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A shield against distraction

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ABSTRACT

In this paper, we apply the basic idea of a trade-off between the level of concentration and distractibility to test whether a manipulation of task difficulty can shield against distraction. Participants read, either in quiet or with a speech noise background, texts that were displayed either in an easy-to-read or a hard-to-read font. Background speech impaired prose recall, but only when the text was displayed in the easy-to-read font. Most importantly, recall was better in the background speech condition for hard-to-read than for easy-to-read texts. Moreover, individual differences in working memory capacity were related to the magnitude of disruption, but only in the easy-to-read condition. Making a task more difficult can sometimes facilitate selective attention in noisy work environments by promoting focal-task engagement.

The vigilant ability of the auditory system is exceptional for detecting events in the environment that may be valuable or potentially dangerous. In modern society, however, a continuous analysis of the auditory environment often becomes distracting rather than helpful. For instance, background speech typically impairs word processed writing (Sörqvist, Nöstl, & Halin, 2012a), reading comprehension (Oswald, Tremblay, & Jones, 2000; Sörqvist, Halin, & Hygge, 2010), proofreading (Halin, Marsh, Haga, Holmgren, & Sörqvist, 2013; Venetjoki, Kaarela-Toumaala, Keskinen, & Hongisto, 2007), prose memory (Bell, Buchner, & Mund, 2008; Sörqvist, 2010a) and other work related tasks (Banbury and Berry, 1997, 1998; Beaman, 2005; Jahncke, Hygge, Halin, Green, & Dimberg, 2011; Morris & Jones, 1991). In noisy conditions, the human mind must find a way to attenuate the undesired influence of the auditory analysis.

One way in which this can be accomplished is by increasing the amount of engagement with a focal task (in essence, concentrating harder). The view we take here is that task engagement reflects strategic cognitive control that protects against distraction, and is, in part, modulated by factors such as warnings of impeding distraction (Hughes, Hurlstone, Marsh, Vachon, & Jones, 2013; Sussman, Winkler, & Schröger, 2003), incentives to perform well (Engelmann, Damaraju, Padmala, & Pessoa, 2009) and task difficulty (Halin et al., 2013). Strategic cognitive control takes the form of a more steadfast locus-of-attention – thus overruling the call-for-attention by task-irrelevant information – and a more constrained neural processing of the task-irrelevant information at the sensory stage (Sörqvist & Rönnberg, 2014).

Laboratory studies have shown that the disruption from task-irrelevant background noise is attenuated when a participant engages with more difficult to-be-attended visual tasks (Hughes, Hurlstone, Marsh, Vachon, & Jones, 2013; Kim, Kim, & Chun, 2005; SanMiguel, Corral, & Escera, 2008). For example, the auditory-perceptual analysis of task-irrelevant background sound, as shown in auditory brainstem responses, is attenuated when the participants undertake a difficult version of the visual-verbal n-back task (i.e., 3-back) in comparison with an easier version (i.e., 1-back; Sörqvist, Stenfelt, & Rönnberg, 2012; see also Hairston, Letowski, & McDowell, 2013). Moreover, a deviant sound that is embedded in an otherwise repetitive sound sequence (e.g., the sound "k" in the sequence "c c c c c c k c c") impairs the ability to report back, in order, a visually presented sequence of items (i.e., serial short-term memory), because the deviant sound captures attention. If the visually presented items are masked by visual noise, however, serial short-term memory is spared, as the deviant sound loses its capacity to capture attention (Hughes et al., 2013). In a recent study, we attempted to bridge these laboratory findings to an applied context (Halin et al., 2013). More specifically, we asked participants to undertake a proofreading task (i.e., to search for

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semantic/contextual errors in written texts) against a background of speech or in silence. In Experiment 1, the texts were displayed in either an easy-to-read font (Times New Roman) or a hard-to-read font (Haettenschweiler); and in Experiment 2, all texts were displayed in the easy-to-read font but they were either masked by visual noise or not masked by visual noise. In both experiments, background speech impaired proofreading for semantic/contextual errors, but only when the text was easy to read, not when it was hard to read (presented in a hard-to-read font or masked by visual noise). A cross-experimental analysis showed that the two ways of manipulating task difficulty shielded from distraction in functionally similar ways. Arguably, higher task difficulty promotes focal-task engagement, reduces the neural processing of background sound (Sörqvist, Stenfelt, & Rönnberg, 2012) and potentiates the capability to block the sound's call for attention (Hughes et al., 2013).

One factor that influences distractibility is, thus, task difficulty. Another influential factor in moderating the susceptibility to distraction is working memory capacity (Engle, 2002; Sörqvist & Rönnberg, 2014). High-capacity individuals are generally less susceptible to auditory distraction than their low-capacity counterparts (Sörqvist, 2010c), both in the context of cross-modal distraction (e.g., Sörqvist et al., 2012b) and in the context of within-modal distraction (Sörqvist & Rönnberg, 2012), and across a wide variety of tasks including visual-verbal short-term memory (Beaman, 2004; Sörqvist, 2010b) and long-term memory for written prose (Sörqvist, 2010a; Sörqvist, Ljungberg, & Ljung, 2010). For example, in a study by Sörqvist et al. (2010b), participants first undertook a complex-span task called size-comparison span (SICSPAN) that was designed to measure individual differences in working memory capacity. Next, the participants read prose passages, either in silence or against a background of speech. Background speech disrupted memory for prose: Fewer questions – tapping long-term memory for the text – were subsequently answered correctly when the texts had been studied in the presence of background speech as compared to silence. This disruption of prose memory by background speech, however, was greater for participants with low working memory capacity.

In previous experiments that have tested the relation between individual differences in working memory capacity and effects of background speech on long-term memory for prose (e.g., Sörqvist, 2010a; Sörqvist, Ljungberg, et al., 2010), the text has been displayed in an easy-to-read font and there has been no manipulation of task difficulty. An interesting extension of this paradigm would be to test whether the relationship between working memory capacity and distractibility is modulated by a task difficulty manipulation (e.g., by manipulating the readability of the text by changing font type). One possibility is that low-capacity individuals, who – under 'normal' conditions – are relatively susceptible to distraction, will be aided by the increase in task difficulty (e.g., the hard-to-read font helps them achieve a steadfast locus-of-attention) and thereby become less susceptible to distraction. Conversely, the high-capacity individuals, who are relatively immune to distraction under 'normal' conditions may not experience any benefit from an increase in task difficulty, because their locus-of-attention is already steadfast. An increase in task difficulty could, therefore, reduce the gap in susceptibility to distraction that exists between low- and high-capacity individuals.

In this paper, we extend the basic idea of a trade-off between task difficult and distractibility to a task that is particularly relevant to educational settings: Memory for written prose. The participants read texts that were displayed either in an easy-to-read (Times New Roman) or a hard-to-read font (Haettenschweiler). Reading was undertaken either in a quiet environment or accompanied by a speech noise background, and the participants were required to attempt to remember as much of the text as possible for later recall. We expected to find a cross-over interaction, demonstrating disruption from the background speech, but only when the text was displayed in an easy-to-read font, not when it was displayed in a hard-to-read font. Moreover, we explored the relationship between individual differences in working memory capacity and distractibility in these two task difficulty conditions, respectively.

1. Methods

1.1. Participants

Thirty-two Swedish students participated for a small honorarium. All reported normal hearing, normal or corrected-to-normal vision and Swedish as their native language.

1.2. Materials

Sound. The background speech was comprised of a male voice that described a fictitious culture called *the Ansarians*. It was recorded in an echo-free chamber and played back through Sennheiser HD202 headphones (Leq ≈ 65 dBA).

Reading speed. We asked participants to read two shorter texts (160 words long) about the planets Mars and Neptune. All texts in the experiment were written in Swedish (font size 12 pt. and spacing between lines 1.00), in the two fonts Times New Roman (easy-to-read) and Haettenschweiler (hard-to-read), and were displayed on a computer screen with both margins evenly adjusted. The computer measured the time it took to read each text.

Memory for prose. We adopted a modified version of a test that has been used previously to measure memory for written prose (Sörqvist, 2010a) and spoken discourse (Sörqvist & Rönnberg, 2012). Four memory tests were developed. Each test had a reading phase and a test phase. In the reading phase, 5 paragraphs (approximately 85 words each) about fictitious cultures (not the same culture as the one described in the background speech) were displayed simultaneously on the computer screen. The paragraphs described, for example, the rise of the culture, advances in technology, and warfare. The paragraphs were displayed for 4 min. When the allocated time was up, the computer moved to the test phase. Prose memory was tested with 20 multiple-choice questions (5 options per question; 4 questions per paragraph) that concerned detailed information in the text (e.g., "How many regions were the land of Timad divided in?"). The questions were presented sequentially (in Arial font). The first four questions concerned the first text paragraph; the next four concerned the second paragraph, and so on. The participants were allowed to use a maximum of 15 s for each question.

Working memory capacity task. We used the size-comparison span (SICSPAN) task to tap working memory capacity (Sörqvist, Ljungberg, et al., 2010). In this task, pairs of words were presented on the computer screen and participants were required to compare them in size (e.g., "Is STRAWBERRY bigger than PINEAPPLE?"). Participants answered this question by using the 'Y' and 'N' keys on the keyboard. The participants had a maximum of 5 s to respond to each comparison. After a response, or if the time was up, the computer screen went blank for 500 ms. And thereafter, a to-be-remembered word was presented (e.g., PAPAYA) for 800 ms. This procedure was repeated two to six times before participants were asked to recall the to-be-remembered words in serial order by typing with the keyboard. The recall phase was self-paced. All presented words within a list were drawn from the same semantic category (e.g., Fruits) and each word (and category) appeared only once during the task. The total number of lists was 10 (i.e., two of each list length) and the lists were presented in a fixed ascending order (e.g., starting with the two-word lists) for all participants. Their SICSPAN score

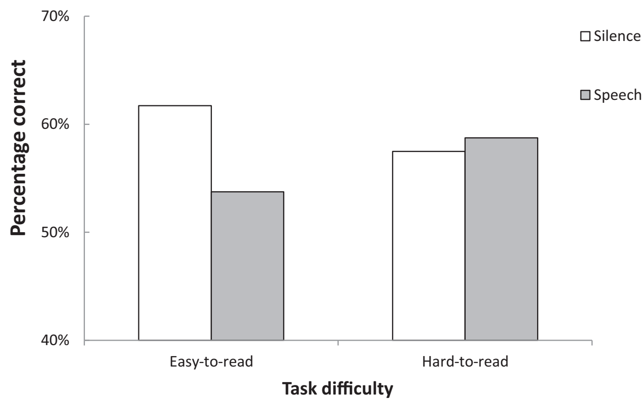

Fig. 1. Mean number of the percentage of correct answers on a test of memory for prose displayed in two task difficulty conditions (easy-to-read and hard-to-read texts) and read in two background conditions (silence and background speech noise).

was based on a strict serial recall criterion whereby they received one point for each to-be-remembered word that was placed in the correct serial position.

1.3. Procedure and design

A within-participant design was used with two factors: Task difficulty (easy-to-read vs. hard-to-read font) and background condition (silence vs. background speech). Participants were instructed throughout the experiment to wear headphones, to ignore any sound, and to work as fast as they could without compromising accuracy. Reading speed was measured first by requesting participants to read the two texts about the planets Mars and Neptune (written in the two fonts respectively) in silence (the presentation order of this task was counterbalanced between participants). Next, participants undertook the four memory tests. The background speech was played during the reading phase of two of the four memory tests. The presentation order between easy-to-read font (Times New Roman) and hard to-read font (Haettenschweiler), between the two background conditions, and between the four memory tests, was counterbalanced between participants. After the memory tests, the participants were asked to rate (on a 7-point scale) how demanding and how difficult the task was in the two task difficulty conditions, respectively. Finally, they conducted the SICSPAN task in silence. In all, the experiment took approximately 35 min.

2. Results

2.1. Task difficulty ratings and reading speed

The task was perceived as more difficult ($M = 2.63$ vs. $M = 4.88$, $t(31) = 7.31$, $p < .001$) and more demanding ($M = 2.41$ vs. $M = 5.28$, $t(31) = 8.35$, $p < .001$) when the text was displayed in the hard-to-read compared with the easy-to-read font. This corroborates the effectiveness of the font manipulation in making the task more difficult. Reading took somewhat longer with the hard-to-read font but this difference was not significant ($M = 53.31$ s vs. $M = 51.92$ s, $t(31) = 0.93$, $p = .359$). One interpretation of these results is that the participants compensated for the greater demand on reading by concentrating harder and thus engaging more with the task.

2.2. Memory for written prose

As can be seen in Fig. 1, this greater need for concentration benefited prose memory. The background speech impaired memory when the text was easy-to-read but not when the text was hard-to-read. Most importantly, recall was better for texts read in a hard-to-read font against a speech noise background than for texts read in an easy-to-read font in the same background condition. This conclusion was supported by a 2(task difficulty: easy-to-read vs. hard-to-read font) × 2(background condition: Silence vs. background speech) analysis of variance that revealed no significant main effect of task difficulty, $F(1, 31) = 0.12$, $p = .729$, $\eta_p^2 = .004$, and no significant main effect of background condition, $F(1, 31) = 1.39$, $p = .234$, $\eta_p^2 = .04$, but a significant interaction between the two factors, $F(1, 31) = 31.01$, $p = .004$, $\eta_p^2 = .23$. Simple main effects analysis (with LSD adjustment) showed that recall was impaired by background speech in the easy-to-read condition, $p = .002$, $d = 0.48$, but not in the hard-to-read condition, $p = .398$, $d = 0.16$. Furthermore, recall was better in the presence of background speech when the text was hard-to-read compared to when text was easy-to-read, $p = .032$, $d = 0.37$.

2.3. Relation between working memory capacity and distractibility

To analyze the relationship between working memory capacity and distractibility in the two task difficulty conditions, we used the difference scores (i.e., subtracting the memory score in the silent condition with the memory score in the background speech condition) for both task difficulty conditions, respectively, and correlated these difference scores with the SICSPAN scores. The silence and background speech variables had an internal consistency of $\alpha = .80$ (silence, SD = 0.16; background speech, SD = 0.15) in the easy-to-read condition, and $\alpha = .65$ (silence, SD = 0.17; background speech, SD = 0.16) in the hard-to-read condition. As shown in Fig. 2, higher SICSPAN scores were associated with a smaller distraction magnitude when the text was displayed in an easy-to-read font, $r(30) = -.35$, $p = .050$, 95% CI [−.62, −.002], but no such relationship was found when the text was displayed in a hard-to-read font, $r(30) = -.05$, $p = .779$, 95% CI [−.39, .30]. However, the difference between the two r-values (Meng, Rosenthal, & Rubin, 1992) was not statistically significant, $z = -1.01$, $p = .312$.

3. Discussion

Many experiments have shown that memory for written prose is impaired if the prose is read in the presence of background speech (e.g., Banbury & Berry, 1998; Bell et al., 2008; Sörqvist, 2010a; Sörqvist, Ljungberg, et al., 2010). The experiment reported here qualifies this general finding, by demonstrating that background speech impairs memory of written prose, but only when the text is easy to read, not when the text is displayed in a hard-to-read font. Most importantly, prose recall was better in the presence of background speech when the text was displayed in a hard-to-read font compared to an easy-to-read font. It seems, therefore, that higher task difficulty can facilitate selective attention and shield against distraction.

The results reported here extend the assumption of a trade-off between task difficulty and distractibility, as shown in laboratory-motivated studies (Hughes et al., 2013; Kim et al., 2005; SanMiguel, Corral, & Escera, 2008; Sörqvist, Stenfelt, & Rönnberg, 2012), into an applied context, especially relevant for educational settings. The results corroborate the findings of Halin et al. (2013): The potentially disruptive effects of background speech on proofreading become manifest only when the text is displayed in an easy-to-read font, not when it is displayed in a hard-to-read font. The experiment reported here extends these findings by showing that the disruption by background speech of memory for written prose can also be attenuated by a task-engagement manipulation. Based on what is

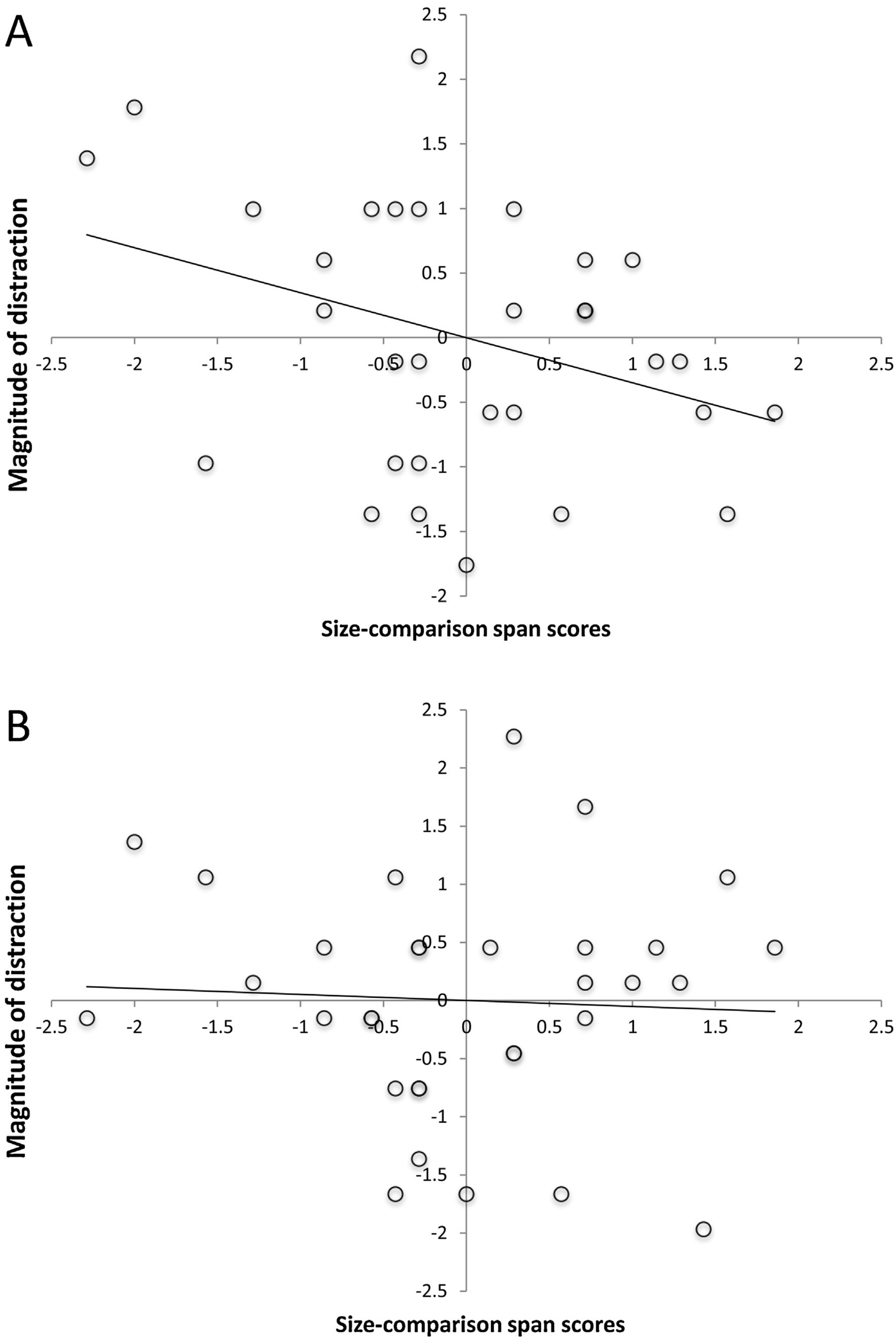

Fig. 2. The figure shows the relationship between individual differences in working memory capacity (i.e., size-comparison span scores) and the magnitude of the effects of background speech on prose recall (all z-values) in the easy-to-read condition (panel A) and in the hard-to-read condition (panel B).

known from the basic research findings, our interpretation of these results is that increased task difficulty leads to a more steadfast locus-of-attention (Hughes et al., 2013), and a more constrained neural auditory-sensory processing of the background sound (Sörqvist, Stenfelt, & Rönnberg, 2012). Because of this, the sound loses its capability to capture attention and disrupt performance.

Individual differences in person-specific distractibility were associated with individual differences in working memory capacity, at least when the text was displayed in an easy-to-read font. There was no relationship between working memory capacity and distractibility when the text was displayed in a hard-to-read font. The absence of a relationship in the hard-to-read font condition could be due to the relatively small sample size and the relatively low statistical reliability in the hard-to-read condition. Because of these limitations, the interpretation of the individual difference analyses are questionable, especially as the relationship between working memory capacity and distractibility in the easy-to-read condition did not differ in magnitude from the corresponding relationship in the hard-to-read condition. Yet, the results reported here may lead to an explanation of the often-replicated finding of a relation between working memory capacity and distractibility (see Sörqvist, 2010c; Sörqvist & Rönnberg, 2014, for reviews). The typical finding is that working memory capacity is related to the difference between a baseline condition without distraction and a condition with distraction (Domkin, Sörqvist, & Richter, 2013; Rönnberg et al., 2013; Sörqvist, Stenfelt, & Rönnberg, 2012). For example, the difference between memory for a text read in silence and for a text read against a background of speech is related to individual differences in working memory capacity, under 'normal' task conditions (e.g., when the font of the to-be-remembered text is ordinary; Sörqvist, Ljungberg, et al., 2010). One possibility is that low-capacity participants, who cannot engender a locus-of-attention steadfast enough to resist distraction under normal task conditions (i.e., when the font is easy to read), wherein this relationship between working memory capacity and distractibility emerges, are helped when task difficulty increases (i.e., when the font is hard to read), as they are forced to concentrate harder (thereby boosting cognitive control). High-capacity individuals, who have a locus-of-attention steadfast enough already in the normal task conditions, do not benefit as much from an increase in task difficulty. As low-capacity individuals approach the cognitive control abilities of their high-capacity counterparts under high task difficulty conditions, the relationship between working memory capacity and distractibility becomes less pronounced.

3.1. Practical applications

Making a task more difficult (e.g., by forcing a more disfluent reading) can sometimes facilitate memory (Diemand-Yauman, Oppenheimer, & Vaughan, 2010) and problem solving (Thompson et al., 2013) by leading people to deploy deeper processing strategies, with better performance as an outcome (Alter, Oppenheimer, Epley, & Eyre, 2007). Research on "desirable difficulties" indicates that increased task difficulty has its greatest beneficial impact for learning in the long term, while the short term benefits are relatively limited (Bjork, 1994). Our results highlight the potential benefits of desirable difficulties also in the short term, especially in noisy work environments.

As is well known, noise impairs learning (Hygge, Evans, & Bullinger, 2002; Klatte, Bergstroem, & Lachmann, 2013) and can be harmful to performance in open offices (Jahncke et al., 2011; Mak & Lui, 2012) and other environments that require intellectual work. The simple means with which task engagement can be manipulated, and distraction thereby attenuated, may not only serve as a practical intervention to attenuate the impairment produced by sound to the performance of cognitive tasks in office and learning environments. It can also reduce the distractibility associated with specific populations of individuals with poor attentional control, such as those with ADHD (Pelletier, Hodgetts, Lafleur, Vincent, & Tremblay, 2013). As ADHD individuals typically have lower working memory capacity than their counterparts (Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005), the relationships between individual differences in working memory capacity and distractibility speak in favor of this possibility. It should be noted, however, that disfluency does not always lead to a more desirable difficulty (Yue, Castel, & Bjork, 2013). Exploring the boundary conditions of desirable difficulty in the context of auditory distraction is therefore a target for future research.

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4. Conflicts of Interest

The grant providers had no involvement in the study design or writing of this paper. The authors have no conflict of interest.

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