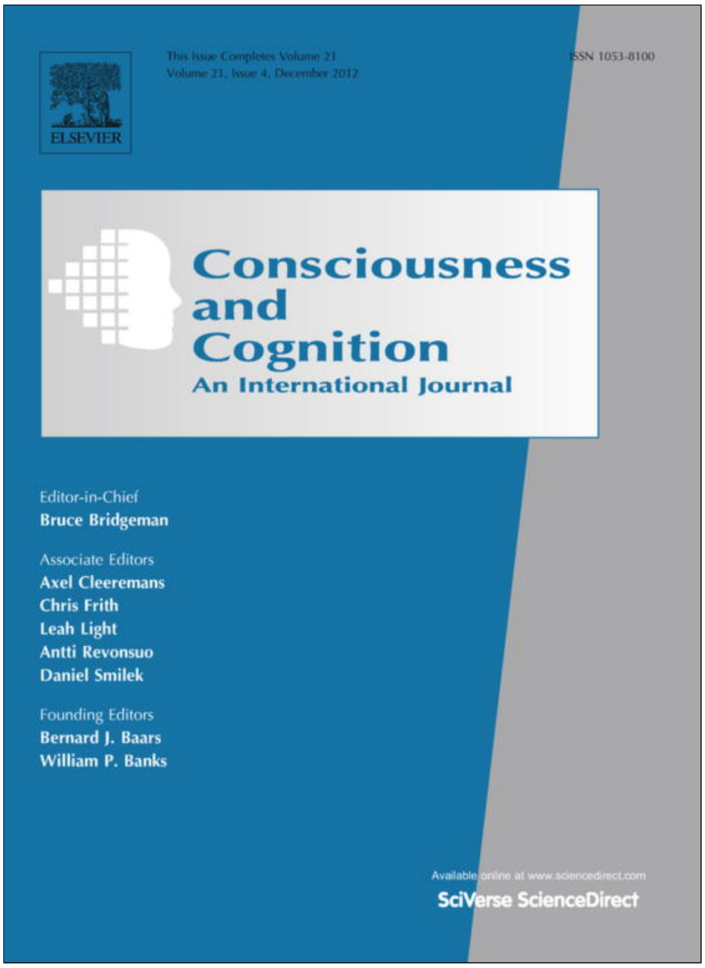
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Short Communication

Perceptually specific and perceptually non-specific influences on rereading benefits for spatially transformed text: Evidence from eye movements

Heather Sheridan *, Eyal M. Reingold

Department of Psychology, University of Toronto at Mississauga, Canada

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The present study used eye tracking methodology to examine rereading benefits for spatially transformed text. Eye movements were monitored while participants read the same target word twice, in two different low-constraint sentence frames. The congruency of perceptual processing was manipulated by either applying the same type of transformation to the word during the first and second presentations (i.e., the congruent condition), or employing two different types of transformations across the two presentations of the word (i.e., the incongruent condition). Perceptual specificity effects were demonstrated such that fixation times for the second presentation of the target word were shorter for the congruent condition compared to the incongruent condition. Moreover, we demonstrated an additional perceptually non-specific effect such that second reading fixation times were shorter for the incongruent condition relative to a baseline condition that employed a normal typography (i.e., non-transformed) during the first presentation and a transformation during the second presentation. Both of these effects (i.e., perceptually specific and perceptually non-specific) were similar in magnitude for high and low frequency words, and both effects persisted across a 1 week lag between the first and second readings. We discuss the present findings in the context of the distinction between conscious and unconscious memory, and the distinction between perceptually versus conceptually driven processing.

1. Introduction

The levels-of-processing (LOP) framework (Craik & Lockhart, 1972) was influential in promoting the idea that "deep" semantic processing produces a more durable and elaborate memory representation than "shallow" perceptual processing. However, since the 1970s, a variety of memory theories have acknowledged the role of perceptual (in addition to semantic) influences on memory performance, in response to evidence that memory for perceptual details can be surprisingly long-lasting. Much of this evidence came from memory studies that manipulated the congruency of surface variables (i.e., font, color, etc.) across the study and test phases of the experiment, to show that memory performance was better when perceptual aspects of the stimulus were the same rather than different during encoding and retrieval. Such perceptual specificity effects were most frequently shown with perceptual implicit (or indirect) tasks (for reviews, see e.g., Levy, 1993; Roediger & McDermott, 1993; Roediger & Srinivas, 1993; Roediger, Weldon, & Challis, 1989; Schacter, 1987; Tenpenny, 1995) that employed a variety of physically degraded (i.e., data-limited) retrieval cues (e.g., masked words, word stems, word fragments,

* Corresponding author. Address: Department of Psychology, University of Toronto at Mississauga, 3359 Mississauga Road N. RM 2037B, Mississauga, Ontario, Canada L5L 1C6. Fax: +1 905 569 4326.
E-mail address: heather.sheridan@utoronto.ca (H. Sheridan).

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picture fragments, etc.), but similar effects were also occasionally shown with explicit (or direct) tasks, such as recognition memory tasks (Beiderman & Cooper, 1992; Cave, Bost, & Cobb, 1996; Cooper, Schacter, Ballesteros, & Moore, 1992; Jolicoeur, 1987; Kolers, Duchnicky, & Sundstroem, 1985; Milliken & Jolicoeur, 1992; Rajaram, 1996; Ray & Reingold, 2003; Reingold, 2002; Srinivas, 1995, 1996).

Of particular relevance to the present study, the rereading paradigm has also been used to study the perceptual specificity of memory representations. The rereading paradigm examines the magnitude of the processing advantages that occur when the same text is read more than once (for reviews, see Levy, 1993; Raney, 2003). Because such rereading benefits (also referred to as text repetition effects, or priming effects) are assessed without explicitly instructing participants to refer back to their previous encounter with the text, the rereading task constitutes an implicit, or indirect, measure of readers' memory for their prior encounter with the text (Rayner, Raney, & Pollatsek, 1995). The rereading paradigm was used by Kolers (1975, 1976, 1979) in a seminal series of studies that pioneered the study of perceptual specificity effects during rereading. In Kolers' studies, participants were asked to read transformed text that had been derived from normal text by applying certain geometrical transformations, such as rotation about axes, inversion, and mirror reflection (Kolers, 1968). Using this approach, Kolers (1975) demonstrated that readers were faster at rereading inverted text if they had previously read the text in the same inverted text transformation, relative to text that was previously read in a normal typography. Furthermore, Kolers (1976) showed that readers were faster at rereading inverted text 1 year after the first presentation of the inverted text, even if they did not remember previously reading the text. In interpreting such findings, Kolers argued strongly that readers retain highly specific visual pattern-analyzing operations for over 1 year.

Kolers' conclusions generated a great deal of controversy (Craik, 1989; Graf, 1981; Graf & Levy, 1984; Horton, 1985, 1989; Masson, 1984, 1986; Masson & Sala, 1978; Tardif & Craik, 1989; for a review, see Levy, 1993), and several researchers have argued strongly that Kolers' findings were due to conceptual rather than perceptual influences (e.g., Graf & Levy, 1984; Horton, 1985; Masson & Sala, 1978; Tardif & Craik, 1989). According to these critics, transformed text receives more extensive conceptual (or semantic) processing than normal text, and this enhanced conceptual processing produces the superior rereading benefits in the transformed text conditions used by Kolers. This criticism is difficult to refute because Kolers' use of identical sentences and passages during both readings makes it is difficult to rule out the possibility that readers were using their memory for the gist, or meaning, of the passages to assist them during rereading.

To address past criticisms of Kolers' work, an eye tracking and rereading paradigm (Sheridan & Reingold, 2012) was recently used to examine perceptual specificity effects for individual target words that were read twice in two different sentences. A key advantage of this paradigm is that it isolates perceptual processing because the change in context prevents readers from using their memory for the meaning of the sentence to help them to decipher the target word. Using this paradigm, Sheridan and Reingold (2012) presented target words (e.g., "success") in a variety of distortion typographies (e.g., ). Perceptual specificity effects were demonstrated such that fixation times were shorter on target words that were previously read in the same distortion typography (i.e., the congruent condition), relative to target words that were previously read in a different distortion typography (i.e., the incongruent condition). These perceptual specificity effects were significant for low frequency, but not for high frequency target words, and they persisted across a 1 week lag between the first and second readings (for similar findings of long-lasting perceptual specificity effects, see e.g., Goldinger, 1996; Kolers, 1976; Ray & Reingold, 2003; Roediger & Blaxton, 1987; for reviews, see Levy, 1993; Roediger & McDermott, 1993).

However, Sheridan and Reingold (2012) demonstrated no significant differences in fixations times across the incongruent condition and an additional baseline condition that employed a normal typography (i.e., non-distorted) during the first reading and a distortion typography during the second reading. Since both the incongruent and baseline conditions involved a change in typography across readings, the incongruent versus baseline contrast provided a way to assess whether initially reading text in a distortion typography rather than normal text produces perceptually non-specific rereading benefits. It is somewhat surprising that Sheridan and Reingold (2012) did not show any incongruent versus baseline differences, in light of past claims that difficult-to-read typographies enhance rereading benefits by producing more extensive conceptual processing relative to normal text (e.g., Horton, 1985).

One possible reason for why there were no baseline versus incongruent differences is that the distortion typographies used by Sheridan and Reingold (2012) were not as extreme as Kolers' geometrical transformations (Kolers, 1968). We hypothesize that using transformations might reveal perceptually non-specific rereading benefits, by magnifying processing differences during encoding across the baseline versus the incongruent conditions. Accordingly, the goal of the present study is to employ the Sheridan and Reingold (2012) paradigm while using similar transformations to the ones employed in Kolers' original studies. We expect to replicate Sheridan and Reingold (2012)'s perceptual specificity effects (i.e., shorter fixation times for the congruent relative to the incongruent condition) for low frequency words, and to possibly extend this finding to high frequency words. Moreover, we predict that the transformations might reveal perceptually non-specific effects (i.e., shorter fixation times for the incongruent relative to the baseline condition). Similar to Sheridan and Reingold (2012), we explore these two types of effects under a variety of conditions, by manipulating target word frequency (high frequency, low frequency) and by examining the impact of a 1 week lag between the first and second presentations of the target words.

2. Method

2.1. Participants

All 72 participants were undergraduate students at the University of Toronto. The participants were all native English speakers and were given either one course credit, or $10.00 (Canadian) per hour. All participants had normal or corrected to normal vision.

2.2. Materials and design

The present study's stimuli were taken from the appendix in Sheridan and Reingold (2012). Specifically, the target words consisted of 108 low frequency nouns and 108 high frequency nouns, which ranged in word length from 5 to 9 letters ($M = 6.4$). The mean word frequency was 2.9 occurrences per million for the low frequency targets, and 106.1 occurrences per million for the high frequency targets, according to the SUBTLex corpus of American English subtitles (Brysbaert & New, 2009). For each participant, a total of 108 target words (54 high frequency words and 54 low frequency words) were each presented twice in two different low-constraint sentence frames. To give an example, the target word *table* was presented in the two sentences (A and B) that are shown below:

(A) John decided to sell the *table* in the garage sale.
(B) I was told that the *table* was made out of expensive wood.

Target word predictability in these sentence frames was assessed by providing an additional group of 10 participants with the beginning of each sentence frame and asking them to write a word that could fit as the next word in the sentence. Average predictability was extremely low, amounting to 1.3% for the high frequency target words and 0.1% for low frequency target words.

The target words were shown either in normal text (i.e., a mono-spaced courier font), or in the transformations shown in Table 1. For Transformation A, the letters of the word were written in a backwards order (e.g., "table" was written as "elbat"), and a left facing arrow was displayed above the target word to indicate that participants were required to read the word backwards. For Transformation B, participants read the target word in a forwards direction (no arrow was shown), but the individual letters in the word were flipped either from right to left, or upside down. To increase the difficulty level of Transformation B, we used capital letters only, and whenever possible we flipped the letters along a dimension that was not symmetrical (e.g., the letter "E" was flipped from right to left rather than upside down). This pair of transformations was used to setup three different transformation conditions (i.e., congruent, incongruent, baseline). For the congruent condition (one third of trials), the target word was presented in the same transformation for both the first and second readings (50% of trials = Transformation A was used for both presentations, 50% of trials = Transformation B was used for both presentations). For the incongruent condition (one third of targets), the type of transformation changed across the two readings (50% of trials = Transformation A was followed by Transformation B, 50% of trials = Transformation B was followed by Transformation A). Finally, for the baseline condition (one third of trials), the target was shown in normal text during the first reading, and in transformed text during the second reading (50% of trials = the second presentation was Transformation A, and 50% of trials = the second presentation was Transformation B). For all of the above transformation conditions, the sentence frames surrounding the target words were presented in normal text.

In addition, we manipulated the amount of time between the first and second presentations of the target word. For the immediate condition, the second presentation of the target words occurred in the same session as the first presentation, with the constraint that the first and second presentations of the target words occurred in separate blocks, and these two blocks were separated by 20 filler sentences that served as buffer trials. In contrast, for the 1 week lag condition, the first and second presentations of the target words occurred in two different sessions that were scheduled a minimum of 7 days apart.

Table 1
An illustration of the transformations used in the present studies. Sample target words are shown by text difficulty (normal, Transformation A, Transformation B), and word frequency condition (high frequency, low frequency).

Typography	High frequency	Low frequency
Normal	student	sparrow
Transformation A	← tneduts	← worraps
Transformation B	STUDENT	SPARROW

Table 2
First reading processing times by text difficulty (normal, Transformation A, Transformation B) and word frequency condition (high frequency, low frequency).

	High frequency			Low frequency		
	Normal	Transformation A	Transformation B	Normal	Transformation A	Transformation B
Variable						
First-fixation	205 (3.3)	240 (5.0)	237 (5.6)	224 (3.9)	235 (4.9)	234 (5.8)
Gaze duration	242 (6.3)	1339 (57.3)	1176 (56.8)	341 (12.5)	1759 (83.2)	1444 (67.4)
Go-past time	292 (9.6)	1742 (72.8)	1653 (75.3)	431 (17.9)	2246 (96.0)	2122 (86.3)
Total time	343 (11.6)	2074 (82.0)	1997 (89.3)	519 (25.1)	2952 (102.6)	2831 (104.2)

Note: The means and standard errors shown in the table are based on the by-participant analyses.

Thus, a total of 12 experimental conditions resulted from crossing word frequency (high frequency, low frequency), transformation condition (congruent, incongruent, baseline), and lag condition (immediate, 1 week lag). The word frequency and transformation condition variables were manipulated within subjects, and the lag condition variable was manipulated between subjects such that 36 participants were assigned to the immediate condition, and the remaining 36 participants were assigned to the 1 week lag condition. Each participant read each target word twice, but they saw a given sentence frame only once. The order of trials was randomized, and the assignment of target words and sentence frames to conditions was counterbalanced across participants. Participants read five practice sentences followed by 274 sentences (108 first presentation sentences, 108 second presentation sentences, and 58 non-experimental filler sentences). In the immediate condition, all of the sentences were presented during a single 1 h session, whereas in the 1 week lag condition the sentences were distributed across two 30 min sessions.

2.3. Apparatus and procedure

Eye movements were measured with an SR Research EyeLink 1000 system with high spatial resolution and a sampling rate of 1000 Hz. Viewing was binocular, but only the right eye was monitored. A chin rest and forehead rest were used to minimize head movements. Following calibration, gaze-position error was less than 0.5°. The sentences were displayed on a 21 in. ViewSonic monitor with a refresh rate of 150 Hz and a screen resolution of 1024×768 pixels. All letters were lowercase unless capitals were appropriate, with the exception that Transformation B employed only capital letters. The text was presented in black (4.7 cd/m^2) on a white background (56 cd/m^2). Participants were seated 60 cm from the monitor, and 2.4 characters equaled approximately 1 degree of visual angle.

Prior to the experiment, the participants completed a short practice task that was designed to familiarize them with the transformations used in the experiment. In this task, participants were asked to read 48 single words that were shown in the transformations from Table 1. Participants were able to correctly decipher the practice words 99% of the time. At the start of the experiment, participants were informed that they would be reading sentences that would occasionally contain words written in transformed text. Participants were told to read the sentences silently and for comprehension, but they were not told about the occurrence of repeated targets. After reading each sentence, they pressed a button to end the trial and proceed to the next sentence. To ensure that participants were reading for comprehension, about 15% of the sentences were followed by multiple-choice comprehension questions. The average accuracy rate was 96%.

3. Results

The following variables, which are standard for eye movement studies (for a review, see Rayner, 1998), were used to examine processing times for the target words: (1) first-fixation duration (i.e., the duration of the first forward fixation on the target, regardless of the number of subsequent fixations on the target)[1]; (2) gaze duration (i.e., the sum of all the consecutive first-pass fixations on the target word, before a saccade to another word); (3) go-past time (i.e., the sum of all fixations from the first fixation on the target up to and including the fixation prior to the reader moving past the target to a later part of the sentence.)[2]; (4) total time (i.e., the sum of all the fixations on the target, including regressions back to the target). In the analyses below, we first briefly examine processing times during the first reading of the target words, and we then report the results for the second reading of the target words.

For the first reading analyses, 2.3% of trials were removed due to skipping of the target, and an additional 1.6% of trials were removed because the total time measure for the target exceeded an outlier rejection cut-off point of 10 s. Table 2 contains the means and standard errors for the first reading of the target words, by text difficulty (normal, transformation), and

[1] Note that we do not report the single-fixation variable (i.e., the first-fixation value for the subset of trials in which there was only one first-pass fixation on the target) because this variable produced too many missing values for the transformed text conditions. More specifically, the transformations produced an average of 3–5 first-pass fixations on the target, such that the probability of a single first-pass fixation was extremely low (less than 20% of trials).

[2] Therefore, go-past time is equal to gaze duration for trials in which the first-pass fixation(s) on the target were immediately followed by a saccade to a later part of the sentence. However, for trials in which there was a regression from the target, go-past time includes gaze duration plus all subsequent fixations on earlier parts of the sentence (and any subsequent refixations on the target) up until the reader moved past the target to a later part of the sentence.

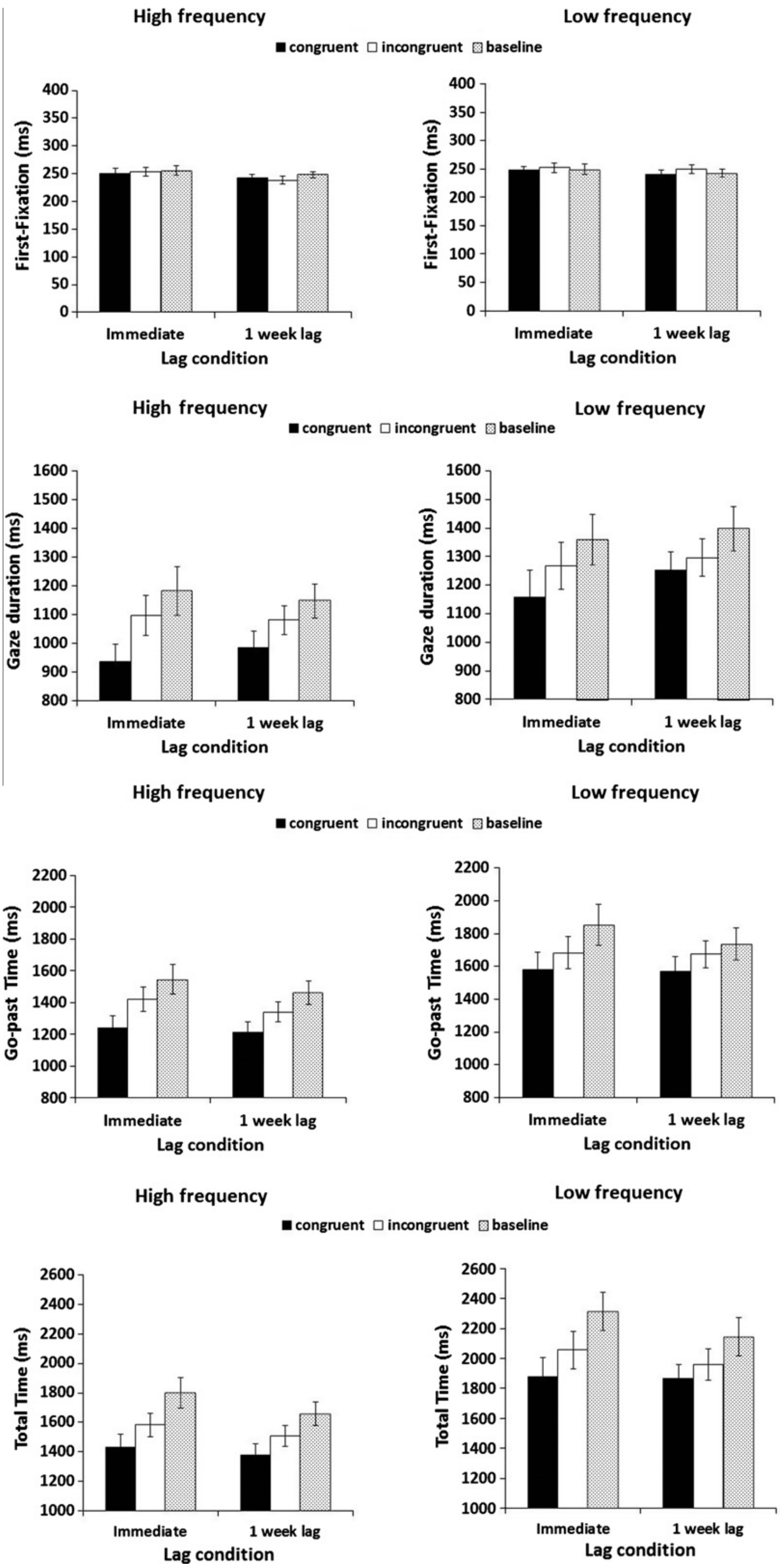

Fig. 1. Second reading processing times by transformation condition (congruent, incongruent, baseline), word frequency (high frequency, low frequency), and lag condition (immediate, 1 week lag).

word frequency condition (high frequency, low frequency). To confirm that the transformed text was read more slowly than normal text, we conducted 2×2 analyses of variance (ANOVAs) that were carried out on the mean fixation time data via both participants (*F*1) and items (*F*2), and with text difficulty (normal, transformation) and frequency (high frequency, low frequency) as independent variables. These ANOVAs were carried out separately for each measure (i.e., first-fixation, gaze duration, go-past time, total time) and for each transformation (i.e., Transformation A, Transformation B). As can be seen from Table 2, for all of the measures, the transformed text produced longer fixation times than normal text (all *F*s > 15, all *p*s < .001), and the magnitude of this effect for gaze duration and total time was at least three times larger than the effect produced by the distortion typographies in Sheridan and Reingold (2012). In addition, three of the measures (i.e., gaze duration, go-past time, and total time) consistently showed word frequency effects for both the transformed and normal text conditions, such that fixation times were longer for low frequency relative to high frequency targets (all *F*s > 25, all *p*s < .001), and such word frequency effects were larger for transformed relative to normal text (all *F*s > 7, all *p*s < .01). Overall, the pattern of results for these three measures (i.e., gaze duration, go-past time, and total time) replicates previous findings that difficult-to-read typography conditions typically produce longer fixation times and larger word frequency effects relative to normal text (Barnhart & Goldinger, 2010; Paterson & Tinker, 1947; Rayner, Reichle, Stroud, Williams, & Pollatsek, 2006; Sheridan & Reingold, 2012; Slattery & Rayner, 2010; Tinker & Paterson, 1955). For the remaining measure (i.e., first-fixation duration), planned comparisons revealed significant word frequency effects for the normal text condition (all *t*s > 5, all *p*s < .001), but not for the transformations (all *t*s < 2, all *p*s > .2), as reflected by a significant interaction between text difficulty and word frequency (all *F*s > 12, all *p*s < .001). It is possible that the transformed text condition did not show first-fixation word frequency effects because lexical processing is delayed in this condition relative to normal reading.

For the second reading analyses, 3.2% of trials were removed because the target word was skipped during the first and/or the second reading, and an additional 0.4% of trials were removed because the total time measure for the target exceeded an outlier rejection cut-off point of 10 s. Fig. 1 displays the means and standard errors for the second reading of the target words, by transformation condition (congruent, incongruent, baseline), word frequency condition (high frequency, low frequency), and lag condition (immediate versus 1 week lag). To test for the perceptual specificity effects, we contrasted the congruent and incongruent transformation conditions, and to test for perceptually non-specific effects, we contrasted the incongruent and baseline transformation conditions. For each type of analysis (perceptually specific versus non-specific) and each measure (i.e., first-fixation, gaze duration, go-past time, and total time), we used separate $2 \times 2 \times 2$ analyses of variance (ANOVAs) that were carried out on the data via both participants (*F*1) and items (*F*2), and with transformation condition (perceptually specific analysis: congruent versus incongruent; perceptually non-specific analysis: incongruent versus baseline), word frequency condition (high frequency, low frequency) and lag condition (immediate, 1 week lag) as independent variables.

As can been seen from Fig. 1, the present study's transformations produced evidence for both the perceptually specific and non-specific effects. Specifically, three of the measures (i.e., gaze duration, go-past time, and total time) showed significant perceptual specificity effects such that fixation times were shorter in the congruent relative to the incongruent condition (all *F*s > 15, all *p*s < .001), as well as significant perceptually non-specific effects such that fixation times were shorter in the incongruent condition relative to the baseline condition (all *F*s > 9, all *p*s < .01). Both of these effects did not significantly differ in magnitude across the high versus low frequency and the immediate versus l week lag conditions, as indicated by a lack of two-way and three-way interactions (all *F*s < 3, all *p*s > .1). In addition, there were significant word frequency effects (all *F*s > 20, all *p*s < .001) for all three measures (i.e., gaze duration, go-past time, and total time). The remaining measure (i.e., first-fixation duration) did not show any significant perceptually specific or non-specific effects (all *F*s < 2, all *p*s > .2), or word frequency effects (all *F*s < 1) or interactions (all *F*s < 4, all *p*s > .06).

To further test if the perceptually specific and non-specific effects could persist across the 1 week lag, we separately analyzed the data in the 1 week lag condition using 2×2 ANOVAs that were carried out on the data via both participants (*F*1) and items (*F*2), and with transformation condition (perceptually specific analysis: congruent versus incongruent; perceptually non-specific analysis: incongruent versus baseline) and word frequency condition (high frequency, low frequency) as independent variables. Following the lag, the perceptual specificity effects were significant for go-past time and total time (all *F*s > 4, all *p*s < .05), and for gaze duration the perceptual specificity effects were significant by-participants ($F1(1,35) = 4.36$, $p < .05$), and marginal by-items ($F2(1,107) = 3.57$, $p = .061$). In addition, all three of the measures showed significant perceptually non-specific effects following the lag (all *F*s > 4, all *p*s < .05), and significant word frequency effects (all *F*s > 20, all *p*s < .001), and none of the above effects interacted with word frequency (all *F*s < 1).

Thus, the present study's transformation conditions replicated the long-lasting perceptual specificity effects reported by Sheridan and Reingold (2012), and extended this finding by also revealing perceptually non-specific effects. Both of these effects (i.e., perceptually specific and non-specific) persisted across a 1 week lag between the first and second readings. Moreover, although Sheridan and Reingold (2012) reported significant perceptual specificity effects for low frequency but not for high frequency words, the present study's effects did not vary as a function of word frequency.

4. Discussion

Using a rereading and eye movements paradigm (Sheridan & Reingold, 2012), we demonstrated that rereading benefits for spatially transformed text (Kolers, 1968) are modulated by both perceptually specific and perceptually non-specific influences. In support of perceptually specific influences, fixation times were shorter on target words that were previously read in the same transformation (i.e., the congruent condition), relative to target words that were previously read in a different transformation (i.e., the incongruent condition). Moreover, in support of additional perceptually non-specific influences, fixation times were shorter for the incongruent condition relative to an additional baseline condition that employed a normal typography during the first reading and a transformation during the second reading. Both of these effects (i.e., perceptually specific and non-specific) were similar in magnitude for high and low frequency words, and both effects persisted across a 1 week lag between the first and second readings.

Similar to Sheridan and Reingold (2012), the present study demonstrated perceptual specificity effects using a paradigm that was designed to address past criticisms of Kolers' work (e.g., Graf & Levy, 1984; Horton, 1985; Masson & Sala, 1978; Tardif & Craik, 1989). Specifically, the paradigm employed a change in context across readings, to rule out the possibility that readers were relying on their memory for the meaning of the sentence to help them to decipher the target words. Moreover, an additional advantage of the paradigm is that it uses a pair of transformations to manipulate perceptual congruency. As discussed by Sheridan and Reingold (2012), such a design is preferable to contrasting normal text with a single transformation (see e.g., Kolers, 1975), because the same transformations are used equally often in the congruent and incongruent conditions during both encoding and retrieval (for a similar approach, see Horton, 1985; Tardif & Craik, 1989). Overall, these methodological innovations served to isolate perceptual processing, such that the present findings can be interpreted as strong evidence for perceptual specificity effects. Such findings provide convergent evidence for a wide range of memory and rereading studies that have shown long-lasting memory benefits when perceptual aspects of the stimuli are congruent rather than incongruent across study and test (for reviews, see Levy, 1993; Roediger & McDermott, 1993; Roediger & Srinivas, 1993; Roediger et al., 1989; Schacter, 1987; Tenpenny, 1995).

Furthermore, the transformations employed in the present study produced stronger and more pervasive perceptual specificity effects as compared to the distortion typographies that were used by Sheridan and Reingold (2012). This pattern across studies is consistent with prior evidence that more difficult typographies tend to show stronger perceptual specificity effects than less difficult typographies (Brown & Carr, 1993; Carr, Brown, & Charalambous, 1989; Graf & Ryan, 1990; Horton & McKenzie, 1995; Jacoby & Hayman, 1987; Levy, 1993). In addition, the substantially greater disruption caused by the transformations as compared to the distortion typographies might also explain why Sheridan and Reingold (2012) showed perceptual specificity effects for low frequency words only, whereas the present study demonstrated equivalent effects for both high and low frequency words. The enhanced processing fluency of high frequency words might explain why these words require more extreme distortions or transformations than low frequency words in order to show perceptual specificity effects. However, an alternative explanation for why the transformations produced greater disruption and a qualitatively different pattern of word frequency results compared to the distortion typographies, is that the two tasks were driven by different underlying processes. Specifically, the transformations may have induced additional problem-solving strategies that are not normally used during reading, whereas the processing of the distortion typographies may have been more similar to normal reading. Clearly, the above speculations require further research.

In addition to demonstrating perceptual specificity effects for both high and low frequency words, the present study revealed an additional perceptually non-specific effect that was not previously shown by Sheridan and Reingold (2012), such that rereading benefits were greater if readers initially encountered transformed target words rather than normal text. This perceptually non-specific rereading benefit from the present study is reminiscent of the *generation effect* (Slamecka & Graf, 1978; for a review, see Yonelinas, 2002) that reflects enhanced memory performance for words that were generated rather than simply read at study. The generation effect has been demonstrated with a wide range of generation cues (e.g., an antonym, a synonym, a clue, an anagram), including a backwards reading condition (e.g., generating "table" from "elbat"; Sheridan & Reingold, 2011) that closely resembles one of the transformations used in the present study. Although generation effects were primarily demonstrated with explicit memory tasks, they have also been shown with implicit tasks that tap conceptually driven rather than perceptually driven processing (e.g., Blaxton, 1989; Roediger & Blaxton, 1987; Roediger et al., 1989). Accordingly, one possible interpretation of the perceptually non-specific effect shown in the present study is that it is driven by conceptual implicit memory. Based on such an interpretation, the present paradigm simultaneously produced both conceptually driven rereading benefits (i.e., the perceptually non-specific effect), and perceptually driven rereading benefits (i.e., the perceptual specificity effect).

However, while it is possible that the perceptually non-specific effect reflects conceptual implicit memory influences, an alternative possibility is that participants adopted a conscious strategy of attempting to recall previous words (i.e., *conscious contamination*). As discussed elsewhere (e.g., Reingold & Merikle, 1990; Reingold & Toth, 1996; Toth, Reingold, & Jacoby, 1994), it is often quite difficult to rule out conscious contamination on implicit or indirect tasks. With respect to the present findings, one argument against the involvement of conscious or explicit memory is that both the perceptually specific and non-specific rereading benefits were equivalent in magnitude across the immediate and the 1 week lag conditions, which stands in contrast to findings that explicit memory performance tends to decay more quickly than implicit memory performance (e.g., Jacoby & Dallas, 1981; Tulving, Schacter, & Stark, 1982; for reviews, see Roediger & McDermott, 1993; Schacter, 1987). To further investigate the degree of conscious contamination, future research could examine the performance of amnesic patients on the rereading tasks developed in the present study and in the prior investigation (Sheridan & Reingold, 2012). Given that amnesic patients have previously shown perceptual specificity effects on rereading tasks (e.g., Cohen & Squire, 1980; Moscovitch, 1982), it would be interesting to examine whether they would also demonstrate perceptually specific and non-specific effects with the present paradigm.

In addition to the above methods of examining conscious contamination, another approach is the speeded reaction time task that was introduced by Horton, Wilson, and Evans (2001). Specifically, assuming that consciously controlled processing tends to be slower than unconscious or automatic processing (de Houwer, 1997; Richardson-Klavehn & Gardiner, 1995, 1996, 1998; Yonelinas & Jacoby, 1994), Horton et al. (2001) argued that the presence of conscious contamination in an implicit task would be reflected in longer reaction times. Unfortunately, at the present time there are no clear estimates for the critical temporal threshold above which conscious contamination might be implicated. Nevertheless, it is interesting to note that the mean gaze duration values for the transformed targets in the present study (i.e., >1100 ms) were somewhat longer than the range of reaction times (i.e., 741–911 ms), which Horton et al. (2001) argued reflected unconscious or automatic influences. Consequently, based on Horton et al. (2001)'s approach, it is not possible to rule out conscious contamination with respect to the perceptually non-specific effects. In contrast, the previously demonstrated perceptual specificity effects using distortion typographies that produced gaze duration values as short as 354 ms (Sheridan & Reingold, 2012) are by this logic much less likely to reflect conscious contamination. Clearly, further studies are required in order to explore the factors which mediate both the perceptually specific and non-specific rereading benefits. However, one clear advantage of the eye movements paradigm used in the present study is that it can be used to derive fixation time measures (for a review, see Rayner, 1998), which can provide fine-grained time course information.

To sum up, long-standing theoretical debates have revolved around the relative contributions of conceptual and perceptual influences on rereading performance (for reviews, see Bowers, 2000; Kolers & Roediger, 1984; Levy, 1993; Reingold, 2002; Roediger & Srinivas, 1993; Tenpenny, 1995). To shed light on this issue, the present study combined a rereading and eye movements paradigm (Sheridan & Reingold, 2012) with Kolers' approach of using transformed text. Using this approach, we demonstrated that a mixture of perceptually specific and perceptually non-specific influences can contribute to long-lasting rereading benefits for transformed text.

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