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OBSERVATIONS

An Eye Movement Analysis of Topic-Shift Effect During Repeated Reading

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This study replicated previous reading time studies that have observed increased reading times for sentences introducing a new subtopic in a text, compared with sentences that are continuations of a subtopic. This topic-shift effect was obtained for the initial reading but not when the same text was reread. The absence of topic-shift effect was taken to suggest that readers construct a mental representation of the text's topic structure during the initial reading. The topic-shift effect was primarily due to regressive fixations, which tended to land in the first half of sentences. Regressions were typically launched at the end of sentences, with topic-shift sentences also well before the sentence end was reached. These findings are interpreted as evidence for the integrative nature of regressive fixations.

Studies of on-line text processing have shown that sentences introducing a new discourse topic or a new episode are allocated more processing time than sentences that are continuations of the same topic or episode (Haberlandt, 1980; Haberlandt, Berian, & Sandson, 1980; Kieras, 1981; Lorch, Lorch, & Matthews, 1985; Lorch, Lorch, & Morgan, 1987; Mandler & Goodman, 1982). The effect is referred to here as the *topic-shift effect* (Lorch and colleagues call it the topic effect). The effect is shown to be larger with a more abrupt change in the discourse topic than with a relatively more subtle change (Lorch et al., 1985, 1987; Vauras, Hyönä, & Niemi, 1992). It is not restricted to skilled reading as it is also observed among younger, elementary school-aged readers (Hyönä, 1994; Lorch, Lorch, Gretter, & Horn, 1987). Hyönä further demonstrated that with difficult expository texts, adults manifest a proportionately greater topic-shift effect than fifth-grade children, which was not found to be the case with easier narrative texts. Similarly, Lorch et al. (1987) observed a more pronounced topic-shift effect for better than for poorer adult recallers.

According to Gernsbacher's (1990) structure building framework, the extra processing time at topic shifts or episode boundaries is spent on encoding that new topic or episode, integrating it with the previous topic, activating a new memory frame in which to organize the upcoming information, and terminating the previous topic (see also Haberlandt et al., 1980; Lorch et al., 1985). The outcome of this kind of topic structure processing is presumed to be a mental representation comprising a list of topics encountered in the text (see Kieras, 1981; Meyer, Brandt, & Bluth, 1980).

In the present study, the topic-shift effect was further examined by registering readers' eye movements while they reread the same text three times, twice in the same session, and once approximately a week later. I conducted the study to test if the topic-shift effect is restricted to the initial reading of a text or if it appears also during repeated reading. My second objective of the study was to determine more precisely the locus of the effect. Previous studies have used the sentence reading time paradigm, which is a global on-line processing measure. In eye tracking, first-pass readings of sentences can be distinguished from their later reinspections. Moreover, a question can be addressed of whether the effect is due to topic-shift sentences being read with longer fixations, with shorter saccades, or with more regressions. This would help determine how higher order integration processes influence the immediate information intake in reading.

The following hypotheses were entertained. First, the topic-shift effect should, of course, appear in the initial reading of a text. However, it is not known if it would show up also during repeated reading of the same text. If readers construct a good representation of the topic structure on first reading, as proposed by previous research, then there should be substantial savings in the amount of processing necessary on rereading because the topics and their relations will already be included in the readers' text representations. Thus, the topic-shift effect should greatly be reduced in magnitude on the second and third readings. However, if readers do not adequately represent the text's topic structure on the initial reading or they fail to use that representation to guide subsequent readings, then the magnitude of the topic-shift effect should remain the same over repeated readings.

Second, with respect to the issue of eye movement guidance, Hyönä and Niemi (1990) showed that there is a global facilitation effect that is due to repeated reading of the same text as reflected in readers' eye fixation patterns: Fixations

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become shorter, saccades longer, and regressions fewer. This general facilitation effect in the eye fixation patterns has recently been confirmed by two other studies (Inhoff, Topolski, Vitu, & O'Regan, 1993; Raney & Rayner, in press). Thus, one possible hypothesis is that the topic-shift effect would manifest as a global effect affecting all eye movement components. Such a finding would support the so-called gain models of eye guidance (see Bouma & deVoogd, 1974; Rayner & McConkie, 1976), which claim that difficulties in text processing would be manifested in the reader sampling the text with slower pace, which in turn would show up in shorter saccades and longer fixation durations. There is, however, little empirical evidence supporting this notion (see, for example, Hyönä, 1993a; Rayner & McConkie, 1976). On the other hand, there is some evidence demonstrating that text integration processes influence the frequency of immediately rereading parts of a sentence that introduce a momentary processing difficulty (Blanchard & Iran-Nejad, 1987; Vauras et al., 1992). Such a finding is consistent with a view advocated, for example, by Pollatsek (1993), who maintains that higher order integration processes have the potential of only intervening in the normal progress of the eyes (i.e., presumed to be governed by the word recognition processes) by occasionally disrupting the processing for integrative purposes. This disruption should be reflected in regressive fixations, whereas progressive fixations would be less affected. In other words, by adopting this view, one would predict text structure effects to manifest as a delayed rather than an immediate effect.

Method

Participants

Eighteen university students at the University of Turku served as participants. They were recruited from an introductory psychology course, and they were given course credit for their participation.

Apparatus

Eye movements were recorded by using an Applied Science Laboratories Model 1994 eye tracker. This monitoring system is video based and makes use of pupil and corneal reflections. Its accuracy has been estimated as 0.65° horizontally and 0.35° vertically by using a 16° × 16° stimulus array (Muller, Cavegn, d'Ydewalle, & Groner, 1993). A chin rest and a head restraint were used to restrict possible head movements. In addition, a head-movement compensation system is built into the monitoring system. In the data reduction algorithm, a window size of 2.5 character spaces was used. Thus, two consecutive fixations less than 2.5 character spaces apart were combined to a single fixation. Fixations less than 100 ms were excluded from the analysis (this procedure is not likely to change any of the results, as fixations shorter than 100 ms are very infrequent in reading; see Rayner & Pollatsek, 1987).

Materials

The text was in Finnish and was titled *William Pitt as the Builder of the British Empire in the 18th Century.* Its length was 351 words in 48 sentences. It was adopted from Vauras (1991; see also Hyönä & Niemi, 1990; Vauras et al., 1992), who constructed the text on the basis of 3–4 authentic texts on history. The global structure of the text complied roughly with the framework proposed by Thorndyke (1977). Although the text has an episode structure typical of many narratives, it is also similar to expository texts in having a hierarchical topic structure, in which some topics are subsumed under other higher order topics (noted below). The story consisted of four global constituents: setting, theme, plot, and resolution. In setting, the main character, William Pitt, is introduced followed by information about the political situation in England and Europe at his time. In theme, Pitt's main goal, that is, to build Britain to a world power, is outlined, and France is introduced as the chief opponent to be overcome. The plot section comprises six action episodes, each of which conforms to a subgoal–attempt–outcome sequence. Each action episode describes one instantiation of the realization of the main goal. The story ends with the resolution node, in which the end results of Pitt's efforts are concluded. The English translation of the text is presented in the Appendix.

The target sentences were the subgoal–attempt sentence pairs in the plot section, the six subgoal sentences being the topic-shift (or episode-shift) sentences, and the six attempt sentences being the topic-progression sentences. Each of the six episodes begins with a topic-shift sentence stating the goal of a particular action (e.g., to conquer Canada), after which, in a separate sentence, an attempt at achieving the goal is described (the topic-progression sentence; e.g., attacks are executed against the main cities), followed by a sentence depicting the outcome of the action (e.g., France has to surrender Canada). The action episodes were not chained causally or temporally to each other but were independent action sequences subordinated to the main goal (i.e., theme; cf. and-connected episodes in Johnson & Mandler, 1980, p. 62). The first three action episodes dealt with how Pitt tried to destroy France's economical and military power in Europe, whereas the last three provided information on how Pitt tried to conquer French colonies. The six subtopics were as follows: to secure the British Islands, to help Prussia, to break off France's trade links, to conquer Canada, to cease Frenchmen's fishing, and to throw France out of India. Each episode took place in a different geographical location: in Britain, in Prussia, on the French coast, in Canada, on the Canadian coast, and in India. In three topic-shift sentences the change in place was made explicit in the sentence beginning (i.e., "In the continent," "In North-America," and "In India"); in the rest of the topic-shift sentences the change in place became apparent only later on in the sentence (see the Appendix).

The target sentence pairs were matched as closely as possible for length and syntactic structure (see Table 1). All target sentences comprised one main clause. As is evident from Table 1, the topic-shift

Table 1
Some Characteristics of Topic-Shift and Topic-Progression Sentences

Characteristic	Topic shift	Topic progression
Words	7.5	6.8
High frequency	8.0	6.0
Medium frequency	20.0	23.0
Low frequency	11.0	10.0
Letters	70.8	70.5
Nouns	3.7	4.3
New nouns	2.3	2.2
Verbs	1.3	1.3
Adjectives	0.7	0.7
Adverbs	0.8	0.3

Note. The number of items per word frequency category is given in absolute values; others are sentence averages. High-frequency words have a token frequency of at least 440 per million, medium-frequency words vary between 20 and 440 occurrences per million, and low-frequency words have a frequency of less than 20 per million (Saukkonen, Haipus, Niemikorpi, & Sulkala, 1979; the proper noun *Pitt* was excluded from the frequency counts).

sentences contained slightly less nouns and more adverbs than the topic-progression sentences. This results in the topic-shift sentences comprising slightly more words (common adverbs being of shorter length). When assuming that the encoding of content words requires more processing time than that of function words (Carpenter & Just, 1983), this slight difference, if relevant, would shorten the processing time for topic-shift sentences.

The distribution of words in target sentences over different word frequency bands (high vs. medium vs. low frequency) was controlled (see Table 1). Although word frequency was identified as a possible confounding variable, it should be noted that word frequency is not shown to interact with repeated reading. Raney and Rayner (in press) obtained a comparable facilitation effect because of repetition for both low- and high-frequency words. In addition, in that study the word frequency effect was observed in the rereading as well as in the initial reading.

The number of new nouns per target sentence was also controlled (see Table 1). There is evidence that sentence reading times increase as a function of the number of new nouns (Graesser, Hoffman, & Clark, 1980; Haberlandt & Graesser, 1989).

To examine whether the target sentences differed in their relative importance to the global theme, I asked a separate set of 16 participants to rate the relative importance of all the sentences in the text by using a scale ranging from 1 (*unimportant*) to 4 (*highly important*). The topic-shift sentences were rated somewhat more important ($M = 2.56$, $SD = 0.5$) than the topic-progression sentences ($M = 1.84$, $SD = 0.4$). However, in the present data, the relative importance does not account for much variance of sentence reading times. For the total set of sentences in the text, the correlation between importance rating and the first-pass reading time was practically nonexistent ($r = .006$, $r = .002$, and $r = .05$ for the first, second, and third reading, respectively; for more details, see Hyönä & Niemi, 1990). Consequently, it is quite unlikely that the small variation in the importance ratings between the topic-shift and the topic-progression sentences would significantly affect reading times.

The text was displayed on a computer screen and was seen as white against a dark background. Both upper- and lowercase letters were used. One page on the computer screen comprised three lines of text throughout the text, and each page ended with a complete sentence. Each target sentence extended a full line. The topic-shift sentence was always the first sentence on the screen and was immediately followed by the topic-progression sentence. With the viewing distance of 60 cm, one character space subtended a visual angle of 15 min of arc horizontally. The text lines were double-spaced and were 2 cm apart, which equals a vertical angle of 2°.

Procedure

Each participant took part in two test sessions. In the first session, participants were asked to read the text twice so they would be able to write a summarizing essay about it afterward. The task was assumed to encourage relatively detailed reading of the text. Reading was self-paced with the restriction that returning to a previous page was prevented. Participants changed the page by pressing the space bar on the computer keyboard. Before the reading, the eye movement device was calibrated for each participant. For the calibration, three fixation points were used for each of the three stimulus lines. Between the first and second reading, there was a short pause followed by a calibration check. After reading the text twice, participants wrote a summarizing essay about the content of the text. The third reading took place about a week after the first session. The reading instruction was the same as in the first session. After the third reading, the essay the participant had written during the initial session was handed to her or him, and the participant was asked to improve it.

Results

Readers' eye movements coinciding with the target sentences were parcelled out into two processing phases that were temporally consecutive: first-pass readings and reinspections. First-pass reading refers to all eye movements executed during the initial reading of a target sentence, that is, before moving away from it to the next sentence (including within-sentence regressions). Reinspections include all look-backs to the target sentences that are executed from a subsequent sentence after first-pass reading. For first-pass reading, data for progressive and regressive fixations are reported separately. The sentence averages for all eye movement parameters are given in Tables 2 and 3.

Repeated measures analyses of variance were performed on the data using two within-subject variables: sentence type (topic shift vs. topic progression) and repetition (first vs. second vs. third reading; for the main effects of repetition, see also Hyönä & Niemi, 1990).

First-Pass Reading Time

In the first-pass reading time, there was a significant main effect of sentence type, $F(1, 17) = 6.31$, $MSE = 66{,}110$, $p < .05$, demonstrating that topic-shift sentences resulted in longer reading times (2,831 ms) than topic-progression sentences (2,706 ms; see Table 2). This is a direct replication of the topic-shift effect. The main effect of repetition also reached

Table 2
Eye Movement Parameters During First-Pass Reading and Reinspections for Topic-Shift and Topic-Progression Sentences as a Function of Repetition

Eye movement parameter	Topic shift	Topic progression
First-pass reading time[a]		
First reading	3,287	2,850
Second reading	2,862	2,867
Third reading	2,343	2,402
Total no. of fixations/first-pass		
First reading	12.18	10.21
Second reading	10.41	10.39
Third reading	9.47	9.41
Average saccade length/first-pass[b]		
First reading	10.35	10.33
Second reading	10.79	11.44
Third reading	11.64	11.54
Average fixation duration/first-pass[a]		
First reading	268	277
Second reading	271	268
Third reading	245	251
Summed reinspection time[a]		
First reading	432	437
Second reading	387	497
Third reading	248	348
No. of reinspection fixations		
First reading	1.85	1.87
Second reading	1.70	2.11
Third reading	1.13	1.40

Note. All values are sentence averages.
[a]Indicates data measured in milliseconds. [b]Indicates number of characters in sentence.

Table 3
Progressive and Regressive Fixations During First-Pass Reading for Topic-Shift and Topic-Progression Sentences as a Function of Repetition

Eye movement parameter	Topic shift	Topic progression
Summed progressive fixation time[a]		
First reading	2,504	2,312
Second reading	2,388	2,193
Third reading	1,961	1,965
Number of progressive fixations		
First reading	9.08	8.31
Second reading	8.55	8.00
Third reading	7.84	7.63
Summed regressive fixation time[a]		
First reading	784	538
Second reading	474	674
Third reading	383	437
Number of regressive fixations		
First reading	3.09	1.91
Second reading	1.86	2.39
Third reading	1.63	1.78

Note. All values are sentence averages.
[a]Indicates data measured in milliseconds.

significance, $F(2, 34) = 13.62$, $MSE = 338{,}365$, $p < .0001$. An analysis of simple effects revealed that the facilitation effect that was due to repetition was separately significant for the topic-shift sentences, $F(2, 34) = 21.70$, $MSE = 207{,}894$, $p < .0001$, and for the topic-progression sentences, $F(2, 34) = 6.51$, $MSE = 218{,}083$, $p < .01$. It should be noted that for the topic-progression sentences the effect appeared only in the third reading. Of more interest, the main effects were qualified by a reliable Sentence Type × Repetition interaction, $F(2, 34) = 5.72$, $MSE = 116{,}430$, $p < .01$. As is obvious from Table 2, the interaction points to the fact that more reading time was devoted to the topic-shift sentences only in the first reading of the text; in other words, the topic-shift effect was observed in the initial reading but not when the text was reread.

Number of Fixations in First-Pass Reading

The number of fixations in first-pass reading paralleled the results for the first-pass reading time (see Table 2). There was a main effect of sentence type, $F(1, 17) = 11.05$, $MSE = 1.137$, $p < .01$; topic-shift sentences resulted in more fixations (10.7) than topic-progression sentences (10.0). The main effect of repetition, $F(2, 34) = 8.05$, $MSE = 3.450$, $p = .001$, was due to fewer fixations on target sentences during the second and third reading. An analysis of simple effects showed that the facilitation that was due to repetition was independently reliable for topic-shift sentences, $F(2, 34) = 13.81$, $p < .0001$, and for topic-progression sentences, $F(2, 34) = 3.25$, $p = .05$. As in first-pass reading time, the main effects were qualified by a reliable Sentence Type × Repetition interaction, $F(2, 34) = 5.17$, $MSE = 2.145$, $p = .01$, suggesting that the topic-shift sentences differed from the topic-progression sentences in the *initial reading* but not in repeated reading.

Saccade Length and Average Fixation Duration in First-Pass Reading

The mean length of forward saccades (i.e., from left to right) during first-pass reading became longer as a function of repetition, $F(2, 34) = 7.37$, $MSE = 1.935$, $p < .01$. Similarly, the average fixation duration associated with first-pass fixations became shorter because of repetition, $F(2, 34) = 9.59$, $MSE = 1{,}667$, $p < .001$. All other effects were nonsignificant ($F < 2$).

Reinspections From Subsequent Sentences

An analysis of the reinspections, that is, fixations returning back to a target sentence from a subsequent sentence, did not yield any reliable effects ($F < 2$; see Table 2).

Progressive Fixations in First-Pass Reading

To obtain a more detailed view of the topic-shift effect observed in the initial reading, I further divided the first-pass fixations into progressive and regressive fixations. By definition, progressive fixations include all fixations that land on yet unread text, whereas regressive fixations consist of all rereadings that take place during the first-pass reading[1] (reinspections are excluded).

The summed fixation time associated with progressive fixations yielded a reliable main effect of sentence type, $F(1, 17) = 16.03$, $MSE = 27{,}175$, $p < .001$. Readers devoted more progressive fixation time to topic-shift (2,284 ms) than to topic-progression sentences (2,157 ms; see Table 3). An analogous effect was also observed for the number of progressive fixations, $F(1, 17) = 33.23$, $MSE = 0.213$, $p < .0001$; topic-shift sentences resulted in more progressive fixations than topic-progression sentences (8.5 vs. 8.0).[2] There was a highly significant repetition effect both for progressive fixation time, $F(2, 34) = 19.75$, $MSE = 96{,}949$, $p < .001$, and for the number of progressive fixations, $F(2, 34) = 13.85$, $MSE = 0.600$, $p < .001$. In progressive fixation time, the main effects were qualified by a reliable Sentence Type × Repetition interaction, $F(2, 34) = 3.54$, $MSE = 32{,}934$, $p < .05$. An analysis of simple effects revealed that during the initial and second reading, topic-shift sentences obtained significantly longer progressive fixation times than topic-progression sentences: $F(1, 17) = 21.36$, $p < .001$, for the first reading; $F(1, 17) = 7.64$, $p < .05$, for the second reading.

[1] This notion of regressive fixations should be kept apart from the definition that considers only those fixations as regressions that are directed from right to left. The critical point here is whether or not a fixation lands on a text segment that has already been fixated. The first fixation on a line is often an undershoot, and it is hence regularly followed by a right-to-left saccade (see Rayner, 1978). These fixations were not regarded here as regressive fixations, however, but were included in the progressive fixation measure.

[2] There was a reliable topic-shift effect in the initial reading even when the occasional regressive fixations in the beginning of lines were excluded from the progressive fixation measure: $F(1, 17) = 7.82$, $p < .05$, $MSE = 0.379$, for the number of fixations; $F(1, 17) = 9.34$, $MSE = 18{,}152$, $p < .01$, for the fixation time.

Regressive Fixations in First-Pass Reading

In the summed fixation time for regressive fixations executed during the first-pass reading, there was a significant repetition effect, $F(2, 34) = 3.80$, $MSE = 153{,}995$, $p < .05$, which was statistically marginal in the number of regressive fixations, $F(2, 34) = 2.91$, $MSE = 1.962$, $p < .1$. A contrast analysis showed that regressive fixation times were longer in the initial reading than in the third reading ($p < .05$). The Sentence Type × Repetition interaction proved reliable in regressive fixation time, $F(2, 34) = 6.04$, $MSE = 76{,}893$, $p < .01$, and in the number of regressive fixations, $F(2, 34) = 6.50$, $MSE = 1.121$, $p < .01$. An analysis of simple effects showed that during the initial reading, topic-shift sentences resulted in significantly more regressive fixations and regressive fixation time than topic-progression sentences: $F(1, 17) = 12.31$, $p < .01$, for regressive fixation time; $F(1, 17) = 14.25$, $p < .01$, for the number of regressive fixations.

The analysis of progressive and regressive fixations suggests that the topic-shift effect observed in the initial reading was due to readers making more progressive and more regressive fixations on the topic-shift sentences. However, a further analysis qualified this observation by showing that the occurrence of regressive fixations seems to affect the number of progressive fixations. For sentences with at least one regressive fixation cycle, there was, on average, one additional progressive fixation on topic-shift sentences (9.29 vs. 8.23). The number of progressive fixations for sentences in which no regressions occurred was almost identical for topic-shift and topic-progression sentences (8.40 vs. 8.47). This evidence suggests that when the left-to-right progress of the eyes is interrupted by a regressive fixation cycle, the disruption in processing has consequences also for the subsequent progressive fixations.

Sentence Landing Site Distribution of Progressive Fixations

The final analyses dealt with how progressive and regressive fixations were distributed across the sentence and where in the sentence regressive fixations were initiated. The first analysis examined whether progressive fixations in first-pass reading are distributed in a similar manner for the topic-shift and topic-progression sentences. In Figure 1, the landing position of all progressive fixations in the initial reading of the text are separately plotted for the two sentence types. The data are based on a total of 1,860 progressive fixations. The landing positions were averaged out for every 10 letters (except for the last category, which included the few final letters). As is evident from Figure 1, there were somewhat more progressive fixations in the first half than in the second half of sentences. The dip in the last zone suggests that the few last letters of the sentence-final word were fixated fairly rarely. The relative distribution of progressive fixations did not differ between the two sentence types, as tested by Pearson's chi-square test ($p > .1$; a two-way frequency table: two sentence types and seven sentence positions).

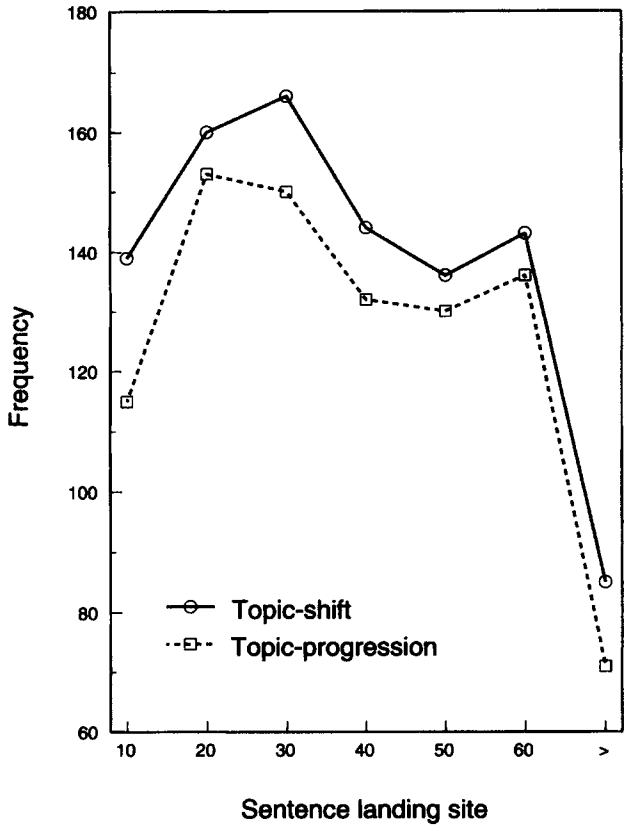

Figure 1. Sentence landing site distribution of progressive fixations for topic-shift and topic-progression sentences for the initial reading of the text.

Sentence Landing Site Distribution of Regressive Fixations

The next analysis examined possible differences between the two sentence types in the landing site of regressive fixations initiated during the first-pass reading (i.e., within a sentence). In Figure 2, the distribution of regressive fixations in the initial reading of the text are plotted separately for topic-shift and topic-progression sentences. The data are based on a total of 524 regressive fixations. Topic-shift sentences resulted in proportionately more regressive fixations landing on the first half of sentences than topic-progression sentences, a difference which proved statistically marginal, $\chi^2(6) = 11.04$, $p = .09$.[3]

Launch Site Distribution of Regressive Fixations

The final analysis examined where in the sentence regressive fixations were launched during first-pass reading. In Figure 3,

[3] As noted in the Method section, there were two kinds of topic-shift sentences: those in which a topic shift was signaled in the sentence beginning, and those in which it became apparent later in the sentence. The sentence landing site distributions were not qualitatively different for the two types of topic-shift sentences, however, as the major peak occurred in the first half of the sentence for both types. The launch site distributions were also comparable for the two types of topic-shift sentences.

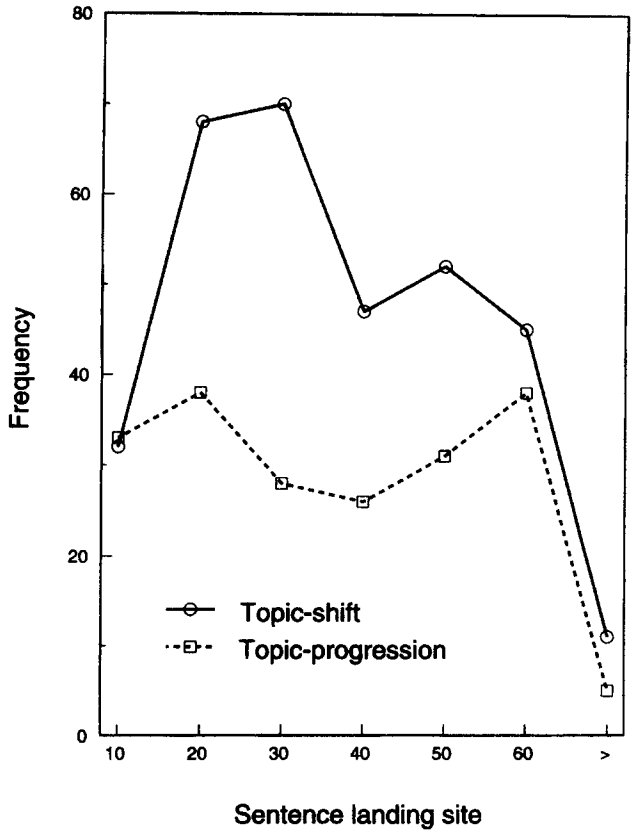

Figure 2. Sentence landing site distribution of regressive fixations for topic-shift and topic-progression sentences for the initial reading of the text.

the launch sites of regressive fixations during the initial reading are separately plotted for the topic-shift and topic-progression sentences. The data are based on a total of 262 regressive fixation cycles. As can be seen from Figure 3, both distributions display a peak toward the sentence end. The sentence types differ in that the topic-shift sentences produced a second peak slightly before the middle of the sentence, $\chi^2(6) = 20.48, p < .01$. In other words, a regressive fixation cycle is typically initiated after reaching the end of sentence; with topic-shift sentences, regressions are frequently made also around the middle of sentence clearly before reaching the sentence end.

Discussion

This study demonstrated that the processing of topic shifts is notably facilitated during repeated reading. Sentences that introduced a new subtopic in the text were given extra processing time during the initial reading compared with sentences that continued an already initiated subtopic; however, in repeated reading, the processing of these topic-shift sentences was facilitated to the extent that topic shifts no longer required an additional processing effort. This finding lends support for the notion that readers construct a mental representation of the text's topic structure in the initial reading and make use of it to guide subsequent readings. During rereading the reader needs only to reinstate the new topic from his or her mental representation. The extra processing that is needed at episode boundaries during the initial reading for "laying a foundation for a new mental substructure" (Gernsbacher, 1990) is no longer necessary when the text is reread. This finding compares favorably with Lorch et al. (1985), who found that prior information about the topic structure, in the form of an introductory paragraph, attenuated the topic-shift effect.

The observation that the topic-shift effect did not reappear in the third reading implies that the memory representation that was constructed in the first two readings is relatively long lasting as facilitation in processing of topic shifts was also observed a week after the initial reading. An adequate memory of the text's topic structure was probably enhanced by the recall task that was completed by the participants after the second reading. Alternatively, it is also possible that in the third reading participants performed at a generally more superficial level by being already familiar with the criterion task.

In the presentation of the text, the topic-shift sentence always appeared on the top of a three-line page so that a page change preceded its reading. Thus, it is plausible to argue that this type of text presentation could have made the topic shifts more salient and thus exaggerated the observed topic-shift effect. However, previous evidence does not support this

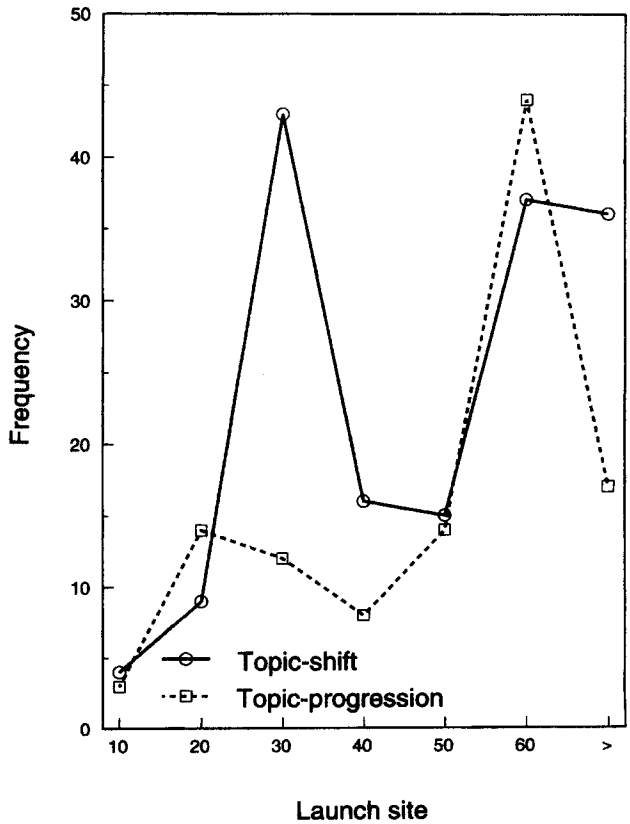

Figure 3. Launch site distribution of regressive fixations for topic-shift and topic-progression sentences for the initial reading of the text.

argument. Hyönä (1994) did not find any evidence for the notion that visual signaling of topic shifts would influence the effect; there was a comparable topic-shift effect with and without visual signals. In the Hyönä study, topic shifts were cued by paragraphing where subtopics were separated from each other on the computer screen by extra spacing between subtopics.

The topic-shift effect observed in the present study for the first-pass reading time (i.e., 437 ms) was a result of a couple of additional fixations being devoted to sentences that initiated a new subtopic. The effect was primarily due to regressive fixations. A subsequent analysis indicated that a regressive fixation cycle was typically initiated at the end of a sentence (see also Hyönä, 1993b). This is evidence for the integrative nature of regressions. The finding suggests that after reaching the sentence boundary and before moving to a subsequent sentence, the reader makes a regressive movement, which gives the reader some extra time to wrap up the meaning of the sentence as a whole. Inherent in this view is the idea that these regressions are not executed because the end of sentence hosts information that is difficult to process but because the reader is not ready to encounter novel information before the meaning of the current sentence is satisfactorily understood and integrated. This argument is compatible with Just and Carpenter (1980), who observed increased fixation times for sentence-final words, which they interpreted as a sentence wrap-up effect (see also Rayner & Morris, 1990). It is also consistent with a so-called *suspension hypothesis* of regressions proposed by Blanchard and Iran-Nejad (1987). Their suspension hypothesis states the following:

> The increased processing puts the mind into a state where it is not ready to incorporate new visual information from the text, and the regressions and rereads are made to hold the eye at one place until the comprehension processes are ready to acquire new information. (p. 136)

In this study I also observed a cluster of regressive fixations that is difficult to interpret as wrap-up fixations. They are the regressions that are launched toward the sentence beginning well before a sentence boundary is reached and are typical, particularly for topic-shift sentences. These regressions are compatible with Blanchard and Iran-Nejad's (1987) *double-intake hypothesis,* which holds that regressive fixations serve the purpose of rechecking and reprocessing pieces of information that cause a momentary processing difficulty (see also Carpenter & Daneman, 1981; Carpenter & Just, 1977; Daneman & Reingold, 1993; Ehrlich, 1983; Frazier & Rayner, 1982; Hyönä, 1993b; Just & Carpenter, 1978). In other words, the double-intake hypothesis assumes that regressions will be located on specific, relevant parts of the text, which is not postulated by the suspension hypothesis. A plausible explanation for why there are more regressive fixations on the beginning part of topic-shift sentences is that there is no obvious connection between what is said in the sentence beginning and what is said in the previous sentence. This is not the case with topic-progression sentences, which are quite closely connected to the preceding sentence. Dee-Lucas, Just, Carpenter, and Daneman (1982), as well as Hyönä and Jarvella (1993), demonstrated that noun phrases that introduce a new topic in the sentence beginning receive extra fixation time during first-pass reading and additional regressions onto the phrases.

In summary, in this article I suggest that regressions in reading serve two purposes: (a) they take the eyes back to a previous text to lend time for the text integration processes to catch up with more elementary word recognition processes, and (b) they send the eyes to a specific text location for additional processing. That regressions are used for integrative purposes has also been shown in other eye-movement studies that have examined the processing of lengthier discourse (see Blanchard & Iran-Nejad, 1987; Shebilske & Fisher, 1983; Vauras et al., 1992).

This study did not provide much evidence for eye guidance models such as the gain model (Bouma & deVoogd, 1974). This model posits that difficulties in carrying out higher order text integration would show up in a global slow down in processing that is manifested in the reader sampling the text in shorter saccades together with more and longer fixations across a cluster of subsequent fixations. Underlying this model is the assumption that higher order processes are the principal driving force that govern the eyes through a text. In the present study, the topic-shift effect was not manifested in shorter saccades, longer average fixation durations, or both. In accordance with gain models, topic-shift sentences produced more progressive fixations than topic-progression sentences. This finding cannot be regarded as conclusive, however, as the number of progressive fixations was found to be confounded with the occurrence of regressive fixations.

The fact that the topic-shift effect was primarily reflected in regressive fixations is consistent with the view emphasizing that the normal progress of the eyes is basically governed by ongoing word recognition processes. According to this view, higher order processes, such as topic structure processing, influence the left-to-right sampling of the text only by occasionally disrupting the processing for integrative purposes (see Pollatsek, 1993). The results of this study suggest that a disruption in processing, and the ensuing additional processing that is due to a shift in the discourse topic, appear either immediately after the reader has encountered some evidence for a shift in the sentence beginning or after first reading through the whole sentence. Strictly speaking, both effects should be interpreted as delayed effects. However, it should be noted that no effects were observed for fixations coming back to the target sentence once the reader had moved away from it. This suggests that readers do not tend to postpone the interpretation of a sentence beyond sentence boundaries.

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Appendix

English Translation of the Stimulus Text

The target sentences are in italics; the topic-shift sentence is the initial sentence in the paragraph, and the topic-progression sentence appears immediately following it.

William Pitt as the builder of the British empire in the 18th century.
William Pitt was the most prominent English statesman in the 18th century. When only 27 years of age, Pitt was elected to the House of Commons, where he firmly criticized the government's conservative foreign policy. In the 1750's the situation in Europe and the colonies began to grow more and more critical. As a result, a seven-year war broke out upsetting the whole world. During the first years of the war England suffered from great losses, especially to France. The English government proved incapable to change the course of the war. The desperate Englishmen had trust only in one man, and so Pitt took leadership in the new government in 1756. Pitt's leading motive was to raise England to a world power. However, the major obstacle was the militarily and economically strong France. Therefore, the war was primarily aimed at overthrowing France. The competing France should no more threaten England's domination in the future. Pitt began to take measures on the basis of a highly controlled plan. Above all, France's economy and its military power in Europe had to be broken down.

Pitt wanted to secure Britain itself against the enemy's disembarkation.
On the islands, civilian troops were formed to help the military forces.
Due to efficient defense, France's attempts to disembark on the islands failed.

In the continent, the idea was to help Prussia to a victory over France.
Pitt sent his own army to fight along with the Prussian troops.
In less than a year, the allied troops' victory lead to France's withdrawal.

France's trade links had to be broken off to the colonies.
French ports were blockaded by Pitt from the sea.
Consequently, the French fleet was almost totally destroyed by the Englishmen.

The most important battles, however, took place in the colonies and on the ocean. There, Pitt's goal was to destroy the enemy's naval forces and conquer its territories. It was especially in the colonies where Pitt achieved his most glorious victories.

In North America, Pitt's primary purpose was to conquer the rich Canada.
Surprise attacks were directed against Canada's most significant cities.
The French colonial army that defended Canada had to surrender soon.

The profitable fishing by the French had to be ceased on the Canadian coast.
In the peace treaty France was forced to give up its fishing privileges.
However, most of the water areas were eventually left for the Frenchmen.

In India, France had to be thrown out of its trading territories.
The private war of the British trading companies was backed up with governmental troops.
The Frenchmen surrendered their territories one by one after their military bases were destroyed.

So the French domination and its constant threat to England came to an end. Pitt was successful in weakening France's trading conditions and in unstabilizing the nation's status as a strong naval power. In the peace treaty, France was forced to conform to very stringent conditions. The English government, however, thought that Pitt had gone too far in his claims, and so Pitt, giving up his dream, resigned from his office in 1761. The new government abandoned all the occupied territories, except Canada. Thus, France got another chance to compete for world domination. Pitt bitterly criticized the final fate his victories suffered in the peace pact. After all, thanks to Pitt, England accomplished a leading status in the world, although the new government had ruined most of Pitt's achievements. Under Pitt's leadership, a sound basis was established for the British world power.

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