

## How Prior Knowledge, WMC, and Relevance of Information Affect Eye Fixations in Expository Text

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This study examined how prior knowledge and working memory capacity (WMC) influence the effect of a reading perspective on online text processing. In Experiment 1, 47 participants read and recalled 2 texts of different familiarity from a given perspective while their eye movements were recorded. The participants' WMC was assessed with the reading span test. The results suggest that if the reader has prior knowledge related to text contents and a high WMC, relevant text information can be encoded into memory without extra processing time. In Experiment 2, baseline processing times showed whether readers slow down their processing of relevant information or read faster through the irrelevant information. The results are discussed in the light of different working memory theories.

How a reader's goal or perspective influences text processing has attracted a lot of interest in reading research since the seminal study by Anderson and Pichert in 1978 (e.g., Anderson, 1982; Anderson, Pichert, & Shirey, 1983; Baillet & Keenan, 1986; Borland & Flammer, 1985; Borland, Flammer, & Wearing, 1987; Flammer & Tauber, 1982; Goetz, Schallert, Reynolds, & Radin, 1983; Grabe, 1979, 1981; Kaakinen, Hyönä, & Keenan, 2001, 2002; Kardash, Royer, & Greene, 1988; Rothkopf & Billington, 1979). Anderson and Pichert (1978) asked their participants to read a text describing three houses from either a burglar's or a home-buyer's perspective and to recall the text after reading. Their findings suggested that a reading perspective did not result in selective memory for a text. Baillet and Keenan showed that Anderson and Pichert's testing conditions did not allow them to detect a perspective effect because they used a very short text with intentional memory instructions followed by immediate recall. Research since then has supported Baillet and Keenan's finding that with longer texts, incidental recall, and delayed recall, the standard result is that perspective-relevant information is better recalled than perspective-irrelevant information.

What still needs to be determined, however, is what causes perspective-relevant information to be remembered better. Is the memory advantage for relevant information solely the result of extra

processing time on relevant information during the encoding of the text? We examined this question in an earlier study (Kaakinen et al., 2002) by giving participants a reading perspective before they read an expository text describing and comparing four remote countries: Honduras, Pitcairn, Anguilla, and Andorra. The reading perspective was induced by instructing the participants to imagine that they were going to live in one of these countries. The participants were asked to define what good and what bad sides there would be to living in that country. The readers' eye movements were recorded during reading, and after reading they wrote a free recall of the text. We found that readers recalled more information relevant to the imagined new home country than relevant to the other countries. More important, readers made more and longer fixations on sentences that described the conditions of that country than on other sentences. We suggested that a reading perspective guides readers to use a selective online processing strategy, which leads to selective recall of text (see also Anderson, 1982; Reynolds, 1992).

The results of Kaakinen et al. (2002) were consistent with some earlier studies showing that the reader's goal or perspective directs the reader to process the perspective-relevant information longer than perspective-irrelevant information, which supports the view that the better memory for perspective-relevant information is a result of time-consuming encoding processes (Goetz et al., 1983; Rothkopf & Billington, 1979). However, there also are studies suggesting that a reading perspective does not have any effect on processing time (Anderson, 1982; Grabe, 1979, 1981); they suggest that encoding of relevant information into memory can be a fast and efficient process, which does not necessarily require extra processing time. In other words, empirical evidence on whether a reading perspective influences online text processing is contradictory.

In this article, we propose and test the suggestion that factors related to working memory may control whether encoding of relevant information to memory requires extra processing time. Working memory is generally assumed to play a crucial role in text comprehension (e.g. Just & Carpenter, 1992; Kintsch, 1998; Kintsch & van Dijk, 1978). Furthermore, it has been shown that there are individual differences in working memory capacity (WMC) that are related to differences in text comprehension abili-

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ties (e.g., Daneman & Carpenter, 1980). It is reasonable, therefore, to think that individual differences in working memory might be related to how one processes relevant and irrelevant information.

Exactly how they are related may depend on one's theory of working memory. We propose two factors that might modulate the perspective effect: prior knowledge of the text contents and the reader's working memory span (WMS). According to some theorists, these two factors are basically the same thing because prior knowledge is what controls the capacity of working memory (e.g., Ericsson & Delaney, 1999). According to other theorists, WMC is fixed and separate from prior knowledge (e.g., Just & Carpenter, 1992). In this article, we examine both factors to understand how individual differences in working memory might influence the perspective effect.

We begin with discussing how differences in readers' prior knowledge of the text contents might influence processing of perspective-relevant and perspective-irrelevant information in text. We then consider how individual differences in working memory span might influence perspective effects.

### The Role of Prior Knowledge in Text Comprehension

According to Kintsch's (1988, 1998) construction integration (CI) theory, the reader's background knowledge plays a crucial role in text comprehension. The theory assumes that comprehension processes proceed in a two-phase cycle. First, during the *construction* phase, the text input launches a dumb bottom-up process in the reader's knowledge base. The construction phase resembles the resonance process described by Myers and O'Brien (1998): All concepts associated to the text in the reader's knowledge base will get activated, and the resulting knowledge network will consist of both relevant and irrelevant concepts. Next, in the *integration* phase, the activation in the knowledge network will stabilize by a constraint-satisfaction process: Those concepts that fit in with the text and each other are retained, but the others become deactivated. As sentences are read, new propositions are integrated to the developing memory structure via this kind of construction-integration process. The resulting representation contains both text information and information retrieved from the reader's knowledge base.

According to the long-term working memory (LT-WM) model (Ericsson & Kintsch, 1995), the concepts active in short-term memory (text input) serve as retrieval cues for concepts in long-term memory: A cue in short-term memory can make available a whole subset of information in the reader's knowledge base. These activated concepts in the reader's knowledge base can be quickly retrieved to the focus of attention if necessary. When a reader has prior knowledge related to the text, the LT-WM provides relatively quick access to relevant knowledge in the reader's knowledge base, thus enabling the construction of a comprehensive representation of a text (Kintsch, Patel, & Ericsson, 1999). However, when there is no or only little prior knowledge related to the text's topic in the reader's knowledge base, the LT-WM is not available, and the comprehension process has to rely solely on the use of short-term working memory, which has limited capacity (Kintsch et al., 1999). Thus, if the LT-WM is not available, the construction of retrieval structures requires time and resources (Ericsson & Kintsch, 1995; Kintsch, 1998).

Evidence from memory studies shows that prior knowledge is used in text comprehension (e.g., Kintsch & Franzke, 1995; McNamara & Kintsch, 1996; Moravcsik & Kintsch, 1995; Voss & Silfies, 1996). For example, Kintsch and Franzke (1995) found that specific knowledge of the text's topic is needed for constructing a comprehensive representation of the text. Without such knowl-

edge, readers were not able to make the correct elaborative inferences, resulting in a poorer representation of the text. However, little is known about how available prior knowledge might influence online processing strategies (Soederberg Miller & Stine-Morrow, 1998; Wiley & Rayner, 2000), especially when the reader has adopted a specific goal or perspective for reading.

According to Kintsch's (1998) CI theory and the LT-WM model (Ericsson & Kintsch, 1995), encoding of perspective-relevant information may not necessarily require extra processing time. Specifically, if the reader had sufficient prior knowledge about the relevant text contents, then LT-WM would mediate both the determination of relevance and the encoding of it into memory. This would be done on the basis of the connections between text information and the reader's knowledge base. So, if a reader has sufficient knowledge of a topic, that knowledge will be generally activated by the perspective, and when specific concepts occur in the text, they will automatically resonate with the reader's knowledge structures. However, if the reader does not have sufficient background knowledge, the LT-WM is not available either to determine relevance or to help associate the text elements to knowledge structures, and the comprehension process will have to rely solely on the contents of short-term working memory. It is easy to see how encoding of relevant text information to memory in this case will require extra time relative to the case where the reader has knowledge and can use LT-WM because links will not fall out of the memory representation but rather will have to be constructed by the reader.

### Individual Differences in WMC

According to Ericsson and Kintsch (1995, see also Ericsson & Delaney, 1999), a person's WMC is not fixed but varies with one's expertise in a knowledge domain. Other researchers, however, tend to think of working memory as having a fixed capacity that can be measured by WMS tasks (e.g., Engle, Cantor, & Carullo, 1992; Just & Carpenter, 1992).

Whereas the Ericsson and Kintsch (1995) view predicts possibly no perspective effect under conditions of high knowledge, the capacity views of working memory (e.g., Just & Carpenter, 1992; Engle et al., 1992) may make similar predictions albeit for different reasons. One general reason for this prediction that the perspective effect is weaker in the high-knowledge than in the low-knowledge text is because the high-knowledge text does not tax the processing resources to the same extent. The more specific reason is that readers with low WMC would pay relatively more attention to perspective-relevant than to perspective-irrelevant text information, because selectivity in processing would reduce the processing demands and thus better accommodate their reduced resources. High-span readers, on the other hand, are assumed to have enough processing capacity to encode all text information and thus might be less likely to show differential processing of relevant and irrelevant information. Lee-Sammons and Whitney (1991) have in fact proposed just such an explanation for their finding that low-span readers showed a greater effect of a reading perspective on text *memory* than high-span readers. Note, however, that they only measured memory performance; they did not measure reading time and, in fact, only gave all readers a fixed amount of time to read. Thus, it is difficult to infer anything about encoding from their results. Further, they might have forced readers with less capacity to adopt a special strategy for dealing with the time pressure. Clearly, what is needed is an experiment, such

as the present one, that actually measures encoding times as a function of individual differences in working memory.

A variant of the capacity view of working memory is the *controlled attention view of working memory* (Engle, Kane, & Tuholski, 1999), in which individual differences in WMC reflect individual differences in the capability for “controlled, sustained attention in the face of interference or distraction” (Engle et al., 1999, p. 104). In other words, high-span readers are thought to be better than low-span readers in allocating their attention to task-relevant information and away from task-irrelevant information. If the controlled attention view (Engle et al., 1999) is correct, both low- and high-span readers might show perspective effects, but high-span participants would show an effect of a reading perspective already during early phases of processing, whereas low-span readers would show only delayed effects, if any. This would be true for both the low- and high-prior-knowledge texts. We have found support for this view (Kaakinen et al., 2002): High-span readers showed an effect of a reading perspective during the initial reading of perspective-relevant text, whereas low-span readers showed effects only later in the looks back. Along the lines of the controlled attention view of working memory, we have argued that high-span readers are better in allocating their attentional resources to perspective-relevant information during reading than low-span readers.

### Overview of the Present Study

The purpose of the present study was twofold: (a) to examine the influence of prior knowledge on online processing of perspective-relevant and perspective-irrelevant information in expository text and (b) to determine if possible differences in perspective effects occur between low- and high-WMS readers.

In Experiment 1, participants read two texts: the familiar diseases text and the rare diseases text. All participants had a rich knowledge base related to the diseases described in the familiar diseases text: The text described the symptoms, causes, treatment, and prevention of diarrhea, flu, chicken pox, and AIDS. In contrast, participants had no or only minimal prior knowledge related to the topics discussed in the rare diseases text, which described the symptoms, origin, treatment, prevention, and patient support groups for trigeminal neuralgia, typhus, cystic fibrosis, and scleroderma.

Before reading each text, the participants were given a reading perspective. For example, before reading the familiar diseases text, participants were instructed to imagine that they were elementary school teachers and that they would have to tell children about a disease: what caused it and how it could be treated and prevented. Half were told to imagine that they would have to tell the children about flu, and the other half were told they would have to tell the children about diarrhea. During reading, each participant’s eye-fixation patterns were recorded, and fixation times were extracted for predefined, matched sentences containing perspective-relevant and perspective-irrelevant information. After the participants read the texts, the reading span test (Daneman & Carpenter, 1980) was administered, followed by a free recall of both texts.

Note that the specific items of information considered relevant or irrelevant were counterbalanced across participants, so that across participants, there were no material differences that could account for any obtained differences between memory or fixation times on relevant and irrelevant items because the very same sentences that were relevant for one participant were irrelevant for another participant. For example, if the reader had adopted the flu perspective for reading the familiar diseases text, flu-relevant

sentences were considered to be perspective-relevant information, whereas diarrhea-relevant sentences were perspective-irrelevant information; whereas a different participant would have diarrhea as the reading perspective, and what was relevant for the flu perspective would now be irrelevant and vice versa.

We also examined whether the reading perspective influenced online processing by speeding up the processing of irrelevant information or by slowing down processing of relevant information, or both. To determine this, it was necessary to establish a baseline encoding time for the sentences used in the analyses. In Experiment 2, participants read the texts without a specific reading perspective, and their reading times were used as a baseline against which the data from Experiment 1 were compared.

Finally, note that although other studies have tried to determine the effects of perspective on encoding of text contents (e.g., Anderson, 1982; Goetz et al., 1983; Grabe, 1979, 1981; Rothkopf & Billington, 1979), none have had the methodological sophistication of using eye tracking to examine readers’ online processing of text. There are important advantages in modern eye-tracking technology when compared with other online methods such as probe reaction time or sentence reading time measurements. First, it allows normal reading of text by not posing extra requirements on the reader, such as pressing a button after each sentence to advance in text or reacting to a probe in the middle of reading. Second, it allows the reader to freely inspect the text, which in turn enables the analysis of the reading behavior into first-pass reading and later look-backs.

## Experiment 1

### Method

#### Participants

Forty-seven students from the University of Turku served as participants. The participants either fulfilled a course requirement or received a lunch coupon for participation.

#### Apparatus

Eye movements were collected by the EYELINK eye tracker manufactured by SR Research Ltd. (Toronto, Ontario, Canada). The eye tracker is an infrared video-based tracking system combined with hyperacuity image processing. There are two cameras mounted on a headband (one for each eye), including two infrared LEDs for illuminating each eye. The headband weighs 450 g in total. The cameras sample pupil location and pupil size at the rate of 250 Hz. Registration can be done either monocularly or binocularly. We performed it for the selected eye (usually the right eye) by placing the camera and the two infrared lights 4–6 cm away from the eye. The resolution of eye position is 15 s of arc and the spatial accuracy is approximately 0.5°. Head position with respect to the computer screen is tracked with the help of a head-tracking camera mounted on the center of the headband at the level of the forehead. Four LEDs are attached to the corners of the computer screen, which are viewed by the head-tracking camera, once the participant sits directly facing the screen. Possible head motion is detected as movements of the four LEDs and is compensated for online from the eye position records. The compensation is better than 1° over the acceptable range of head motion.

#### Materials

The experimental materials consisted of two texts written in Finnish (the language studied here).<sup>1</sup> One text contained information unfamiliar to the

<sup>1</sup> English translations are available on request from Johanna K. Kaakinen.

readers (rare diseases text). The other text contained information familiar to the readers (familiar diseases text).

The rare diseases text described four diseases: trigeminal neuralgia, typhus, cystic fibrosis, and scleroderma. The text contained five subtopics, each marked with a subheading (How to Recognize the Disease, Origin and Causes, Treatment, Prevention, and Support Groups), and each disease was presented under each subtopic by comparing and contrasting the diseases to each other. There were two possible reading perspectives that could be adopted before reading the text: One perspective was related to trigeminal neuralgia, and the other was related to typhus. The reading perspective was induced by instructing the participant to

Imagine that a close friend of yours has been diagnosed with trigeminal neuralgia/typhus. Everybody is very worried about this common friend, and you have agreed to find out some facts about the disease and to inform the others about it.

Half of the participants were given the trigeminal neuralgia perspective, and half the participants were given the typhus perspective before reading. The title of the text was always consistent with the reading perspective, such as, Trigeminal Neuralgia/Typhus, a Rare and Difficult Disease.

The familiar diseases text described four relatively familiar diseases: flu, diarrhea, chicken pox, and AIDS. The text contained five subtopics, each marked with a subheading (Symptoms Reveal the Disease, Mild Diseases Can Be Treated at Home, Medication, When Should I Contact a Doctor, and How to Avoid the Infection), and each disease was presented under each subtopic by comparing the diseases with each other. The two potential reading perspectives were induced by instructing the participants to

Imagine that you are going to give a health education class for elementary school pupils. You are supposed to tell them about flu/diarrhea: for example, what causes it, how you can treat it, and how to prevent from getting the disease."

Half of the participants were given the flu perspective, and half were given the diarrhea perspective before reading. The title of the text was always consistent with the reading perspective: Flu/Diarrhea Is One of the Scourges of Mankind.

The rare diseases text included 10 selected target sentences relevant to trigeminal neuralgia and 10 relevant to typhus. Similarly, the familiar diseases text contained 10 selected target sentences relevant to flu and 10 relevant to diarrhea. Because the reading perspectives were counterbalanced across participants, for half of the participants, the flu-relevant target sentences in the familiar diseases text were the perspective-relevant sentences, and the diarrhea-relevant target sentences were the perspective-irrelevant sentences; whereas for the other half, the diarrhea-relevant sentences were the perspective-relevant sentences, and the flu-relevant sentences were the perspective-irrelevant sentences. The same was true for the trigeminal neuralgia and typhus sentences in the rare diseases text. Despite the counterbalancing, we also matched the target sentences (trigeminal neuralgia vs. typhus and flu vs. diarrhea sentences) for the mean length and for the mean frequencies of the words in the sentences (frequencies were calculated from an unpublished newspaper corpus with the help of the WordMill database program of Laine & Virtanen, 1999).

In preparing the target sentences, 19 participants who did not participate in the actual experiment were given the reading perspectives (one perspective at a time) for the rare diseases text and were asked to write down everything that came into their mind about each disease in 90 s. Sixteen participants who did not participate in the actual experiment completed the same task for the perspectives of the familiar diseases text. The results of these tests were used as guidelines when writing the texts. For the rare diseases text, target sentences were prepared so that they did not contain ideas that were spontaneously mentioned by the participants in the test. For the familiar diseases text, target sentences were written so that they did contain information produced in the test.

To make sure that the text contents indeed differed in familiarity, the amount of prior knowledge related to the texts was assessed for each partici-

pant of the actual experiment by a questionnaire given in the end of the experimental session. In the questionnaire, the participant was asked to rate how familiar each disease was to her or him before she or he read the texts, on a scale ranging from 1 (*I had never heard of the disease*) to 5 (*The disease was very familiar to me*). All 47 participants ranked the diseases described in the rare diseases text as less familiar (mean rank = 1.67) than the diseases in the familiar diseases text (mean rank = 4.32),  $t(46) = 27.13, p < .01, SE = 0.10$ . There were no differences between the WMS groups in familiarity ratings,  $F(2, 44) = 1.47, p > .1, MSE = 0.36$  for the familiar diseases text, and  $F(2, 44) = 0.60, p > .1, MSE = 0.26$  for the rare diseases text.

We used the reading span test (Daneman & Carpenter, 1980) to measure the WMS of the participants. A Finnish version of the test was administered after participants read the text but before they wrote what they could recall. In the test, participants read aloud sets of unrelated sentences. After reading the sentences of a particular set, the participant was to recall the last word of each sentence in the set. The final words of the sentences were carefully matched for frequency, length, and inflectional case. The test began with sets of two sentences, and the set size increased as long as the participant successfully recalled the sentence's final words. Each set size was repeated three times. Testing terminated when the participant failed to recall the sentence's final words of all three repetitions of a particular set size. A computer program was used to present the test items on a computer screen. A practice session with 3 sets of two sentences preceded the test. The test was scored for the total number of final words the participant recalled correctly. A tertile split was used to assign the participants to low-, medium-, and high-span groups (Lee-Sammons & Whitney, 1991). Fourteen participants were assigned to the low-span group (scores 17–21), 18 to the medium-span group (scores 22–31), and 15 to the high-span group (scores 32–73).

## Design

The data were analyzed by means of a 2 (Text)  $\times$  2 (Perspective Relevance)  $\times$  3 (WMS) mixed factors design. Text and perspective relevance were within-subjects factors, and WMS was a between-subject factor. The conditions of text were low and high prior knowledge, and the conditions of perspective relevance were perspective relevant and perspective irrelevant. Three levels of WMS were established: low, medium, and high span. The presentation order of the texts and the assigned reading perspective (trigeminal neuralgia/typhus for the rare diseases text and flu/diarrhea for the familiar diseases text) were counterbalanced across participants.

## Procedure

Participants read the texts at their own pace from the computer screen while their eye movements were recorded. Eight lines of text were presented in one screen, and the participant could proceed in the text by pressing a button on a game pad. A short practice trial preceded each text to adjust the participants to the eye-tracking equipment and to present the instructions. The reading perspective was introduced in the instructions. After the participants read the texts, the reading span test (Daneman & Carpenter, 1980) was administered. The reading span test took approximately 15 min. It was succeeded by the recall, where participants were given the reading perspectives they had adopted before reading and the titles of the texts as the recall cues. The participants were instructed to write down everything they could remember of the text, not just what was related to the title. After completing the recall, participants filled out a questionnaire about the amount of prior knowledge they had of the diseases described in the texts. The participants were allowed to leave whenever they were ready. The total time of the session was about 1.5 hr.

## Results

### Recall

Recall data for 2 participants were dropped because their recall protocols included only material relevant to their reading perspec-

Table 1  
*Mean Recall Performance and Differences (Diff.) Between Means for Relevant and Irrelevant Information in Familiar and Rare Diseases Texts as a Function of Working Memory Span (WMS)*

WMS	<i>n</i>	Familiar diseases					Rare diseases				
		Relevant		Irrelevant		Diff.	Relevant		Irrelevant		Diff.
		<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>		<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	
Low	12	.59	.05	.33	.05	.26	.36	.06	.14	.05	.22
Medium	18	.56	.04	.39	.06	.17	.39	.04	.22	.04	.17
High	15	.53	.07	.37	.07	.16	.40	.03	.20	.04	.20
Total		.56		.37		.19	.39		.19		.20

tive. It was apparent that they had ignored the instructions to try to recall everything they could from the texts. The remaining recall protocols (i.e., for 45 participants) were scored for the number of target sentences recalled. Twenty-four protocols were scored by two independent raters, with the interrater disagreement of 7.3%. The inconsistencies were resolved through discussion, which provided guidelines for scoring the rest of the protocols. The percentage of recalled target sentences in proportion to the number of the target sentences in the information set was used as a measure of the recall.

The data were analyzed with a mixed factors analysis of variance (ANOVA), with text and perspective relevance as within-subjects factors and WMS as a between-subjects factor. All reported effects were significant beyond the .05 level, unless noted otherwise. The results, presented in Table 1, showed that we replicated the classic perspective effect on text memory. Readers recalled more perspective-relevant than perspective-irrelevant information, indicated by a significant main effect of perspective relevance,  $F(1, 42) = 48.68$ ,  $MSE = 0.04$ . There was also a significant main effect of text,  $F(1, 42) = 39.98$ ,  $MSE = 0.03$ , indicating that memory for the familiar diseases text was better than for the rare diseases text. None of the interactions proved significant (all  $F_s < 1$ ).<sup>2</sup>

### Fixation Time Measures

Three processing measures were derived from readers' eye fixation patterns: (a) first-pass progressive fixation time, (b) first-pass rereading time, and (c) look-back time (see Hyönä, Lorch, & Rinck, in press). The first-pass reading time measures tap the comprehension processes while the reader is going through the sentence for the first time. Progressive fixations are forward-going fixations that land on unread parts of a sentence and are thought to index the most immediate processing. It is possible that readers proceed slowly in the text when they expect to encounter relevant information, resulting in longer first-pass progressive fixation times on relevant than on irrelevant sentences. First-pass rereading time is the summed duration of fixations landing on the already read parts of a sentence during the first-pass reading and it reflects the reader's immediate need to reread a sentence. It is possible that readers invest more effort in comprehending relevant than irrelevant sentences, thus showing longer first-pass rereading times for relevant than for irrelevant sentences. Finally, the look-back time is a measure of later processing: Look-backs are fixations returning to a sentence from subsequent sentences. Readers look back in the text to reinstate text information to their working memory (see, e.g., Walczyk & Taylor, 1996). Thus, we could expect readers to go back to relevant sentences more than to irrelevant sentences. The saccadic direction is not decisive in defining the first-pass rereadings and look-back fixations; rather, fixations that

land on a previously fixated sentence are defined either as first-pass rereadings (when rereading parts of the currently fixated sentence) or look-backs (when rereading parts of a previously read sentence). A first-pass rereading and look-back fixation are always initiated with a regression, but subsequent rereadings or look-back fixations can be either progressive or regressive.

Mixed factors ANOVAs were conducted for each fixation time measure, with text and perspective relevance as within-subjects factors and WMS as a between-subjects factor. All reported effects were significant beyond the .05 level, unless noted otherwise.

*First-pass progressive fixation time.* The progressive fixation times were generally longer in the rare diseases than in the familiar diseases text,  $F(1, 44) = 46.43$ ,  $MSE = 53,502$  (see Table 2). Also, relevant sentences attracted longer fixation times than irrelevant sentences,  $F(1, 44) = 16.94$ ,  $MSE = 96,788$ . The interaction between text and perspective relevance indicated that the perspective effect was more prominent in the rare diseases than in the familiar diseases text,  $F(1, 44) = 19.08$ ,  $MSE = 37,280$ . Moreover, there was a significant three-way interaction among text, perspective relevance, and span group,  $F(2, 44) = 3.75$ ,  $MSE = 37,280$ . This interaction was followed with separate two-way ANOVAs for each span group.

For the low-span group, there were significant main effects of text,  $F(1, 13) = 8.06$ ,  $MSE = 80,446$ , and perspective relevance,  $F(1, 13) = 6.75$ ,  $MSE = 143,575$ . The Text  $\times$  Perspective Relevance interaction was not significant,  $F(2, 13) = 2.72$ ,  $p > .1$ ,  $MSE = 37,600$ .

Also for the medium-span group, there were main effects of text,  $F(1, 17) = 27.58$ ,  $MSE = 47,087$ , and of perspective relevance,  $F(1, 17) = 5.32$ ,  $MSE = 91,546$ . The Text  $\times$  Perspective Relevance interaction was not significant,  $F(1, 17) = 1.58$ ,  $p > .1$ ,  $MSE = 33,684$ .

The high-span group, on the other hand, showed a significant interaction between text and perspective relevance,  $F(1, 14) = 19.40$ ,  $MSE = 41,349$ , as well as main effects of text,  $F(1, 14) =$

<sup>2</sup> We also analyzed the recall protocols by first parsing the experimental texts into meaningful phrases and then coding each sentence in the recall protocols with respect to these phrases. We then analyzed the amount of recalled material in proportion to the number of phrases appearing in the text with a mixed factors ANOVA. The results were similar to those based on the analysis of the recall of the 20 predefined text regions: Participants recalled more material from the familiar diseases than from the rare diseases text,  $F(1, 42) = 16.95$ ,  $MSE = 0.02$ , and more material related to their reading perspective than related to the other diseases,  $F(1, 42) = 64.85$ ,  $MSE = 0.02$ . The three-way interaction among text, perspective relevance, and WMS was clearly nonsignificant,  $F(2, 42) < 1$ .

Table 2  
*Mean First-Pass Progressive Fixation Times in ms and Differences (Diff.) Between Means for Relevant and Irrelevant Sentences as a Function of Text and Working Memory Span (WMS)*

WMS	<i>n</i>	Familiar diseases text				Diff.	Rare diseases text				Diff.
		Relevant		Irrelevant			Relevant		Irrelevant		
		<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>		<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	
Low	14	1,990	181	1,812	191	178	2,290	169	1,942	177	348**
Medium	18	1,981	89	1,870	131	111	2,304	137	2,085	146	219**
High	15	1,817	78	1,913	109	-96	2,258	101	1,891	89	367**
Total		1,929		1,865		64 <sup>a</sup>	2,284		1,973		311 <sup>a</sup>

<sup>a</sup> This difference was not tested with a *t* test.

\*\*  $p < .05$ .

18.20,  $MSE = 36,274$ , and perspective relevance,  $F(1, 14) = 4.63$ ,  $MSE = 59,710$ . As can be seen in Table 2, the high-span readers showed no difference in fixation time between perspective-relevant and perspective-irrelevant sentences for the familiar diseases; there was even a slight trend for perspective-irrelevant information to attract somewhat longer progressive fixation times than the perspective-relevant sentences, although this difference was not significant,  $t(14) = 1.27$ ,  $p > .1$ ,  $SE = 75.36$ . Only for the rare diseases text were fixation times longer on relevant than on irrelevant information,  $t(14) = 4.16$ ,  $SE = 88.29$ .

*First-pass rereading time.* The analysis of the first-pass rereading time revealed significant main effects of text,  $F(1, 44) = 38.42$ ,  $MSE = 57,887$ , and perspective relevance,  $F(1, 44) = 21.36$ ,  $MSE = 136,350$  (see Table 3). In addition, there was a significant Text  $\times$  Perspective Relevance interaction,  $F(1, 44) = 16.51$ ,  $MSE = 43,028$ , showing that the perspective effect was stronger in the rare diseases than in the familiar diseases text. The three-way interaction among text, perspective relevance, and span group was only marginally significant,  $F(2, 44) = 2.69$ ,  $p = .079$ ,  $MSE = 43,028$ .

*Look-back time.* There were significant main effects of text,  $F(1, 44) = 16.59$ ,  $MSE = 283,678$ , and of perspective relevance,  $F(1, 44) = 20.25$ ,  $MSE = 189,949$  (see Table 4). A significant interaction between text and perspective relevance indicated that the perspective effect was significantly smaller in the familiar diseases than in the rare diseases text,  $F(1, 44) = 5.55$ ,  $MSE = 269,301$ . Moreover, a significant Perspective Relevance  $\times$  WMS interaction suggested that the span groups showed different perspective effects,  $F(2, 44) = 4.50$ ,  $MSE = 189,949$ . This interaction was further examined with repeated measures ANOVAs separately for each span group. The low-span readers made more look-backs to perspective-relevant than to perspective-irrelevant information,  $F(1, 13) = 27.69$ ,  $MSE = 161,231$ . For both the medium-span group and the high-span group, the perspective effect was not significant,  $F(1, 17) = 1.72$ ,  $p > .1$ ,  $MSE = 201,677$ , and  $F(1, 15) = 2.07$ ,  $p > .1$ ,  $MSE = 189,039$ .<sup>3</sup>

### Discussion

As in earlier studies (e.g., Baillet & Keenan, 1986; Kaakinen et al., 2001), the results show that more perspective-relevant than perspective-irrelevant information was recalled. The perspective effect in recall is robust and held regardless of prior knowledge or WMS.

On the other hand, the magnitude of the perspective effect on encoding times, as evidenced by the fixation time data, showed that the perspective effect is in fact affected by prior knowledge

and WMS. Low-span readers showed a perspective effect in the first-pass progressive fixation times, indicating that low-span readers proceeded relatively slowly in the text if the sentence was relevant to their reading perspective. This perspective effect was observed for both the familiar diseases and the rare diseases texts. Low-span readers also made more look-backs to relevant than to irrelevant sentences, indicating that the low-span readers reinstated relevant information to their working memory by looking back to relevant sentences from subsequent sentences. High-span readers, on the other hand, showed a perspective effect in the first-pass progressive fixation time for the rare diseases text but not for the familiar diseases text. In other words, when high-span readers had ample prior knowledge, they did not slow down the initial reading of relevant sentences. Moreover, high-span readers' look-backs were not affected by the reading perspective.

How should we interpret these findings? The differences between the span groups emerged in the processing of the high-prior-knowledge text, whereas the span groups did not differ in the processing of the low-prior-knowledge text: Prior knowledge seemed to facilitate more high-span readers' than low-span readers' encoding of relevant information to memory. Thus, the results indicate that the individual differences in the WMS task reflect differences in the ability to make use of prior knowledge during reading. Just recently, Hambrick and Engle (2002) reported a memory study going in the same direction. They examined memory performance for auditorily

<sup>3</sup> The distribution of low-, medium-, and high-WMS participants to different perspective conditions was balanced in the familiar diseases text: Six low-, 9 medium-, and 8 high-WMS participants were assigned to the flu condition, and 8 low-, 9 medium-, and 7 high-WMS participants were assigned to the diarrhea condition. As for the rare diseases text, 8 low-, 11 medium-, and 5 high-WMS participants were assigned to the trigeminusneuralgia condition, whereas 6 low-, 7 medium-, and 10 high-WMS participants were assigned to the typhus condition. Because the participants were relatively unevenly distributed to different perspective conditions in the rare diseases text, the potential span group differences in this text could be confounded by assigned perspective. However, we did not find span group differences in the processing of the rare diseases text. Moreover, confounding would be a problem only if the two perspectives produced different perspective effects. To examine this possibility, we conducted mixed factors ANOVAs for each dependent measure with relevance as a within-subjects factor and reading perspective as a between-subjects factor. The results indicated that the two perspectives of the rare diseases text produced similar perspective effects: For all dependent measures, the Relevance  $\times$  Reading Perspective interaction was clearly nonsignificant (all  $F_s < 1$ ).

Table 3  
*Mean First-Pass Rereading Times in ms and Differences (Diff.) Between Means for Relevant and Irrelevant Sentences as a Function of Text and Working Memory Span (WMS)*

WMS	<i>n</i>	Familiar diseases text					Rare diseases text				
		Relevant		Irrelevant		Diff.	Relevant		Irrelevant		Diff.
		<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>		<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	
Low	14	572	113	428	85	144*	957	155	472	88	485**
Medium	18	461	79	264	56	197**	729	142	477	94	252**
High	15	431	101	391	95	40	805	143	420	76	385**
Total		484		354		130 <sup>a</sup>	821		457		364 <sup>a</sup>

<sup>a</sup> This difference was not tested with a *t* test.

\*  $p < .1$ . \*\*  $p < .05$ .

presented baseball game commentaries and found that high WMC enhanced the memory advantage for domain-relevant information. Based on offline data of listening comprehension, Hambrick and Engle suggested that high WMC is associated with the efficacy in utilizing prior knowledge. We draw a similar conclusion. We suggest that our findings are consistent with the LT-WM model (Ericsson & Delaney, 1999; Ericsson & Kintsch, 1995), which assumes that in some situations differences in WMC could be explained as differences in accessing and retrieving information from long-term memory. In other words, we argue that high-span readers can encode relevant information to memory without extra processing time because they are better at accessing and retrieving information from long-term memory than are low-span readers.

Moreover, the finding that low-span readers engaged in later processing of perspective-relevant information, whereas high-span readers did not suggests that high-span readers invest so much attentional resources to relevant text information already during the first-pass reading that they do not need to reread relevant information to be able to recall it later. This finding supports the view that the individual differences in WMC are actually differences in the capacity to control attentional resources (Engle et al., 1999). High-span readers seem to direct their attentional resources more effectively than low-span readers. We are not claiming that the low-span readers do not direct their attention at all; the results show that low-span readers do show a strategy of returning back to relevant text information. Instead, we suggest that high-span readers may have the capacity to allocate their attentional resources more effectively: They encode relevant information to memory during a single reading while showing no time cost in processing, whereas low-span readers need to reread relevant text segments to encode them to memory.

The span groups did not differ in the processing of the low-prior-knowledge text: Both low- and high-span readers showed a clear perspective effect in the first-pass readings. However, there might be qualitative differences between the span groups in the perspective effects. The effects of a reading perspective on fixation times were thus further studied in Experiment 2.

## Experiment 2

The results of Experiment 1 raise the question of exactly how does a reading perspective influence text processing: Does it increase the attention paid to relevant text information or decrease the attention directed to irrelevant text information? The purpose of Experiment 2 was to determine how a reading perspective influences text processing for low- and high-span readers. In Experiment 2, a different sample of participants read the experimental texts without any specific reading perspective. From these data, we calculated baselines separately for low- and high-span readers, which we then used to examine whether a reading perspective slows down processing of relevant information or speeds up processing of irrelevant information in text.

## Method

### Participants

Sixteen students enrolled in the introductory psychology course at the University of Turku served as participants.

### Apparatus

Same apparatus was used as in Experiment 1.

Table 4  
*Mean Look-Back Fixation Times in ms and Differences (Diff.) Between Means for Relevant and Irrelevant Sentences as a Function of Text and Working Memory Span (WMS)*

WMS	<i>n</i>	Familiar diseases text					Rare diseases text				
		Relevant		Irrelevant		Diff.	Relevant		Irrelevant		Diff.
		<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>		<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	
Low	14	439	83	91	32	348	968	210	186	80	782
Medium	18	281	60	231	76	50	823	220	595	193	228
High	15	301	119	373	243	-72	722	174	331	99	391
Total		334		235		99	834		389		445

## Materials

Same texts were used as in Experiment 1 (the familiar diseases text and the rare diseases text). The texts were given neutral titles: Infectious Diseases, the Common Headache of Mankind for the familiar diseases text and Rare and Troublesome Diseases for the rare diseases text, respectively.

The amount of prior knowledge related to the texts was assessed with the same questionnaire as in Experiment 1. All participants ranked the diseases described in the rare diseases text as less familiar (mean rank = 1.78) than the diseases described in the familiar diseases text (mean rank = 4.44),  $t(15) = 16.01, p < .001$ . There were no differences between the span groups in the familiarity ratings ( $F_s < 1$  for both the familiar and the rare diseases text).

## Design

The data were averaged across the target sentences to form a baseline against which the results of Experiment 1 could be compared with one-sample  $t$  tests. We calculated separate baselines for low- and high-span readers (assignment to the WMS group was done by the same criteria as in Experiment 1) and made separate comparisons for low- and high-span groups. The presentation order of the texts was counterbalanced across participants.

## Procedure

The procedure was identical to that of Experiment 1 with the exception that no specific reading perspective was induced. The participants were instructed to read the text so that you understand what you have read and can write a short summary of the text.

## Results

The same fixation time measures were computed from the eye-movement data as in Experiment 1. We computed mean fixation times across all target sentences (i.e., across the relevant and irrelevant sentences in Experiment 1) for the 7 low-span and 6 high-span participants (assignment to low- and high-span groups was defined by the same criteria as in Experiment 1) in Experiment 2 and compared the data from Experiment 1 with these baselines. We tested whether the fixation times for perspective-relevant and perspective-irrelevant sentences in Experiment 1 differed from the baselines with separate one-sample  $t$  tests for each fixation time measure. All reported effects were significant beyond the .05 level, unless noted otherwise.

### First-Pass Progressive Fixation Time

For the low-span group, the perspective effect in the first-pass progressive fixation time was due to a decrease in processing time for irrelevant information,  $t(13) = 1.92, p = .078, SE = 191.17$ , for the familiar diseases text, and  $t(13) = 2.05, p = .061, SE = 177.17$  for the rare diseases text (see Figure 1). For the high-span group, however, a reading perspective produced a general slowdown in processing. For the familiar diseases text, the slowdown occurred for both relevant and irrelevant information,  $t(14) = 2.34, SE = 77.83$ , for the relevant information and  $t(14) = 2.56, SE = 108.62$ , for the irrelevant information. In the rare diseases text, a reading perspective increased the progressive fixation time on only the relevant text information,  $t(14) = 2.89, SE = 101.36$ .

### First-Pass Rereading Time

For both span groups, reading perspective decreased the processing time for the irrelevant information in the rare diseases text only,

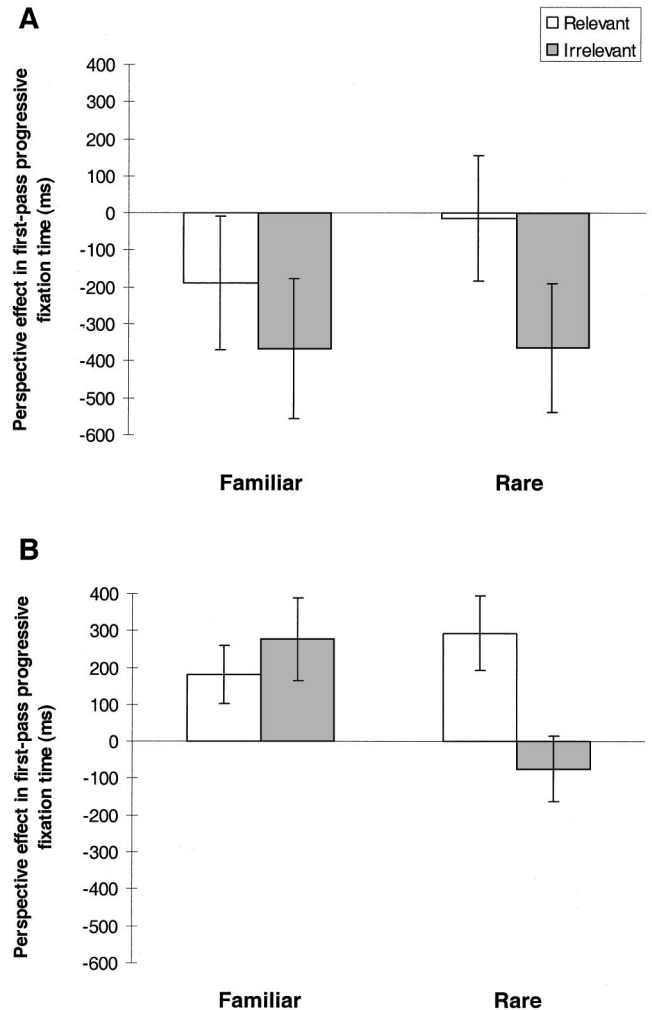


Figure 1. Differences from the baseline in the first-pass progressive fixation time (in milliseconds) for relevant and irrelevant sentences as a function of text, presented separately for low-span (A) and high-span (B) groups. Error bars represent standard errors.

$t(13) = 6.56, SE = 88.23$ , for the low-span readers and  $t(14) = 4.04, SE = 76.48$ , for the high-span readers, respectively (see Figure 2).

### Look-Back Time

When given a reading perspective, low-span readers made more look-backs to relevant sentences,  $t(13) = 3.16, SE = 82.65$ , for the familiar diseases and  $t(13) = 2.92, SE = 210.32$ , for the rare diseases text (see Figure 3). Low-span participants also made fewer look-back fixations to irrelevant information,  $t(13) = 2.73, SE = 32.01$ , for familiar diseases and  $t(13) = 2.08, p = .058, SE = 80.03$ , for the rare diseases text. As was already indicated by the results of Experiment 1, the high-span readers' look-back fixations were not significantly affected by reading perspective.

## Discussion

The low- and high-span groups differed in how reading perspective influenced text processing. For the low-span group, the perspective effects were mainly due to a decrease in the time used for

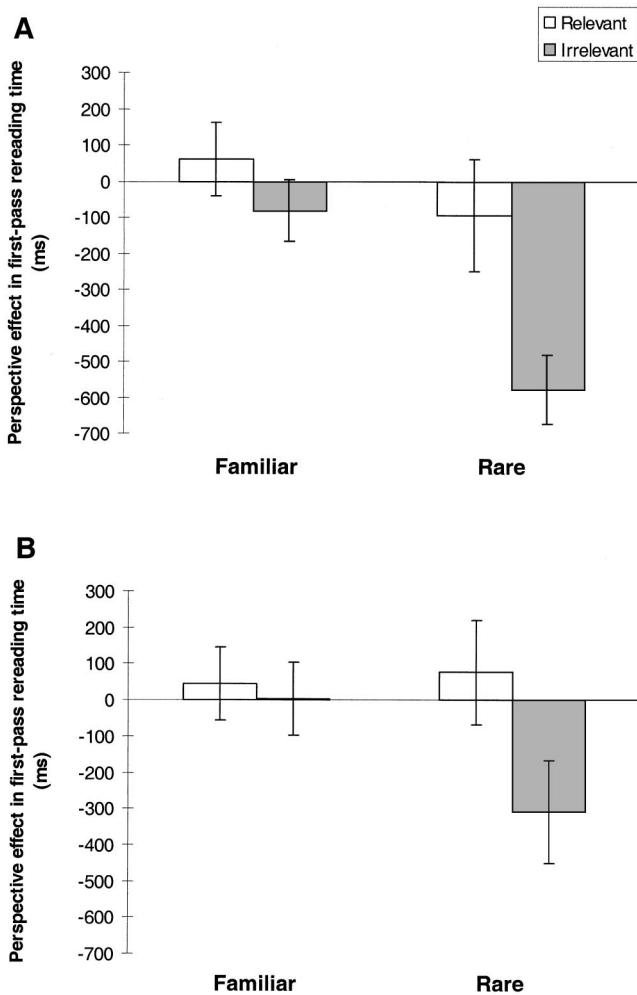


Figure 2. Differences from the baseline in the first-pass rereading time (in milliseconds) for relevant and irrelevant sentences as a function of text, presented separately for low-span (A) and high-span (B) groups. Error bars represent standard errors.

processing the perspective-irrelevant information in texts. First-pass progressive fixation times were shorter for the perspective-irrelevant sentences in both texts. Low-span readers also made shorter first-pass rereadings in irrelevant sentences in the rare diseases text. As for the look-backs, low-span readers made both more look-backs to perspective-relevant and less look-backs to perspective-irrelevant information.

For the high-span readers, the observed perspective effect in the first-pass progressive fixation time for the rare diseases text was due to an increase in the processing time for the relevant information in the text. Just like the low-span readers, high-span readers also showed shorter first-pass rereading times for the irrelevant information in the rare diseases text.

These findings shed additional light on the results of Experiment 1, which showed that both high- and low-span readers showed an effect of a reading perspective on processing the low-prior-knowledge text. High-span readers seem to invest extra processing time to relevant information already during first-pass progressive fixations, whereas low-span readers speed up processing of irrelevant information. Low-span readers invest extra effort later: They tend to go back to relevant information from subsequent text.

The span groups also differed in how reading perspective influenced processing of a high-prior-knowledge text. High-span readers showed a general slowdown in the first-pass progressive fixation time: They used longer time processing both relevant and irrelevant information. Low-span readers, on the other hand, simply used less time on first-pass progressive fixations in irrelevant information.

### General Discussion

As in a number of earlier studies (e.g., Baillet & Keenan, 1986; Kaakinen et al., 2001), the results showed that participants recalled more perspective-relevant than perspective-irrelevant information. What was interesting, however, was our finding that increased memory for perspective-relevant information is not always due to increased processing time. Specifically, readers who scored high in the reading span task did not need extra processing time to encode relevant information to memory when reading a text of familiar contents. Because low-span readers did need extra time, it appears

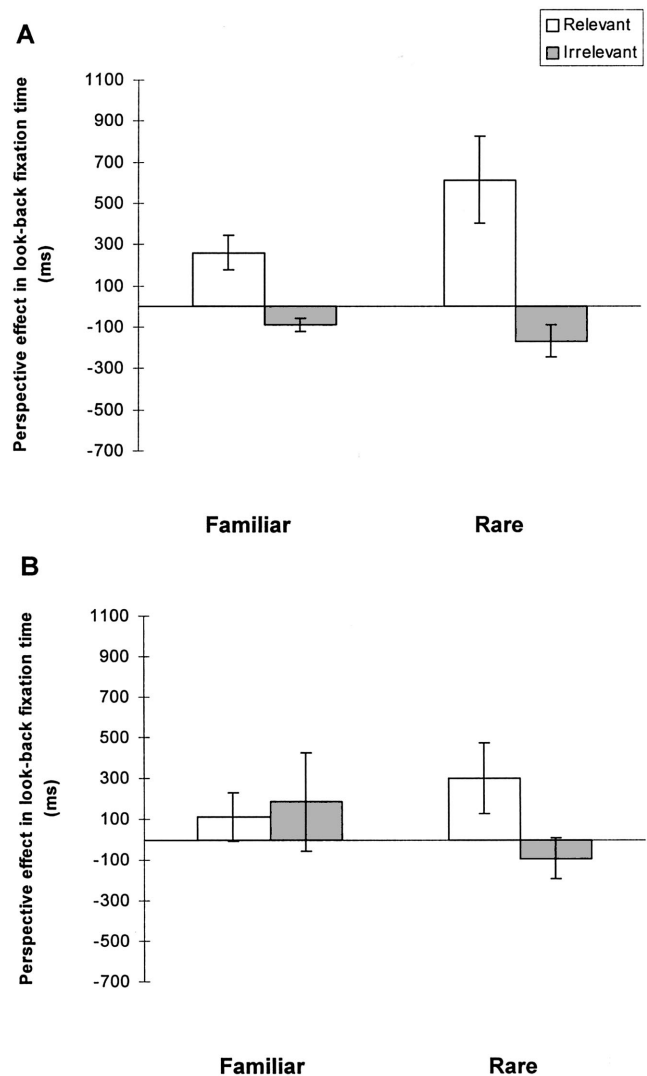


Figure 3. Differences from the baseline in the look-back fixation time (in milliseconds) for relevant and irrelevant sentences as a function of text, presented separately for low-span (A) and high-span (B) groups. Error bars represent standard errors.

that high-span readers are able to make use of their prior knowledge more efficiently during reading than low-span readers do in accord with the LT-WM view (Ericsson & Delaney, 1999; Ericsson & Kintsch, 1995), which assumes that individual differences in WMC can be explained as differences in the ability to encode to and retrieve information from long-term memory by using already existing knowledge structures.

Both low- and high-span readers showed a perspective effect in processing the rare diseases text. For the low-span readers, the perspective effect was due to faster first-pass reading of irrelevant information and to increased look-back time on relevant information. For the high-span readers, the perspective effect in the rare diseases text was a consequence of increased first-pass progressive fixation time on relevant information in text. This finding supports the notion that high-span readers are better at allocating their attentional resources to relevant information than low-span readers: They invest extra effort to relevant information already during initial reading of sentences, whereas low-span readers invest extra effort only later (Engle et al., 1999; Kaakinen et al., 2002).

Even though the capacity constrained view of comprehension (e.g., Engle et al., 1992; Just & Carpenter, 1992) might predict that the perspective effects are in general smaller in the high-prior-knowledge text than in the low-prior-knowledge text, which is exactly what we found, it does not seem to explain other aspects of our results. First of all, the span group differences did not emerge in the low-prior-knowledge text: Low-span participants did not show a larger perspective effect than high-span readers, as would have been expected if low-span readers had less capacity available and adopted a more selective encoding strategy to reduce the processing demands. Moreover, low-span participants were not generally slower readers and did not show a worse recall performance than high-span participants, as would also be expected on the basis of the capacity constrained view of comprehension.

In sum, the present study supports the theories that assume that prior knowledge influences online text processing, such as Kintsch's (1998) CI model and the resonance model proposed by Myers and O'Brien (1998), by showing that prior knowledge facilitates encoding of relevant information to memory. Moreover, our study shows that the critical link between the individual differences observed in the reading span task and online text processing are not necessarily the capacity to perform the storage and processing functions required for text comprehension (e.g., Just & Carpenter, 1992) but something else. Namely, our results suggest that the ability to use prior knowledge as suggested by the LT-WM model (Ericsson & Kintsch, 1995) and the reader's ability to efficiently control attentional resources (Engle et al., 1999) may be common factors connecting the reading span task and text comprehension.

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