Complexities of fonts in disfluent experiments

Abstract

This study focuses on how fonts selected from different families have been used to test for disfluency. The motivation and standard for choosing a particular font for an experiment are not yet clearly defined from past studies. Drawing on methods in a systematic review of 10 articles published between 2007 and 2020, this article shows that authors prefer to use sans serif fonts in fluent conditions and serifs, scripts or handwritten fonts in disfluent conditions. In this study, disfluency manipulations were limited to reducing font sizes and percentages of grey or black. The largest size used was 56pt (fluent) and 18pt (disfluent) while the smallest was 12pt (fluent) and 10pt (disfluent). We observed that the opacity values of disfluent fonts ranged between 10% and 60%, making it unclear how disfluent a font can be. Apart from font sizes, fixation time, familiarity with materials and other controls influenced the results. This article reveals that a major gap still exists in research because of a lack of standard methods for determining the fonts used for testing subjects.

Keywords

Complexities, disfluent, dual-process, fonts, fluent

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INTRODUCTION

Typography is an indispensable element of design and an important medium for transferring information and knowledge. Typography cuts across all fields of communication, such as printing, advertising, television, film and other media. Typography has been a part of our lives since the 18th century, with visual and semiotic elements (Serafini & Clausen, 2012:31), and is linked to visual perception and memory (Rhodes & Castel, 2008:137). The human mind perceives several objects in the environment that influence perceptual judgement. The details of an object, such as luminance, size and weight, can determine how they are recalled later (Jacoby & Whitehouse, 1989:118).

Text and visual images are incorporated into books to present a multimodal interpretation (Kress, 2003:208). The legibility of a font (used in text and visual images) is important to educators and literacy theorists, making it crucial for cognitive development. While some educators and literary theorists have suggested the use of several fonts to facilitate and help to improve learning, other research suggests that using a hard-to-read font strikes a good chord in the cognitive process by activating a secondary phase of analytical and effortful reasoning (Alter et al., 2007:136, Alter & Oppenheimer, 2009:13). The theory of this cognitive process expounded by social theorists such as William James is the dual-process model that specifies two different modes of processing, namely Systems 1 and 2 (Kahneman & Frederick, 2002:103; Kahneman & Frederick, 2005:256).

System 1 is fast, associative and intuitive, while System 2 is analytical, slow and deliberate (Chaiken, 1980:39; Evans, 2006:13; Stanovich, 1999). An example of System 1 reasoning is when an individual decides to travel in an aeroplane or a car. The person may quickly imagine a wrong image of a plane crash and decide not to fly. In a typical System 2 scenario, a more thoughtful decision would be made by looking at safety and the number of accidents associated with travelling by car (Alter et al., 2007:136). By comparing what happens when an individual faces a difficult cognitive task to reading an illegible text, Bjork and Bjork (2011) argue that challenges in reading an illegible text or any cognitive task foster memory recall.

"Fluency" and "disfluency" are used in the literature to describe any information that is easy to read or difficult to read, respectively. Discrepancies in empirical studies cast doubt on whether enhanced learning can be achieved through a disfluent text (Alter et al., 2007:136). Kress (2003:208) contends that analytical processing in difficult reading tasks only worked for subjects with special reading skills, high memory capacities, previous experience and knowledge (Alter et al., 2007:136). Others attest that participants measure a likelihood of remembering information captured in bigger fonts (Rhodes & Castel, 2008:137).

DISFLUENCY, TYPOGRAPHY AND THE DUAL-PROCESS MODEL

The dual-process cognitive model is a two-system thinking process that coexists (Gronchi & Giovannelli, 2018:9). At the first level, quick representations or conclusions are made about a piece of information. The second level engages the brain in a deeper analysis that leads to enhanced memory (Alter et al., 2013:128; Weltman & Eakin, 2014:15). Fluency and disfluency are psychological conditions of speech or reading interference (Pieger et al., 2018:3). While developmental disfluency is normal for a growing child, other types of disfluency are caused by neurological factors (Cullatta & Leeper, 1990:17). Other terms for dual-process model include heuristic and systematic (Chaiken, 1980:39), intuitive and analytic (Sanderson, 1980:9), and reflexive and reflective (Lieberman, 2003:44).

Cognitive processes leading to System 2 processing vary for individuals (Geller et al., 2018:46; Yue et al., 2013:41). Lack of consistency in materials, methods and procedures makes it difficult to determine the benefits of subjective cues. A visual stimulus may be perceptually disfluent because the information is not readable or clear enough to understand. People usually find disfluent stimuli difficult to comprehend, but this does not have any effect on memory (Xie, Zhou & Liu 2018:30).

A person can sound disfluent or read disfluently because of disruptions in a visual stimulus such as an unclear font or text. Frederick (2005:19) and Seufert et al. (2016:45) studied font disfluency and its relation to the dual-process model. A font's disfluency depends on legibility (Arditi & Cho 2005:45). Font legibility dwells on how a font is structured (Arditi & Cho, 2007:47, Dillon et al., 2006; Tinker 1963:47). The font type, line width, leading, arrangement, colour and printing surface all affect legibility. Papadima and Kourdis

(2015) state that font selection, size, weight and colour contribute to text comprehension.

Serifs were used in the early days of printing until modern san serifs were developed for display. San serifs are legible because of the absence of strokes or "serifs" (Arditi & Cho, 2005:45). Large fonts played a major role in the judgments of learning (JOLs) – a method of assessing how well a material is studied (Myers et al., 2020:48). Most educationists and graphic designers consider Tinker's (1963:47) factors for book production as important. The general rule regarding the legibility of a font is multi-faceted because of variables that include sex, age and visual problems (Dyson & Stott, 2012:20). Reading cursive and handwriting is difficult for adults and children (Perea et al., 2016). This article explores and discusses ideas and opinions expressed in the literature regarding font pairs and disfluency manipulations through a review of selected articles between the years 2007 and 2020. Two research questions arise from this objective: 1) What are the implications of different pairs in disfluent experiments; and 2) What is the solution for standardising font pairs in disfluent experiments.

METHODOLOGY

This article discusses the complex aspects of fonts in determining disfluency. Drawing from techniques used in systematic review analysis, our method employs standardised steps for data sampling or collection, known as PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (Page M.J. et al., 2021). These steps include stating the research question, identifying databases, screening, inclusion and exclusion criteria, and extracting and interpreting data.

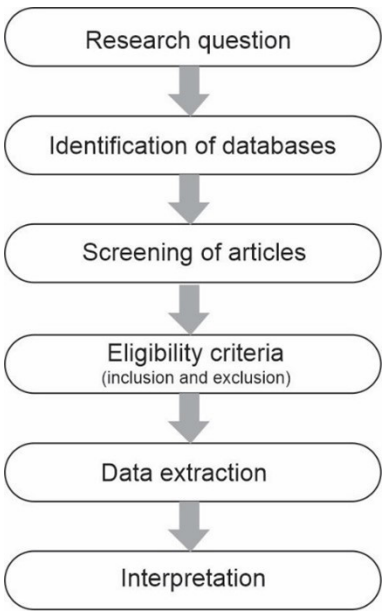

Figure 1: Research design adopted from PRISMA (Page, M.J. et al., 2021)

The initial search for articles on disfluency yielded more than 50 results through Google Scholar. The keywords used were "disfluent" and "fonts". Google Scholar was used in identifying repositories or databases like PubMed, Scopus, ScienceDirect, DOAJ, EBSCO and Web of Science for the search of articles. The abstracts of the articles from the initial search were screened by reading them to ascertain their relevance to the study. The screening reduced the number of articles to 40. Our inclusion criteria were all articles that focused on the subjects' design and those that employed two sets of font (fluent/disfluent) for testing. Articles excluded were those on other aspects of disfluency in psychology without any reference to fonts. Using the inclusion and exclusion criteria further reduced the number of articles to 10. The article by Alter et al. (2007) was selected first because it offered a good theoretical framework

for the study of disfluency and also had the highest number of citations. Codes identified in this research data are the type of experiments, reading comprehension or arithmetic, font type (whether serif or san serif, font colour and size). Some font manipulations were changed in Adobe Illustrator, based on the experiments.

Table 1: List of articles

	Author(s)	Title of article	No. of citations	Link
1	Alter et al. (2007)	*Overcoming intuition: Metacognitive difficulty activates analytic reasoning*	1242	https://doi:10.1037/0096-3445.136.4.569
2	Song and Schwarz (2008)	*Fluency and the detection of misleading questions: Low processing fluency attenuates the Moses illusion*	303	https://doi.org/10.1521/soco.2008.26.6.791
3	Slattery and Rayner (2010)	*The Influence of text legibility on eye movements during reading*	91	https://doi.org/10.1002/acp.1623
4	Diemand-Yauman et al. (2011)	*Fortune favors the bold: Effects of disfluency on educational outcomes*	581	https://doi.org/10.1016/j.cognition.2010.09.012
5	Katzir et al. (2013)	*The effect of font size on reading comprehension on second and fifth grade children: Bigger is not always better*	85	https://doi:10.1371/journal.pone.0074061
6	Weltman and Eakin (2014)	*Incorporating unusual fonts and planned mistakes in study materials to increase business student focus and retention*	85	https://doi.org/10.1287/ited.2014.0130
7	Magreehan et al. (2015)	*Further boundary conditions for the effects of perceptual disfluency on judgments of learning*	23	https://doi.org/10.1007/s11409-015-9147-1
8	Seufert et al. (2016)	*The effects of different levels of disfluency on learning outcomes and cognitive load*	58	https://doi.org/10.1007/s11251-016-9387-8
9	Geller et al. (2018)	*Would disfluency by any other name still be disfluent? Examining the disfluency effect with cursive handwriting*	31	https://doi.org/10.3758/s13421-018-0824-6
10	Sirota et al. (2020)	*Disfluent fonts do not help people to solve math and non-math problems, regardless of their numeracy*	10	https://doi.org/10.1080/13546783.2020.1759689

FONT MANIPULATIONS

Previous studies have revealed various manipulations of font pairs in disfluent experiments. Researchers and scientists have employed different controls in each experiment that are targeted at specific cues. Despite these controls, an inconsistent pattern for fonts still raises a question of how disfluent a font can be in practice. The article titled 'Overcoming intuition: metacognitive difficulty activates analytic reasoning' by Alter et al. (2007:136) sets a precedent for our discourse because it provides valuable

information on the dual-process model of cognition. Furthermore, it provides evidence on how disfluency positively affects memory outcomes in the presence of different cues. Four experiments were conducted. The primary objective of Experiment 1 was to establish the fact that individuals may adopt a systematic reasoning approach when perceiving any disfluent information. Forty university students were tasked with completing a Cognitive Retention Test (CRT). Subjects were asked to read materials presented in fluent condition. The disfluent fonts were determined by another group on a 5-point Likert scale. As predicted, more questions were answered in the disfluent condition. The font parameters for Experiment 1 exhibit a very high level of disfluency because 10% black is almost white. This may have activated secondary cognitive resources.

Myriad Web Black, 12 pt

Myriad Web Black, 10 pt 10% black

Figure 2: Font pairs by Alter et al. (2007:136)

A second experiment was carried out to investigate other systematic cues in persuasive communication by adopting the heuristic–systemic model (Chaiken, 1980:39). According to Chaiken's analysis, a high level of involvement in persuasive communication makes recipients employ systematic processing. Heuristic processing is fast and exerts less cognitive effort because it depends on existing knowledge. Systematic processing is more analytical and depends on the facts presented. The stimulus presented was two advertisements for an MP3 player, as seen in Figure 3.

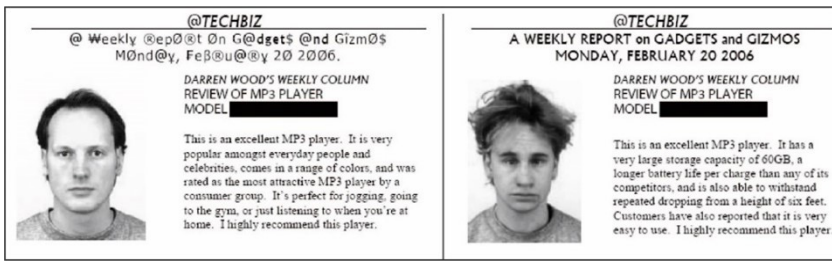

Figure 3: The stimulus presented by Alter et al. (2007) shows a strong heuristic (left slide with disfluent masthead) and systematic cue (right slide with fluent masthead)

The two advertisements in Figure 3 were about the same product and were all set in the same fonts. The left section had a positive heuristic (usual-looking face with a disfluent masthead) but a negative systematic condition (a review of irrelevant features of the MP3 player). On the right are the negative heuristic (non-conforming face) and positive systematic (details about relevant features of the MP3 player). In both conditions, participants' favorability ratings were influenced by the systematic cue in the disfluent condition.

In Experiment 3, participants adopted two different facial distractions, puffing cheeks (fluent) and furrowing brows (disfluent) to test the relationship between heuristic cues and representativeness. As predicted, participants in the disfluent condition were less confident in answering the questions whereas those in the fluent condition were more confident in a pilot study. Even though participants in the experiment with puffed cheeks were more confident in answering questions, this could also allude to the fonts presented in the experiment.

The fourth experiment by Alter et al. (2007:136) tested whether participants would easily answer syllogisms in disfluent fonts. As expected, more questions were answered correctly in disfluent fonts. Again, the font manipulation had no impact on the mood of the participants. All four experiments are insightful but raise questions about the level of disfluency experienced. For example, the first experiment used 10% black while the second created a distortion by mixing alpha-numeric characters.

Following these findings, a similar study was conducted using undistorted and distorted questions

(Song & Schwarz, 2008). The questions were: "Which country is famous for cuckoo clocks, chocolate, banks, and pocket knives?" (undistorted), and the second distorted question read: "How many animals of each kind did Moses take on the Ark?" (Erickson & Mattson, 1981). The questions were set in two different fonts, namely Arial (fluent) and Brush Script (disfluent) set in 12 pt.

Figure 4: Font pairs by Song and Schwarz (2008)

In the first distorted question, more participants answered correctly in the fluent condition. In the second distorted question, more subjects answered "2" to the first question about the Ark without noticing that Moses did not build an Ark. Even though font sizes played a role in Song and Schwarz's case, other variables such as familiarity can influence participants in such conditions. A person who is familiar with the "Moses illusion" question may notice the distortion in the fluent condition. From this experiment, we can assume that an illegible font may be difficult to read but may not be a hindrance to comprehension if the reader is very familiar with the text. Conversely, a legible font may not guarantee memory outcomes if the reader is not familiar with the text.

Apart from other cues such as relatedness that may influence memory recall, large font sizes played a major role in the judgment of learning (JOL) (Rhodes & Castel, 2008:137). Participants were exposed to words set in 18pts and 48pts in three different experiments. In all three, the large fonts made a positive impact on recall, with a disregard of all other cues. In addition, Slattery and Rayner (2010:24) presented passages on a computer monitor (1280 by 1024px) to participants in the popular Times New Roman, Harrington and Script MT Bold typefaces. In that experiment, subjects' fixation on monitors was recorded. Even though the fonts did not dramatically influence comprehension, they found that reading in Times New Roman took a shorter fixation duration. This was consistent with similar experiments by Alter et al. (2007:136) in which words that were presented in a clearer format without slanted strokes and curves were processed faster than words typed in script fonts.

Figure 5: Fonts by Slattery and Rayner (2010:24)

Interestingly, Diemand-Yauman et al. (2011:118) and Jacoby and Whitehouse (1989:118) combined Comic Sans and Bodoni in 12pt with a 60% grey in the disfluent condition and an Arial black font in 16pt for the fluent condition. Participants were tasked with studying three unfamiliar alien species. This task prevented a condition of prior knowledge from influencing retention outcomes. While in some previous experiments manipulations were obvious in the disfluent condition, it was the same condition in this case. Font pairs were all san serif. They were all legible, despite their font sizes and colour, and there were no obvious discrepancies in memory retention between participants in the fluent and those in the disfluent condition. The results from this experiment agree that not all difficult-to-read fonts lead to System 2 processing.

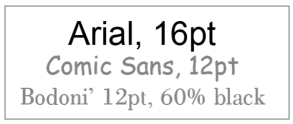

Figure 6: Fonts by Diemand-Yauman et al. (2011:118)

In one of three studies, Thompson et al. (2013:128) investigated the role of perceived effort and competence in disfluency. In the fluent condition, Arial 12pt in black was presented on a white background. In the disfluent condition, the font colour was changed to light blue on a white background. The exact colour values for the light blue colour were not stated, but participants found it difficult to read them. The authors concluded that there was a positive impact on expected value when readers of a target service experience some difficulty in reading information about the service.

Katzir et al. (2013:8) found that the effects of font manipulations vary across different age groups. In the first experiment with second-grade students, it was observed that reducing the font size and increasing the length of lines led to significantly poorer comprehension scores, while altering the spacing between lines did not have any impact on performance. In the second experiment with fifth-grade students, a decreased font size resulted in improved comprehension scores, but no significant effects were found for line length and line spacing. These findings point to the fact that disfluency cannot always be a "desirable difficulty". For second graders (Experiment 1), decreased font size and increased line length yielded significantly lower comprehension scores. Line spacing did not affect performance. For fifth graders (Experiment 2), decreased font size yielded higher comprehension scores, yet there were no effects on line length and line spacing. Results are discussed within a "desirable difficulty" approach to reading development.

Weltman & Eakin (2014:15) conducted a test that provides support for the notion that difficult-to-read fonts enhance learning. In an experiment involving 155 undergraduate students, the researchers presented materials in three different forms, both fluent and disfluent. The control and pedagogically modified materials were set in Gill Sans 16pt font, black. The disfluent set was presented in Dakota 12pt font in 50% grey colour. The mean scores obtained from the disfluent set were higher. Interestingly, the presence of pedagogical errors did not have an impact on the results, as they were not overtly noticeable.

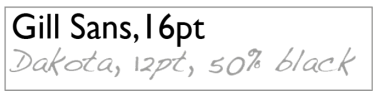

Figure 7: Weltman and Eakin (2014:15)

Magreehan et al. (2015:11) repeated the experiment by Rhodes and Castel (2008) to further understand how perceptual disfluency influences JOLs. The materials presented were unrelated and related word pairs. The experiments were done in an isolated lab cubicle. Words presented were set in an Arial bold (56pt) for the fluent set and in 32pt italicised Times New Roman on a white background for the second level of disfluency. The third level was the same 32pt Times New Roman on a grey background. Words in the disfluent condition were tinted in grey colour. Results from this study showed that participants in both conditions spent an equal amount of time studying. However, study time was higher for the related pairs. The recall was better for the related word pairs than for the unrelated word pairs. The participants had trouble reading, but did not recognise that the font was disfluent until it was on a grey background.

Further, a word set in an italicised 32pt Times New Roman in a grey-on-white background is quite legible, as seen in Figure 8. People only notice the font is disfluent when it has been adjusted to a certain level.

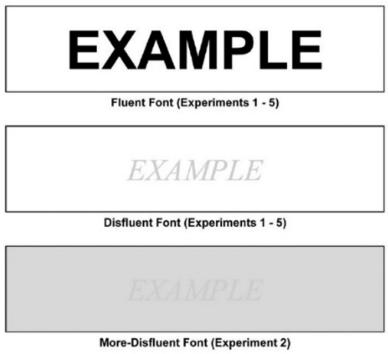

Figure 8: Fluent and disfluent manipulations by Magreehan et al. (2015:11)

Seufert et al. (2016:45) examined four learning materials at different levels of font manipulation. In the first experiment, materials presented were in a 12pt Times New Roman for the first level of disfluency, 14pt Haettenschweiler black for the second level, 14pt Haettenschweiler in 25% grey for level three and 15% grey for level 4. The participants were asked in the first experiment to read a 270-word passage about a chocolate factory. Disfluency influenced learning outcomes significantly but this was attributed to the simplicity and familiarity of the material. Participants' perceived legibility was highest in the fluent condition.

In the first disfluent condition (12pt Times New Roman), the highest learning outcomes were observed. Interestingly, the third level of disfluency (14pt Haettenschweiler' in 25% grey) resulted in a high level of concentration that led to slower reading. Building upon these preliminary findings, a second experiment involving 73 students was conducted. The participants were presented with a 1,100-word scientific text about time zones, and the test duration was limited to 13 minutes.

The fonts and sizes used were of third level disfluency. The results from the second experiment recorded significantly high scores for comprehension in the third level of disfluency (Monotype Corsiva 12pt in 25% grey). Again, in Experiment 2, participants scored highest for comprehension in the first level of disfluency (Monotype Corsiva black 12pt), and the best recall results were in the second level (Monotype Corsiva 12pt in 25% grey). The investigators attributed the high memory recall scores to other resources such as motivation and concentration during the test but give credence to the fact that a cognitive load triggers the second level of reasoning (Alter et al., 2007:136).

Times New Roman, black, 12 pt	Arial, black, 12 pt
Haettenschweiler, black, 14 pt	*Monotype Corsiva, 12pt*
Haettenschweiler, black, 14 pt 25% black	Monotype Corsiva, 12 pt 25% black
Haettenschweiler, black, 14 pt 15% black	Monotype Corsiva, 12 pt 25% black

Figure 9: Fonts by Seufert et al. (2016: 45)

Three variations of a cursive font were employed in three levels of legibility, namely type print, hard-to-read and easy-to-read cursive. The cursive fonts were created by a Livescribe digital pen – almost equal to a 44pt Courier New font. The materials presented had 198 words (Geller et al., 2018:46). From the experiment, cursive words were found to stimulate better memory recall than the type printed ones, which was consistent with other studies. In agreement with Thompson et al. (2013:128), it was observed that disfluency was consistently determined by the level of font manipulation.

Figure 10: Fonts by Geller et al. (2018:46)

A recent study by Sirota et al. (2020) disagreed that disfluency helps in analytical reasoning. About 311 participants were tested in two experiments by employing a numerical and verbal CRT test. The numerical test involved 11 simple mathematical problems, which required subjects to understand basic concepts such as percentages. In the verbal CRT, participants were asked to solve simple word problems that did not require any calculation. Font manipulation in this study was similar to the one used by Alter et al. (2007:136). The results of Experiment 1 showed that there was no significant effect of the test on cognitive reflection.

In the disfluent condition, more questions were solved by the subjects than in the fluent condition. No significant relationship was found between disfluency and subjects with high numerical skills. In the fluent font condition, participants correctly answered more word problems. In Experiment 2, with the introduction of an additional manipulation (explicit instructions), participants spent more time answering questions in the disfluent condition. However, this outcome was not attributed to the disfluent font. Determining the cognitive impact of the presented font sizes proved challenging, despite participants rating the fluent font as easier to read.

Figure 11: Font pairs by Sirota et al. (2020)

DISCUSSION AND IMPLICATIONS FOR THEORY AND PRACTICE

In all the experiments analysed in this paper, we discovered that different methods and procedures were exploited to understand and support or refute the disfluency effect. The fonts presented are also varied in every instance. To say that disfluency is a "desirable difficulty" that improves learning outcomes remains questionable (Taylor et al., 2018). Disfluency has different levels, therefore, certain levels of manipulation can impede the learning process (Seufert et al., 2016:45). Discrepancies in font manipulation also influence the outcome of experiments. There is no standardised method of selecting font sizes in disfluency experiments, which could be a reason the test results are different. A font may be legible in a particular font size but is disfluent when changed to another font. Typical examples are the Arial and Times New Roman fonts (Magreehan et al., 2015:11).

These two fonts are very legible by default. This was clear because participants in that experiment did not recognise the disfluency manipulations without the grey background. The opacity values of the disfluent fonts were observed to range from 10% to 60%. Variations in opacity during font display must be considered in the analysis of font disfluency. By using different opacity levels, it becomes unclear how much disfluency a font possesses. For example, there is a noticeable difference between a 25% grey rendering of Monotype Corsiva and a 60% grey representation of Comic Sans. This difference may be due to the possibility of disfluency being connected to particular fonts as proposed in other studies but may not be as strong as first thought. An interesting pattern employing sans serif fonts in the fluent condition was found.

Arial was the most used font in the fluent condition because of its legibility. While fonts in the disfluent condition were mostly san serifs and scripts or handwritten fonts, a few authors employed fonts that seem legible in both conditions. The highest font size was 56pt (fluent) and 18pt (disfluent) in the examples discussed in this article. It was found that disfluency manipulations are mostly limited to making the fonts grey. In some experiments, participants were keen on recognising and memorising information despite the font type and sizes presented (Thompson et al., 2013).

Disfluency is very subjective. Therefore, materials presented are processed across a broad range of variables (Seufert et al., 2016:45). Whereas some were presented with mathematical problems, others solved word problems. Some experiments had materials that required more time to study. Cognitive load cannot be measured by any instrument because people have different IQ levels that do not work in the same condition every day. The time allocation and interaction during every task led to different outcomes

of cognitive load. Therefore, disfluency cannot be adapted to normal learning environments because of the complexities involved. Even though metacognitive loads lead to deeper processing, they may not help a class of students to perform well.

CONCLUSION

Fonts play a central role in these experiments, yet researchers have not discovered standard parameters (such as size, width, serif, sans serif, bold, italic, cursive) for defining an easy-to-read or difficult-to-read font. This article discussed the complexities associated with fonts in experiments conducted to test disfluency in text-based research. It established that improved memory outcomes are not always a direct result of perceptual disfluency. Attempts to generalise findings related to disfluency have proven unsuccessful, indicating the need for further research in this area. The study also highlighted the intricate nature of disfluent experiments on fonts. While this study uncovered an unexplored avenue for researchers studying disfluency, it cannot propose an ideal font for conducting disfluency experiments.

Using different fonts by authors in research makes it challenging to assess individuals' cognitive loads accurately. To bridge the gap between psychologists and typographic designers, there must be collaboration in knowledge sharing, designing of stimuli and interpretation of results so disfluency experiments can take on a holistic approach that integrates psychological theory and typographic expertise. This will help to foster a holistic methodological approach to experiments. It would also enhance the validity and impact of the research findings and contribute to advancing knowledge in the field.

CONFLICT OF INTEREST

The authors admit that there is no conflict of interest regarding this manuscript.

DISCLOSURE

The authors declare that this is an original article, which is not in consideration for publishing by another journal.

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