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Effects of task instructions and topic signaling on text processing among adult readers with different reading styles: An eye-tracking study

Dexiang Zhang[a], Jukka Hyönä[b,c,**], Lei Cui[a], Zhaoxia Zhu[a], Shouxin Li[a,*]

[a] Department of Psychology, Shandong Normal University, Jinan, China
[b] Department of Psychology, University of Turku, Turku, Finland
[c] Tomsk State University, Russia

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ABSTRACT

Effects of task instructions and topic signaling on text processing among adult readers with different reading styles were studied by eye-tracking. In Experiment 1, readers read two multiple-topic expository texts guided either by a summary or a verification task. In Experiment 2, readers read a text with or without the topic sentences underlined. Four types of readers emerged: topic structure processors (TSPs), fast linear readers (FLRs), slow linear readers (SLRs), and nonselective reviewers (NSRs). TSPs paid ample fixation time on topic sentences regardless of their signaling. FLRs were characterized by fast first-pass reading, little rereading of previous text, and some signs of structure processing. The common feature of SLRs and NSRs was their slow first-pass reading. They differed from each other in that NSRs were characterized by spending ample time also during second-pass reading. They only showed some signs of topic structure processing when cued by task instructions or topic signaling.

1. Introduction

Text comprehension is an essential part of our everyday life with adequate text comprehension skills being a necessity for successful participation in society. Comprehending a text is more than an ability to memorize a set of isolated facts. It requires that readers construct a coherent mental representation that, for example, can be applied to solving problems (Kintsch, 1988, 1998). The mental representation refers to an internal representation of the text elements (events, facts, etc.) interconnected through semantic relations and formed into an integrated whole (Kintsch & Van Dijk, 1978; van den Broek & Espin, 2012).

When reading expository texts, especially those that present information about multiple, hierarchically-organized topics, readers often construct a mental representation of the text by using the text's topic structure as their guide (Lemarié, Lorch, Eyrolle, & Virbel, 2008; Lorch, Lemarié, & Chen, 2013; Ray & Meyer, 2011). Topic structure is defined as the arrangement of topics, subtopics and their interrelation (Lorch, Lorch, & Mogan, 1987). By identifying the text's topic structure, readers can integrate subordinate information with its corresponding topic, integrate new topics with the previous topics, and eventually construct a topic structure representation of the text with the support of relevant prior knowledge (Hyönä & Lorch, 2004; Lorch, Lorch, & Inman, 1993). The constructed topic structure representation in turn supports upcoming reading activities (Lorch et al., 2013; van den Broek & Espin, 2012). Consistent with this assumption, readers are found to be much slower in reading sentences introducing a new topic than those continuing with the same topic (Hyönä, n1994, 1995; Lorch et al., 2013). This is referred to as the topic-shift effect.

Constructing a comprehensive topic structure representation is a demanding task, even college students may fail to adequately monitor a text's topic structure (Hyönä, Lorch, & Kaakinen, 2002; Hyönä & Nurminen, 2006; Minguela, Solé, & Pieschl, 2015). For example, Hyönä et al. (2002) found that only about 20% of their adult reader sample made extensive use of the text's topic structure when reading a multiple-topic expository text. In order to help readers identify the text's structure, authors of expository texts often use different ways to make the topic structure more explicit (Lemarié et al., 2008; Mautone & Mayer, 2001; Ray & Meyer, 2011). The text's topic structure may be signaled by topic headings that not only cue the topic of the subsequent text section but also signal topic boundaries, or by typographically highlighting (e.g., by underlining or bolding) key text contents. It also can be highlighted by explicit task instructions given ahead of reading, such as instructing readers to summarize the main points of a text

* Corresponding author. Department of Psychology, Shandong Normal University, Jinan, China
** Corresponding author. Department of Psychology, University of Turku, Turku, Finland.
E-mail addresses: hyona@utu.fi (J. Hyönä), shouxinli@sdnu.edu.cn (S. Li).

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(Hyönä & Lorch, 2004; Lorch et al., 1987; Wang, Sabatini, O'Reilly, & Feng, 2017).

Typographical textual cues operate via the so-called exogenous attentional guidance mechanism. Via exogenous guidance, attention is attracted to visually salient features of the text, such as highlighted or underlined text. Exogenous attentional guidance is assumed to work automatically without voluntary control. Reading instructions, on the other hand, operate via the endogenous attentional mechanism. It is voluntary, goal-directed behavior where attention is guided toward elements that are relevant to the reader's goal, as defined by instructions or personal motives.

According to the goal-focus model (Bråten, McCrudden, Stang Lund, Brante, & Strømsø, 2017; McCrudden & Schraw, 2007), both task instructions and text signals work as relevance cues that help readers focus on relevant text segments. They differ from each other in that task instructions influence endogenous attentional guidance, as they require that the readers keep the reading goal active in their working memory, whereas text signals exert their effect via exogenous attentional guidance, as the signals appear as visually salient in the text (Hyönä, 2010). In goal-directed activity, these relevance cues provide criteria for readers to determine the relevancy of specific information to the reading task. Text information that coincides closely with the reading task or is visually signaled is more relevant than other information. Based on the criteria determined by the endogenous relevance cues, readers set a specific reading goal and generate a specific reading strategy. Reading strategy refers to a form of procedural knowledge that readers deliberately use to acquire, organize, or transform information as well as to reflect on and guide their text-based learning (Afflerbach, Pearson, & Paris, 2008; Alexander, Graham, & Harris, 1998). By using a specific type of strategy, readers allocate their limited attentional resources to relevant information and develop a better understanding and memory of such information. On the other hand, as visual signals operate via exogenous attention control, no internal guidance is required to devote particular attention to cue-relevant information.

In the present study, we examined the effects of two types of relevance cues on text processing among adult readers with different reading styles. Readers' eye movements were registered when they read multiple-topic expository texts with different task instructions (Experiment 1) and when the topic structure was signaled by underlining the topic sentences expressing the key points or when it was not typographically signaled (Experiment 2). We were particularly interested in individual differences in comprehension monitoring on the basis of task instructions and signaling of text structure. Eye-tracking is an attractive method to study individual differences in reading styles, as it provides a real-time protocol of the reading process as it evolves through time and space (Hyönä, 2010; Hyönä, Lorch, & Rinck, 2003). For example, it yields data on how much visual attention readers pay to topic sentences expressing the key points in text, as a function of reading task and signaling of topic sentences. Following Hyönä et al. (2002) and Hyönä and Nurminen (2006), we conducted a cluster analysis on the readers' eye movement patterns to identify individual reading styles in expository text comprehension. Before discussing the present study in more detail, we first review the literature on the effects of task instructions and signaling devices on reading.

1.1. Effects of task instructions on reading

Task instructions orient readers to the assigned reading task, such as instructing readers to summarize the main ideas of a text. The task cues readers' attention to specific information that is relevant to the task, which affects both their moment-to-moment online as well as their offline reading performances (Kaakinen & Hyönä, 2010, 2014; McCrudden, Magliano, & Schraw, 2010; McCrudden & Schraw, 2007). By using instructions from which to approach the reading task, readers devote more attention toward, and have better memory for, task-relevant information than task-irrelevant information (Bråten et al., 2017; Kaakinen & Hyönä, 2007, 2010; Kaakinen, Hyönä, & Keenan, 2003; McCrudden & Schraw, 2007), and they are more likely to build connections between that information and information in other texts (Anmarkrud, McCrudden, Bråten, & Strømsø, 2013).

Providing readers with different task instructions induces them to adopt different reading strategies that have consequences to online processing and its subsequent end results. Readers with an outlining task perform better in processing and recalling the topic structure information than those given a true or false sentence verification task (Lorch et al., 1987). Readers instructed to read for study purposes are more likely to use paraphrasing, repeating and evaluating strategies and focus more on coherence building than those reading for entertainment (Linderholm & van den Broek, 2002; Narvaez, van den Broek, & Ruiz, 1999; van den Broek, Lorch, Linderholm, & Gustafson, 2001; Yeari, van den Broek, & Oudega, 2015). Preparing for a multiple-choice questionnaire that probes word-level surface features leads to less careful reading than preparing to answer questions targeting semantic relations (Radach, Huestegge, & Reilly, 2008). Finally, readers devote more attention to word-level orthographic and lexical-semantic processing in a proofreading task than in a comprehension task (Kaakinen & Hyönä, 2010; Schotter, Bicknell, Howard, Levy, & Rayner, 2014).

1.2. Effects of signaling devices on reading

Signaling devices are writing devices that are used by authors to emphasize important content or to highlight the organizational structure of a text (Lorch, 1989; Meyer, 1975). Lorch (1989) categorizes signaling devices into two types: organizational and typographical signals. Organizational signals, such as headings, preview sentences, and summaries, emphasize the structure of a text. On the other hand, typographical signals, such as capitalization, boldface, and underlining, emphasize individual words or text sections.

Numerous studies have shown that organizational signals benefit readers' processing, representation and memory of the text's topic structure. In comparison to texts without signaling devices, those containing organizational signaling devices guide readers to identify the text's topics and facilitate their processing of the topic structure (Hyönä & Lorch, 2004; Lorch, Chen, & Lemarié, 2012; Lorch et al., 2013; Lorch & Lorch, 1996a; Sanchez, Lorch, & Lorch, 2001). Headings as organizational signals have also been shown to support the identification of referents in a text and the integration of new information with previous knowledge (Bransford & Johnson, 1972; Wiley & Rayner, 2000). In addition, the presence of organizational signals facilitates the creation of a more coherent and integrated representation of the text's topic structure (Lorch et al., 2012; Lorch, Lemarié, & Grant, 2011a, 2011b; Lorch & Lorch, 1996a, 1996b) and improves the retrieval of text information from memory (Hyönä & Lorch, 2004; Lorch et al., 2012, 2013; Ritchey, Schuster, & Allen, 2008).

Typographical signals have been shown to benefit readers' processing and memory of the signaled information; however, their effects are modulated by the quality of the devices and the structural importance of signaled and unsignaled information. Appropriate typographical signals, such as signaling important information or concepts in the body of a text with underlining, improve readers' memory and comprehension of the signaled information, while their memory and comprehension of the unsignaled information are unaffected (Lorch, Lorch, & Klusewitz, 1995; Ponce & Mayer, 2014; Scheiter & Eitel, 2015; Yeari, Oudega, & van den Broek, 2017). On the other hand, inappropriate signaling, such as highlighting task-irrelevant text disrupts the reading and recall of text information (Gier, Herring, Hudnell, Montoya, & Kreiner, 2010; Gier, Kreiner, Hudnell, Montoya, & Herring, 2011; Gier, Kreiner, & Natz-Gonzalez, 2009). In addition, highlighted structural information improves readers' representation and memory of text by reducing reading of peripheral information. However, when peripheral information is highlighted, processing and memory of peripheral information are improved without affecting that of structural information (Yeari et al., 2017).

1.3. Individual differences in reading styles

As argued above, when reading multiple-topic expository texts, it is important for readers to use the topic structure of the text to construct a coherent mental representation of text's core contents. However, several studies have demonstrated that readers differ in their reading styles (Goldman & Saul, 1990; Hyönä et al., 2002; Hyönä & Nurminen, 2006; Meyer, Brandt, & Bluth, 1980). For example, Meyer and Poon (2001) asked readers to read an expository text to write down anything they could recall from the text. Based on these free recalls collected after reading, they found that some of the readers could follow the text's structure and focus on the text's main message, while the others encoded the text as a list of facts and simply tried to remember detailed facts from the text. Goldman and Saul (1990) studied individual reading styles by recording traces of online reading behavior. They observed three different patterns of reading: once-through, review, and regress strategies. Readers adopting the once-through reading style read the texts straight through to the end without rereading. Using the review style, readers selectively reread parts of the text information after reaching the end of the text for the first time. With the regress style, readers selectively reread parts of the text information both prior to and after reaching the end of the text. Goldman and Saul argued that readers who adopted the last two reading styles read the text more flexibly, but they found no difference in recall performance among the three groups.

Most importantly for the present study, Hyönä et al. (2002) examined individual differences in reading styles among competent adult readers (university students) using the eye-tracking methodology. They were interested in characterizing different ways multiple-topic expository texts are read and the consequences of the adopted style to the constructed mental representation of the text. Readers' eye fixation patterns were recorded while they read two multiple-topic expository texts for the purpose of summarizing the main ideas of the text. Using the cluster analysis, Hyönä et al. (2002) distinguished four groups of readers: fast linear readers (FLRs), slow linear readers (SLRs), non-selective reviewers (NSRs) and topic structure processors (TSPs). FLRs and SLRs read each text linearly without looking back to previous sentences. SLRs were distinguished from FLRs by frequently rereading parts of each sentence prior to moving to the next. Unlike linear readers, NSRs and TSPs frequently looked back to previous sentences after the first-pass reading. TSPs differed from NSRs by paying close attention to the topic structure (topic sentences and topic headings) during the first- and second-pass reading, while NSRs extensively and non-selectively reread previous parts of the text. Among the four types of readers, TSPs had the highest working memory capacity and they were also the most efficient readers among the four groups, as reflected by their superior performance in summarizing the main text contents. Hyönä and Nurminen (2006) re-established the reading styles of TSPs, FLRs and SLRs using another sample of competent adult readers. Using a self-report questionnaire, they also found that readers are to some degree aware of their reading style, as reflected in their eye behavior.

1.4. The present study

The present study builds on the study of Hyönä et al. (2002) in that (a) eye-tracking combined with cluster analysis was used to identify different reading styles among adult readers and (b) reading of long, multi-topic expository texts was studied. One of its aims was to test whether the reading styles identified by Hyönä et al. can be re-established with another sample of adult readers from a different educational culture (China). The study of Hyönä et al. was conducted with a sample of Finnish university students. As the Finnish teenage students are at the world-top in reading comprehension (Pisa = Program for International Student Achievement, OECD), it is not at all self-evident that the reading styles observed by Hyönä et al. would necessarily generalize to other adult reader populations.

The more newsworthy aspect of the present study is that it investigated individual differences in responding to task instructions and signaling of the text's topic structure. In Experiment 1, readers read two expository texts guided either by a summary task or a verification task. In the summary task, they were instructed to read the texts to write down the main ideas mentioned in the texts. In the verification task, readers were instructed to read the texts to respond (true or false) to 12 verification statements. In Experiment 2, readers read two long expository texts with the topic sentences either signaled with underlining or without any signaling. In Experiment 2, reading was done in preparation for summarizing the main ideas of the texts.

With respect to Experiment 1 on the effects of task instructions, the following predictions were made. First, if we are to replicate the results of Lorch et al. (1987), readers should pay more attention to topic sentences with the summary instructions than with the verification instructions. This is because the summary task encourages readers to identify topic sentences to formulate a topic structure representation of the text. In comparison, the verification task encourages readers to devote more attention to detailed information to respond to the verification statements. Second, readers are likely to write poorer summaries of the main text contents when reading the texts with verification than summary instructions. These results would demonstrate adult readers' ability to adjust their reading behavior in response to task demands. With respect to the individual reading styles identified by Hyönä et al. (2002), structure processors should emerge in the summary task but not necessarily in the verification task. Moreover, in the summary task, topic structure processors (if identified) should demonstrate most pervasive task effects.

Explicit signaling devices studied in Experiment 2 alert readers to the highlighted topic information and help them to formulate a topic structure representation of the text compared to texts without signaling (Lemarié et al., 2008; Meyer & Poon, 2001; Yeari et al., 2017). More specifically, highlighting topic sentences with underlining should direct readers' attention to the topic sentences to a greater extent than when they are unsignaled. With respect to the reading styles identified by Hyönä et al. (2002), signaling may be beneficial for linear readers and non-selective reviewers (if such subgroups are identified in the present sample) who do not spontaneously pay extensive attention to the text's topic structure, while topic structure processors might not be affected by signaling because they are endogenously guided to the text's topic structure.

2. Experiment 1

In Experiment 1, adult readers read two multiple-topic, hierarchically structured expository texts while their eye movements were recorded. The specific contents of the two experimental texts, the Energy and Endangered Species text, were unfamiliar to the participants. Half of the participants read the texts to write a summary of the main points of the text, while the other half of the participants were asked to read the texts to answer true or false verification statements. A cluster analysis was performed on the eye movement data to distinguish systematic individual reading styles. It groups together individuals who are maximally similar to each other in selected characteristics and distinguishes groups that differ in their mean profiles (Everitt, Landau, Leese, & Stahl, 2001). It has shown to be an effective method to distinguish individual reading styles based on eye movement data (Hyönä et al., 2002; Hyönä & Nurminen, 2006). The summary task was given to both groups after reading of the two texts (for the readers in the verification task, it came as a surprise). It was used to measure the mental representation constructed of the main points of the texts.

2.1. Method

2.1.1. Participants

Ninety university students (55 women; age range 19–22 years) from the Department of Psychology in a university in the east of China participated in the experiment for course credit or monetary compensation. Participants were native Chinese speakers who all had normal or corrected-to-normal vision. All participants reported that they were not familiar with the reading materials. The participants were recruited by randomly choosing them from a student list and asking their willingness to take part in the study.

To ensure sufficient statistical power, the required sample size was calculated by a power analysis based on the predicted effect size using G* Power 3.1 (Faul, Erdfelder, Buchner, & Lang, 2009). We predicted a medium effect size ($f = 0.25$) for our experimental design. With 95% power at the 0.05 significance level, the suggested sample size was approximately 40 individuals for both Experiments 1 and 2. To ensure that the sample size was large enough for running the cluster analysis, we also calculated the sample size based on Formann (1984) who suggests the minimal sample size to include no less than 2^k cases (k = number of variables), preferably 5×2^k (see also Dolnicar, 2002). In our study, we adopted 4 eye movement measures, thus the minimal sample size is $2^4 = 16$ and the preferable sample size is $5 \times 2^4 = 80$. The chosen sample size is also comparable to that of the previous eye-tracking studies in which cluster analysis was adopted to distinguish individual reading styles (Hyönä et al., 2002; Hyönä & Nurminen, 2006).

2.1.2. Apparatus

Eye movements were recorded using an EyeLink 1000 eye-tracker (SR Research Ltd., Toronto, Ontario, Canada). The sampling frequency was 1000 Hz, and only the left eye was tracked. The stimuli were presented at a viewing distance of 70 cm from the participant on a 21-in. CRT screen with a resolution of 1024 × 768 pixels and a 75 Hz refresh rate. The spatial accuracy of the eye-tracker was approximately 0.5 degrees of visual angle.

2.1.3. Materials

Two multiple-topic expository texts were used as stimuli: the Energy and Endangered Species texts (Hyönä et al., 2002; Hyönä & Lorch, 2004). The Energy text was approximately 2200 words, began with a short introduction and then discussed 8 distinct topics organized into two major sections, and ended with a short conclusion. The first section discussed four types of environmental damage and the second section discussed four types of energy sources. Each text topic was preceded by a heading that labeled it; the headings were presented on the first line of the screen in boldface. Each topic was developed in two paragraphs, each of which discussed a different aspect and was treated as a subtopic. The initial sentence of each topic paragraph introduced the main idea of that paragraph. All the following sentences in the paragraph elaborated the initial sentence; the end sentence was a summary sentence of that topic. Each topic paragraph was broken down into topic, medial and end sentences. The topic and end sentences are both relevant to the text's topic structure. The medial sentences provided detailed elaborations of the topic sentence so they are not directly relevant to the topic structure and thus serve as a baseline for comparisons with the topic and end sentences.

The Endangered Species text was approximately 2100 words and described 8 endangered species. Four of the species were endangered birds and the other four were endangered mammals. The structure was identical to that of the Energy text. Following Hyönä et al. (2002), each topic was presented as a separate page on the computer screen. Thus, readers were able to go back in the topic before proceeding to the next. The text appeared double-spaced on the screen with a maximum of 10 lines of text at a time. The location of the first line on each page was always fixed. Each sentence was presented left-justified with a line width maximum of 30 words. Long sentences were broken into two lines. The lines were double-spaced so that their vertical separation was about 1.6 degrees of visual angle.

2.1.4. Experimental design

The experimental design was a 2 (Task Instruction: summary task vs. verification task) × 3 (Sentence Type: topic, medial vs. end sentences) mixed design. Task Instruction was a between-subjects variable and Sentence Type was a within-subjects variable.

2.1.5. Procedure

Participants were assigned either to the summary or the verification task so that every other student received the summary instruction and every other the verification instructions. There were 45 participants in each condition. Each participant was tested individually. At the start of the experiment, the eye-tracker was calibrated with a 9-point calibration grid. Calibration was immediately followed by a validation routine that determined the stability and accuracy of the initial measurement. Successful calibration was followed by the presentation of a fixation point which appeared in the center of the screen.

The task instructions were presented following successful calibration of the eye-tracker. In the verification task, the reading materials and the procedure were the same as in the summary task with the following exceptions. Participants were instructed to read two multiple-topic expository texts to perform a "true or false" sentence verification task for 12 verification statements after reading each text. In each text, half of the verification statements were true (paraphrases of text sentences), and the other half were false. The verification statements contained both topical and detailed information. After completing the verification task of both texts, they were required, without being pre-informed, to write down a summary of the main content of the texts.

In the summary task, participants were instructed to read two multiple-topic expository texts to write down the main ideas mentioned in the texts after reading both of them. The reason we asked them to summarize the texts after reading both texts was to make the summary task comparable for the verification and the summary groups. A short practice text preceded the first text to allow participants to familiarize themselves with the eye-tracking equipment and the procedure. The reading was self-paced with the restriction that participants were prevented from returning to previous screens. Participants were permitted a 2-min rest after reading the first text. After reading both texts, participants were asked to write a summary of the two texts on a piece of paper. In both task conditions, participants read the texts in the same order. The experiment lasted for approximately 40–45 min.

2.1.6. Analyses of the dependent measures

2.1.6.1. Analyses of the online measures. The eye movement data were extracted using the Data Viewer program (SR Research, Canada). Fixations shorter than 70 ms and longer than 1,000 ms (less than 2% of all fixations) were removed from the analyses (cf. Radach et al., 2008). Type of sentence (topic, medial and end) was established as an area of interest (AoI). According to previous studies (Hyönä et al., 2002; Hyönä & Nurminen, 2006), there are two key dimensions regarding individual differences in reading processes among adult readers: the speed with which each sentence is read for the first time (first-pass reading time) and the rereading behavior (second-pass reading time). Thus, to examine the online text processing, we analyzed four types of eye movement measures for each AoI: (1) first-pass reading time—the sum of durations of all fixations landing on the target segment during the initial reading and before exiting the text segment to the next segment; (2) number of first-pass fixations—number of all fixations landing on the target segment during the initial reading and before exiting the text segment to the next segment; (3) second-pass reading time—the sum of the durations of all look-back fixations performed after the first-pass reading; and (4) number of second-pass fixations—number of all look-back fixations performed after the first-pass reading (Hyönä & Lorch, 2004). First-pass reading measures reflect the initial processing of a text segment, such as lexical access, semantic encoding and syntactic analysis, whereas second-pass measures reflect delayed processing, for example, readers' attempt to integrate new information with the preceding text and with their contextually relevant prior knowledge as well as rereading important text information (Hyönä et al., 2002). All the reading time and fixation frequency measures in the first- and second-pass reading were divided by the number of words in the sentence to yield word reading time (milliseconds/word) and fixation frequency per word. Longer reading times and more numerous fixations are interpreted as indicators of more attentional resources being devoted to text processing and integration (Rayner & Sereno, 1994). The measures were aggregated over the two experimental texts.

The eye-tracking data were analyzed in a two-step manner using SPSS 17.0. First, we computed two-way ANOVAs on the first- and second-pass reading times using Sentence Type as a within-subjects variable and Task Instruction as a between-subjects variable. Significant interactions were further analyzed using simple effect models and significant main effects were followed up by Bonferroni-adjusted post hoc comparisons. Second, we used cluster analysis to reveal different reading styles adopted by the participants in the different task conditions based on first- and second-pass reading times as well as the corresponding fixation frequencies on the topic, medial and end sentences. We then describe in more detail the eye movement behavior of different cluster profiles separately for each task condition. As is typical of eye movement data for longer text regions, corresponding fixation frequency and duration measures correlate strongly with each other (Hyönä et al., 2002). Thus, we only report the results for fixation times. The fixation frequency data yielded very similar results.

2.1.6.2. Analyses of the offline measures. To examine the offline reading performance, we analyzed the text summary scores for all participants (Hyönä et al., 2002; Lorch et al., 1987). The summary scores were calculated on the basis of the summary protocols the participants wrote after reading. We analyzed the number of topics represented in the summary. The text summaries were scored by giving 1 point for each topic mention and 0.5 point for each mention of the main idea in a subtopic. Thus, with 8 topics and 16 subtopics in each text, the maximum score of each text was 16. The final summary score of each participant was the average score of the two texts. Two raters independently scored a random subset of 20 protocols; their interrater reliability was 0.90. The discrepancies were resolved by averaging the scores of the two raters. A *t*-test was computed to compare the summary scores in the two task instruction conditions. Unless noted otherwise, the $p < .05$ level was considered statistically significant.

2.2. Results

2.2.1. The effect of task instructions on reading times and summary scores

First-pass reading time. There was a significant interaction between Sentence Type and Task Instruction in the first-pass reading time, F (2, 176) = 12.61, $p < .001$, $\eta_p^2 = 0.125$. As is apparent from Fig. 1 (Panel A), reading times on topic sentences were longer in the summary than in the verification task, F (1, 88) = 12.61, $p < .001$, $\eta_p^2 = 0.13$, while no effects of Task Instructions were found for the medial or end sentences, Fs < 1. The main effect of Sentence Type on first-pass reading time was also significant, F (2, 176) = 45.57, $p < .001$, $\eta_p^2 = 0.34$, but it is not readily interpretable in the presence of a significant interaction.

Second-pass reading time. There was a significant interaction between Sentence Type and Task Instruction in the second-pass reading time, F (2, 176) = 19.99, $p < .001$, $\eta_p^2 = 0.19$. As shown in Fig. 1 (Panel B), reading times for the topic sentences were longer in the summary than in the verification task, F (1, 88) = 19.77, $p < .001$, $\eta_p^2 = 0.18$, while no effect of Task Instructions was found for the medial or end sentences, Fs < 1. Again, the main effect of Sentence Type was also significant, F (2, 176) = 70.24, $p < .001$, $\eta_p^2 = 0.44$.

Summary scores. An independent *t*-test revealed a significant effect of Task Instruction on the summary scores, t (88) = 2.90, $p = .005$, $d = 0.61$, suggesting that readers obtained higher summary scores in the summary task ($M = 7.13$, $SD = 1.37$) than in the verification task ($M = 6.31$, $SD = 1.31$).

2.2.2. Cluster analysis results

We used cluster analysis (Ward's method, a hierarchical agglomerative procedure that identifies clusters in which the variance of cases within a cluster is relatively small) to distinguish different reading styles among the participants based on four eye movement measures. As in the previous analysis, the eye movement data entered in the cluster analysis comprised averages of the two texts. The analysis was done separately for the participants in the summary and verification conditions.

We considered 2- to 5-cluster solutions. We first opted for a 4-cluster solution for both the summary and verification tasks based on the previous study of Hyönä et al. (2002). The four clusters that emerged in the summary task matched our hypothesis. Thus, we adopted the 4-cluster solution as the best description of the data set in the summary task. The four groups that emerged from the cluster analysis were FLRs (n = 24, 53%), SLRs (n = 6, 13%), NSRs (n = 6, 13%) and TSPs (n = 9, 20%). On the other hand, the four clusters that emerged in the verification task did not match our hypothesis, because two of them could not be distinguished from each other. We then considered the other cluster solutions for the verification task: a 3-cluster solution was adopted as the best description of the data set in the verification task. The three groups were FLRs (n = 31, 69%), SLRs (n = 6, 13%) and NSRs (n = 8, 18%).

We used the split-half method to test the stability of the adopted cluster solutions (Dolnicar, 2002). The participants of both the summary task and the verification task were randomly split into two groups (each group with 22 or 23 participants) and the cluster analysis was then recomputed for the two subgroups. The analysis distinguished four types of readers for both subgroups in the summary task condition and three types of readers for both subgroups in the verification task condition. Chi-squared tests showed no difference between the two groups in the summary task condition, χ^2 (3) = 4.21, $p = .24$, or between the two groups in the verification task condition, χ^2 (2) = 0.01, $p = .99$. These results indicate that the adopted cluster solutions were stable.

The overall description of the reader groups is provided below when presenting the fixation time data for the first- and second-pass reading separately for the different reader groups in each task condition. The correlations between the eye fixation measures and summary scores are reported in the Appendix separately for each sentence type and reader group.

2.2.3. Reading times of the different reader groups

The means and standard errors of the first- and second-pass reading times are presented in Fig. 2 for the different reader groups, separately for the summary and verification tasks. In order to analyze the reading behavior of the different reader clusters, three-way ANOVAs were conducted separately for each reading task using Sentence Type and Reading Pass (first-pass vs. second-pass reading time) as the within-subjects variables and Reader Group as the between-subjects variable.

Summary task. The Reader Group × Reading Pass interaction [F (3, 41) = 31.39, $p < .001$, $\eta_p^2 = 0.70$], and the Reader Group × Sentence Type interaction [F (6, 82) = 93.28, $p < .001$, $\eta_p^2 = 0.87$], were both significant, but the Reader Group × Reading Pass × Sentence Type interaction was not [F (6, 82) = 1.40, $p = .223$]. Although the three-way interaction was not significant (it proved significant in all subsequent analyses), the two 2-way interactions were. Thus, we followed them up with a 2 (Reading Pass) × 3 (Sentence

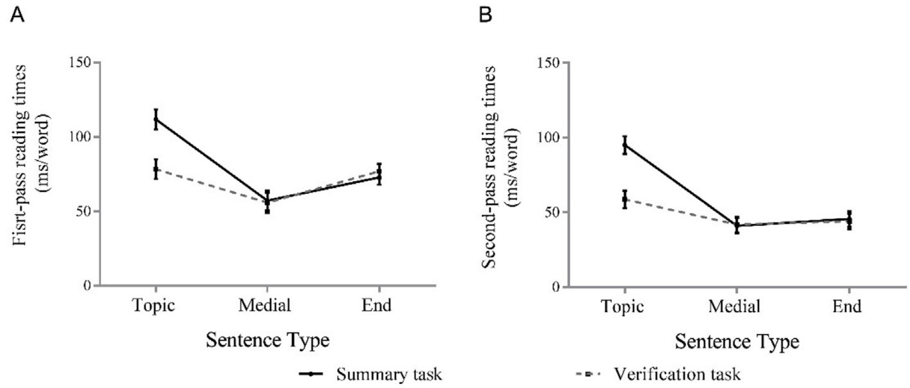

Fig. 1. Mean first-pass (Panel A) and mean second-pass (Panel B) reading times (± *SE*) in milliseconds (ms) per word in Experiment 1 for the different sentences in the summary and verification tasks, separately for the Topic, Medial, and End sentences.

Type) repeated measures ANOVA separately for each group to characterize their reading patterns.

TSPs. The main effect of Sentence Type [F (2, 16) = 1667.37, $p < .001$, $\eta_p^2 = 1.00$] and Reading Pass [F (1, 8) = 24.48, $p < .001$, $\eta_p^2 = 0.75$] were significant for TSPs, and so was their interaction [F (2, 7) = 2686.97, $p < .001$, $\eta_p^2 = 1.00$]. The interaction was followed up by simple effect analyses of Sentence Type within each level of Reading Pass. An effect of sentence type was observed both for first-pass [F (2, 7) = 2686.97, $p < .001$, $\eta_p^2 = 1.00$] and second-pass [F (2, 7) = 1720.78, $p < .001$, $\eta_p^2 = 1.00$] reading. Multiple comparisons showed that TSPs spent longer time reading topic sentences than medial and end sentences, and spent longer time reading end sentences than medial sentence both during the first- and second-pass reading ($ps < .001$). In other words, TSPs showed clear sensitivity to the text's topic structure by spending ample time on topic sentences.

FLRs. The main effect of Sentence Type [F (2, 16) = 1667.37, $p < .001$, $\eta_p^2 = 1.00$] and Reading Pass [F (1, 8) = 24.48, $p < .001$, $\eta_p^2 = 0.75$] proved significant for FLRs. Their interaction was marginally significant [F (2, 46) = 3.12, $p = .054$, $\eta_p^2 = 0.12$]. The main effect of Sentence Type emerged for both first-pass [F (2, 22) = 22.35, $p < .001$, $\eta_p^2 = 0.67$] and second-pass [F (2, 22) = 27.62, $p < .001$, $\eta_p^2 = 0.71$] reading. Multiple comparisons showed that during first-pass reading FLRs spent longer time reading topic and end sentences than medial sentences ($ps < .001$), but showed no differences reading

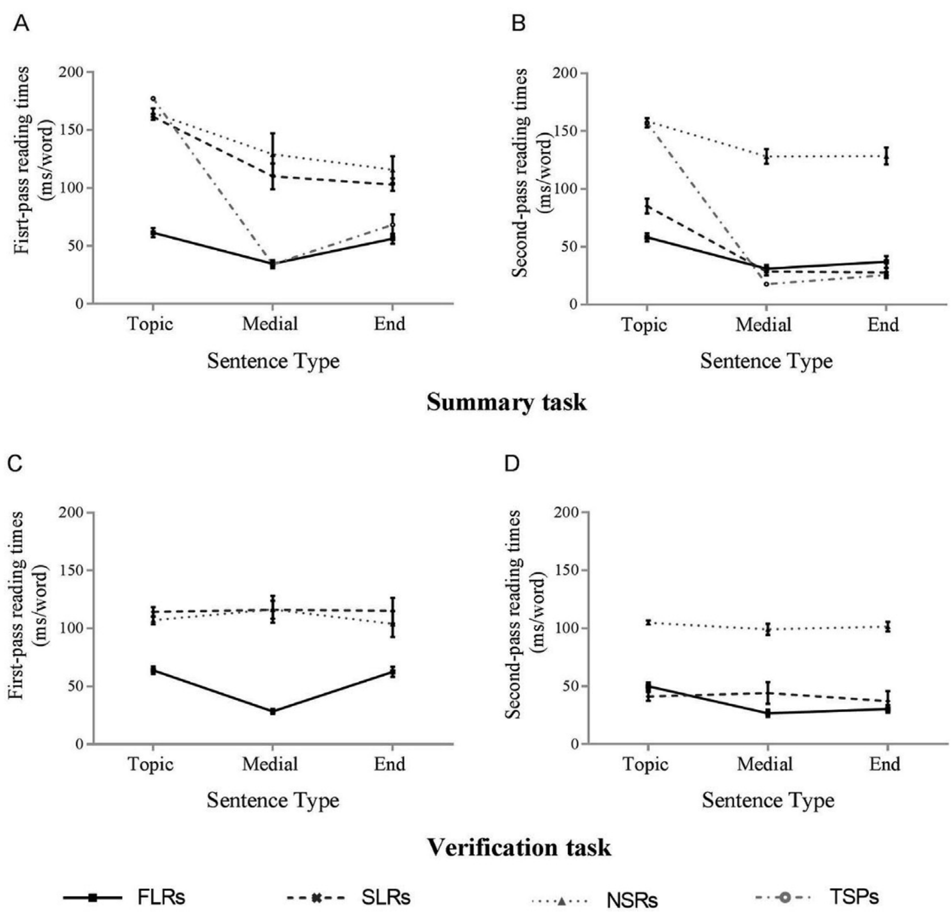

Fig. 2. Mean first-pass and mean second-pass reading times (± *SE*) for the different reader groups in the summary (Panels A and B) and verification tasks (Panels C and D) in Experiment 1, as a function of the sentence type.

topic and end sentences ($p = .980$). Moreover, during second-pass reading they spent longer time reading topic sentences than medial and end sentences ($ps < .001$), but showed no difference in reading medial and end sentences ($p = .846$). In other words, during first-pass reading FLRs showed sensitivity to paragraph structure (more fixation time on initial and final sentences), while their second-pass reading showed sensitivity to topic structure (additional fixation time spent on topic sentences). Their reading was also characterized by spending little time overall in second-pass reading.

SLRs. The main effect of Sentence Type [F (2, 10) = 129.45, $p < .001$, $\eta_p^2 = 0.96$] and Reading Pass [F (1, 5) = 210.48, $p < .001$, $\eta_p^2 = 0.98$] proved significant for SLRs, but their interaction did not ($F < 1$). SLRs spent longer time reading the sentences during first-pass than second-pass reading. Moreover, multiple comparisons showed that they spent longer time reading topic sentences than medial or end sentences ($ps < .001$), but showed no difference in reading medial and end sentences ($p = 1.00$). Thus, SLRs showed some sensitivity to topic structure.

NSRs. Only the main effect of Sentence Type was significant for NSRs [F (2, 10) = 14.85, $p < .001$, $\eta_p^2 = 0.75$; Fs < 1 for other effects]. NSRs spent longer time reading topic than medial ($p = .065$) or end ($p = .015$) sentences, but showed no difference in reading medial and end sentences ($p = .347$). Thus, NSRs showed some sensitivity to topic structure. However, their characteristic feature was that they spent comparable amount of time during first- and second-pass reading.

Verification task. The Reader Group × Reading Pass × Sentence Type interaction was significant, F (4, 84) = 3.13, $p = .019$, $\eta_p^2 = 0.13$. To characterize the reading patterns of each group, we followed it up with a 2 (Reading Pass) × 3 (Sentence Type) repeated measures ANOVA separately for each group.

FLRs. The main effect of Reading Pass [F (1, 30) = 23.21, $p < .001$, $\eta_p^2 = 0.44$] and the main effect of Sentence Type were significant for FLRs [F (2, 60) = 76.21, $p < .001$, $\eta_p^2 = 0.72$]. Moreover, the Reading Pass × Sentence Type interaction was significant [F (2, 60) = 17.24, $p < .001$, $\eta_p^2 = 0.36$]. Simple effect analysis of Sentence Type within each level of Reading Pass showed that FLRs demonstrated an effect of Sentence Type both for the first-pass [F (2, 29) = 162.33, $p < .001$, $\eta_p^2 = 0.92$] and second-pass [F (2, 29) = 32.95, $p < .001$, $\eta_p^2 = 0.69$] reading time. Multiple comparisons showed that during the first-pass reading FLRs spent longer time reading topic and end sentences than medial sentences ($ps < .001$), but showed no differences in reading topic and end sentences ($p = 1.00$). Moreover, during the second-pass reading they spent longer time reading topic sentences than medial and end sentences ($ps < .001$), but showed no differences in reading medial and end sentences ($p = .234$). Thus, the first-pass reading of FLRs showed sensitivity to paragraph structure (more fixation time on initial and final sentences), while their second-pass reading showed some sensitivity to topic structure (additional fixation time spent on topic sentences). They were also characterized by spending the majority of time in first-pass reading.

SLRs. The main effect of Reading Pass was significant for SLRs [F (1, 5) = 40.50, $p < .001$, $\eta_p^2 = 0.89$]. However, neither the main effect of Sentence Type nor the interaction proved significant (Fs < 1). Thus, SLRs did not show sensitivity to the text's topic structure. On the other hand, they were characterized by spending ample time during first-pass reading and little time in second-pass reading (see Fig. 2).

NSRs. The data for NSRs revealed no significant effects (Fs < 1.64). In other words, they spent similar amount of time during first- and second-pass reading and showed no sensitivity to topic structure (see Fig. 2).

2.2.4. Summary scores of the reader groups

The summary scores are presented in Table 1. The interaction between Task Instruction and Reader Group was significant, F (2, 75) = 5.26, $p = .007$, $\eta_p^2 = 0.12$. Simple effect analysis showed a significant effect of Task Instruction for NSRs [F (1, 75) = 7.45, $p = .008$, $\eta_p^2 = 0.09$] and SLRs [F (1, 75) = 5.64, $p = .02$, $\eta_p^2 = 0.07$], who obtained higher summary scores in the summary task than in the verification task. However, no effect of Task Instruction was found for FLRs, F (1, 75) = 0.22, $p = .641$. To further analyze this interaction, we computed a separate analysis for the summary and verification tasks. In the summary task, the summary scores were different for the four reader groups, F (3, 83) = 8.17, $p < .001$, $\eta_p^2 = 0.23$. The summary scores for TSPs were higher than for FLRs ($p < .001$) and SLRs ($p = .009$), while no differences were found among the other reader groups (TSPs versus NSRs, $p = .111$; SLRs versus NSRs, $p = .329$; NSRs versus FLRs, $p = .067$). In the verification task, the summary scores differed among the three reader groups, F (2, 83) = 3.64, $p = .030$, $\eta_p^2 = 0.08$. The summary scores were higher for FLRs than SLRs ($p = .017$), while no difference was found between SLRs and NSRs ($p = .396$) or FLRs and NSRs ($p = .117$).

Table 1
Mean summary scores (standard deviations in parentheses) for different reader groups as a function of task in Experiment 1.

Reader groups	Summary task	Verification task
FLRs	6.46 (1.17)	6.61 (1.35)
SLRs	7.00 (1.26)	5.33 (.52)
NSRs	7.66 (1.03)	5.88 (1.23)
TSPs	8.66 (.71)	

2.3. Discussion

The results of Experiment 1 showed that the summary task induced more reading of topic sentences and better summary performance compared to the verification task. These results are in line with previous findings (Lorch et al., 1987; Wang et al., 2017). They demonstrate that adult readers are able to endogenously direct particular attention to the text's main points using task instructions as their guide. This pays off as selective guidance resulted in better memory for the text topics and key points.

In the cluster analysis that was performed to analyze individual reading styles, four clusters emerged in the summary task that are analogous to those observed by Hyönä et al. (2002). FLRs and SLRs read the texts straight through and rarely looked back to previous sentences, hence the name (linear readers). FLRs differed from SLRs in being able to encode the text quicker (i.e., without much rereading) during first-pass reading. NSRs and TSPs differed from the linear readers by making frequent look-backs to previous sentences. TSPs differed from NSRs in extensively looking back to topic sentences, whereas the look-back behavior of NSRs was relatively non-selective in nature. It is also noteworthy that NSRs spent roughly as much time rereading the text as during the first-pass reading.

A group of TSPs emerged in the summary task but not in the sentence verification task. This is understandable, as the verification task discourages topic structure processing and encourages processing of detailed information (Lorch et al., 1987; Radach et al., 2008). In the summary task, TSPs demonstrated strategic selectivity in their processing of topic structure by paying extensive attention to topic sentences and also devoted extra attention to the summarizing end sentences during their first- and second-pass reading.

Three reader clusters emerged that were common to the summary and the verification task: NSRs, SLRs and FLRs. NSRs and SLRs were affected by the task instructions, whereas the reading styles of FLRs were similar in both tasks. NSRs and SLRs devoted somewhat more attention to topic sentences than other types of sentences in the summary task that emphasizes the topic structure, while they read the three types of sentences with no difference in the verification task that emphasizes detailed information. This was somewhat unexpected, as we suspected that NSRs and SLRs may not be capable of strong endogenous

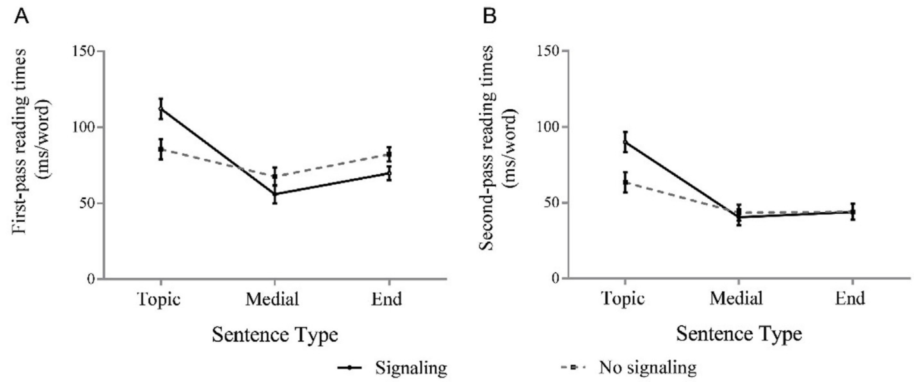

Fig. 3. Mean first-pass (Panel A) and mean second-pass (Panel B) reading times (± *SE*) in Experiment 2 for the different sentences of the text with and without signaling.

attentional guidance. However, as is apparent from Fig. 2, they did that to a much less extent than TSPs. Moreover, the results of Experiment 2 did not provide support for endogenous guidance by NSRs and SLRs (see below).

FLRs paid more attention to topic and end sentences in both the summary and the verification task, indicating that task instructions did not modulate their reading. The tendency of FLRs to process topic and end sentences more slowly than medial sentences reflects structure processing. However, based on the present data it is not clear whether it reflects sensitivity to the text's topic structure or simply to the paragraph structure (i.e., slowing down reading at paragraph boundaries), or both.

3. Experiment 2

In Experiment 1, we examined effects of task instructions on text processing among readers with different reading styles. A specific reading task was provided to readers before presenting the reading materials, which served to help readers adjust endogenously their reading behavior to fit the designated reading goal (Lorch et al., 1987; Radach et al., 2008). However, as discussed in the Introduction, text processing is influenced not only by the reading goal maintained in readers' working memory but also by bottom-up signaling devices often presented in expository texts (Lemarié et al., 2008). In Experiment 2, our aim was to examine effects of topic signaling on text processing among readers with different reading styles. Specifically, in one text the topic sentences were signaled by underlining, whereas in the other text signaling was absent.

3.1. Method

3.1.1. Participants

Ninety university students (50 women; age range: 18–22 years) from the Department of Journalism and Communication in a university in the east of China participated in the experiment for course credit or monetary compensation. Participants were native Chinese speakers who all had normal or corrected-to-normal vision. All participants reported that they were not familiar with the experimental materials. The recruitment procedure was analogous to the one used in Experiment 1.

3.1.2. Apparatus and materials

The apparatus and reading materials were identical to those used in Experiment 1. The only difference was that two versions of the texts were created, one with signaling and the other without signaling. In the signaled version of the text, the topic sentence of each topic was underlined; in the unsignaled version underlining was absent.

3.1.3. Experimental design

The experiment used a 2 (Signaling: underlining of topic sentence present vs. absent) × 3 (Sentence Type: topic, medial vs. end sentences) mixed design, with Signaling as a between-subjects variable and Sentence Type as a within-subjects variable. The classification of text sentences was the same as in Experiment 1.

3.1.4. Procedure

The procedure was identical to that of the summary task of Experiment 1 except that participants were assigned to read the two texts either with or without topic signaling by selecting every other student in the signaling condition and every other in the no signaling condition. There were 45 participants in each signaling condition.

3.1.5. Analyses of the measures

The same online and offline measures and statistical methods were used as in Experiment 1. With respect to the offline measure, two raters independently scored a random subset of 20 summary protocols using the same procedure as in Experiment 1; the interrater reliability between the two raters was 0.97. The discrepancies were resolved by averaging the scores of the two raters.

3.2. Results

3.2.1. The effect of topic signaling on reading times and summary scores

First-pass reading time (see Fig. 3, Panel A). There was a significant interaction between Sentence Type and Signaling in the first-pass reading time, F (2, 176) = 15.60, $p < .001$, $\eta_p{}^2 = 0.15$. Simple effect analysis revealed that first-pass reading times on topic sentences were longer in the signaling condition than in the no signaling condition, F (1, 88) = 8.04, $p = .006$, $\eta_p{}^2 = 0.08$, whereas no reliable signaling effect was found for medial sentences, F (1, 88) = 1.96, $p = .165$, or end sentences, F (1, 88) = 3.65, $p = .059$. The main effect of Sentence Type was also significant, F (2, 176) = 43.95, $p < .001$, $\eta_p{}^2 = 0.74$.

Second-pass reading time (see Fig. 3, Panel B). There was a significant interaction between Sentence Type and Signaling in the second-pass fixation time, F (2, 176) = 6.72, $p = .002$, $\eta_p{}^2 = 0.071$. Simple effect analysis showed that second-pass reading times on topic sentences were longer in the signaling condition than in the no signaling condition, F (1, 88) = 8.14, $p = .005$, $\eta_p{}^2 = 0.09$; whereas no signaling effect was observed for medial or end sentences, $Fs < 1$. The main effect of Sentence Type was also significant, F (2, 176) = 38.20, $p < .001$, $\eta_p{}^2 = 0.30$.

Summary scores. There was a significant effect of Signaling in the summary scores, t (88) = 3.02, $p = .01$, $d = 0.46$, suggesting that the summary scores were higher in the signaling condition ($M = 6.84$; $SD = 1.18$) than in the no signaling condition ($M = 6.27$; $SD = 1.32$).

3.2.2. Cluster analysis results

We used the same cluster analysis method as that used in Experiment 1 to categorize the participants into different reader groups. We considered 2- to 5-cluster solutions and eventually selected the 4-cluster solution for both the signaling and no signaling condition. The four groups that emerged from the cluster analysis in the signaling condition were FLRs (n = 21, 47%), SLRs (n = 7, 16%), NSRs (n = 8, 18%) and TSPs (n = 9, 20%). The four groups in the no signaling condition were FLRs (n = 20, 45%), SLRs (n = 11, 24%), NSRs (n = 8, 18%) and TSPs (n = 6, 13%). The number of FLRs and NSRs were identical in the two signaling conditions, but there was a slight increase in the number of TSPs and decrease in the number of SLRs in the signaling condition.

Similarly to Experiment 1, we used the split-half method to test the stability of the adopted cluster solution. Participants of both the signaling and no signaling condition were randomly split into two subgroups (each with 22 or 23 participants). Using the cluster analysis, we found four types of readers in each subgroup in both signaling conditions. A Chi-squared test showed no difference between the two groups in the signaling condition, χ^2 (3) = 0.66, $p = .88$, or in the no signaling condition, χ^2 (3) = 0.07, $p = .99$. These results indicate that the adopted cluster solutions were stable.

3.2.3. Reading times of the different reader groups

In order to analyze the reading behavior of the four reader groups, three-way ANOVAs were conducted separately for each signaling condition using Sentence Type and Reading Pass as the within-subjects variables and Reader Group as the between-subjects variable. The means and standard errors of the first- and second-pass reading times are presented in Fig. 4 for the different reader groups, separately for the signaling and no signaling conditions.

Signaling condition. The Reader Group × Reading Pass × Sentence Type interaction was significant, F (6, 82) = 5.39, $p < .001$, $\eta_p^2 = 0.28$. To characterize the reading patterns of each reader group, we followed up the three-way interaction with a 2 (Reading Pass) × 3 (Sentence Type) repeated measures ANOVA separately for each group.

TSPs. The main effect of Sentence Type [F (2, 16) = 1290.35, $p < .001$, $\eta_p^2 = 0.99$] and Reading Pass [F (1, 8) = 19.98, $p = .002$, $\eta_p^2 = 0.71$] were significant, and so was their interaction [F (2, 16) = 7.12, $p = .006$, $\eta_p^2 = 0.47$]. The interaction was followed up by a simple effect analysis of Sentence Type within each level of Reading Pass. TSPs demonstrated an effect of Sentence Type both in first-pass [F (2, 7) = 583.99, $p < .001$, $\eta_p^2 = 0.99$] and second-pass [F (2, 7) = 808.88, $p < .001$, $\eta_p^2 = 0.99$] reading. Multiple comparisons showed that TSPs spent longer time reading topic sentences than medial and end sentences ($ps < .001$) both during first- and second-pass reading, and also spent longer time reading end sentences than medial sentences ($p < .001$) during first-pass reading. In sum, TSPs showed strong sensitivity to topic structure by spending a considerable amount of time in reading topic sentences (see Fig. 4).

FLRs. A reliable main effect of Sentence Type [F (2, 40) = 62.78, $p < .001$, $\eta_p^2 = 0.75$] and Reading Pass [F (1, 20) = 9.66, $p = .006$, $\eta_p^2 = 0.33$] emerged for FLRs, but their interaction was not significant [F (2, 40) = 1.93, $p = .159$]. Multiple comparisons revealed that FLRs spent longer time reading topic sentences than medial and end sentences ($ps < .001$), and also spent longer time reading end sentences than medial sentences ($p = .006$). In other words, FLRs showed sensitivity to topic structure. The main effect of Reading Pass reflects the fact that FLRs spent more time during first-pass than second-pass reading.

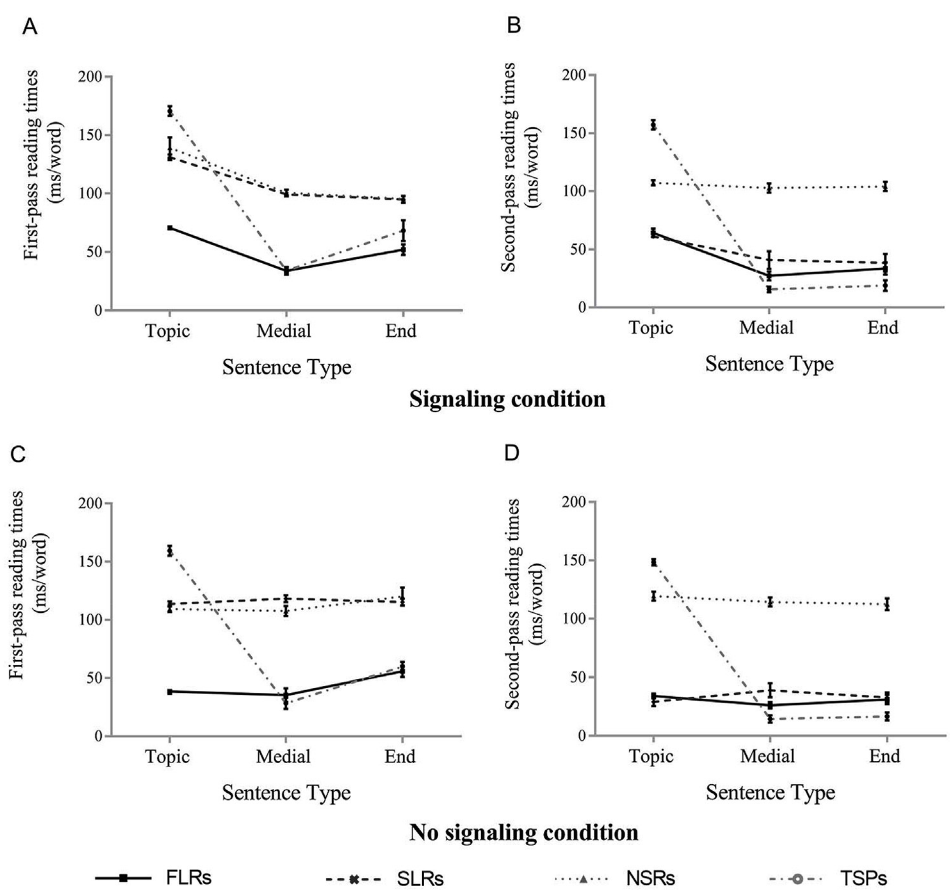

Fig. 4. Mean first-pass and mean second pass reading times (± SE) in Experiment 2 for the different reader groups in the signaling (Panels A and B) and no signaling (Panels C and D) conditions, as a function of sentence type.

SLRs. A reliable main effect of Sentence Type [F (2, 12) = 25.79, $p < .001$, $\eta_p^2 = 0.81$] and Reading Pass [F (1, 6) = 113.69, $p < .001$, $\eta_p^2 = 0.95$] emerged for SLRs, but their interaction did not [F (2, 12) = 2.27, $p = .146$]. SLRs spent longer time reading topic sentences than medial ($p = .008$) and end sentences ($p = .002$), but showed no differences in reading medial and end sentences ($p > .05$). Thus, SLRs showed some sensitivity to topic structure. The main effect of Reading Pass reflects the fact that they spent much more time during first-pass than second-pass reading (see Fig. 4).

NSRs. Both the main effect of Sentence Type [F (2, 14) = 28.62, $p < .001$, $\eta_p^2 = 0.80$] and Reading Pass [F (1, 7) = 8.29, $p = .023$, $\eta_p^2 = 0.54$], proved significant for NSRs, and so did their interaction [F (2, 14) = 7.63, $p = .006$, $\eta_p^2 = 0.52$]. NSRs demonstrated an effect of Sentence Type during the first-pass reading [F (2, 6) = 12.38, $p = .007$, $\eta_p^2 = 0.81$], however, they showed no effect of Sentence Type during the second-pass reading ($F < 1$). Multiple comparisons showed that during first-pass reading NSRs spent longer time reading topic sentences than medial ($p = .014$) and end ($p = .005$) sentences, but showed no differences reading medial and end sentences ($p > .05$). The primary difference in their first- and second-pass reading was due to spending additional time on topic sentences during first-pass reading (see Fig. 4).

No signaling condition. The Reader Group × Reading Pass × Sentence Type interaction was significant, F (6, 82) = 2.23, $p = .048$, $\eta_p^2 = 0.14$. To characterize the reading patterns of each group, we again followed up the three-way interaction with two separate 2 (Reading Pass) × 3 (Sentence Type) repeated measures ANOVAs separately for each group.

TSPs. The main effect of Sentence Type [F (2, 10) = 844.36, $p < .001$, $\eta_p^2 = 0.99$] and Reading Pass [F (1, 5) = 58.09, $p < .001$, $\eta_p^2 = 0.92$] were significant for TSPs, as was their interaction [F (2, 10) = 9.52, $p = .005$, $\eta_p^2 = 0.66$]. TSPs demonstrated an effect of Sentence Type both in the first-pass [F (2, 4) = 686.01, $p < .001$, $\eta_p^2 = 0.99$] and second-pass [F (2, 5) = 351.89, $p < .001$, $\eta_p^2 = 0.99$] reading time. Multiple comparisons showed that TSPs spent longer time reading topic sentences than medial and end sentences ($ps < .001$) in the first- and second-pass reading, and also spent longer time reading end sentences than medial sentences ($p = .043$) during first-pass reading. Thus, TSPs showed strong sensitivity to topic structure (see Fig. 4).

FLRs. Reliable main effects of Sentence Type [F (2, 38) = 7.41, $p = .002$, $\eta_p^2 = 0.28$] and Reading Pass [F (1, 19) = 22.27, $p < .001$, $\eta_p^2 = 0.54$] were observed for FLRs. Moreover, their interaction was also significant [F (2, 36) = 14.11, $p < .001$, $\eta_p^2 = 0.44$]. FLRs demonstrated an effect of Sentence Type during the first-pass reading [F (2, 17) = 14.46, $p < .001$, $\eta_p^2 = 0.63$], and a suggestion for an effect of Sentence Type during the second-pass reading [F (2, 17) = 3.03, $p = .074$]. Multiple comparisons showed that during first-pass reading FLRs spent longer time reading end sentences than topic ($p = .007$) and medial ($p < .001$) sentences, but showed no differences in reading topic and medial sentences ($p = .090$). Thus, FLRs showed sensitivity in their processing for paragraph breaks (longer reading of paragraph-final than other sentences). They also spent more time overall during first-pass than second-pass reading.

SLRs. Only the main effect of Reading Pass proved significant [F (1, 10) = 460.82, $p < .001$, $\eta_p^2 = 0.98$; F (2, 20) = 1.28, $p = .299$, for the main effect of Sentence Type; $F < 1$, for the interaction] for SLRs. They spent much more time during first-pass than second-pass reading (see Fig. 4).

NSRs. No effect approached significance for NLRs [$Fs < 1$, for the main effects; F (2, 14) = 2.80, $p = .094$, for the interaction]. Thus, NSRs are characterized by spending comparable time during first- and second-pass reading and not showing sensitivity to topic structure.

3.2.4. Summary scores of the reader groups

The summary scores are presented in Table 2. There was a significant interaction between Signaling and Reader Group, F (3, 82) = 4.09, $p = .009$, $\eta_p^2 = 0.13$. The simple effect analysis showed no effect of Signaling for TSPs and NSRs, $Fs < 1$, whereas the effect was significant for FLRs [F (1, 82) = 10.61, $p = .002$, $\eta_p^2 = 0.12$] and SLRs [F (1, 82) = 13.62, $p < .001$, $\eta_p^2 = 0.14$], who obtained higher summary scores in the signaling condition than in the no signaling condition. The nature of the interaction was further analyzed by computing an ANOVA separately for the signaling and no signaling conditions. For the signaling condition, the summary scores differed across the four reader groups, F (3, 82) = 9.54, $p < .001$, $\eta_p^2 = 0.26$, showing that TSPs and SLRs obtained higher summary scores than FLRs and NSRs ($ps < .001$). For the no signaling condition, the summary scores also differed across the four reader groups, F (3, 82) = 17.43, $p < .001$, $\eta_p^2 = 0.39$, showing that TSPs obtained higher summary scores than the other groups ($ps < .001$).

Table 2
Mean summary scores (standard deviations in parentheses) for different reader groups as a function of signaling device in Experiment 2.

Reader group	Signaling device	No signaling device
FLRs	6.19 (.98)	5.25 (.85)
SLRs	7.29 (1.11)	5.64 (.81)
NSRs	6.00 (.76)	5.88 (1.23)
TSPs	7.89 (.93)	8.33 (.82)

3.3. Discussion

Underlining topic sentences induced more processing of and better summary performance for topic information compared to texts without signaling. These findings are in line with previous studies (e.g., Lorch et al., 2013, 2012; Yeari et al., 2017). They demonstrate that visually highlighting key points in text attract extra attention to them presumably via exogenous attentional guidance. Allocation of attention to key points paid off in that readers' memory for topical information was improved. The cluster analyses yielded four reader groups: TSPs, FLRs, SLRs and NSRs both in the signaling and no signaling conditions. The four reader groups responded differently to the presence or absence of topic sentence signaling by underlining.

TSPs paid ample attention to the topic sentences during first- and second-pass reading regardless of topic signaling that had no effect on their reading behavior. This demonstrates that their processing is endogenously governed. Another sign of their structure processing was that during first-pass reading they spent more time reading the paragraph-final sentences than paragraph-medial sentences. Their topic structure strategy paid off in that among the four reader groups they wrote the most comprehensive text summaries. This was true for both signaling and no signaling conditions. The results for TSPs are in line with previous findings obtained for readers whose dominant strategy is structure strategy. Such readers are able to adopt a strategic approach to reading (Meyer & Poon, 2001; Naumann, Richter, Flender, Christmann, & Groeben, 2007).

Unlike TSPs, the other reader groups demonstrated different reading patterns for the texts with and without signaling. In the signaled text, all three groups devoted extra attention to topic sentences during first-pass reading. FLRs and SLRs did so also during second-pass reading. However, all of them (FLRs, SLRs, and NSRs) read the unsignaled text without prioritizing in their processing topic sentences over other sentences. Yet, FLRs spent a bit more time during the first-pass reading on end sentences than medial sentences. These results suggest that signaling topic sentences by underlining help less strategic readers pay particular attention to key points in text (see also Lorch et al., 2012; Lorch et al., 2013).

4. General discussion

In the Introduction, we outlined two main aims for the present study. The first aim was to test whether the reading styles identified by Hyönä et al. (2002) can be re-established with another sample of adult readers from a different educational culture (China). The second aim, and also a more newsworthy aspect, was to investigate individual differences in responding to task instructions and topic signaling when reading long expository texts.

4.1. Individual differences in reading styles

By using the cluster analysis, we established four distinct reading styles among Chinese adult readersreading a multiple-topic expository text in Chinese in order to summarize the main contents. The observed reading styles were stable across different samples and different signaling conditions when readers were instructed to read the texts in preparation for a summary task. The four reading styles are highly similar to those observed in a previous study using Finnish native speakers reading similar texts in Finnish (Hyönä et al., 2002). This convergence indicates that the observed reading styles generalize across distinct writing systems (logographic vs. alphabetic) and educational cultures. In other words, we assume that they reflect universal processing styles. However, it should be noted that at a more micro-level, differences in script exert pervasive effects on reading. Liversedge et al. (2016) demonstrated robust differences in average fixation duration and saccade length in reading Chinese versus Finnish. In that study, the texts were identical in meaning (they were translations of English texts). Yet, at the sentence-level, reading appeared similar in that comparable amount of time was spent in Chinese and Finnish (and English). This is taken to suggest universality in reading comprehension despite fundamental orthographic and linguistic differences. The present results are consistent with the notion of universality of reading process.

4.2. Effects of relevance cues on text processing among readers with different reading styles

According to the goal-focus model (Bråten et al., 2017; McCrudden & Schraw, 2007), both task instructions and signaling devices are relevance cues that explicitly guide readers' attention to relevant text segments. Task instructions operate via endogenous attentional guidance in that they require that the readers keep the reading goal active in their working memory. Text signaling devices, on the other hand, exert their effect via exogenous attentional guidance, as the signals are visually available in the text. These relevance cues help readers adjust their reading behavior to focus on relevant information and develop a better understanding of such information.

In the present study, we found that the four groups of readers differ in their use of relevance cues. TSPs flexibly adjusted their reading according to task instructions. However, their reading was not influenced by exogenous topic signaling by underlining in that they paid ample attention to topic structure regardless of topic signaling. The lack of signaling effects speaks for the endogenous nature of their attentional guidance. Thus, they keep the reading goal active in mind and guide their text processing accordingly toward key points in text without the aid of topic signaling (Hyönä & Lorch, 2004; Meyer & Poon, 2001; Naumann et al., 2007; Wang et al., 2017). These features qualify them as highly competent readers (Minguela et al., 2015). Finally, it is notable that TSPs' sensitivity to topic structure was stable across different reader samples (students of psychology vs. students of journalism and communication).

A common feature of FLRs in all analyses was that they spent relatively little time in rereading the text and were also quite fast during their first-pass reading. With regard to structure processing, the overall pattern of results across the four analyses was not as clear for FLRs as for TSPs. FLRs demonstrated extra processing of paragraph boundaries (i.e., first and final sentences) in the summary and the verification task as well as in the topic-signal condition, but the structure processing observed in the non-signaled text was limited to additional processing time devoted to paragraph-final sentences. Thus, FLRs showed signs of structure processing, but unlike with TSPs, their processing style is more likely to reflect the paragraph structure rather than the text's topic structure. If so, their processing may be governed more by exogenous than endogenous cues. Also the finding that their text summaries were influenced by topic signaling is compatible with exogenous guidance. On the other hand, FLRs' endogenously guided structure processing is backed up by them slowing down their reading on topic sentences appearing as the paragraph-initial sentences as well as on paragraph-final sentences that are summary statements of the paragraph contents. Yet, it should be noted that these signs of structure processing are generally small compared to those demonstrated by TSPs (see Figs. 2 and 4).

Across the four analyses, the common feature of SLRs and NSRs was their slow first-pass reading. They differed from each other in that NSRs were characterized by spending as much time during second-pass as first-pass reading, whereas SLRs spent little time rereading text. With respect to structure processing, the evidence was much less clear-cut than for TSPs. On one hand, SLRs and NSRs devoted some attention to topic structure when provided with a summary task but not with a verification task. Similarly, these readers paid extra attention to topic sentences when they were signaled by underlining but did not do so when they were not signaled. Thus, we observed evidence for both endogenous and exogenous attentional guidance for SLRs and NSRs. The evidence for endogenously guided processing came from a sample (Experiment 1) whose members were among the best students in Chinese universities. On the other hand, the evidence for more exogenously guided processing was obtained with a sample (Experiment 2) that comprises academically less competent university students. The observed signaling effect suggests that these readers need the help of explicit relevance cues to provide criteria in determining information relevance and to systematically allocate their limited attentional resources to relevant information for better understanding of such information (Bråten et al., 2017; McCrudden et al., 2010; McCrudden & Schraw, 2007). However, processing guidance by visual signals may be superficial in that the extra attention paid to key text elements does not necessarily result in better memory performance (Yeari et al., 2015). Indeed, in the present study, NSRs' additional allocation of reading time to topic sentences in the signaling condition did not improve their text summary scores. In future studies, the above speculation needs to put to test by examining the stability of the reader groups across different samples.

4.3. Practical implications

Perhaps the most important practical implication of the present study is that even competent adult readers (university students) demonstrate significant individual differences in their text reading styles. The good news is that we observed in both experiments a group of readers (TSPs) who strategically focus their attention on main points in the text. Their processing is internally guided and they do not need external support to selectively guide their attention to key points. However, the majority of readers was found to benefit from visual signals (underlining) to main points. Thus, even in university-level textbook materials it makes sense to visually highlight important text elements. Underlining is one way to do it, but separate textboxes summarizing each key point could be another method.

Less strategic readers may also be taught to mimic the cognitive processes carried out by strategic processors. The following guidelines may be offered: (1) If the task is to understand and remember the main points in the text (as it is usually the case when learning from long expository texts), keep that goal constantly in mind. (2) Look for main points; when you find one, pay particular attention to it. It may be advisable to return to it from time to time to activate it more strongly in your mind. (3) Relate and integrate detailed information to the main point you have identified. (4) Keep in mind that in many expository texts the first sentence in the paragraph may express the main point that is then elaborated in the remaining part of the paragraph. Alternatively or in addition, a text paragraph may end in a short summary of the paragraph's key contents.

The present study also informs teachers that rereading and looking back in text is not necessarily a sign of incompetent behavior, as it is quite often believed. In contrast, selective looking back to and rereading the text's main points represents advantageous behavior and signs of smart behavior. It is true that rereading may sometimes be a sign of comprehension struggle, as it may be the case to some extent with SLRs. Extensive and non-selective rereading of long text segments also reflects a non-optimal processing strategy, as witnessed among NSRs.

4.4. Shortcomings of the present research

There are three shortcomings in the present study. One limitation is that the two texts were presented in the same order without counterbalancing. Thus, it limits us to analyze the cluster stability within an individual between two texts. Another shortcoming is that the two samples between the experiments were not completely comparable. Although highly similar cluster solutions were obtained in the two experiments, the reader clusters, apart from TSPs, did not demonstrate completely comparable reading behavior across the two experiments. Thus, some of the reader profiles were not as uniform as one would have hoped. On the other hand, the choice of two somewhat distinct samples brought about results that suggest avenues for future research. It would be interesting to replicate the present study with less competent readers than university students, such as high school students. Finally, we did not assess the cognitive profiles of the reader groups. Future research should characterize the underlying cognitive underpinnings (e.g., general language skills, working memory span, and fluid intelligence) of the four reading styles.

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Appendix

Table 1
Correlations between fist-pass reading time, second-pass reading time, and summary score in the summary task for each reader group.

Reader Group	Sentence type		Second-pass reading time	Summary score
FLRs	Topic sentence	First-pass reading time	.028	.193
		Second-pass reading time		-.533**
	Medial sentence	First-pass reading time	.338	.141
		Second-pass reading time		-.053
	End sentence	First-pass reading time	.022	.010
		Second-pass reading time		-.260
SLRs	Topic sentence	First-pass reading time	-.276	.595
		Second-pass reading time		.555
	Medial sentence	First-pass reading time	-.552	-.393
		Second-pass reading time		.221
	End sentence	First-pass reading time	.234	-.044
		Second-pass reading time		.906*
NSRs	Topic sentence	First-pass reading time	.287	-.162
		Second-pass reading time		-.660
	Medial sentence	First-pass reading time	-.555	-.113
		Second-pass reading time		.342
	End sentence	First-pass reading time	-.163	.341
		Second-pass reading time		-.851*
TSPs	Topic sentence	First-pass reading time	-.357	-.417
		Second-pass reading time		-.161
	Medial sentence	First-pass reading time	-.288	-.470
		Second-pass reading time		.180
	End sentence	First-pass reading time	-.658	-.377
		Second-pass reading time		.272

Note: *p < .05; **p < .01.

Table 2
Correlations between fist-pass reading time, second-pass reading time, and summary score in the verification task for each reader group.

Reader Group	Sentence type		Second-pass reading time	Summary score
FLRs	Topic sentence	First-pass reading time	-.125	-.432*
		Second-pass reading time		.193
	Medial sentence	First-pass reading time	-.054	.032
		Second-pass reading time		-.074
	End sentence	First-pass reading time	.254	.002
		Second-pass reading time		.111
SLRs	Topic sentence	First-pass reading time	.840*	-.673
		Second-pass reading time		-.654
	Medial sentence	First-pass reading time	-.887*	.058
		Second-pass reading time		-.303

(continued on next page)

Table 2 (*continued*)

Reader Group	Sentence type		Second-pass reading time	Summary score
	End sentence	First-pass reading time	-.781	.263
		Second-pass reading time		-.506
NSRs	Topic sentence	First-pass reading time	-.179	.194
		Second-pass reading time		.248
	Medial sentence	First-pass reading time	-.793*	-.567
		Second-pass reading time		.263
	End sentence	First-pass reading time	.151	.168
		Second-pass reading time		.970**

Note: *p < .05; **p < .01.

Table 3
Correlations between fist-pass reading time, second-pass reading time, and summary score in the signaling condition for each reader group.

Reader Group	Sentence type		Second-pass reading time	Summary score
FLRs	Topic sentence	First-pass reading time	-.363	.090
		Second-pass reading time		-.079
	Medial sentence	First-pass reading time	.449*	.271
		Second-pass reading time		-.138
	End sentence	First-pass reading time	-.118	.052
		Second-pass reading time		-.266
SLRs	Topic sentence	First-pass reading time	.357	-.532
		Second-pass reading time		.025
	Medial sentence	First-pass reading time	.064	-.253
		Second-pass reading time		.135
	End sentence	First-pass reading time	-.385	.370
		Second-pass reading time		.308
NSRs	Topic sentence	First-pass reading time	-.438	.448
		Second-pass reading time		-.159
	Medial sentence	First-pass reading time	-.274	-.121
		Second-pass reading time		.258
	End sentence	First-pass reading time	-.298	-.324
		Second-pass reading time		.669
TSPs	Topic sentence	First-pass reading time	-.295	-.404
		Second-pass reading time		-.057
	Medial sentence	First-pass reading time	-.509	.032
		Second-pass reading time		-.525
	End sentence	First-pass reading time	-.632	.147
		Second-pass reading time		-.388

Note: *p < .05.

Table 4
Correlations between fist-pass reading time, second-pass reading time, and summary score in the no signaling condition for each reader group.

Reader Group	Sentence type		Second-pass reading time	Summary score
FLRs	Topic sentence	First-pass reading time	.159	-.184
		Second-pass reading time		.209
	Medial sentence	First-pass reading time	-.020	.133
		Second-pass reading time		-.286
	End sentence	First-pass reading time	.643**	-.088
		Second-pass reading time		-.421
SLRs	Topic sentence	First-pass reading time	.702*	.171
		Second-pass reading time		-.235
	Medial sentence	First-pass reading time	.236	.639*
		Second-pass reading time		.022
	End sentence	First-pass reading time	.076	.534
		Second-pass reading time		-.247
NSRs	Topic sentence	First-pass reading time	-.546	-.055
		Second-pass reading time		.610
	Medial sentence	First-pass reading time	.543	-.357
		Second-pass reading time		-.205
	End sentence	First-pass reading time	.267	-.069
		Second-pass reading time		-.173

(*continued on next page*)

Table 4 (*continued*)

Reader Group	Sentence type		Second-pass reading time	Summary score
TSPs	Topic sentence	First-pass reading time	-.616	-.502
		Second-pass reading time		.141
	Medial sentence	First-pass reading time	-.373	.456
		Second-pass reading time		-.538
	End sentence	First-pass reading time	.637	-.716
		Second-pass reading time		-.202

Note: *p < .05; **p < .01.

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