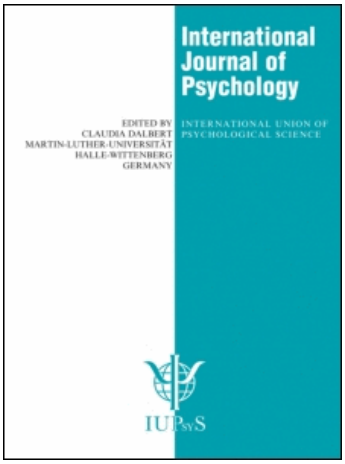

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Vertical perceptual span and the processing of visual signals in reading

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Vertical perceptual span and the processing of visual signals in reading

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A previous study by Pollatsek et al. (1993) claims that the perceptual span in reading is restricted to the fixated line, i.e. readers typically focus their visual attention on the line of text being read. The present study investigated whether readers make use of content structure signals (paragraph indentations and topic headings) present several lines away from the currently fixated line. We reasoned that as these signals are low-resolution visual objects (as opposed to letter and word identity), readers may attend to them even if they are located some distance away from the fixated line. Participants read a hierarchically organized multi-topic expository text containing structure signals in either a normal condition or a window condition, where the text disappeared above and below a vertical 3° gaze-contingent region. After reading, participants were asked to produce a written recall of the text. The results showed that the overall reading rate was not affected by the window. Nevertheless, the headings were reread more in the normal condition than in the window one. In addition, more topics were recalled in the normal than in the window condition. We interpret the results as indicating that the readers visually attend to useful text layout features while considering bigger units than single text lines. The perception of topic headings located away from the fixated line may favour long-range regressions towards them, which in turn may favour text comprehension. This claim is consistent with previous studies that showed that look-back fixations to headings are performed with an integrative intent.

Une étude précédente par Pollatsek et al. (1993) propose que l'empan perceptuel en lecture est restreint à la ligne fixée, i.e. typiquement, les lecteurs focalisent leur attention visuelle sur la ligne de texte qui est en train d'être lue. La présente étude a examiné si les lecteurs utilisent des signaux de structure de contenu (l'indentation du paragraphe et les titres thématiques) qui sont présents dans plusieurs lignes loin de la ligne qui est actuellement fixée. Nous avons argumenté que ces signaux sont des objets visuels d'une faible résolution (par opposition à l'identité de la lettre ainsi que du mot) et que les lecteurs peuvent leur allouer de l'attention même s'ils sont placés à une certaine distance loin de la ligne fixée. Les participants ont lu un texte informatif multi-thèmes hiérarchiquement organisé qui contient des signaux de structure, soit dans une condition normale soit dans une condition fenêtre, où le texte a disparu au-dessus et au-dessous d'une région verticale de 3° dépendante du regard. Après la lecture, les participants ont été invites à produire un rappel écrit du texte. Les résultats ont indiqué que, globalement, le rythme de lecture n'était pas affecté par la fenêtre. Cependant, les titres ont été relus dans la condition normale plus que dans la condition fenêtre. De plus, plus de thèmes ont été rappelés dans la condition normale que dans la condition fenêtre. Nous inteprétons les résultats comme indiquant que les lecteurs allouent de l'attention visuelle à des caractéristiques structurelles du texte qui sont efficaces tout en considérant des unités plus grandes que les lignes de texte seules. La perception des titres thématiques placés loin de la ligne fixée peut favoriser des régressions vers eux qui sont à longue portée, ce qui par la suite pourrait favoriser la compréhension

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du texte. Cette proposition est consistante avec les études antérieures qui ont indiqué que les refixations des titres sont faites avec une intention intégrative.

Un estudio anterior llevado a cabo por Pollatsek et al. (1993) mantiene que el espacio perceptivo en la lectura está restringido a la línea de fijación, ej. los lectores normalmente fijan su atención en la línea de texto que están leyendo. El presente estudio investiga si los lectores utilizan las señales de estructura del contenido (sangrías y encabezamientos) presentes varias líneas de distancia de la línea de fijación. Hemos razonado que dado que estas señales son objetos visuales de baja resolución (a diferencia de la identidad de letras y palabras), los lectores pueden atenderlos incluso si están situadas a cierta distancia de la línea de fijación. Los participantes leyeron un texto informativo multi – tema organizado jerárquicamente que contenía señales de estructura o bien en una condición normal, o bien en una condición de ventana donde el texto desaparecía por encima y por debajo de la tercera región vertical del conjunto de fijación. Después de la lectura, se pidió a los participantes que produjesen un recuerdo del texto por escrito. Los resultados demostraron que el ratio general de la lectura no se vio afectado por la ventana. No obstante, los encabezamientos fueron re-leídos más en la condición normal que en la de ventana. Además, más temas fueron recordados en la condición normal que en la de ventana. Interpretamos que los resultados indican que los lectores atendieron de forma visual las facetas útiles del diseño del texto cuando consideraban unidades más grandes que una sola línea de texto. La percepción de los encabezamientos de los temas situados fuera de la línea de fijación pueden favorecer las regresiones de gran alcance, lo cual a la vez puede favorecer la comprensión del texto. Esta afirmación es consistente con los estudios anteriores en los que se demostró que las fijaciones atrás hacia los encabezamientos se llevaban a cabo con el propósito de integración.

Keywords: Eye movements; Attention; Perceptual span; Reading; Visual signals.

When we look at the world around us, we sometimes have the impression that we can take in its full visual richness all at once. However, numerous studies have shown that, because of the limitations of both the visual system and the cognitive processing system, this impression is partly an illusion. The perceptual span, also called the visual span, refers to the region around a fixation point from which useful information can be obtained (Rayner & Liversedge, 2004). Exactly how much information can be obtained during a fixation is a question that has prompted a great deal of research, not only in the context of reading (see Rayner, 1998, for a review), but also in the context of other tasks such as scene perception (Saida & Ikeda, 1979), visual search (Bertera & Rayner, 2000), music reading (Gilman & Underwood, 2003) and playing chess (Reingold, Charness, Pomplun, & Stampe, 2001).

In reading, words are high-resolution objects that require particularly good visual acuity if they are to be identified. As visual acuity drops rapidly as the distance from the fovea increases, the perceptual span in reading is demonstrated to encompass a relatively small proportion of the entire visual field. For readers of alphabetic orthographies (e.g., English, French and Dutch) it extends horizontally, from 3–4 letter spaces to the left of fixation to about 14–15 letter spaces to the right (Rayner, 1998). This horizontal asymmetry indicates that the perceptual span depends on both acuity constraints and attentional processes. During a fixation, the readers covertly attend to the right of fixation to prepare a subsequent rightward eye movement and to preprocess the following word. This facilitates the identification of the word when it is subsequently fixated and thus speeds up the reading process (Balota, Pollatsek, & Rayner, 1985). By contrast, although visual acuity allows it, readers of English or French pay little attention to the words left of fixation, because the information entailed in this text region has already been processed. On the other hand, in orthographies such as Hebrew, which are printed from right to left, the relevant new information is located to the left of fixation, therefore the span is asymmetric to the left (Pollatsek, Bolozky, Well, & Rayner, 1981).

Of particular relevance here, Pollatsek, Raney, Lagasse and Rayner (1993) found that the span does not extend vertically below the currently fixated line. In their study Pollatsek et al. used the gaze-contingent window technique, also called the moving window technique (McConkie & Rayner, 1975; see also the abovementioned studies), to determine the visual span. In gaze-contingent window studies of reading, the text within an experimenter-defined "window" region is kept intact, but the text outside the window is mutilated in some way (e.g., all the letters are replaced by the letter 'x'). Each time the reader's gaze moves to another fixation location, the window moves to this new location too. The logic behind the use of this technique is that when the window is smaller than the visual span it will slow down reading and

possibly impair comprehension, whereas when it is as large as or larger than the span, it will not. In Pollatsek et al.'s (1993) study, the window region was restricted to the currently fixated line and the text lines below the fixated one were changed in four different ways: All the letters were replaced by (a) the letter 'x', (b) visually similar letters, (c) visually dissimilar letters, or (d) lines from another passage. The results showed that the texts were read slightly faster either when there was no window or when the letters were replaced by 'x'. The other conditions did not differ from each other. Pollatsek et al. concluded that no useful information beyond the fixated line is extracted in normal reading. This in turn suggests that readers typically focus their visual attention on the line of text being read, while ignoring information from the contiguous lines presumably because of their irrelevance to the ongoing comprehension process.

The goal of the present study was to investigate whether readers process (either preattentively or attentively) text layout features signalling the content structure of expository texts. In the case of typical expository texts, the textual information is visually and spatially organized at a level larger than single sentences or text lines. The sentences are merged into paragraphs that are in turn separated from each other by indentation, and section headings are visually and spatially distinguished from the rest of the page. Given that these signals are low-resolution visual objects (as opposed to letter and word identity information), readers are at least in principle able to perceive them and perhaps process them, even if they are located some distance away from the fixated line. Note that the texts used in Pollatsek et al.'s (1993) study did not contain any such signals.

Previous studies have shown that signals that cue the content structure of a text are very useful in processing hierarchically organized expository texts. More text topics are recalled of a multiple-topic expository text if it contains headings that systematically label the topics than if no headings are provided (Lorch, Lorch, & Inman, 1993). When the text places high demands on the readers due to a complex structure, looking back to previously read text parts plays a crucial role in integrative processing. Fixation time spent rereading and looking back in multiple-topic expository texts has proved to be positively correlated (r = .51) with text recall (Hyönä & Nurminen, 2006). Headings in particular are frequently looked back to in order to facilitate the integration of the currently processed text information with the topic it is subsumed to (Hyönä & Lorch, 2004; Hyönä, Lorch, & Kaakinen, 2002).

In the present study, participants read a hierarchically structured multiple-topic expository text. As shown in Figure 1 (normal condition), the hierarchical structure of the text content was signalled by paragraph indentation and the type of headings used. First, text paragraphs subsumed to a lower-level topic were indented more to the right than paragraphs occupying a higher status in the content hierarchy. Second, headings signalling topics low in the content hierarchy (e.g., oil spills) appeared in a smaller and different type of font than headings signalling higher-order text topics (e.g., environmental damage). The text was presented either normally (i.e., a whole text page was

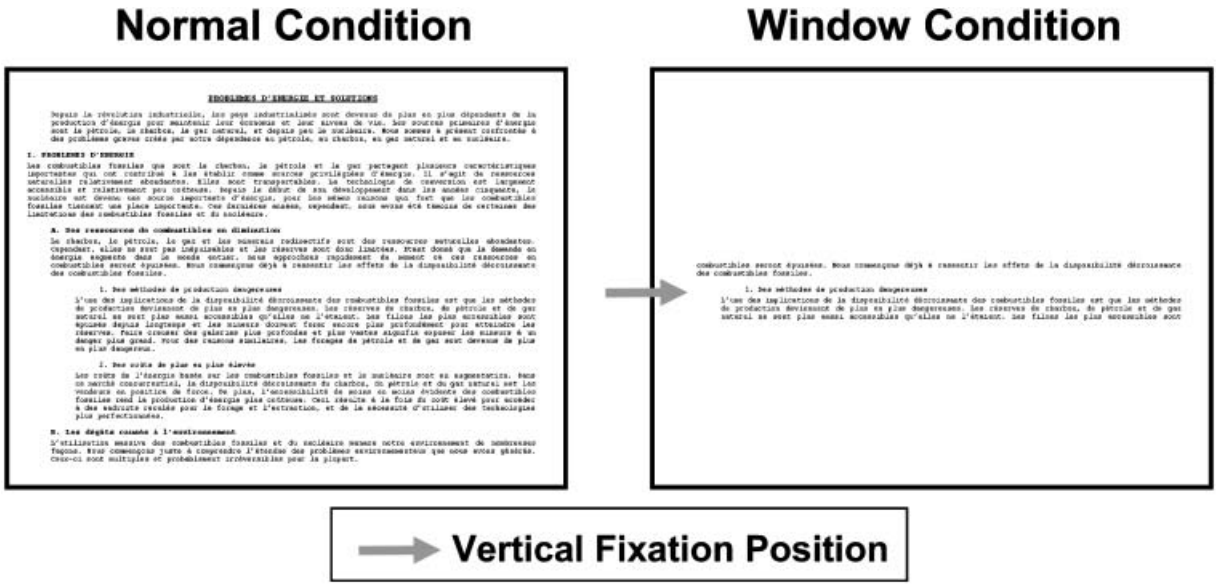

Figure 1. Illustration of the gaze-contingent window technique used in the experiment.

presented at once) or via the gaze-contingent window technique, where the text above and below a vertical 3° gaze-contingent region was always masked (i.e., in addition to the fixated text line, the reader saw about three lines above and below the fixated line). As is apparent from Figure 1, the window was not large enough to include two headings at the same time, with the result that the signals that highlighted the hierarchical structure of the text content were far less visible in the window condition than in the normal one. After the reading phase, the participants were asked to provide a written recall of the text.

If the processing operations that occur during reading are entirely restricted to the fixated line, no differences with respect to eye movement behaviour and text recall should be observed in the window condition in comparison to the normal condition. On the other hand, if readers also attend to the structure signals located away from the fixated line (i.e., beyond three lines above and below the fixated line), the window condition should bring about adverse effects in processing and/or memory for text. As stated above, headings are frequently looked back to during expository text processing. Because in the window condition long-range saccades cannot be accurately targeted, we expected a lower number of look-backs to headings in the window condition in comparison to the normal condition. In addition, if look-backs to headings indeed improve text integration (Hyönä et al., 2002; Hyönä & Lorch, 2004; Hyönä & Nurminen, 2006), a lower number of look-backs to headings in the window condition should lead to a poorer recall of the text in comparison to the normal condition. Finally, it is also possible that readers process visual signals only preattentatively or by covert attention. If so, the eye movement records indexing overt shifts of attention would not be different between the two text presentation conditions. On the other hand, if such processing is sufficient to enhance the processing of the text's content structure, a difference may be predicted in text memory.

METHOD

Participants

A total of 59 university students were given movie theatre tickets in exchange for taking part in this study. Three participants had to be excluded due to poor calibration. The ages of the remaining 56 participants ranged from 18 to 31 years, with a mean age of 22 years. Forty-one participants were women. They were all skilled readers and native French speakers, with normal uncorrected vision.

Apparatus

The texts were presented on an LG Flatron L2010P 20-inch monitor interfaced with an HP Compaq Pentium IV computer, which in turn was interfaced with an Applied Science Laboratories Model 504 eyetracker. The monitor had a 60-Hz refresh rate. The eyetracker was a remote infrared video-based tracking system placed below the monitor. The camera sampled pupil location and pupil size at the rate of 50 Hz (i.e., 20 ms temporal resolution).[1] Registration was monocular. Head movements were restricted by means of a chinrest, so that measurements were spatially accurate to within 0.5°. The distance between the participant's eyes and the screen was held constant at 80 cm. At this distance, a character subtended horizontal and vertical visual angles of .22° and no more than .30° respectively, and the whole screen covered about 27° horizontally and 21° vertically. The gaze-contingent window, which subtended a vertical visual angle of exactly 3.2°, was continually centred on the participant's current gaze position with one restriction. Once the window was centred on a fixation, the centre of the window remained on the same text line for as long as the new fixations remained within a vertical distance of 1 cm (0.7°) from the centre of the window. As soon as a fixation moved beyond this margin of tolerance, the window immediately centred itself on this new location. The goal of this procedure was to suppress a potential flicker effect caused by microsaccades, drift or small inaccuracies in the eye signal.

Materials

Two expository texts were adapted from a previous study (Klusewitz & Lorch, 2000) and translated into French. One text was about energy use, the other about fire-fighting. Both texts discussed 12 core topics and were hierarchically organized into three structural levels. The 12 core topics (e.g., oil spills, global warming, and acid rain) constituted the lowest hierarchical level (i.e.,

[1]The temporal resolution of the eyetrackers used in eye-contingent display change studies is usually more fine-grained. These devices usually sample the signal every millisecond, whereas ours only sampled it every 20 ms. A coarse sampling rate is obviously not ideal for carrying out eye-contingent display change studies, but the window used in this study was large enough to avert any major problems in this respect.

the subsections). The second hierarchical level comprised five sections (e.g., environmental damage), each containing two or three core topics. These sections combined to form two main sections (e.g., energy problems and alternative energy sources), forming the highest hierarchical level. Each text began with a general title and a short introduction.[2]

Several visual devices were used to emphasize the hierarchical topic structure of the text. Each section and subsection was labelled by a heading, which explicitly identified its topic. The hierarchical level of each section was visually signalled by typographical (font size and type) and spatial devices (degree of indentation). The two headings at the highest hierarchical level were capitalized and boldfaced; moreover, they were marked with Roman numerals (i.e., I and II). The five headings at the intermediate level were boldfaced but not capitalized; moreover, they were marked with capital letters (i.e., A, B, C, D and E). The 12 headings at the lowest level were neither capitalized nor boldfaced, but were numbered using Arabic numerals. The lower the hierarchical level of the section, the more we increased the spatial indentation of the heading and the body of the text (see Figure 1).

Each text occupied three full screen pages and was approximately 1,500 words in length (approximately 8,500 characters). In addition to the two experimental texts, a short practice text about the geographical and economic characteristics of Brazil was drafted. It occupied two full screen pages and was approximately 650 words in length.

Prior to the experiment proper, the reading span test (Daneman & Carpenter, 1980) was administered to the participants in order to rule out the possibility that the two experimental groups would differ in working memory capacity. A French-language version of the test was used (Desmette, Hupet, Schelstraete, & Van der Linden, 1995). In the test, participants read aloud sets of unrelated sentences. After reading the sentences of a particular set, they had to recall the last word of each of these sentences. The test began with a set of two sentences, and the set size increased as long as the participant successfully recalled the sentences' final words. Three repetitions of each set size were successively administered to the participants (the set-sizes ranged from two to six sentences in maximum). The test was scored for the total number of correctly recalled final words.

[2]English translations of the texts are available on request from the authors.

The participants were then assigned at random to the normal vs. window condition, and to the energy vs. fire-fighting text, with the restriction that an equal number participated in each of the four resultant conditions. The eyetracker was calibrated using a nine-point calibration grid that covered the entire computer screen. The participants were instructed to read the text carefully and at their own pace so that they understood it properly, as they would subsequently be required to "answer questions about the text". Participants turned the pages of the text by pressing a mouse button. Before a new text page was displayed, a white page with a cross in the top left-hand corner was displayed. As soon as the participant's gaze moved to this cross, a new text page was automatically displayed. The location of the cross in these intermediate pages (i.e., at the top-left corner) ensured that the readers fixated the beginning of each new text page once it appeared. The practice text was read in the same display condition (i.e., window or normal) as the following experimental text. This practice session served to familiarize the participants with the eye-tracker and with the eye-contingent text window presentation. No recall of the practice text was requested.

After reading the experimental text, the participants were instructed to write down everything they could remember from it. They were told they could have as much time as they wanted. At the end, they were asked to fill in a brief questionnaire to record their age and sex and to assess their knowledge of the text's subject. An item in the questionnaire asked participants to rate their knowledge of the subject matter in the last text they had read (i.e., the energy text or the fire-fighting text). The experiment lasted approximately 50 min.

RESULTS

All the dependent measures were submitted to a 2 (window vs. normal) × 2 (energy text vs. fire-fighting text) between-subjects analysis of variance (ANOVA). The experimental groups showed no difference in their reading span scores or in their self-reported knowledge of the text's subject, as indicated by the lack of any significant effect of the two factors (all F values<1). Interaction between the window and the text factor never approached significance. Hence, for the sake of brevity, the means for the energy and fire-fighting texts have been aggregated in Table 1 (the means separately for both texts may be requested from the authors).

TABLE 1
Recall and eye movement results for the window and normal conditions

	Normal condition		*Window condition*		
	M	*SE*	*M*	*SE*	*Diff.*
Recall measure					
Topic recall (%)	.58	.04	.41	.03	.17**
Global eye movement measures					
Total fixation time	413,576	18,977	393,048	18,377	20,528
Total number of fixations	1,311	68	1,223	34	88
Probability of regression	.24	.01	.25	.01	−.01
Average saccade length (°)	.95	.01	.95	.01	0
Local eye movement measures					
First-pass time on headings	23,609	1,306	23,491	1,177	118
Number of first-pass fixations on headings	67	3	69	3	−2
Second-pass time on headings	7,070	1,059	3,486	694	3,584**
Number of second-pass fixations on headings	30	7	14	3	16*
Total fixation time on headings	30,679	1,499	26,977	1,583	3,702
Total number of fixations on headings	97	7	83	5	14

All fixation times are in ms. $n = 28$ in both conditions. * $p<.05$; ** $p<.01$.

All reported results were significant at the .05 level unless otherwise stated.

Recall results

The participants' recall performances were computed using the procedure of Lorch et al. (1993). The energy and fire-fighting texts were divided into idea units corresponding roughly to the main clauses of the sentences. The topic recall measure indexes the percentage of idea units the participants could remember of the 12 topics constituting the core content of the text. We deemed a topic correctly recalled either when it was explicitly referred to or when at least one of its idea units was recalled. The means of the topic recall measure are presented in Table 1. In order to assess scoring reliability, two raters independently scored 14 recall protocols. Agreement between the two raters on the specific topics recalled was good ($\kappa = .90$). The ANOVA computed on the topic recall measure yielded a significant effect of the window factor, $F(1, 57) = 10.55$, $MSE = .417$, $p<.01$. The participants recalled fewer topics after reading a text in the window condition ($M = .41$) than in the normal one ($M = .58$).

Eye movement results

Both global and local measures were computed on the basis of the eye movement data. Global measures include total fixation time, total number of fixations, probability of regressions, and average saccade length (Rayner, 1998). Local measures were computed with respect to the critical regions of interest, namely the text headings. These include first-pass fixation time, number of first-pass fixations, second-pass fixation time, number of second-pass fixations, total fixation time and total number of fixations (Rayner, 1998). The fixations landing on a region of interest (i.e., a heading) from the first fixation in the region until moving out of it were defined as first-pass fixations, whereas fixations that went back to the region in order to reread its content were defined as second-pass fixations.[3] Less than 3% of the data were lost due to track loss.

Global measures

The means of the overall measures are reported in Table 1. The analysis of total fixation time, total number of fixations, probability of regression, and average saccade length failed to yield any significant effect (all F values <1.9, all p values $>.17$).

Local measures

The analysis of the first-pass fixation time spent on headings revealed a main effect of text, $F(1, 57) = 8.56$, $MSE = 329{,}800{,}179$, $p<.01$, as did the analysis of the number of first-pass fixations on headings, $F(1, 57) = 11.13$, $MSE = 1{,}897$, $p<.01$. The headings in the energy text were read with more first-pass fixations and more first-pass time ($M = 74$ and $M = 25{,}976$, respectively) than the headings in the fire-fighting text ($M = 62$ and $M =$

[3]Second-pass fixations are sometimes referred to as look-back fixations in the literature (Hyönä et al., 2002; Hyönä & Lorch, 2004; Hyönä & Nurminen, 2006).

21,123, respectively). However, an additional analysis showed that this text effect could be entirely attributed to the fact that the headings in the energy text contained slightly more characters (570) than the headings in the fire-fighting text (472). The text effect indeed disappeared when we adjusted the number of first-pass fixations and the first-pass time by the number of characters in the corresponding headings (both F values <1).

Of more relevance here, the analysis of the second-pass fixation time spent on headings yielded a main effect of the window factor, $F(1, 57) = 7.99$, $MSE = 179{,}780{,}612$, $p<.01$, as did the analysis of the number of second-pass fixations on headings, $F(1, 57) = 4.54$, $MSE = 3{,}779$, $p<.05$. As can be seen in Table 1, headings were reread with less second-pass time and fewer second-pass fixations in the window condition ($M = 3{,}486$ and $M = 14$, respectively) than in the normal one ($M = 7{,}070$ and $M = 30$, respectively).

The analysis of the total fixation time spent on headings and the total number of fixations on headings failed to reveal any significant effects (all F values <2.9, all p values $>.1$).

DISCUSSION

The goal of the present study was to investigate whether readers process text layout features, present in the visual periphery, that signal the content structure of complex expository texts (i.e., paragraph indentations and topic headings). This was done by employing the gaze-contingent window paradigm where all text approximately three lines above and below the currently fixated line was masked. The results did not reveal any pervasive effects of text presentation (i.e., window vs. normal presentation) on online processing measures. In particular, the overall reading rate was not affected by the text window. However, predicted differences appeared with respect to topic headings. First, headings were looked back to more in the normal condition than in the window one (in respect to both look-back fixation time and number of look-backs). Second, more topics were recalled of the texts in the normal than in the window condition.

We interpret the absence of pervasive effects of text presentation on online processing measures as suggesting that *most* of the processing operations carried out by the readers are restricted to the fixated line or near it (the text window included three lines on both sides of the fixated line). However, the look-back data indicate that readers do allocate attention to headings located more than three lines away from the fixated line, in order to prepare long-range saccades towards them, which makes possible their reprocessing. Paying attention to topic headings is advantageous when reading complex expository texts, as look-back fixations to headings have proved to be performed in the service of integrative processing of text information subsumed to the text topic signalled by the heading (Hyönä et al., 2002; Hyönä & Lorch, 2004; Hyönä & Nurminen, 2006). The finding that text recall was better in the normal condition than in the window one, where there was a smaller number of look-backs, is indeed consistent with the idea that look-back fixations to headings are performed with an integrative intent.

To conclude, in the absence of pervasive effects of the text window on online measures, the present data do not contradict Pollatsek et al.'s (1993) claim that readers typically focus their visual attention on the currently fixated line of text (i.e., that the perceptual span in reading is restricted to the fixated line). Rather, our data suggest that letter and word information present in the fixated line is not the only source of visual information processed by the readers. The readers also attend to useful text layout features while considering bigger units than single text lines. This finding fits favourably with scene perception studies which have provided evidence that observers process individual scene objects as well as a scene's overall spatial layout (e.g., Sanocki, 2003).

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REFERENCES

Balota, D., Pollatsek, A., & Rayner, K. (1985). The interaction of contextual constraints and parafoveal visual information in reading. *Cognitive Psychology*, *17*, 364–390.

Bertera, J. H., & Rayner, K. (2000). Eye movements and the span of the effective stimulus in visual search. *Perception & Psychophysics*, *62*, 576–585.

Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior*, *19*, 450–466.

Desmette, D., Hupet, M., Schelstraete, M. A., & Van der Linden, M. (1995). Adaptation en langue française du 'Reading Span Test' de Daneman et Carpenter (1980). *L'Année Psychologique*, *95*, 459–482.

Gilman, E., & Underwood, G. (2003). Restricting the field of view to investigate the perceptual spans of pianists. *Visual Cognition*, *10*, 201–232.

Hyönä, J., & Lorch, R. F. (2004). Effects of topic headings on text processing: Evidence from adult

readers' eye fixation patterns. *Learning and Instruction*, *14*, 131–152.

Hyönä, J., Lorch, R. F., & Kaakinen, J. K. (2002). Individual differences in reading to summarize expository text: Evidence from eye fixation patterns. *Journal of Educational Psychology*, *94*, 44–55.

Hyönä, J., & Nurminen, A. M. (2006). Do adult readers know how they read? Evidence from eye movement patterns and verbal reports. *British Journal of Psychology*, *97*, 31–50.

Klusewitz, M. A., & Lorch, R. F. (2000). Effects of headings and familiarity with a text on strategies for searching a text. *Memory & Cognition*, *28*, 667–676.

Lorch, R. F., Lorch, E. P., & Inman, W. E. (1993). Effects of signaling topic structure on text recall. *Journal of Educational Psychology*, *85*, 281–290.

McConkie, G. W., & Rayner, K. (1975). The span of the effective stimulus during a fixation in reading. *Perception & Psychophysics*, *17*, 578–586.

Pollatsek, A., Bolozky, S., Well, A. D., & Rayner, K. (1981). Asymmetries in the perceptual span for Israeli readers. *Brain and Language*, *14*, 174–180.

Pollatsek, A., Raney, G. E., Lagasse, L., & Rayner, K. (1993). The use of information below fixation in reading and in visual search. *Canadian Journal of Experimental Psychology*, *47*, 179–200.

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin*, *124*, 372–422.

Rayner, K., & Liversedge, S. (2004). Visual and linguistic processing during eye fixations in reading. In J. M. Henderson & F. Ferreira (Eds.), *The interface of language, vision, and action: Eye movements and the visual world* (pp. 59–104). New York: Psychology Press.

Reingold, E., Charness, N., Pomplun, M., & Stampe, D. M. (2001). Visual span in expert chess players: Evidence from eye movements. *Psychological Science*, *12*, 48–55.

Saida, S., & Ikeda, M. (1979). Useful visual field size for pattern perception. *Perception & Psychophysics*, *25*, 119–125.

Sanocki, T. (2003). Representation and perception of scenic layout. *Cognitive Psychology*, *47*, 43–86.