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Do adult readers know how they read? Evidence from eye movement patterns and verbal reports

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The present study was carried out to investigate individual differences in reading styles among competent adult readers and to examine whether readers are aware of their reading style. Individual reading strategies were studied by having the participants read a long expository text while their eye fixation patterns were registered. A cluster analysis was performed on the eye movement data to distinguish between different reading styles. The analysis revealed three types of readers that were coined, following Hyönä, Lorch, and Kaakinen (2002), fast linear readers, slow linear readers, and topic structure processors. Readers' procedural awareness of their reading behaviour was assessed by a questionnaire. The verbal reports obtained by the questionnaire were then correlated with the corresponding eye behaviour to investigate the extent to which the readers behave the way they report doing. The correlations showed that adult readers are well aware of their general reading speed and reasonably aware of their lookback and rereading behaviour. The amount of time spent looking back in text also correlated positively with the relative success in recalling the main points expressed in the text. It is concluded that systematic and extensive looking back in text is indicative of strategic behaviour.

The present study was carried out to examine (1) individual differences in reading styles among competent adult readers, and (2) the degree to which readers are consciously aware of their reading style. It stands at the crossroad of two research traditions – one that has evolved within cognitive psychology and another that is characteristic of the reading research done within the domain of educational psychology. In cognitive psychology, mental processes related to reading have been intensively investigated during the past two decades using different kinds of on-line measurements (for a review, see e.g. Kieras & Just, 1984), such as readers' eye movement recordings (for a review, see Rayner, 1998). This line of research has led to the development of detailed processing models depicting how competent readers recognize words, parse the syntactic structure of sentences, and make inferences on-line. These studies have primarily concentrated on mental processes characteristic of all or most adult readers.

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Moreover, reading-related mental processes have typically been studied by presenting to the participants relatively short texts comprising no more than a few sentences. This is understandable as the focus has been on relatively micro-level analyses of reading behaviour.

In educational psychology, on the other hand, the focus has been more on the differences between competent and less competent readers (see e.g. Jenkins, Fuchs, van den Broek, Espin, & Deno, 2003; Oakhill & Beard, 1999; Stanovich, 1982a, 1982b), and how to promote reading proficiency and efficient reading strategies among readers of different ages and skill levels (see e.g. De Corte, Verschaffel, & van de Ven, 2001; Garner, 1987; Paris & Oka, 1986). Moreover, in this research tradition, it has also been fairly common to make inferences about the actual reading processes on the basis of off-line measures, such as verbal reports, structured interviews, or free recalls collected after reading (for a review, see Pressley & Afflerbach, 1995). In contrast to the cognitive research tradition, in educational psychology longer texts (e.g. authentic textbook passages) are typically used as the study materials. This has the consequence that more strategic components of reading are tapped into than in the cognitive research that has concentrated on more automatized processes.

We think the time is ripe to start integrating these two research traditions in order to arrive at a more comprehensive understanding of reading as a cognitive skill (for a similar argument, see Lorch & van den Broek, 1997). The specific objective of the present study was to examine individual reading strategies by using both an on-line (eye tracking) and an off-line (verbal reports) measure. We were particularly interested in examining the degree to which readers are aware of specific aspects of their own reading behaviour, particularly the act of reinspecting previously read text (see below for the motivation of this choice). Recording of readers' eye movement patterns is very well suited to study spontaneous reading strategies, (1) because eye movements are a necessary and integral part of normal reading, (2) because the method allows the readers to freely inspect the text in the way they find it appropriate and suitable, and (3) because it yields a temporally and spatially precise record of where readers look in the text and how long they inspect different text regions.

To date, on-line studies of individual reading strategies are scarce. Goldman and Saul (1990) studied on-line reading strategies among college students using a procedure where the reader proceeded in the text by pressing with the computer mouse on the sentence s/he wanted to read. Only one sentence was visible at a time (other sentences were visually masked). Each text was presented on the same computer screen; thus the texts were relatively short. Goldman and Saul distinguished three global reading styles and several more specific strategies. Here we focus only on the more global reading styles (for local reading strategies, see also Aaronson & Ferres, 1984; Graesser, Haberlandt, & Schneider, 1989; Olson, Kliegl, Davidson, & Foltz, 1985; for reading strategies of older readers, see Stine, 1990; Soederberg Miller & Stine-Morrow, 1998). One global strategy was to read the text linearly once through without looking back in text. The second strategy was one, where readers first read the text through, after which they reread parts of it. Readers adopting the third strategy made look-backs also prior to reaching the end of the text.

Hyönä *et al.* (2002) registered university students' eye movement patterns while they read two similarly structured long expository texts in preparation to write a summary of the text. To distinguish between different reading styles, a cluster analysis was performed on the eye movement measures. The following sentence-level eye movement measures were employed: the progressive first-pass fixation time, the

rereading fixation time, and the look-back fixation time (see Hyönä, Lorch, & Rinck, 2003, for further details). The progressive fixation time is the sum of fixations landing on an unread part of the sentence when first passing through it. Thus, this measure reflects an immediate encounter with each new sentence in the text. For the rereading fixation time measure, the durations of fixations that are made back to a previously read part of a sentence prior to going to the next sentence are summed up. This measure reflects the immediate reprocessing of each sentence. Finally, the look-back fixation time is the summed duration of fixations that land on a previous sentence that has once been fully read. As discussed further below, the look-back fixations presumably reflect the most strategic aspect of readers' eye behaviour.

Hyönä *et al.* (2002) computed these eye movement measures separately for different types of sentences in the text's content structure. The two expository texts used consisted of multiple, relatively independent subtopics subsumed under one main topic. One of the texts, the endangered species text comprised 10 subtopics, each of which discussed in two text paragraphs an endangered animal. Each subtopic was signalled with a topic heading. The first sentence of each paragraph (the *topic sentence*) conveyed a key statement that was then elaborated in the remaining part of the paragraph.

Using cluster analyses, Hyönä *et al.* (2002) distinguished four groups of readers among their adult reader sample. These groups were coined *fast linear readers, slow linear readers, topic structure processors*, and *non-selective reviewers*. What was common to the linear readers was the almost total absence of look-back fixations. The slow linear readers were distinguished from the fast ones by making many more rereading fixations prior to moving to the next sentence. Unlike the linear readers, the topic structure processors and the non-selective reviewers made frequent look-backs to earlier parts of the text. The two reader groups differed in that topic structure processors showed sensitivity to the text's content structure by looking back primarily to the topic headings and the topic sentences (i.e. the main points), whereas the look-backs of the non-selective reviewers were more evenly distributed across the different type of sentences. The adopted reading style had consequences for the mental representation constructed of the text. The text summaries written by the topic structure processors reflected most faithfully the text contents, whereas the poorest summaries were written by the slow linear readers.

Linear readers of Hyönä *et al.* (2002) closely correspond to one of the three global reading styles of Goldman and Saul (1990); readers who read the text linearly from top to bottom without looking back. The other two global reading styles of Goldman and Saul were characterized by making look-backs in text; the readers who reread the text (or a significant part of it) after once reading it through resembles the reading style of non-selective reviewers of Hyönä *et al.* On the other hand, as Goldman and Saul used rather short texts, a reading style equivalent of topic structure processors cannot be readily established.

Concerning individual differences in reading behaviour among competent adult readers, the study of Hyönä *et al.* (2002) points to two key dimensions: one is the speed with which each sentence is read for the first time, and the other is the look-back behaviour (i.e. the frequency of look-backs and their destination; see also Goldman & Saul, 1990). Although Hyönä *et al.* found the reading style to be consistent within each reader (most readers were assigned to the same reader group using the eye movement data for another, similarly structured text), it is less clear whether the same reader groups could be established using another sample of adult readers. Thus, the first aim of

the present study was to try to replicate the results of Hyönä *et al.* using a new sample of adult readers. To replicate Hyönä *et al.*, a 4-cluster solution should give us (a) two reader groups (i.e. two groups of linear readers) who make very little look-backs and show little sensitivity to the text's topic structure in their look-back behaviour (they would differ from each other in the amount of time spent reading the text sentences for the first time), and (b) two reader groups (topic structure processors and non-selective reviewers) who make frequent look-backs in text (they should differ in one group making look-backs particularly to topic sentences and headings, whereas the other group should distribute the look-backs relatively evenly between the different types of sentences). Finally, as a further validation of the reader groups, topic structure processors should demonstrate the most comprehensive internal representation of the subtopics and main points mentioned in the text.

The second aim was to examine how conscious readers are about their own style of reading. Are they aware of their reading speed in relation to their peers? Are look-back fixations (or the lack thereof) a result of conscious decisions (i.e. a form of strategic behaviour) in that readers can adequately report their actual behaviour? Or is the observed reading style rather an automatized routine developed during the course of skill development?

To call a mental procedure a strategy, the following criteria should be met (see Alexander, Graham, & Harris, 1998): the procedure should be purposeful, effortful, wilful, essential, and facilitative. Look-back behaviour seems to meet most of these criteria. Think-aloud studies reviewed by Pressley and Afflerbach (1995) show that competent readers do report looking back in text for various reasons. What is particularly relevant in the present context is that some readers report looking back to topic sentences to ensure that they have understood the text and can remember the main points conveyed in the text. Thus, the review of Pressley and Afflerbach suggests that look-backs are purposeful and wilful behaviour. (According to their review, competent readers also appear to be able to provide verbal comments on their reading speed.) However, as Pressley and Afflerbach point out, the validity of the verbal reports may be questioned, as only few attempts are made to relate them to objective performance (Fletcher, 1986; Olson, Duffy, & Mack, 1984; Trabasso & Suh, 1993; for the need of triangulation of on-line and off-line measures, see also Graesser, Bertus, & Magliano, 1995). Particularly relevant in the present context is the study of Alexander, Hare, and Garner (1984), who investigated the look-back behaviour when answering text-based questions. They found that during question answering, less than half of the undergraduate students returned to a previous sheet that contained the answer to the question. More interestingly, most of the ones who did look back to a previous page also reported doing so – a finding consistent with the view that look-backs index strategic behaviour. Other, albeit indirect, evidence in support of the strategic nature of look-backs comes from developmental studies that demonstrate the occurrence of text look-backs to be indicative of more mature comprehension and reading skills (August, Flavell, & Clift, 1984; Garner, 1982; Garner, Macready, & Wagoner, 1984; Garner & Reis, 1981; Garner, Wagoner, & Smith, 1983; Hahn & Smith, 1983; Kinnunen, Vauras, & Niemi, 1998). These studies support the strategic nature of look-backs on the assumption that proficient readers demonstrate more strategic (i.e. purposeful) behaviour than less proficient readers do.

By definition, look-backs are effortful in the sense that they 'require an added commitment of time and consume mental resources' (Alexander *et al.*, 1998, p. 131). Finally, they are facilitative as they improve memory for text contents (Hyönä *et al.*,

2002) and the success in answering text-based questions (Alvermann, 1988; Bossert & Schwantes, 1995; Garner, 1982, 1984; Garner & Hare, 1984; Garner, Hare, Alexander, Haynes & Winograd, 1984).

In the present study, we presented a group of 44 university students the endangered species text adopted from Hyönä *et al.* (2002). To distinguish between different reading styles, a cluster analysis was performed on the eye fixation measures mentioned above. After reading the text, the participants filled in a questionnaire, where they were asked to report on specific aspects of their general reading behaviour (no reference was made to the text just read). We chose to collect the verbal reports after reading rather than during reading in order to be able to record readers' spontaneous reading behaviour. Had we asked the readers to report on their behaviour during reading, it is probable that it would have affected their performance. In the questionnaire, we asked the participants to evaluate their reading speed, the frequency with which they typically reread a sentence before moving to the next, and the frequency with which they look back in text in general and to specific text segments, such as headings and topic (i.e. paragraph-initial) sentences. These reports were then correlated with the actual reading behaviour of each participant. At the end of the test session, participants wrote a summary of the main points mentioned in the text.

We expected to find the same reading styles observed by Hyönä *et al.* (2002). Moreover, we reasoned that if look-backs are strategically governed, then we should find a strong correlation between the verbally reported (i.e. conscious) and observed look-back behaviour. Furthermore, if look-backs facilitate comprehension, then there should be a positive correlation between the amount of time spent looking back in text and in the amount of relevant text information recalled.

Method

Participants

Forty-four students of the University of Turku participated in the study (33 female, 11 male). The study participants were either volunteers or received course credit for their participation. All had normal or corrected-to-normal vision and had Finnish as their native language.

Apparatus

Eye movements were collected by the EyeLink I eyetracker manufactured by SR Research Ltd. (Toronto, Ontario, Canada). The eyetracker is an infrared video-based tracking system combined with hyperacuity image processing. The two cameras (one for each eye) sample pupil location and pupil size at the rate of 250 Hz. Registration was done monocularly (typically using the right eye). The spatial resolution of eye position is 15 seconds of arc and the spatial accuracy better than 0.5° of arc.

Text

Because Hyönä *et al.* (2002) observed the cluster assignments to be very stable across two similarly structured texts (the cluster assignment of the few subjects who were clustered differently for the two texts changed between the two linear reader groups), we used only one text, the endangered species text that was adopted from Hyönä *et al.*. The text was written in Finnish with the help of wildlife encyclopaedias. The text described 10 species whose existence has recently become threatened for different

reasons. The text began with a short introduction, and then discussed the 10 topics organized into two major sections. The first major section was on endangered birds, and it discussed five birds (lesser white-fronted goose, falcon, white-tailed eagle, parrot, and penguin), each in its own section. The second major section was on endangered mammals, and it consisted of a discussion of five endangered mammals (flying squirrels, pandas, whales, bats, and spotted cats). Each text topic was preceded by a heading that labelled the topic, and each topic was developed in two paragraphs, each of which discussed a different aspect of the topic. The sentences of each topic paragraph were categorized into topical (paragraph-initial), paragraph-final, and paragraph-medial sentences. The topic sentences were somewhat shorter (8.5 words, 73.3 characters) than the medial (10.7 words, 86.4 characters) and final (10.4 words, 87.9 characters) sentences. Each topic sentence mentioned a main point that was subsequently elaborated in the remaining part of the paragraph. The text ended with a short conclusion section. The text was presented double-spaced on the computer screen, with a maximum of 12 lines of text at a time. Each subtopic was presented on a separate page. In total, the text consisted of 12 pages and 1,319 words.

Questionnaire

The participants were told that the questionnaire was designed to look for individual reading styles. The participants were instructed to respond to the questions on the basis of their own reading behaviour as they see it rather than based on their reflections on how a good reader should read a text. No reference was made to the text they had just read. As the first part of the questionnaire, the participants were asked to freely describe their reading behaviour. This question served the purpose of activating readers' meta-cognitive knowledge that could then brought to bear on answering the subsequent questions. These descriptions were not analysed, as the information they contained was redundant with the more detailed questions that followed.

The participants were asked to assess their general reading speed by marking in a 10 cm line the position where they think they stand in relation to other adult readers (left end = very slow; right end = very fast; the middle position was marked with 0). The reading speed estimate was the length in mm from the middle position of the line to the marked position (positions to the left obtained a negative value).

The next test question concerned rereading and look-back behaviour, which was assessed using a 6-point Likert scale (1 = very appropriate description of my behaviour; 6 = does not at all match my behaviour). The participants responded to the following statements (English translations of the original test items are given):

(1)   I reread single words.
(2)   I reread each sentence before moving to the next.
(3)   I reread sections larger than a single sentence.
(4)   I look back to the initial sentences of text paragraphs.
(5)   I look back to headings.
(6)   As a habit, I look back non-selectively in text.
(7)   I return to text regions that I would like to learn and memorize.
(8)   I return to text regions I have had problems understanding during the first reading.

Text summaries

After reading, the participants were asked to write down on paper the main points mentioned in the text. The text summaries were scored by giving two points for each

mention of a species name. An additional point was credited for each main point mentioned in the text for each subtopic (i.e. the main content of the two topic sentences, and an additional piece of text information that was considered relevant). Thus, with 10 subtopics, the maximum score was 50. As apparent from the above description, the rating was geared to reflect readers' internal representation of the subtopics and the main points mentioned in the text. The participants were encouraged to just list the main points without worrying about the internal coherence of their summary. They could spend as much time as they wished to write the summary; the length of the summary was also unlimited.

Procedure
The eye tracker was first calibrated, after which the participants read the instructions presented on the computer screen analogously to the experimental text. They were asked to read the text at their own pace in order to be able to write a summary of the main points of the text. They were free to go back in text as they wished, but for technical reasons, returning to a previous page was not possible. To proceed to the next page, they were instructed to press a key in the gamepad. Prior to each new page, a fixation point appeared on the upper left corner of the screen. The participant looked at the point, and the eye tracker automatically adjusted the calibration if necessary. After reading the text, the participants filled in the questionnaire. As the final part of the study, they wrote a summary of the text. The test session lasted approximately for 1 hour.

Results

Cluster analysis
Cluster analysis groups together individuals who are maximally similar to each other on selected characteristics. We used cluster analysis (Ward's method) to categorize readers on the basis of standardized sentence-level eye fixation measures: progressive first-pass fixation time; rereading fixation time; and look-back fixation time (see also Hyönä *et al.*, 2003). The progressive first-pass fixation time is the summed duration of fixations landing on an unread part of a sentence during the initial encounter with the sentence; the rereading fixation time is the time spent reinspecting parts of a sentence prior to moving to the next; the look-back fixation time is the summed duration of fixations going back to previously read sentences.[1]

We considered a 2-, 3- and 4-cluster solution. Following Hyönä *et al.* (2002), we initially opted for a 4-cluster solution. However, we eventually selected the 3-cluster solution because the 4-cluster solution yielded one cluster with a single group member (her reading behaviour closely resembled that of non-selective reviewers in Hyönä *et al.*, 2002). As described in more detail below, the three reader groups that emerged from the cluster analysis closely match with the descriptions provided by Hyönä *et al.* for fast linear readers ($N = 8, 18\%$), slow linear readers ($N = 29, 66\%$), and topic structure processors ($N = 7, 16\%$). (In the 2-cluster solution, the linear readers were grouped together, while the topic structure processors and one non-selective reviewer formed the other group.)

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[1] *We also conducted a cluster analysis, where the fixation frequencies were entered in the analysis, in addition to the fixation durations, but it did not make any difference in the observed clustering of the participants.*

There were two main differences across the studies. First, there was a difference in the cluster sizes between the fast and slow linear readers. In Hyönä *et al.* the fast linear readers comprised 48% of the participants, while the slow linear readers comprised 28% of the readers. In the present study, the slow linear readers formed the largest cluster. On the other hand, the relative size of the topic structure processor cluster is comparable across the two studies (Hyönä *et al.* found 7 topic structure processors in their sample of 40 readers). Second, in the present study the non-selective reviewer cluster did not come out, although the reader forming the fourth cluster in the 4-cluster solution closely resembled the readers constituting the non-selective reviewer group in Hyönä *et al.* (she made an extensive number of look-back and rereading fixations).

The reliability of the clustering was tested by randomly creating 10 split-half samples and recomputing the cluster analysis for these subsamples. All cluster solutions were identical to the one performed for the complete sample in that each subject always grouped into the same cluster as in the main analysis. When the non-selective reviewer (i.e. the subject who formed the single-member cluster in the 4-cluster solution) was chosen to the split-half sample, she formed a separate cluster already in the 3-cluster solution (in that case the two other clusters were linear readers and topic structure processors).

In the following, we describe in more detail the eye movement behaviour of the three reader groups. The eye movement measures are presented separately for the following text regions (averaged over the 10 subtopics): the topic heading, the initial (i.e. topic) sentence of the first and second paragraph of each subtopic, the medial sentences of the first and second paragraph, and the final sentence of the first and second paragraph.

To examine whether the three reader groups devoted the fixation time differently across the text regions, analyses of variance (ANOVAs) were performed on the eye movement parameters using sentence type (topic, medial, end) and paragraph (first versus second) as within-subject variables and the reader group as a between-subject variable. Of particular interest was the reader group × sentence type interaction, which was expected to obtain at least for the look-back fixations (see Hyönä *et al.*, 2002). As topic headings are significantly shorter than all other text regions, their means and standard deviations significantly differed from the other regions. Thus, the fixation times on headings were analysed separately. Greenhouse-Geisser corrected p values are reported whenever necessary.

Progressive first-pass fixation time
The means and standard errors of the progressive first-pass fixation times are presented in Fig. 1 for three reader groups, separately for the aforementioned text regions. The main effect of reader group proved highly significant, $F(2, 41) = 31.47$, $p < .001$; the fast linear readers read the text sentences with much shorter progressive fixation times than the two other groups (a difference of about 1,000 ms). The main effect of sentence type also reached significance, $F(2, 82) = 24.52$, $p < .001$; topic sentences were read with shorter progressive fixation times than paragraph-medial and paragraph-final sentences. This effect simply reflects the fact that topic sentences were somewhat shorter than medial and final sentences. More interestingly, the main effect of sentence type was qualified by a sentence type × reader group interaction, $F(4, 82) = 7.56$, $p < .001$. The nature of the interaction was examined by computing the ANOVA separately for the three reader groups. These separate analyses showed no effect of sentence type for topic structure processors, $F = 1.02$, whereas the effect was
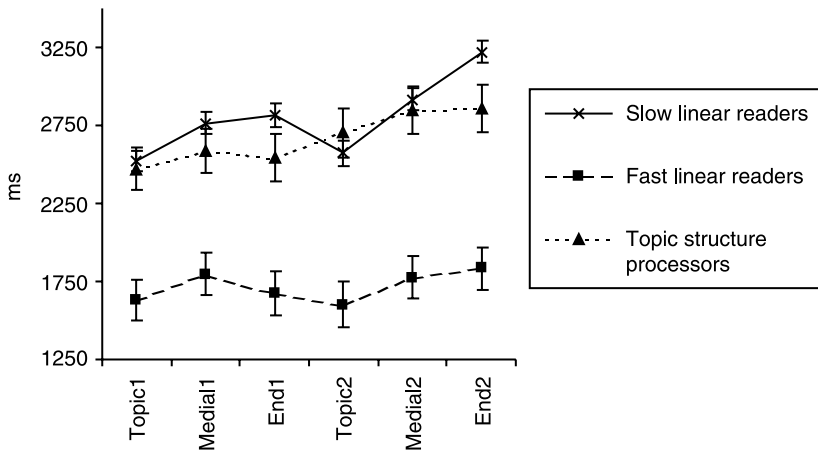
Figure 1. The average progressive first-pass fixation times (in ms) and their standard errors (error bars represent 1 SE above and below the mean) for the fast linear readers, slow linear readers and topic structure processors, as a function of sentence type (Topic1 = the initial sentence of the first paragraph; Medial1 = the medial sentences of the first paragraph; End1 = the final sentence of the first paragraph; Topic2 = the initial sentence of the second paragraph; Medial2 = the medial sentences of the second paragraph; End2 = the final sentence of the second paragraph).

significant for slow linear readers, $F(2, 56) = 84.32$, $p < .001$, and for fast linear readers, $F(2, 14) = 6.86$, $p < .01$. Slow linear readers show a linear increase in progressive fixation time from paragraph-initial to paragraph-final sentence, whereas fast linear readers read the topic (i.e. paragraph-initial) sentences with less progressive fixation time than other sentences. This pattern of results suggests that the linear readers devoted relatively less progressive fixation time to topic sentences than the topic structure processors.

The main effect of paragraph, $F(1, 41) = 24.38$, $p < .001$, reflects the fact that second paragraphs were read with longer progressive fixation times than the first ones (a difference of about 170 ms). This main effect was qualified by two interactions, reader group × paragraph, $F(2, 41) = 3.36$, $p < .05$, and sentence type × paragraph, $F(2, 82) = 4.44$, $p < .02$. The former interaction reflects the fact fast linear readers showed no effect of paragraph, $F < 1$, whereas for the other two groups the effect was significant, $p < .01$. The latter interaction is due to the paragraph effect (longer progressive fixation times for second than first topic paragraphs) being largest for final sentences and smallest for topic sentences. In other words, of all the sentences section-final (i.e. the final sentences of second paragraphs) sentences were read with longest progressive fixation times.

To sum up the key results for progressive first-pass fixation time, (a) fast linear readers read the text with shorter progressive fixation times than the other two groups, (b) linear readers read the somewhat shorter topic sentences with fewer progressive fixations than the other sentences, and (c) topic structure processors devoted relatively more progressive fixation time to topic sentences than the linear readers.

Rereading fixation time
The means and standard errors of the rereading fixation times are presented in Fig. 2. First, there was a main effect of reader group in the rereading fixation time,
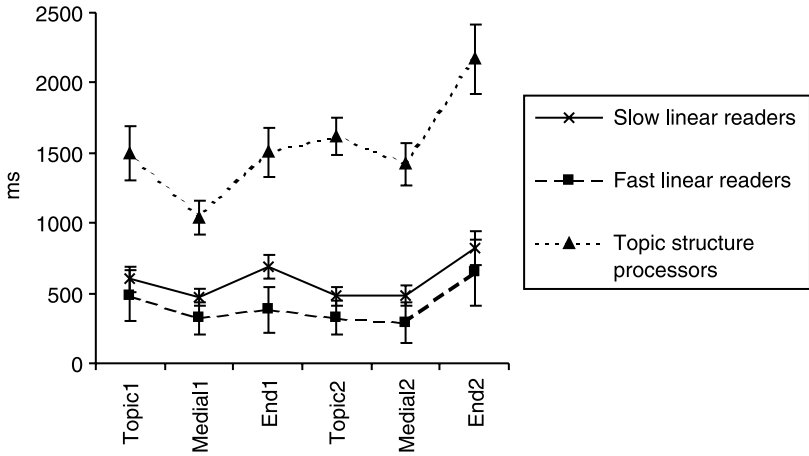
Figure 2. The average rereading fixation times (in ms) and their standard errors (error bars represent 1 *SE* above and below the mean) for the fast linear readers, slow linear readers and topic structure processors, as a function of sentence type (Topic1 = the initial sentence of the first paragraph; Medial1 = the medial sentences of the first paragraph; End1 = the final sentence of the first paragraph; Topic2 = the initial sentence of the second paragraph; Medial2 = the medial sentences of the second paragraph; End2 = the final sentence of the second paragraph).

$F(2, 41) = 19.52, p < .001$; the topic structure processors read the text sentences with much longer rereading fixation times than the two other groups (a difference of approximately 1,000 ms). The main effect of sentence type, $F(2, 82) = 22.03, p < .001$, is due to the fact that paragraph-final sentences were read with longest and paragraph-medial sentences with shortest rereading times. This main effect was qualified by a marginal sentence type × reader group interaction, $F(4, 82) = 2.26, p < .1$. In separate ANOVAs computed for each reader group, all groups demonstrated a reliable sentence type effect, $ps < .05$. The marginal interaction is localized primarily in the differential treatment of paragraph-medial sentences, as the interaction proved non-significant, $F < 1$, when the medial sentences were dropped from the analysis. Linear readers read the medial sentences of first and second paragraph with similar rereading times, whereas topic structure processors spent more rereading time on the medial sentences of the second paragraph.

The main effect of paragraph (rereading fixation times were 140 ms longer for second than first paragraphs), $F(1, 41) = 9.81, p < .01$, was qualified by a sentence type × paragraph interaction, $F(2, 82) = 11.39, p < .001$, and by a reader group × paragraph interaction, $F(2, 41) = 7.14, p < .01$. The former interaction is largely due to the section-final (i.e. the final sentences of second paragraphs) sentences producing much longer rereading fixation times than any other sentence type. This may be interpreted as a major section 'wrap-up' effect. The latter interaction reflects the fact that the paragraph effect was clearly non-significant for the linear readers, $Fs < 1$, but nearly significant for the topic structure processors, $F(1, 6) = 4.73, p < .1$.

To sum up the key results for rereading fixation time, (a) topic structure processors made more rereading fixation times than linear readers, and (b) paragraph-final sentences attracted more rereading fixations than other sentences, which was particularly the case for section-final sentences (i.e. the final sentences of the second paragraph).

Look-back fixation time
The means and standard errors of the look-back fixation times are presented in Fig. 3. The three reader groups differed in the amount of time they looked back in text, $F(2, 41) = 34.70, p < .001$; the topic structure processors looked back on average over 1,000 ms longer than the linear readers. The main effect of sentence type, $F(2, 82) = 20.91, p < .001$, reflects the fact that topic sentences were looked back to the most and the paragraph-final sentences the least. This main effect was qualified by a sentence type × reader group interaction, $F(4, 82) = 10.18, p < .001$. Separate ANOVAs performed for the reader groups yielded a reliable sentence type effect for topic structure processors, $p < .01$, and slow linear readers, $p < .03$, but not for fast linear readers, $F < 1$. Topic structure processors looked back to topic sentences about 1,300 ms longer than to final sentences, while the respective difference for slow linear readers was 175 ms. The sentence type × reader group interaction remained highly significant, $F(2, 68) = 15.77, p < .001$, when only topic structure processors and slow linear readers were included in the analysis.

The main effect of paragraph (200 ms longer look-back time for first than second paragraphs), $F(1, 41) = 4.88, p < .04$, was qualified by a marginal paragraph × sentence type interaction, $F(2, 82) = 2.85, p < .08$. The difference between the two paragraphs was negligible for medial sentences, but larger for topic and final sentences.

To sum up the key results for look-back time: (a) topic structure processors made more look-backs in text than the linear readers, (b) topic structure processors directed most of their look-backs to topic sentences, while fast linear readers showed no sensitivity in their look-back behaviour to the text's topic structure.

Fixation time on topic headings
The mean first-pass fixation time (the sum of progressive and rereading fixation time) and the mean look-back fixation time on topic headings are presented in Fig. 4
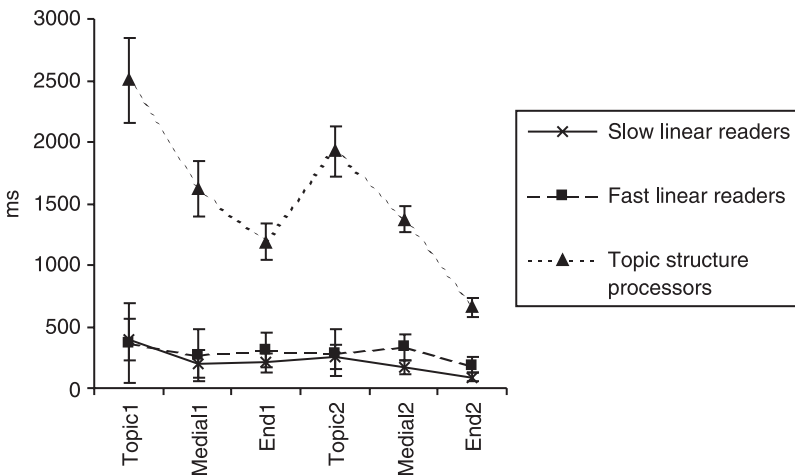

Figure 3. The average look-back fixation times (in ms) and their standard errors (error bars represent 1 *SE* above and below the mean) for the fast linear readers, slow linear readers, and topic structure processors, as a function of sentence type (Topic1 = the initial sentence of the first paragraph; Medial1 = the medial sentences of the first paragraph; End1 = the final sentence of the first paragraph; Topic2 = the initial sentence of the second paragraph; Medial2 = the medial sentences of the second paragraph; End2 = the final sentence of the second paragraph).
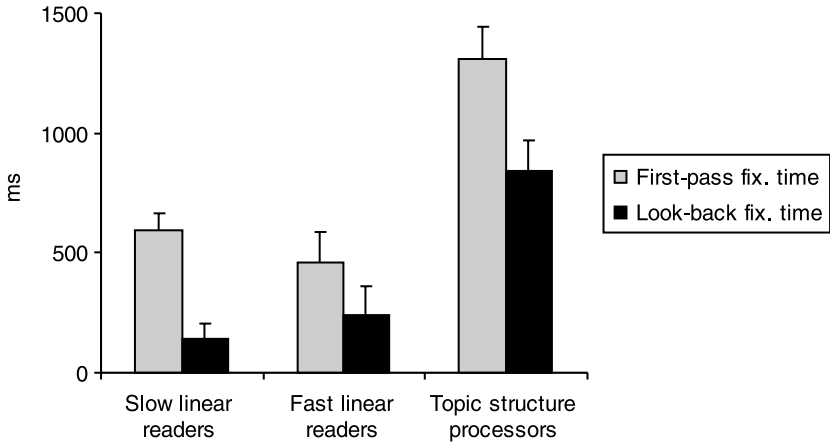
Figure 4. The average first-pass fixation time (in ms), look-back fixation time (in ms), and their standard errors (error bars represent 1 *SE* above and below the mean) of the topic headings for the fast linear readers, slow linear readers, and topic structure processors.

separately for fast linear readers, slow linear readers, and topic structure processors (the error bars show the standard error of the means). A one-way ANOVA revealed a highly significant difference between the reader groups both in the first-pass fixation time, $F(2, 41) = 13.14, p < .001$, and in the look-back fixation time, $F(2, 41) = 12.52$, $p < .001$. Topic structure processors spent about 850 ms longer on headings during the first-pass reading and looked back 600 ms longer than fast linear readers. Pairwise *t* tests revealed a significant difference between topic structure processors and fast linear readers both in the first-pass and look-back fixation time, $ps < .05$. Topic structure processors also differed significantly from slow linear readers both in the first-pass and look-back fixation time, $ps < .001$. Finally, slow linear readers spent significantly more first-pass fixation time on headings than fast linear readers, $p < .03$.

Text summaries
The summaries were scored independently by two raters, who agreed on 97% of the ratings. Inconsistencies were resolved through discussion. The average score differed between the reader groups, with the topic structure processors obtaining a higher score ($36 = 72\%$ recalled) than the two linear reader groups (both had an average score of $26 = 52\%$ recalled). An independent samples *t* test demonstrated a reliable difference between the topic structure processors and the fast and slow linear readers ($p < .015$).

Interim summary
The present study replicated that of Hyönä *et al.* (2002) by delineating reader groups whose profiles were similar to those observed by Hyönä *et al.* (with the exception that a non-selective reviewer group could not be established). The fast and slow linear readers read the text linearly from top to bottom without returning much to already read text segments. The two types of linear readers differed in the amount of progressive fixation time devoted to each sentence, where the fast linear readers read the text with fewer progressive fixations than the slow linear readers. The most characteristic feature of the

topic structure processors was the ample number of look-backs they made particularly to topic sentences that conveyed the main ideas of each subtopic and to headings that labelled each subtopic. They also devoted relatively more first-pass fixation time to topic headings and more rereading time to section-final sentences than the linear readers did. Finally, topic structure processors who frequently looked back in the text (particularly to the topic sentences and topic headings) constructed a more comprehensive mental representation of the text than did the linear readers.

The data presented above demonstrate that individual difference among adult readers manifest in the overall reading speed and in the amount of looking back in text. In the next section, we examine how adequately readers can report these behavioural features.

Correlational analyses

The relationship between the observed and estimated reading speed
A correlation between the overall reading speed (the total time spent fixating on the text) and the reader's estimate of her/his reading speed was quite high ($r = -.53$, $p < .01$; the Pearson correlation coefficient is negative because the reader's estimate was scored to be the greater the faster s/he considered herself/himself to be in the continuum). Thus, this result demonstrates that adult readers are knowledgeable of their own reading speed relative to other adult readers.

The relationship between the observed and verbally reported frequency of rereadings and look-backs
A sum score of the estimated rereading frequency (single words, sentences, and larger text units) was correlated with the summed duration of all rereading and look-back fixations. The Spearman correlation coefficient was relatively modest but significant ($r = -.26$, $p < .05$). The correlation coefficient is negative because of the direction of the scale in the questionnaire. Here and in the subsequent analyses, the significance is estimated by a one-tailed test, because the direction of the correlation could be predicted (the more reported rereadings, the greater the observed value for rereadings).

The relationship between the observed and verbally reported target of the rereading and look-back fixations
The correlations between the observed and verbally reported destination of look-backs are presented in Table 1. We have excluded three questionnaire items (1, 7, 8) from Table 1 because they showed little inter-individual variability (most readers said that they often reread single words, text regions that they want to memorize, and regions they have problems understanding). With respect to the corresponding eye fixation measures, two clarifications may be in place. For the rereading of text sections larger than a sentence, the average duration of all look-backs was used as the corresponding eye movement measure; for the non-selective look-backs (i.e. the last row of Table 1), the look-back fixations to paragraph-medial sentences were used as the eye movement measure. As above, the reported correlation coefficients are negative because of the direction of the scale in the questionnaire (see Methods for details).

As is apparent from Table 1, the correlations are moderate in size (.30–.40) but nevertheless significant. These correlations suggest that readers are to some extent aware of their look-back and rereading behaviour. For example, readers who report

Table 1. The Spearman correlation between the observed frequency and the estimated frequency of rereading and look-back fixations

Type of rereading and look-back fixations	Spearman *r*	*P*
'I reread a sentence before moving to the next'	− .30	<.05
'I reread sections larger than a single sentence'	− .30	<.05
'I look back to the initial sentences of text paragraphs'	− .34	<.05
'I look back to headings'	− .40	<.01
'As a habit, I look back non-selectively in text'	− .36	<.01

looking back to headings and topic sentences a lot tend to behave accordingly, and likewise, readers who report doing it only minimally are likely to behave that way.

The relationship between text recall and the frequency of making rereading and look-back fixations
As the reader group differences in text recall imply, there was a significant positive correlation between the summed fixation time spent on rereading and looking back in text and the text summary score ($r = .51$, $p < .01$).

Discussion

The present study largely replicated that of Hyönä *et al.* (2002) in that three reading styles, coined fast linear readers, slow linear readers, and topic structure processors were observed among adult readers reading a long expository text. On the other hand, the existence of the non-selective reviewer cluster that was considered tentative by Hyönä *et al.* was not corroborated by the present study (we return to this below). Two behavioural features, the overall reading speed and the amount of time spent rereading and look backing in text, were the key elements in distinguishing between these readers. The linear readers are distinguished from the third group in not making look-backs to previous parts of the text; instead, they read each text page linearly from top to bottom, hence the name. Fast linear readers differ from the slow ones by making less progressive fixations during the first-pass reading of each text sentence. Similarly to slow linear readers, they seldom look back in text. On the other hand, frequently looking back in text is a characteristic feature of topic structure processors. They are also characterized by selectively directing their look-backs to pertinent regions of the text: to topic sentences that convey the main ideas for each subtopic, and to topic headings that label each subtopic and thus also signal the content structure of the text (for the effects of topic headings on readers' eye fixation patterns, see Hyönä & Lorch, 2004). As a result of such presumably strategic processing, topic structure processors were able to write the most comprehensive summaries of the main text contents. Look-backs to topic sentences and headings are assumed to serve two purposes: (1) they help identify the subtopics and more firmly establish the main points and the overall content structure of the text; and (2) they help integrate detailed text information into the mental representation constructed of each subtopic (i.e. topic sentences and headings are used as mental substructures around which other text information is integrated; for further discussion on how topic headings and the text's topic structure are utilized in the construction of an internal representation for the text, see Hyönä & Lorch, 2004; Lorch, 1989, 2001; Lorch & Lorch, 1996; Lorch, Lorch, Richey, McGovern, & Coleman, 2001).

When examining the relative sizes of our reader groups, it becomes evident that a linear reading style is clearly the dominant one, as 84% of the readers adhered to it. This compares favourably with the study of Hyönä *et al.* (2002), who found that 75% of the readers to fall in the linear reader category. One difference in the results between the present study and that of Hyönä *et al.* is in the relative size of the two linear reader groups. In the present study, the fast and slow linear readers comprised 16% and 66% of the sample, respectively, whereas in the Hyönä *et al.* study, the respective percentages were 48% and 28%. As there is no pre-set cut-off point to distinguish between fast and slow linear readers, the relative size of these two groups is bound to vary across different samples. As there are no clear qualitative differences in the reading behaviour between the fast and slow linear readers, one may be tempted to consider them a single cluster. We cannot refute this possibility on the basis of the present results, as the text summaries serving as a cross-validation measure did not differentiate between these two groups. However, we do think that qualitative differences probably exist between these two clusters in a more heterogeneous reader sample (e.g. including other than just university students). Hyönä *et al.* observed for their sample that slow linear readers tended to have a smaller working memory capacity and their general linguistic skills were somewhat inferior compared with other readers.

A second difference between the two studies is that the present study was not able to establish the non-selective reviewer cluster obtained by Hyönä *et al.* (2002). However, it should be borne in mind that the non-selective reviewer cluster comprised only three readers, which led Hyönä *et al.* to consider it tentative among competent adult readers. Had we recruited less competent readers, we suspect this cluster may have featured more strongly in the analysis. It should also be noted that the single reader forming the fourth cluster in our 4-cluster solution resembled in her reading behaviour that of non-selective reviewers of the Hyönä *et al.* study.

Overall, we think we can safely conclude that at least two reader clusters, linear readers and topic structure processors, generalize to other competent adult reader samples reading well-structured expository texts. However, the relative size of these reader groups will probably vary depending on the type of expository text used. For example, had we used a more ill-defined content structure in our experimental text or a globally incoherent text, it is possible that we would have found more readers manifesting extensive look-back behaviour. With an ill-defined or an incoherent text structure, increased look-back behaviour is found to be indicative of comprehension obstacles encountered in the text (see Blanchard & Iran-Nejad, 1987; Garner & Reis, 1981; Hyönä *et al.*, 2003; Kinnunen *et al.*, 1998; Rinck, Gamez, Diaz, & de Vega, 2003; Vauras, Hyönä, & Niemi, 1992), and thus, on the assumption that most adult readers are likely to attempt to achieve a sufficient understanding of the main text contents, it is probable that the number of readers making frequent look-backs in text would be considerably higher.[2] It should be noted that the look-backs observed in the present study are not likely to reflect comprehension problems, but rather efforts to build a comprehensive mental representation of the main text contents (see above).

The finding that topic structure processors outperformed the linear readers in the memory for main text contents not only serves as a cross-validation for a qualitative difference between the groups, but it is also an example of a phenomenon where

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[2] *When asked how often they return to text regions that have initially posed a comprehension problem (Item 7 in the questionnaire), all our readers (with two exceptions) chose one of two most frequent values in the 6-point Likert scale.*

information that is carefully attended to is subsequently remembered better. The memory test we used indexes readers' memory for main points in text, the majority of which were conveyed in the topic sentences (also called *macro-propositions*; see van Dijk & Kintsch, 1983), as well as memory for subtopics that were explicitly labelled by topic headings. As may be recalled, topic structure processors directed their look-backs particularly to topic sentences and spent a long time fixating on topic headings. Thus, it may not come as a surprise that their memory for main points and major subtopics was better than that of the linear readers who did not look back to topic sentences and spent less time on headings. This is a replication of Hyönä *et al.* (2002) who also observed the best memory performance for topic structure processors using a different scoring method (for the topic access measure, any information, whether pertinent or detailed, mentioned about a topic was credited with one point; the topic order measure related the order of topics mentioned in the summary to that of the text).

A strong correlation between the overall amount of look-back and rereading done and the accuracy of the text recall was also observed for our reader sample as a whole. This finding demonstrates the usefulness and functionality of the look-back and rereading fixations. Likewise, the research demonstrating the facilitative effects of teaching younger readers a look-back strategy to be used in responding to text-based questions is another demonstration of the usefulness of look-backs (Alvermann, 1988; Bossert & Schwantes, 1995; Garner, 1982, 1984; Garner & Hare, 1984; Garner *et al.*, 1984). These findings contrast with the claims made by the advocates of speed-reading about the non-functionality the rereading fixations (i.e. that making them is 'bad reading habit', something a proficient reader should avoid doing; see e.g. Litherland, 1993).

The second objective of the present study was to examine to what extent readers are aware of their overt reading behaviour, particularly their overall reading speed and the frequency of making look-back fixations. As noted above, these are the features that differentiate between adult readers comprehending long, well-structured expository texts. We found that readers are knowledgeable about their own reading speed in relation to other adult readers and somewhat knowledgeable about their look-back and rereading behaviour, that is, how much they look back in text in general, and to what text regions they typically direct their look-backs. As the questionnaire was given immediately after an actual reading performance, we cannot estimate the extent to which the verbal responses were made on the basis of the specific reading experience the participant just had versus on the basis of a more general trait (which may or may not converge with this specific reading state). Relevant prior studies are faced with the same dilemma. Nevertheless, our results are in general agreement with those of Alexander *et al.* (1984), who found that most readers who during question answering looked back to a previous sheet, which contained the answer to the question, also reported doing so. The strong relation observed by Alexander *et al.* between reported and observed behaviour was probably strengthened by the fact that the look-backs were initiated as a response to a specific question (i.e. after reading) and required the readers to turn over a page lying on the table. Rinck *et al.* (2003) studied the effects of textual inconsistencies on readers' eye movement patterns. Their participants were asked to report after reading whether or not they had detected an inconsistency in the text. Rinck *et al.* found that particularly those readers who reported a local inconsistency in the text looked back to the sentence that was inconsistent with what was just read. This finding suggests that only readers who become conscious of an inconsistency try to repair it by looking back in text. In a similar vein, Garner and Reis (1981) demonstrated that

look-backs are characteristic of good comprehenders trying to fix comprehension obstacles they become aware of in the text.

The size of the correlations between verbally reported and observed behaviour (.30–.40) is somewhat bigger than what has previously been reported between think-alouds and reading times. Fletcher (1986) and Trabasso and Suh (1993) found modest (.23–.24) but significant correlations between the sentence reading time and the likelihood that this sentence contained information just mentioned in the think aloud protocols. In other words, a sentence was found to be easier to read when it was closely linked to the contents of the evolving mental representation of the text. Olson *et al.* (1984) had a group of readers provide think-alouds on-line while they read well-formed and ill-formed stories. Another group of readers read the same texts for comprehension while their sentence-reading times were collected (only one sentence was shown at a time). Regression analyses revealed that those sentences in the well-formed stories that were more likely to produce inferences and predictions during the think-aloud procedure were associated with relatively longer reading times. Such a relationship did not exist for the ill-formed texts.

Before closing, we provide some speculation about the extent to which look-back fixations reflect strategic behaviour. As pointed out in the Introduction, a behavioural procedure is considered strategic when it is purposeful, effortful, wilful, essential, and facilitative (Alexander *et al.*, 1998). Look-back and rereading fixations are effortful as they slow down the reading. They are facilitative because they improve memory for text (see above). The finding that the readers are reasonably well aware of their look-back behaviour suggests that they may also be purposeful, that is, a result of conscious planning. However, the purposefulness of look-back fixations may only hold for the topic structure processors who show clear signs of a smart processing strategy (i.e. selectively looking back to the main points in text). The claim that their reading style may indeed reflect strategic behaviour is further supported by the review of Pressley and Afflerbach (1995) on verbal protocols of reading. Pressley and Afflerbach report on readers who look for topic sentences in text and use them as a point of departure to process other text information.[3] However, the absence of look-back fixations among linear readers may not have developed as a result of conscious, strategic planning (e.g. 'I should not look back in text, as it slows me down, and I do not benefit from it'). Rather, their reading may primarily be driven by the text input, of which they are at least partly aware.

Acknowledgements

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[3] *When topic structure processors were compared with linear readers (fast and slow combined) in the sum score of the reported frequency of making look-backs to paragraph-initial sentences and to text regions they especially wished to memorize (Items 4 and 7 in the questionnaire), a marginally significant difference emerged, $t(41) = 1.68$, $p = .1$. Topic structure processors reported doing more look-backs than linear readers did.*

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