a. "The Effect of Age and Font on Reading Ability." *Visible Language* 53 (2): 51–68.

Beier, Sofie, and Chiron Oderkerk. 2019b. "Smaller Visual Angles Show Greater Benefit of Letter Boldness than Larger T Visual Angles." *Acta Psychologica* 199: 102904. doi:10.1016/j.actpsy.2019.102904.

Beier, Sofie, Katrine Sand, and Randi Starrfelt. 2017. "Legibility Implications of Embellished Display Typefaces." *Visible Language* 51 (1): 112–132.

Berry, JohnD. 2004. *Now Read This: The Microsoft ClearType Font Collection*. www.microsoft.com/typography/ctfonts:Microsoft Corporation.

Bessemans, Ann, Maarten Renckens, Kevin Bormans, Erik Nuyts, and Kevin Larson. 2019. "Visual Prosody Supports Reading Aloud Expressively." *Visible Language* 53 (3): 29–49.

Bjork, Elizabeth L., and Robert A. Bjork. 2011. "Making Things Hard on Yourself, but in a Good Way: creating Desirable Difficulties to Enhance Learning." *Psychology and the Real World: Essays Illustrating Fundamental Contributions to Society* 2 : 59–68.

Brumberger, Eva R. 2003. "The Rhetoric of Typography: The Persona of Typeface and Text." *Technical Communication* 50 (2): 206–223.

Diemand-Yauman, Connor, Daniel Oppenheimer, and Erikka Vaughan. 2011. "Fortune Favors the Bold (and the Italicized): Effects of Disfluency on Educational Outcomes." *Cognition* 118 (1): 111–115. doi:10.1016/j.cognition.2010.09.012.

Dobres, Jonathan, Bryan Reimer, and Nadine Chahine. 2016. "The Effect of Font Weight and Rendering System on Glance-Based Text Legibility." Proceedings of the 8th International Conference on Automotive User Interfaces and Interactive Vehicular Applications. doi:10.1145/3003715.3005454.

Doyle, John R., and Paul A. Bottomley. 2004. "Font Appropriateness and Brand Choice." *Journal of Business Research* 57 (8): 873–880. doi:10.1016/S0148-2963(02)00487-3.

Dunlosky, John, and Michael L. Mueller. 2016. "Recommendations for Exploring the Disfluency Hypothesis for Establishing Whether Perceptually Degrading Materials Impacts Performance." *Metacognition and Learning* 11 (1): 123–131. doi:10.1007/s11409-016-9155-9.

Dyson, Mary C., and Sofie Beier. 2016. "Investigating Typographic Differentiation: Italics Are More Subtle than Bold for Emphasis." *Information Design Journal* 22 (1): 3–18. doi:10.1075/idj.22.1.02dys.

Dyson, Mary C. 2013. "Where Theory Meets Practice: A Critical Comparison of Research into Identifying Letters and Craft Knowledge of Type Design." *The Design Journal* 16 (3): 271–294. doi:10.2752/175630613X13660502571741.

Eitel, Alexander, and Tim Kühl. 2016. "Effects of Disfluency and Test Expectancy on Learning with Text." *Metacognition and Learning* 11 (1): 107–121. doi:10.1007/s11409-015-9145-3.

French, Matthew M. J., Arabella Blood, Naomi D. Bright, Dez Futak, M. J. Grohmann, Alex Hasthorpe, John Heritage, Remy L. Poland, Simon Reece, and Jennifer Tabor. 2013. "Changing Fonts in Education: How the Benefits Vary with Ability and Dyslexia." *The Journal of Educational Research* 106 (4): 301–304. doi:10.1080/00220671.2012.736430.

Gage, Nicole M. and Bernard J. Baars. 2013. *Fundamentals of Cognitive Neuroscience*, edited by Nicole M. Gage. Boston: Academic Press.

Garvey, Phillip M., Wei-Yin Eie, and M. Jennifer Klenna. 2016. "The Effect of Font Characteristics on Large Format Display." *Interdisciplinary Journal of Signage and Wayfinding* 1 (1). doi:10.15763/issn.2470-9670.2016.v1.i1.a3.

Geller, Jason, Mary L. Still, Veronica J. Dark, and Shana K. Carpenter. 2018. "Would Disfluency by Any Other Name Still Be Disfluent? Examining the Disfluency Effect with Cursive Handwriting." *Memory & Cognition* 46 (7): 1109–1126. doi:10.3758/s13421-018-0824-6.

Gonzales Crisp, Denise. 2012. "Typography." In *Graphic Design in Context*, edited by Meredith Davis. London: Thames & Hudson Ltd.

Juni, Samuel, and Julie S. Gross. 2008. "Emotional and Persuasive Perception of Fonts." *Perceptual and Motor Skills* 106 (1): 35–42. doi:10.2466/pms.106.1.35-42.

Karlos, Luna, Marlene Nogueira, and Pedro B. Albuquerque. 2019. "Words in Larger Font Are Perceived as More Important: explaining the Belief That Font Size Affects Memory." *Memory* 27 (4), 555–560. doi: 10.1080/09658211.2018.1529797

Keage, Hannah, Scott Coussens, Mark Kohler, Myra Thiessen, and Owen Churches. 2014. "Investigating Letter Recognition in the Brain by Varying Typeface: An Event-Related Potential Study." *Brain and Cognition* 88: 83–89. doi:10.1016/j.bandc.2014.05.001.

Larson, Kevin, RichardL. Hazlett, BarbaraS. Chaparro, and Rosalind W. Picard. 2007. "Measuring the Aesthetics of Reading." In People and Computers XX – Engage, Proceedings of HCI 2006, 41–56.

Larson, Kevin. 2007. "The Technology of Text: type Designers, Psychologists, and Engineers Are Joining Forces to Improve Reading Onscreen." *IEEE Spectrum* (May 2007): 1–11.

Larson, Kevin, and Matthew Carter. 2016. "Sitka: A Collaboration between Type Design and Science." In *Digital Fonts and Reading*, edited by Dyson, M. C. and Ching Y. Suen. 37–53. Singapore: World Scientific Publishing Co. Pte. Ltd.

Legge, Gordon E., and Charles A. Bigelow. 2011. "Does Print Size Matter for Reading? a Review of Findings from Vision Science and Typography." *Journal of Vision* 11 (5): 8–22. doi:10.1167/11.5.8.

Lewis, Clive, and Peter Walker. 1989. "Typographic Influences on Reading." *British Journal of Psychology* 80 (2): 241–257. doi:10.1111/j.2044-8295.1989.tb02317.x.

Magreehan, Debbie A., Michael J. Serra, Neil H. Schwartz, and Susanne Narciss. 2016. "Further Boundary Conditions for the Effects of Perceptual Disfluency on Judgments of Learning." *Metacognition and Learning* 11 (1): 35–56. doi:10.1007/s11409-015-9147-1.

Moys, Jeanne-Louise. 2013. "Investigating Readers' Impressions of Typographic Differentiation Using Repertory Grids." *Visible Language* 47 (3): 96–123.

Moys, Jeanne-Louise. 2014. "Typographic Layout and First Impressions – Testing How Changes in Text Layout Influence Readers' Judgments of Documents." *Visible Language* 48 (1): 40–67.

Oppenheimer, Daniel, and Michael Frank. 2008. "A Rose in Any Other Font Would Not Smell as Sweet: effects of Perceptual Fluency on Categorization." *Cognition* 106 (3): 1178–1194. doi: 10.1016/j.cognition.2007.05.010.

Oppenheimer, Daniel M. 2008. "The Secret Life of Fluency." *Trends in Cognitive Sciences* 12 (6): 237–241. doi:10.1016/j.tics.2008.02.014.

Osgood, Charles Egerton, George J. Suci, and Percy H. Tannenbaum. 1957. *The Measurement of Meaning*, Vol. 47. Illiniois: University of Illinois press.

Pelli, Denis G., Catherine W. Burns, Bart Farell, and Deborah C. Moore-Page. 2006. "Feature Detection and Letter Identification." *Vision Research* 46 (28): 4646–4674. doi:10.1016/j.visres.2006.04.023.

Perea, Manuel, Victoria Panadero, Carmen Moret-Tatay, and Pablo Gómez. 2012. "The Effects of Inter-Letter Spacing in Visual-Word Recognition: Evidence with Young Normal Readers and Developmental Dyslexics." *Learning and Instruction* 22 (6): 420–430. doi:10.1016/j.learninstruc.2012.04.001.

Pušnik, Nace, Anja Podlesek, and Klementina Možina. 2016. "Typeface Comparison – Does the x-Height of Lower-Case Letters Increased to the Size of Upper-Case Letters Speed up Recognition?" *International Journal of Industrial Ergonomics* 54: 164–169. doi:10.1016/j.ergon.2016.06.002.

Rummer, Ralf, Judith Schweppe, and Annett Schwede. 2016. "Fortune is Fickle: null-Effects of Disfluency on Learning Outcomes." *Metacognition and Learning* 11 (1): 57–70. doi:10.1007/s11409-015-9151-5.

Sanchez, Christopher A., and Allison J. Jaeger. 2015. "If it's hard to read, it changes how long you do it: reading time as an explanation for perceptual fluency effects on judgment." *Psychonomic Bulletin & Review* 22 (1): 206–211. doi:10.3758/s13423-014-0658-6.

Sawyer, Ben D., Jonathan Dobres, Nadine Chahine, and Bryan Reimer. 2017. "The Cost of Cool: Typographic Style Legibility in Reading at a Glance." *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* 61 (1): 833–837. doi:10.1177/1541931213601698.

Schriver, Karen. 1997. *Dynamics in Document Design: creating Texts for Readers*. New York: Wiley Computer Publishing.

Song, Hyunjin, and Norbert Schwarz. 2008a. "Fluency and the Detection of Misleading Questions: Low Processing Fluency Attenuates the Moses Illusion." *Social Cognition* 26 (6): 791–799. doi:10.1521/soco.2008.26.6.791.

Song, Hyunjin, and Norbert Schwarz. 2008b. "If It's Hard to Read, It's Hard to Do: processing Fluency Affects Effort Prediction and Motivation." *Psychological Science* 19 (10): 986–988. doi:10.1111/j.1467-9280.2008.02189.x.

Song, Hyunjin, and Norbert Schwarz. 2010. "If It's Easy to Read, It's Easy to Do, Pretty, Good, and True." *The Psychologist* 23 (2): 108–111.

Spencer, Herbert. 1968. *The Visible Word*. London: Royal College of Art.

Spencer, Herbert, Linda Reynolds, and Brian Coe. 1973. *A report on the relative legibility of alternative letter shapes*. Royal College of Art, Readability of Print Research Unit.

Stroop, J. Ridley. 1935. "Studies of Interference in Serial Verbal Reactions." *Journal of Experimental Psychology* 18 (6): 643–662. doi:10.1037/h0054651.

Strukelj, Alexander, Katharina Scheiter, Marcus Nyström, and Kenneth Holmqvist. 2016. “Exploring the Lack of a Disfluency Effect: Evidence from Eye Movements.” *Metacognition and Learning* 11 (1): 71–88. doi:10.1007/s11409-015-9146-2.

Sungkhasettee, Victor W., Michael C. Friedman, and Alan D. Castel. 2011. “Memory and Metamemory for Inverted Words: Illusions of Competency and Desirable Difficulties.” *Psychonomic Bulletin & Review* 18 (5): 973–978. doi:10.3758/s13423-011-0114-9.

Tantillo, John, Janet Lorenzo-Aiss, and Richard E. Mathisen. 1995. “Quantifying Perceived Differences in Type Styles: An Exploratory Study.” *Psychology and Marketing* 12 (5): 447–457. doi:10.1002/mar.4220120508.

Taylor, A., Sanson, M., Burnell, R., Wade, K. A., & Garry, M. 2020. “Disfluent Difficulties are Not Desirable Difficulties: the (lack of) Effect of Sans Forgetica on Memory.) *Memory*, 1–8. doi:10.1080/09658211.2020.1758726.

Thiessen, Myra, Mark Kohler, Owen Churches, Scott Coussens, and Hannah Keage. 2015. “Brainy Type: A Look at How the Brain Processes Typographic Information.” *Visible Language* 49 (1/2): 175–189.

Tracy, Walter. 1986. *Letters of Credit (a View of Type Design)*. London: Gordon Fraser.

Unger, Gerard. 2007. *While You’re Reading*. New York: Mark Batty Publisher.

Unger, Gerard. 2018. *Theory of Type Design*. Rotterdam: Netherlands Architecture Institute (NAi Uitgevers/Publishers).

Walker, Peter, Sylvia Smith, and Alan Livingston. 1986. “Predicting the Appropriateness of a Typeface on the Basis of Its Multi-Modal Features.” *Information Design Journal* 5 (1): 29–42. doi:10.1075/idj.5.1.02wal.

Walker, Sue, and Linda Reynolds. 2003. “Serifs, Sans Serifs and Infant Characters in Children’s Reading Books.” *Information Design Journal* 11 (3): 106–122. doi:10.1075/idj.11.2.04wal.

Xie, Heping, Zongkui Zhou, and Qingqi Liu. 2018. ”Null Effects of Perceptual Disfluency on Learning Outcomes in a Text-Based Educational Context: A Meta-Analysis.” *Educ Psychol Rev* 30: 745–771. doi:10.1007/s10648-018-9442-x.

Xiong, Ying-Zi, Ethan A. Lorsung, John Stephen Mansfield, Charles Bigelow, and Gordon E. Legge. 2018. “Fonts Designed for Macular Degeneration: Impact on Reading.” *Investigative Ophthalmology & Visual Science* 59 (10): 4182–4189. doi:10.1167/iovs.18-24334.

Yue, Carole L., Alan D. Castel, and Robert A. Bjork. 2013. “When Disfluency is-and is not-a desirable difficulty: the influence of typeface clarity on metacognitive judgments and memory.” *Memory & Cognition* 41 (2): 229–241. doi:10.3758/s13421-012-0255-8.

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