Perceptual Disfluency Through Hard-to-Read Fonts. Is There a Satisfactory Explanation?

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Abstract. Research on perceptual disfluency has demonstrated an apparent memory advantage for hard-to-read (less legible) text. This paper explores the evidence, outlines alternative theories, and discusses the locus of the effect. In particular, accounts which propose a metacognitive explanation are contrasted with those which focus on earlier levels in the reading process: letter and word recognition. The reviewed studies illustrate the unreliability of perceptual disfluency effects and confirm the need for further exploration of boundary conditions and moderating factors.

Introduction

Fluency or disfluency is variously described as a subjective experience of ease or difficulty associated with cognitive tasks (e.g., Diemand-Yauman, Oppenheimer, and Vaughan 2011) or mental processes (e.g., Oppenheimer 2008). When applied to reading, words may be made harder to read through, for example, the use of complicated language (lexical disfluency) or a less legible font or handwriting (perceptual disfluency).

This paper focuses on perceptual disfluency (sometimes described as simply disfluency) as this concerns the graphic representation of language. Studies of perceptual disfluency include manipulations of reading material that change the typeface or variant (e.g., from roman to italic), vary the contrast (e.g., from black to grey type), and compare handwriting to type. All these studies use the Latin script.[1]

The article by Diemand-Yauman, Oppenheimer, and Vaughan (2011), published in the journal *Cognition*, attracted a lot of media attention, as it

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1. I am aware of only one study that used material in Hebrew (Sidi, Ophir, and Ackerman, 2016) in which participants were required to solve misleading maths problems.

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presented empirical evidence for better recall of hard-to-read materials compared with easy-to-read materials. These results were found in a classroom environment as well as a laboratory setting, which perhaps contributed to their impact.

As a psychologist working in the field of typography, I find the apparent memory advantage of material that is hard to read difficult to reconcile with a body of legibility research which promotes ease of reading. Having made my bias explicit, this paper explores the evidence for disfluency effects, alternative theories, and the locus of the effect.

Replications

Since the publication of the article by Diemand-Yauman, Oppenheimer, and Vaughan (2011) reporting these counter-intuitive results, various replications have been attempted and boundary conditions or moderating factors explored (e.g., Kühl and Eitel 2016). These studies were in response to the paucity of studies confirming the basic effect. Based on a meta-analysis of twenty-five empirical studies, the generality of the disfluency effect with respect to learning has been questioned (e.g., Xie, Zhou, and Liu 2018).

Similarly, the creation of a new font, Sans Forgetica,[2] designed to be harder to read to boost memory, has been put to empirical test by various researchers (Geller, Davis, and Peterson, 2020; Taylor et al., 2020; Dyson and Březina, 2021; Eskenazi and Nix, 2021; Wetzler, Pyke, and Werner, 2021). The conclusions are consistent in failing to demonstrate an advantage: 'Although Sans Forgetica is novel and hard to read, its effects might well end there' (Taylor et al., 2020, p. 6); Sans Forgetica is not desirable for learning (Geller, Davis, and Peterson, 2020); disfluent fonts are not always desirable difficulties (Wetzler, Pyke, and Werner, 2021).

Given the inconsistent findings,[3] the theoretical underpinnings of perceptual disfluency could benefit from closer examination.

Metacognitive theory

Diemand-Yauman, Oppenheimer, and Vaughan (2011) refer to the original metacognitive theory of disfluency (e.g., Alter, Oppenheimer, Epley, and Eyre 2007), which is also used to frame the studies published in a special issue of *Metacognition and Learning*, edited by Kühl and Eitel

2. https://web.archive.org/web/20200611220322/http://sansforgetica.rmit/
3. Some of these are summarised in Dyson (2020).

(2016). When applied to perceptual disfluency and memory, this explanation posits that a reader recognises a word, then perceives the difficulty (a metacognitive cue), puts more effort into processing the word, and therefore is more likely to remember what they have read. The difficulty in recognising the letters (in a hard-to-read font) and identifying a word is a perceptual difficulty, yet this perceptual process is explained in cognitive or metacognitive terms.

This theory of disfluency has been linked with two different psychological accounts of processing:

- Typically, disfluency references James (1950) who claimed that we have two processing systems: one is quick, effortless, and intuitive; another is slow, effortful, analytic, and deliberate. If the content of what we read is simple, but in a hard-to-read font, we may be tricked into using the second system which processes more deeply.
- Geller (2017, p. 11) relates the metacognitive theory to the level of processing framework proposed by Craik and Lockhart (1972) whereby words that are processed to deeper levels (i.e., semantic) are better remembered.

Alternatives to metacognitive theory

More recently, studies have proposed and tested alternative accounts of perceptual fluency, perhaps prompted by the difficulties in replicating the findings of better performance with disfluent material.[4]

The locus of the disfluency effect has been explicitly questioned by Geller (2017). Drawing on the Interactive-Activation model of visual word recognition (McClelland and Rumelhart, 1981), Geller characterises the level of theoretical mechanisms as pre-lexical, lexical, or post-lexical. When reading disfluent text, the nature of additional activity required at each level is described:

- At the pre-lexical level, where parallel letter recognition occurs,[5] hard-to-read text would require additional processing to identify the letters.
- At the lexical level, more feedback is needed from the word level down to the letter level to identify the letters.
- At the post-lexical level, more feedback is needed from the semantic level down to the word level—the metacognitive theory.

4. Although fluent or disfluent relates to the processing of the material, rather than the material itself, researchers often use the term to describe the material. This also applies to the use of the term 'legible text', referring to ease of reading.

5. There is broad agreement amongst reading researchers that word recognition is based on parallel letter recognition (Larson, 2005).

In his thesis, Geller (2017) explores the theories associated with each level of processing and examines the evidence for each of these.

Pre-lexical: encoding effort hypothesis

The encoding effort hypothesis proposes that the effort required to identify items enhances memory for these items. One of the experiments conducted by Hirshman, Trembath, and Mulligan (1994) varies the contrast between text and background with either grey letters on a black background or white letters on a black background. Although identification of words in grey was more difficult (took longer), recall was comparable in both conditions.

Lexical: compensatory processing account

Geller, Still, Dark, and Carpenter (2018) introduce the compensatory processing account as a possible explanation for disfluency results. This account is used by Hirshman, Trembath, and Mulligan (1994) to explain their finding that visual masking of words enhances memory. They conclude that higher level processing is compensating for visual processing difficulties and the additional activity is improving memory.

A similar emphasis on word-level processing is proposed by Wetzler, Pyke, and Werner (2021), but in this case, to explain the lack of a memory benefit from the disfluent font (Sans Forgetica). They propose that a disfluent font increases the demands on orthographic processing but does not help, and may even impair, semantic relational processing by slowing down reading. Being aware of the perceptual difficulty (metacognition) did not improve recall.

Handwriting also provides a means of exploring the use of top-down processes as there is an inherent physical variability in letter forms that is not found in a fluent font. A study comparing handwriting to Courier New font found that various lexical effects (word frequency, consistency, and imageability) were enhanced with handwriting compared with Courier New (Barnhart and Goldinger, 2010). They propose that handwriting requires greater use of top-down processing because it departs from the 'more prototypical word forms' (p. 921). The notion of a prototype fits with typographers' belief that typeface familiarity is important to legibility. This prototype hypothesis has been investigated by comparing fonts with common letter shapes and uncommon letter shapes (Beier and Larson, 2013).[6]

6. They found no difference in speed of reading between common and uncommon letter shapes, but participants disliked the uncommon shapes.

An alternative explanation for handwriting needing more top-down processing is that the letters are noisy, ambiguous forms, rather than departing from a prototype. These two hypotheses were tested by Perea, Gil-López, Beléndez, and Carreiras (2016) by comparing difficult-to-read and easy-to-read handwriting with the typeface Century. They found that handwriting was read more slowly, and less accurately than Century. However, there was no difference in lexical effects (word frequency) between the easy-to-read handwriting and Century, whereas harder to read handwriting did show a word frequency effect. The quality of the handwritten words is therefore important in moderating the use of top-down processes.

Load theories

Another way of describing the different levels is in terms of load theory where some researchers have distinguished between sensory, perceptual, and cognitive load in the context of disfluency (Marsh et al., 2018; Hao and Conway, 2022).

Cognitive load has been proposed as an alternative to disfluency theory (Kühl and Eitel, 2016). According to cognitive load theory, learning material should be designed to decrease demands on working memory which has limited capacity. This theory therefore proposes the use of legible or fluent texts to support ease of reading. Their series of four studies produced contradictory results, failing to confirm either cognitive load or disfluency theory. This led them to conclude that the less legible text layout may have increased the perceptual load, rather than cognitive load.

A study that considers the potential effects of different types of load looked at the disruptive effect of background speech on reading comprehension (Hao and Conway, 2022). They found that a disfluent font improved comprehension but there was no benefit from the disfluent font with background speech. The authors argue that a disfluent font introduces a perceptual load. Citing Lavie and De Fockert (2003), they query the extent to which texts with reduced contrast, or smaller font size, can be described as perceptually disfluent as these manipulations may introduce a sensory load, but not a perceptual load. They distinguish between these sensory degradations and a hard-to-read font which may increase perceptual load because additional perceptual operations are required.

Also looking at attention and task engagement, Faber, Mills, Kopp, and D'Mello (2017) investigated the effect of a (supposedly) disfluent font (Comic Sans, italic, grey) on mind wandering and comprehension when reading a text about scientific research. They found less mind wandering with Sans Forgetica but no effect on comprehension and sug-

gest that disfluency may impose an extraneous cognitive load, offsetting the advantage of less mind wandering.

There seems to be disagreement on whether disfluent fonts introduce an additional perceptual or cognitive load. An insight into which stage of the reading process may be affected by background speech comes from eye movement recordings (Vasilev et al., 2019). They found that background intelligible speech only affects the post-lexical stage of processing when readers integrate words into sentences. With the proviso that Vasilev et al. did not include a disfluency manipulation, this finding may contribute to explaining why Hao and Conway (2022) found no shielding effect from the disfluent font in background speech. They claim that the disfluent font introduces a perceptual load, and a high perceptual load filters irrelevant information as the perceptual processes are fully engaged by task-relevant information. If the background speech distraction is indeed affecting a later stage of processing, there will be no shield against the distraction from perceptual disfluency.

Discussion

Unfortunately, a satisfactory explanation for perceptual disfluency has not emerged from the empirical research described above, and further questions are raised. On the one hand, various accounts seek to explain how additional processing enhances memory, and on the other hand theories of extraneous load predict impaired performance. Both strands incorporate different levels of the reading process: pre-lexical, lexical, post-lexical and sensory, perceptual, and cognitive. There is some convergence of evidence that disfluent text requires extra processing at the word level but uncertainty as to whether this aids or impedes memory. This may depend on the reader as a disfluent font may not improve performance unless they have sufficient working memory capacity (Lehmann, Goussios, and Seufert, 2016).

Of particular importance from a verbal graphic language perspective is the need to establish empirically, rather than assume, whether a font used in a study is hard-to-read. The discrepant results, including different qualities of handwriting (Perea, Gil-López, Beléndez, and Carreiras, 2016), highlight the importance of attempting to calibrate degrees of disfluency. There is some evidence for a reverse U-shape curve when plotting performance against level of disfluency (Seufert, Wagner, and Westphal, 2017): learning is improved up to a certain level of disfluency but increasing beyond this point impairs learning. We currently have no means of mapping different fonts or font variants (bold, italic) on a fluency or legibility scale to search for an optimum level of disfluency. But, at the very least, all studies could include participant's comparative

judgements of legibility of test material to validate perceived differences between material labelled as hard- or easy-to read.

The moderation of the use of top-down processes by the quality of handwriting may shed some light on the failure of Sans Forgetica, and other fonts, to display disfluency effects. Perea, Gil-López, Beléndez, and Carreiras (2016) describe the normalisation process that occurs with easy-to-read handwriting, where we tune into the idiosyncrasies of the handwriting. There is a similar process with fonts, described as 'font tuning' where consistency increases letter identification efficiency (Sanocki and Dyson, 2012). With Sans Forgetica, it may be possible to tune into the unusual letter forms, given some exposure. Beier and Larson (2013) confirmed that twenty minutes reading a font with uncommon letter shapes increased speed of reading.

In conclusion, it is reassuring that the early stages of reading (from letter to word) are no longer ignored in explanations of perceptual disfluency. Although the dispute between the beneficial effects of disfluency versus legibility is not yet resolved, useful questions have been asked.

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