Episodically Enhanced Comprehension Fluency

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Abstract  Fluent reading comprehension was explored in a series of experiments involving sentences presented in normal and inverted typography. Sentences read in a test phase had been read earlier in exactly the same form, or in versions that were created by (a) altering the word order within sentences to create randomly ordered word strings or (b) exchanging causally related clauses to form new meaningful sentences. Variation from exact repetition of word order or clause combination increased the time taken to read the test sentences and these effects were evident over retention intervals ranging from one day to four months. Varying word order across repeated presentations of a sentence was also shown to reduce reporting accuracy in a rapid serial reading task. These results support an episodic view of the basis for rereading fluency in which comprehension processes responsible for constructing and integrating propositions are automatically recruited and reapplied when a sentence is reread.

Résumé  La facilité de compréhension de textes a fait l'objet d'une série d'expériences dans lesquelles les sujets devaient lire des phrases dont la typographie était tantôt normale, tantôt inversée. Les phrases présentées à l'étape d'essai avaient été lues auparavant soit sous une forme identique, soit sous une nouvelle forme où a) l'ordre des mots dans les phrases était modifié de manière à créer des suites de mots agencés au hasard ou b) les propositions causales étaient combinées autrement pour créer de nouvelles phrases sensées. Lorsque l'ordre des mots ou l'agencement des propositions était modifié par rapport à celui qui était répété fidèlement, le temps de lecture des phrases présentées à l'essai était plus long, et cet effet se manifestait de façon évidente après les intervalles de rétention allant d'un jour à quatre mois. La présentation répétée d'une même phrase dans laquelle l'ordre des mots était modifié avait également pour effet de réduire l'exactitude des réponses données pendant une tâche de lecture rapide en série. Les résultats obtenus témoignent des bases épisodiques de la facilité de relecture où les processus de compréhension responsables de la construction et de l'intégration des propositions sont automatiquement sélectionnés et réactivés lors de la relecture d'une phrase.

Literacy skills have been cultivated and prized in part for their artistic merits, but their primary function remains that of communicating meaningful messages. Much of the value of written and spoken messages lies in the lasting impact they have on the receiver. A central issue regarding the communicative function of language, therefore, is how the persistent influence of a message is maintained in memory across time and how it is called forward to guide behavior when appropriate. One very fruitful approach to this issue has been the exploration of text structure and its influence on the ability to remember intentionally the content of a text (e.g., Moravcsik & Kintsch, 1993; Trabasso & van den Broek, 1985). A second approach, pursued further in this article, has emphasized the idea that memory for a comprehension episode is captured procedurally and is revealed through the fluent reapplication of these procedures when a previously comprehended message (or critical components of it) is encountered at a later time (e.g., Kolers & Roediger, 1984).

The view that memory for text comprehension episodes is captured in a set of processing operations was advanced by Kolers (1975) as a contrast to the prevailing emphasis on memory for the meaning of text. The procedural nature of memory was demonstrated by showing that the analysis of the surface features of a sentence was an integral part of memory for the sentence. The time taken to reread typographically transformed (e.g., upside down) sentences varied depending on whether sentences were read initially in that form. Sentences read in normal typography on the first occasion (or heard, rather than read) were not read as fluently when re-presented for reading in transformed typography. In a particularly striking demonstration of the long-lasting influence of memory for processing operations, Kolers (1976) showed that typographically transformed texts read one year earlier were reread faster than new texts.

The procedural view of memory for reading episodes has been encouraged by work with certain types of memory-impaired subjects using both normal and typographically transformed materials. Despite impairment in their ability consciously to remember previously read texts, sentences, or words, these subjects nonetheless show normal levels of fluency when rereading these materials (Cohen & Squire, 1980; Moscovitch, Winocur, & McLachlan, 1986; Musen, Shimamura, & Squire, 1990; Musen & Squire, 1991). These results suggest that reapplication of processing operations can go forward without support from consciously recollected aspects of the original reading experience.

Although Kolers emphasized the components of processing operations responsible for analyzing the graphemic aspects of text, there is ample evidence of the important role played by conceptually driven operations in generating rereading fluency. In earlier work, I have found that memory for normal but not typographically transformed sentences can be enhanced by requiring subjects to perform an elaborative encoding task during initial
reading (Masson, 1984; Masson & Sala, 1978). This finding suggests that the task of deciphering typographically transformed sentences recruits an analysis of the meaning of the sentence to provide contextual information. The importance of conceptually driven processes in fluent rereading of typographically transformed texts has been pushed further by Graf and Levy (1984), Horton (1985), and Tardif and Craik (1989), who argued that although subjects developed a general improvement in pattern analyzing skill, the specific influence of prior reading episodes was due entirely to semantic processing operations (e.g., gist and lexical information). In their experiments two different typographical transformations were used and there was no reliable difference in rereading fluency when the original or the alternative transformation was used on the second reading of a text.

More recently, however, Craik and Gemar (cited in Craik, 1991) found that using different transformed typographies on the two readings of a text does produce a small but reliable reduction in rereading fluency. In addition, Jacoby, Levy, and Steinbach (1992) showed that subjects were sensitive to changes in normal type font (e.g., script and elite) across two reading occasions, but only when the task was to read and answer questions. Reading aloud the same questions failed to produce sensitivity to changed font. Jacoby et al. concluded that integrated episodic representations of initial reading experiences are effectively recruited only when reading is carried out in service of some other primary goal, not when the act of reading is the focus of attention, as in reading aloud.

The pattern of results that has followed in the wake of Kolers' original demonstrations is consistent with the major theme he advocated, namely that a variety of processing operations (including analysis of surface features) are integrally represented in memory as a consequence of a reading experience. Although it is clear that conceptually driven operations make a contribution to rereading fluency, we know relatively little about the comprehension processes that contribute to this fluency. A series of proofreading studies with normally typed texts by Levy and her colleagues (Levy & Begin, 1984; Levy, Newell, Snyder, & Timmins, 1986), however, has established a number of important facts. First, proofreading is done more quickly and without loss of accuracy if a text has been read previously, even when errors consist of words that violate semantic or syntactic constraints. This result implies that rereading fluency is attained without attenuating the analysis of the text's meaning. Second, rereading fluency depends on preserving the semantic message in a text. When texts were tested in normal word order following an initial reading, reading time was lower when the initial reading also involved normal rather than scrambled word order. The reverse was true when texts were tested in scrambled word order.

Sensitivity to changes produced by scrambling word order has been explored using other reading tasks, such as reading in preparation for a
memory test (Levy & Burns, 1990; Levy & Kirsner, 1989). For example, Levy and Burns obtained varying degrees of reduction of rereading time on normal texts by applying a range of text scrambling procedures to texts on their first reading. Rereading fluency was not affected by scrambling the order of paragraphs within a text, but was reduced by reordering the sentences, and was eliminated when words were randomly reordered. In contrast to the sensitivity to text meaning indicated by these studies, Carr, Brown, and Charalambous (1989) and Carlson, Alejano, and Carr (1991) obtained inconsistent effects of scrambling on rereading fluency when texts were read aloud. Carr et al. failed to find an effect of scrambling on rereading fluency, but Carlson et al. did find an effect when subjects were directed to focus on the meaning of the texts. Requiring subjects to read texts in a word by word manner with instruction to ignore the meaning of the texts, however, eliminated the scrambling effect. Carlson et al. proposed that attentional focus determines whether scrambling will have an effect on rereading coherent texts. When attention is focused at the level of text meaning, rereading fluency is based in part on text comprehension processes, but when attention is focused at the lexical level, fluency is driven by lexical processes.

An alternative proposal was put forward by Levy, Masson, and Zoubek (1991) on the basis of evidence from their experiments and the Levy and Burns (1990) study. These experiments indicate that for texts tested in normal word order, sensitivity to scrambling of word order during initial reading is obtained across a variety of reading tasks, ranging from oral reading and detecting Greek letters to reading in preparation for recall or summarization tasks. Levy et al. argued that processing the meaning of text and using that experience to enhance later rereading fluency has a Stroop-like quality that is impervious to all but the most extreme task demands. In contrast, when rereading involves scrambled text, the effect of initially reading the text in scrambled or normal form varies with reading task. A reliable advantage for initially normal texts was found with tasks that required processing the meaning of the texts. With superficial reading tasks such as oral reading there was no effect of initial text format. These results suggest that rereading scrambled texts is more susceptible to instructional influences than rereading normal texts.

The line of research involving normal and scrambled texts provides us with the best clue so far concerning the role of comprehension processes in rereading fluency. The Levy and Burns (1990) experiments in which sentence and word order were manipulated offer the most detailed information with respect to specific comprehension processes. The experiments described here were designed to examine sentence-level comprehension processes that contribute to fluent rereading. The general paradigm used in all of the reported experiments involved having subjects read sentences in a training phase, then reread these sentences (sometimes after undergoing a reordering
of units) in a subsequent test phase. Unrelated sentences rather than entire texts were studied because reordering of units applied at one level of a text (e.g., changing sentence order or word order) is bound to influence not only operations that are specific to that level, but also all other higher level operations (e.g., construction of a situation model).

In Experiments 1-4, contributions of conceptually driven processes to fluent rereading of typographically transformed sentences were examined. Transformed typography was used for two reasons: (1) to enhance the role of conceptually driven processes (e.g., Horton, 1985; Masson & Sala, 1978; Tardif & Craik, 1989), thereby increasing the sensitivity of the experiments to manipulations that affect these processes, and (2) to make contact with the rich body of earlier work on reading fluency involving transformed typography. In Experiment 1 three different methods of rearranging words within and across sentences were used to determine the relative importance of lexical, syntactical, and propositional processing for the conceptually driven operations that are invoked when reading typographically transformed sentences. Only propositional operations were found to make a significant contribution to the conceptually driven processes used to decode typographically transformed sentences. Experiments 2 and 3 provide evidence that these operations play a crucial role in fluent rereading of such sentences after delays of up to four months. These results run counter to the conclusion drawn by Kolers (1976) that fluent rereading of typographically transformed texts should be attributed to memory for graphemic pattern analyzing operations. Evidence from Experiment 4 rules out the possibility that rereading fluency is based on sensitivity to repeated word order, independent of any higher order linguistic processing.

In two additional experiments, fluent rereading of sentences in normal typography is examined. The results of Experiment 5 demonstrate that conceptually driven processes operate and form re-useable memory representations even under severely constrained reading conditions. Processes involved in the integration of causally related clauses are shown in Experiment 6 to contribute to the fluent rereading of sentences, extending the range of conceptual processes implicated in fluency effects.

**Experiment 1**

In Experiment 1 the objective was to determine which of several sentence-level comprehension processes are involved in reading typographically transformed sentences. The experiment was patterned after classic studies by Miller and his colleagues (Marks & Miller, 1964; Miller & Isard, 1963) involving perception and recall of aurally presented sentences. They

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1 I use the term *proposition* to refer to a unit of meaning similar to that developed by Kintsch (1974).
used sentences created by varying word order within normal, meaningful sentences (to create scrambled sentences) and by exchanging words across sentences to create grammatically correct but meaningless (anomalous) sentences. Performance on normal sentences was better than on scrambled or anomalous sentences, which yielded similar levels of accuracy. Performance was worst on sentences created by scrambling the word order of anomalous sentences (scrambled-anomalous). The advantage of normal sentences over all other sentence types indicates that construction of meaningful propositions made an important contribution to the perception of word strings. The advantage of the scrambled and anomalous sentences over the scrambled-anomalous items suggests that semantic relatedness of words and syntactical processing, respectively, also served to enhance language perception.

These four sentence types were used in Experiment 1. Sentences were presented visually in transformed typography and the task was to read aloud each sentence. In the training phase of the experiment, one set of sentences of each type was read, then in the test phase these sentences were reread along with one set of new sentences of each type. Repeated sentences were always tested in the same format as that used during training. It was expected that if construction of meaningful propositions was an important component in reading typographically transformed sentences, reading time would be lower in the normal sentence condition than in any other condition. Contributions from semantic relatedness between words and syntactical processes would be reflected in a reading time advantage for scrambled and anomalous conditions over the scrambled-anomalous condition. A subset of the sentences were presented in both phases to determine whether the component processes that contribute to fluent reading change across two readings of the same sentence. If the components remain stable, it would be expected that new and old sentences in the test phase would show the same pattern of reading times across the four sentence types.

**METHOD**

**Subjects**

The subjects were 16 undergraduate students at the University of Victoria who volunteered to participate in the experiment. All subjects who served in the experiments reported here were drawn from this population and each subject took part in only one experiment.

**Materials and design**

A set of 60 sentences was constructed and randomly divided into four lists of 15 sentences each. A sentence occupied about one to one and a half lines on a computer monitor capable of displaying 80 characters on each line (e.g., Water purification techniques will be drastically changed following the commission meeting). Three additional versions of each list of 15 sentences
were created. The scrambled version was created by randomly reordering the words within each sentence (e.g., the drastically following changed techniques will Water purification be meeting commission). The words from each list of 15 sentences were rearranged to form a list of 15 anomalous sentences that were grammatically correct but that constituted meaningless phrases (e.g., Distances in the literary cars can be described as commission following the objective city). For the last version, the words within each of the anomalous sentences were randomly reordered to produce scrambled-anomalous sentences (e.g., Objective be described the can as cars commission literary distances following the in city). An additional set of four sentences, one of each type, was constructed for use as practice items at the start of the experiment.

Subjects read 15 unique sentences in each version. The assignment of lists to subjects was counterbalanced so that each list of 15 sentences was read equally often in each version.

Procedure

Instructions and sentences were presented to subjects using an Apple II+ microcomputer equipped with two green monochrome monitors and a timing card that provided millisecond timing accuracy. One monitor was viewed by the subject and the other was visible only to the experimenter. The second monitor was used to present sentences in normal type font so the experimenter could check the accuracy of the subjects’ reading. This set-up was used in all the experiments reported here.

Subjects were tested individually in two phases. In the training phase of the experiment, subjects were told that they were to read aloud a series of sentences, some of which would not make sense. They were also informed that to make the task more challenging each sentence would be presented upside down. Subjects were encouraged to read the sentences as quickly as possible. At the beginning of a trial the word READY appeared in normal font at the right side of the middle line of the subject’s monitor to indicate the position of the first word in the sentence. The subject pressed a key on a computer keypad, causing the monitor to be cleared and a sentence to be presented 500 ms later. The sentences were presented in a geometrically transformed typography equivalent to the view provided when reading a printed page that has been turned upside down, requiring subjects to read from right to left. The computer clock was started as soon as the sentence appeared on the monitor and stopped as soon as the experimenter pressed a key on the keyboard to indicate that the subject had read the final word of the sentence. The experimenter ensured that the subject correctly read each word. When a word was misread the subject was told immediately to try it again and continued until it was correctly identified. The subject then moved on to the next word. No record was kept of reading errors and time to reread words was included in the reading time measure. The four practice sentences were
TABLE 1
Mean Reading Time (in seconds) in Experiment 1

<table>
<thead>
<tr>
<th>Phase</th>
<th>Normal</th>
<th>Scrambled</th>
<th>Anomalous</th>
<th>Scrambled-anomalous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training</td>
<td>17.31</td>
<td>22.89</td>
<td>25.05</td>
<td>22.60</td>
</tr>
<tr>
<td>Test</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Old</td>
<td>11.27</td>
<td>15.27</td>
<td>15.23</td>
<td>15.30</td>
</tr>
<tr>
<td>New</td>
<td>14.57</td>
<td>19.79</td>
<td>20.44</td>
<td>22.82</td>
</tr>
</tbody>
</table>

Note. The estimated standard deviations of subjects’ mean reading times, pooled across all four sentence conditions, were 11.82, 5.91, and 9.08 in the training, test-old, and test-new conditions, respectively.

presented first, followed by eight randomly selected sentences from each list of 15 sentences assigned to the subject. These 32 critical sentences were presented in a randomly determined order. At the beginning of the test phase subjects were told that they would read another set of sentences, some of which would be the same as the ones they had just read. Subjects then read the entire set of 60 critical sentences presented in a random order.

RESULTS
Reading times greater than 120 s were excluded from the analysis, resulting in a loss of 0.1% of the trials. Three reading time means for each type of sentence were computed for each subject. One mean was based on the eight sentences read in the training phase, another on the same sentences when they were reread in the test phase, and one was based on the seven new sentences of each type that were presented in the test phase. The mean reading time for each of these conditions, computed over subjects, is shown in Table 1.

The mean reading times for the training phase were included in an analysis of variance (ANOVA) with sentence type as a within subjects factor, and type I error rate set at .05 (as in all experiments reported here). There was a reliable effect of sentence type, $F(3, 45) = 9.56, MS_e = 18.14$. As can be seen in Table 1, only in the normal condition was the mean reading time less than that in the scrambled-anomalous condition. Test phase reading times were analyzed in an ANOVA with prior presentation (old, new) and version as factors. Old sentences took less time to read than new ones (14.27 s vs 19.40 s), $F(1, 15) = 27.28, MS_e = 30.98$, and the difference among versions was significant as well, $F(3, 45) = 24.66, MS_e = 9.42$. The interaction between prior presentation and version was not significant, $F(3, 45) = 2.11, MS_e = 11.92$.

Although the interaction was not significant in the analysis of test phase data, the pattern of means suggests that among the new but not the old
sentences there was an advantage for scrambled and for anomalous over scrambled-anomalous sentences. This possibility was tested in two additional ANOVAs. In one, scrambled and scrambled-anomalous versions of old and new sentences were compared. Once again, old sentences were read faster than new ones (15.28 s vs 21.30 s), $F(1, 15) = 21.92$, $M_{S_e} = 26.43$. Scrambled sentences were read faster than scrambled-anomalous sentences (17.53 s vs 19.06 s), $F(1, 15) = 7.17$, $M_{S_e} = 5.24$, and the interaction between prior presentation and version was significant, $F(1, 15) = 5.54$, $M_{S_e} = 6.51$. The reliable interaction indicates that subjects made use of semantic relatedness among words in the scrambled sentences to reduce reading time, but only if the sentences had not been read previously. In the other ANOVA, anomalous and scrambled-anomalous versions of old and new sentences were compared, but only the effect of prior exposure was significant (15.26 s and 21.63 s for old and new sentences, respectively), $F(1, 15) = 23.09$, $M_{S_e} = 28.08$. These results fail to support the proposition that subjects reliably made use of syntactic regularity, independently of semantic content, in reading inverted sentences.

DISCUSSION

Normal sentences were read in less time than any of the other three sentence types, indicating that the advantage associated with these sentences is not due entirely to either the semantic relatedness between words or to syntactic regularity. The most reasonable conclusion is that constraints associated with the construction of meaningful propositions enabled subjects to more quickly read the normal sentences. Moreover, the fact that the normal sentence advantage appeared on both readings of repeated sentences indicates that proposition-construction processes contributed to fluent reading on both reading occasions. This result is important because it supports conclusions drawn from the remaining experiments in this series regarding the basis for rereading fluency.

In contrast to the strong contribution made by proposition construction, there was no evidence that syntactical processing in the absence of meaningful propositions enhanced reading fluency. Evidence regarding the role of semantic relatedness between words, as measured by performance on scrambled sentences, was somewhat ambiguous. Only among new sentences in the test phase was there any evidence that scrambled sentences were read more fluently than scrambled-anomalous sentences. Repeated sentences and sentences in the training phase did not show this effect. A possible account of this difference is that when sentences are reread the reapplication of procedures used during the first reading can inhibit the use of an emerging strategy that involves additional procedures. This notion is rather speculative, given the post hoc nature of the analyses involving scrambled sentences, but it is suggestive of the powerful nature of memory for processing episodes.
Experiment 2

The question addressed in Experiment 2 was whether proposition-building processes applied on the first reading of a sentence are remembered and reapplied to promote fluent rereading. Although the results of Experiment 1 showed that these conceptually driven processes operate when a sentence is reread, that experiment was not designed to detect a contribution of memory for processes executed during the first reading of a sentence. The reapplication of reading operations can be demonstrated, however, by manipulating the word order of sentences across their two readings. When a meaningful sentence maintains its word order across both readings, proposition-building operations can be reapplied on the second reading and should increase fluency. When a sentence initially is read in scrambled word order, then reread with the words arranged in a meaningful order, the subject would not have had prior experience at constructing the appropriate propositions. In this case, fluency should suffer relative to the case in which meaningful word order is maintained across both readings.

In Experiment 2, which was similar to experiments involving normal and scrambled texts (e.g., Carr et al., 1989; Levy & Burns, 1990), subjects first read a set of normal and scrambled sentences in transformed typography, then reread these and new sentences in either normal or scrambled form. If comprehension processes that contribute to the reading of meaningful sentences also contribute to later rereading fluency, rereading time for normal sentences should be less when the original reading involved normal rather than scrambled word order. A transfer-appropriate processing view (e.g., Morris, Bransford, & Franks, 1977; Roediger, Weldon, & Challis, 1989) leads to the prediction that rereading sentences in scrambled word order might be expected to benefit more from an initial reading in scrambled form. Experiments with texts have produced conflicting results regarding this comparison (e.g., Carr et al., 1989; Levy & Begin, 1984; Levy & Burns, 1990; Levy et al., 1991), suggesting that the reading of scrambled texts may be affected by strategies that vary with the reading task set by the experimenter (e.g., read aloud or provide a summary). It was expected that the task of reading individual sentences would not be strongly affected by such strategies and that a more clear test of the transfer-appropriate processing view would be possible. To help discourage the use of strategies that might be motivated by the initial reading of sentences, a delay interval of seven days was inserted between training and test phases for one group of subjects.

METHOD

Subjects

A sample of 36 subjects was randomly assigned to two groups of 18. One group received the training and test phases with no delay interval and the other was tested after a delay interval of seven days.
**Materials and design**
A set of 90 sentences similar to the normal sentences used in Experiment 1 was constructed and randomly divided into six lists of 15 sentences each. A scrambled version of each sentence was also created by randomly reordering the words within each sentence. One list of sentences was assigned to each of six conditions produced by a factorial combination of sentence version presented during the training phase (normal, scrambled, new — meaning that the sentences were presented only in the test phase) and version presented during the test phase (normal, scrambled). This assignment was counterbalanced across subjects so that each sentence appeared in each condition equally often. Two practice sentences, one normal and one scrambled, were constructed for use in the training phase.

**Procedure**
Instructions to subjects and the procedure were the same as in Experiment 1, and all sentences were presented in the same inverted typography as that used in Experiment 1. In the training phase subjects read aloud the two practice sentences followed by four sets of 15 sentences presented in a random order. Two of the sets consisted of sentences with normal word order and the other two sets were scrambled sentences. After the training phase, subjects in the immediate-test group then read aloud all 90 critical sentences. There were 15 sentences in each of the six conditions and they were presented in a random order. Subjects in the delayed-test group were dismissed and reminded to return one week later, at which time the test phase was administered.

**RESULTS**
Reading times longer than 120 s were not included in the analyses, resulting in the exclusion of 0.1% of the trials. Training and test phase reading time means for each sentence condition were computed for each subject. The mean training phase reading time was not reliably different for the two groups of subjects, but across both groups normal sentences were read in less time than scrambled sentences (19.13 s vs 27.23 s), $F(1, 34) = 93.99, MS_e = 13.31$. The mean reading times for the test phase are shown in Figure 1.

The test-phase reading times were submitted to an ANOVA with test delay (immediate, seven days), training version (normal, scrambled, new), and test version (normal, scrambled) as factors. There was a reliable effect of test version, $F(1, 34) = 120.13, MS_e = 15.71$, indicating that normal sentences were read more quickly than scrambled sentences (21.01 s vs 29.35 s). The main effect of training version was significant, $F(2, 68) = 43.88, MS_e = 7.61$, as normal (15.76 s) and scrambled sentences (16.35 s) were read more quickly than new sentences (19.75 s). There also was a reliable training by test version interaction, $F(2, 68) = 5.05, MS_e = 4.06$. None of the effects involving delay were significant.
Fig. 1 Mean reading times in the test phase of Experiment 2. Data in the left panel are from the immediate-test group; data in the right panel are from the 7-day delayed-test group. Error bars indicate one standard error of the difference between means, computed separately for each cluster of three training version conditions.

The training by test version interaction was explored by examining separately the effect of training version on sentences tested in normal and scrambled versions, including delay group as a factor. For normal test sentences, one ANOVA was used to compare originally normal and scrambled sentences. Sentences trained in normal form were reread in less time than sentences trained in scrambled form (12.40 s vs 14.00 s), $F(1, 34) = 22.24$, $MSE = 2.08$, and there was no effect of delay. A second ANOVA compared originally scrambled and new sentences that were tested in normal form. Originally scrambled sentences were read more quickly than new ones (14.00 s vs 16.59 s), $F(1, 34) = 39.65$, $MSE = 3.05$, but this effect interacted with delay, $F(1, 34) = 5.10$, $MSE = 3.05$, indicating that the advantage of the specific

2 An additional experiment, not reported in detail, was conducted as a replication of Experiment 2. In this study delay interval was manipulated within subjects, so that half of the critical sentences were tested immediately and half after a delay of seven days. Only normal word order was used in the two test phases. The pattern of means for each of the three training versions (normal, scrambled, and new) was the same as in Experiment 2, with a robust advantage of normal over scrambled training versions. Moreover, the interaction between delay and training version did not approach significance, indicating no decrease in the potency of memory for comprehension processes over the one-week interval.
reading experience with scrambled sentences was reduced over the seven-day retention interval (an advantage of 3.52 s in the immediate group and 1.66 s in the delayed group). Two similar ANOVAs were applied to data taken from sentences tested in scrambled form. In the analysis comparing originally normal and scrambled sentences (mean reading times of 19.12 s and 18.70 s, respectively), there were no reliable effects ($F$s $< 1$). The other analysis compared normal and new test sentences, and indicated that there was a reliable advantage for sentences that had been read in normal form (19.12 s vs 22.91 s), $F(1, 34) = 24.55$, $MS_e = 10.54$. No other effects were significant ($F$s $< 1$).

**DISCUSSION**

The results of Experiment 2 indicate that sentence comprehension processes applied during the first reading of a meaningful sentence are invoked when that sentence is later reread. Rereading fluency among normal test sentences was also produced by first reading scrambled versions of those sentences. Experience with scrambled sentences either enabled subjects to construct and reuse an impoverished version of a sentence's meaning or provided subjects with word-specific experience that could be reapplied when those words were later encountered in a meaningful sentence.

Reading normal sentences was as beneficial as reading scrambled sentences when scrambled test sentences were assessed, contrary to what would be expected from the transfer-appropriate processing view. This result is in agreement with the results of earlier text reading experiments (e.g., Levy & Burns, 1990, Exp. 4; Levy et al., 1991, Exp. 1), but is inconsistent with the finding that reading words in the context of a text or meaningful sentence produces little or no facilitation on a subsequent word identification task (e.g., Levy & Kirsner, 1989; MacLeod, 1989). The current result involving rereading scrambled sentences, as well as previous studies with scrambled texts, may reflect a strategic use of memory for the message of the earlier reading to construct a meaningful interpretation of the scrambled version of the sentence.

Experiment 3 was conducted to reduce the feasibility of this strategy by imposing a very long retention interval between training and test phases. With such a delay in effect, subjects should be less likely to make intentional use of memory for the message constructed during the first reading of a sentence. It was not expected that this would alter the pattern of results found with normal test sentences inasmuch as rereading fluency is viewed as resulting from automatic reapplication of comprehension processes. In the case of scrambled test sentences, however, the delay might differentially reduce the rereading fluency that arises from first reading the sentences in normal versus scrambled word order. If subjects in Experiment 2 intentionally used memory for a sentence's meaning when rereading it in scrambled form, they should...
have drawn more benefit in doing so from initially normal sentences. Reduction of this benefit brought on by a sufficiently long retention interval could produce a rereading advantage for sentences initially read in scrambled as compared with normal form. This result should occur if prior reading of scrambled sentences can sustain rereading fluency across a long retention interval by enhancing the identification of individual words, independently of the surrounding context.

Experiment 3

METHOD
A sample of 24 subjects was tested. A set of 90 sentences of less than 80 characters in length was constructed and randomly divided into six lists of 15 sentences each (e.g., He had no choice but to sell the house and dismiss all the servants). A scrambled version of each sentence was created as in the earlier experiments. The design and procedure were identical to those of Experiment 2, with the following exceptions. First, only one group of subjects was tested, with a four-month delay interval between training and test phases. Second, at the conclusion of the training phase, subjects were led to believe that the experiment was at an end. They were not told that they would be contacted four months later for a test phase. Third, at the beginning of the test phase, subjects were not told that they would be rereading sentences from the first phase of the experiment.

RESULTS
One subject did not return for the test phase so the data reported here are based on 23 subjects. Reading times greater than 120 s were excluded from the analyses, resulting in the loss of 0.4% of the trials. Because of the shorter sentences, reading times generally were lower than in Experiments 1 and 2. In the training phase normal sentences were read in less time than scrambled sentences (10.10 s vs 15.40 s), t(22) = 7.69, SE_{dm} = 0.69. The mean reading time for each condition in the test phase is shown in Figure 2. The pattern of means was similar to that of Experiment 2, except that the specificity of transfer effects was stronger in Experiment 3.

An ANOVA applied to test phase reading times with training and test version as factors revealed a significant effect of test version, with normal sentences read in less time than scrambled sentences (8.18 s vs 11.80 s), F(1, 22) = 61.65, MS_{e} = 7.35. The effect of training version was also reliable, with normal (9.78 s) and scrambled (9.81 s) sentences read more quickly than new sentences (10.38 s), F(2, 44) = 6.88, MS_{e} = 0.75. The interaction between training and test version was significant as well, F(2, 44) = 5.16, MS_{e} = 1.16. A series of t-tests were used to examine specificity of transfer in each of the test versions. For normal test sentences, reading times were shorter if sentences originally were read in normal rather than scrambled form (7.68 s
Fig. 2 Mean reading times in the test phase of Experiment 3. Error bars indicate one standard error of the difference between means, computed separately for each cluster of three training version conditions.

vs 8.40 s), $t(22) = 3.51, SE_{dm} = 0.21$, and there was no significant benefit of prior reading in scrambled form over reading new normal sentences (8.45 s), $t < 1$. For scrambled test sentences, the advantage for previously reading a scrambled rather than a normal version was significant by a directional test (11.22 s vs 11.88 s), $t(22) = 1.82, SE_{dm} = 0.36$, and the difference between originally normal and new sentences (12.30 s) was not significant, $t(22) = 1.54, SE_{dm} = 0.27$.

DISCUSSION

With an extended delay imposed between readings, the specificity of the effects of initial reading were more pronounced than in Experiment 2. In the task of reading normal test sentences, no benefit was derived from an earlier reading of a scrambled version. This result is particularly interesting in light of Kolers’ (1976) demonstration of fluent rereading of text after a delay of one year. The fluency with previously read texts demonstrated in that study typically has been attributed to memory for pattern analyzing operations of a
perceptual nature. The present results suggest that a more accurate explanation of Kolers' result is that subjects were reapplying comprehension processes that were carried out during the initial reading of the texts. Exposure to component words is not adequate to produce long-lasting fluency effects when meaningful sentences are read.

The pattern of results regarding sentences tested in scrambled form is consistent with the transfer-appropriate view, although the data show a certain reluctance to escape the influence of initially reading a meaningful sentence. There was a trend favoring sentences that first were read in scrambled form. By the transfer-appropriate processing view, this trend is the result of using similar processes on both readings to encode words with little or no contextual assistance when sentences were trained and tested in scrambled form. Contextual support provided by normal training sentences was not available at the time of test, leaving subjects less prepared for the more difficult word identification task engendered by reading scrambled sentences.

**Experiment 4**
Before accepting the conclusions drawn from Experiment 3, an alternative explanation needs to be addressed. The advantage of presenting a sentence in the same version in both the training and test phases might arise not from processing specific to comprehension of sentence meaning or to identification of individual words, but from repetition of the order in which a string of words is presented. This suggestion is plausible, given that Whittlesea (1990) has shown that the second reading of a scrambled text is faster when the same rather than a different random ordering of words is used on the two readings. Whittlesea's account, however, was not one of word order per se, but rather that subjects were able to construct a meaningful message from the scrambled text and that this constructed message was more stable when a fixed random word order was used. Moreover, there is a large amount of variability among texts with respect to whether maintaining the random word order matters (Carr & Brown, 1990). In any case, this view of word order effects is compatible with the present emphasis on the role of comprehension processes in rereading fluency.

A more important concern is whether word order effects might arise from perceptual or lexical processes unrelated to construction of a meaningful message. To test this possibility, Experiment 4 was conducted using randomly ordered lists of unrelated nouns or nonwords. Each list read in the training phase was later presented in the same or a different random ordering. A delay of seven days was imposed between training and test sessions, as in Experiment 2. If lexical or perceptual benefits of maintaining word order across both readings were the critical factor in producing the results of Experiments 2 and 3, rereading lists of unrelated words or nonwords should be more fluent when the order of items is consistent across training and test readings.
METHOD

Subjects
A sample of 18 subjects was tested.

Materials and design
A set of 45 eight-word lists was constructed using unrelated nouns that were five or more characters in length (e.g., curtain sandwich parent octopus mattress pilot empress meteor). A set of 45 lists of eight pronounceable nonwords also was constructed (e.g., misk nin hort cron fum cluve shog hent). The nonwords were only three to five characters in length so that initial reading times for the lists of words and nonwords would be similar. Items in each list were randomly ordered. A second version of each list was constructed by randomly reordering items within the list. The word and nonword lists were treated as three sets of 15 lists each for purposes of counterbalancing. One list of each type was assigned to each of the three conditions in the experiment: trained and tested in the same order, trained and tested in different orders, and not trained. Assignment of lists to conditions was counterbalanced across subjects so that each version of the word and nonword lists appeared equally often in each condition.

Procedure
Subjects were tested using the same procedure and inverted typography as in the earlier experiments. In the training phase they read aloud four practice lists, two of words and two of nonwords, followed by 30 lists of words and 30 lists of nonwords. These 60 critical lists were presented one at a time in a randomly determined order. At the conclusion of the training session subjects were reminded to return seven days later for a second session. At the start of the test session subjects were not told that some of the lists they would read were the same as lists that had been presented in the training session. They read aloud four practice lists followed by 45 lists of words and 45 lists of nonwords, presented in random order. Within each list type, 15 lists had not been read in the training phase, 15 had been read in the same order as they appeared during the test, and 15 lists had been read but the items within a list had been in a different order in the training session.

RESULTS
Reading times longer than 30 s were not included in the analyses, resulting in the exclusion of 3.1% of the trials. Using shorter nonwords was sufficient to produce very similar reading times for the word and nonword lists in the training phase (12.29 s vs 12.43 s), t < 1. The mean reading time for each condition in the test phase is shown in Table 2. The test phase data were analyzed in an ANOVA with list type and training version as factors. There was a reliable effect of training version (9.11 s, 9.18 s, and 10.17 s for same,
TABLE 2
Mean Reading Time (in seconds) in the Test Phase of Experiment 4

<table>
<thead>
<tr>
<th>List</th>
<th>Training version</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Same order</td>
<td>Different order</td>
</tr>
<tr>
<td>Words</td>
<td>8.70</td>
<td>8.82</td>
</tr>
<tr>
<td>Nonwords</td>
<td>9.52</td>
<td>9.53</td>
</tr>
</tbody>
</table>

Note. The estimated standard deviations of subjects’ mean reading times, pooled across all three training versions, were 4.30 and 2.92, for the word and nonword lists, respectively.

different, and new, respectively), $F(2, 34) = 22.82$, $MS_e = 0.56$, and an interaction between list and training version, $F(2, 34) = 6.92$, $MS_e = 0.47$. The list main effect was not significant ($F < 1$). The significant interaction indicates that the effect of prior reading was greater for the lists of words than for the lists of nonwords. Of particular interest was whether changing the order of items within lists influenced the effect of training on rereading time. The same- and different-order conditions were compared for each type of list. Neither comparison resulted in a significant effect, $t$s < 1. Finally, the average reading time across the same and different conditions was compared with the reading time in the new condition for each list type (8.76 s vs 10.31 s for words and 9.52 s vs 10.03 s for nonwords). Both comparisons were significant, $t(17) = 4.95$, $SE_{dm} = 0.31$, and $t(18) = 2.96$, $SE_{dm} = 0.17$, for the word and nonword lists, respectively.

DISCUSSION
The results of Experiment 4 clearly indicate that although lists of words and nonwords both produce a reliable rereading effect, changing the order of items across training and test phases had no influence on this effect. The lack of an order effect suggests that the results of Experiments 2 and 3 were not due to a sensitivity to word order that is independent of the semantic message conveyed by the word string. It appears safe to conclude that in the case of normal test sentences, the effect of training phase version is due to the fluent reapplication of comprehension processes. For scrambled test sentences, memory for specific lexical items and possibly memory for a message constructed from the randomly ordered words are the strongest candidates as sources of rereading fluency that are specific to the original reading episode.

Another feature of Experiment 4 is that its main result, the lack of an item-order effect, is not consistent with the finding reported by Whittlesea (1990). In that study, changing the word order across two scrambled versions of a text reduced rereading fluency relative to the case in which the same scrambled word order was used on both readings. As noted earlier, the sensitivity of rereading fluency in that situation varies considerably across different texts (Carr & Brown, 1990), so it is possible that many texts would
not show the effect obtained by Whittlesea. Moreover, that effect was found using texts, whereas unrelated nouns and nonwords were used in Experiment 4. By design, it is highly unlikely that subjects in Experiment 4 could have formed even rudimentary messages capable of mediating an effect of consistent word order on rereading fluency.

Experiment 5

With evidence in hand for the contribution of comprehension processes to the fluent rereading of typographically transformed sentences, Experiment 5 was designed to demonstrate a similar function in the reading of normally printed sentences. A second objective of this experiment was to test the hypothesis advanced by Levy et al. (1991) that comprehension processes responsible for rereading fluency have a Stroop-like quality, in that they are applied to meaningful sentences even when this activity is counterproductive or contrary to prevailing instructions and task demands. Some evidence for this aspect of comprehension already is available. First, although Carlson et al. (1991) instructed a group of subjects to read aloud texts in a word-by-word manner, disregarding text meaning, subjects took less time on the first reading of texts presented in normal as compared to scrambled word order. Second, Masson and May (1985) found that searching for a predesignated target letter in sentences shown with the rapid serial presentation technique was more accurate when scrambled rather than normal word order was used. This sentence-inferiority effect was attributed to unitized processing of words when they appeared in meaningful sentences.

In Experiment 5 normal and scrambled sentences were read first under conditions that were intended to discourage meaningful processing of sentences. The rapid serial presentation method was used, in which a sentence’s words were presented one at a time for a fixed, brief duration at the center of a computer monitor. The task was to determine whether the sentence contained an item that consisted exclusively of a string of consonants. To discourage post-presentation processing of sentences presented under these conditions (cf. Mitchell, 1984), on each trial a pair of sentences was presented in succession with no pause between them. This procedure has been shown to reduce text comprehension under rapid serial presentation (Masson, 1983). Two different presentation durations, 100 ms and 200 ms, were used. The longer duration is equivalent to a brisk reading rate of 300 words per minute. The shorter duration was used to determine whether proposition-construction processes believed to influence rereading fluency can be executed in much less time than that usually taken to read text.

In the test phase, normal and scrambled sentences were presented one at a time using rapid serial presentation, and the task was to report the words in the sentence. The critical question was whether comprehension processes would operate during the initial search task when normal sentences were
presented and, if so, whether these processes could be reapplied to influence performance on the report task. If both of these conditions were to hold, subjects should more accurately report the content of normal test sentences that appeared in normal rather than scrambled word order during the training phase. This effect should not obtain for scrambled test sentences. Furthermore, if exposure to individual words contributes to fluent reading of sentences, reading scrambled sentences in the training phase should produce at least some advantage over new sentences.

**METHOD**

**Subjects**
A sample of 84 subjects were randomly divided into four groups of 21 subjects each, defined by a factorial combination of presentation duration in the training phase (100 ms, 200 ms) and sentence version during test (normal, scrambled).

**Materials and design**
A set of 60 critical and 120 filler sentences were created so that on each trial in the training phase a pair of sentences could be shown. The two sentences on a trial always consisted of a critical sentence followed by a filler, or two filler sentences. The two sentences shown on a given trial were of the same word order (normal or scrambled).

The 60 critical sentences, each 10-12 words in length, were constructed (e.g., We played a game of chess before our big exam) under the constraint that no word was longer than nine characters. The sentences were divided into three sets of 20 sentences each, and a scrambled version of each sentence was constructed by randomly reordering the words within the sentence. For each subject, one set of 20 sentences was assigned to each of the three training conditions: normal version, scrambled version, and new (not presented during training). This assignment was counterbalanced across subjects so that each set of 20 sentences was used equally often in each condition.

The 120 filler sentences consisted of 60 normal and 60 scrambled sentences. Twenty of the normal filler sentences were reserved for presentation with the 20 normal critical sentences in the training phase, and 20 of the scrambled filler sentences were set aside for presentation with the 20 scrambled critical sentences during training. The remaining 40 normal filler sentences were paired to form 20 pairs of normal fillers, and the remaining 40 scrambled filler sentences were paired to create 20 scrambled pairs. One sentence in each of these 40 pairs of filler sentences was selected to have one of its words replaced by a string of consonants. The consonant string was created by replacing each vowel, and occasionally some of the consonants, in a selected word with consonants (e.g., The salmon travels many difficult miles to sptbn in fresh water). The consonant string appeared in the first sentence
for half of the pairs and in the second sentence for the other half. The lengths of the consonant strings varied as did their positions in the sentences. The filler sentences paired with critical sentences, and the critical sentences themselves, did not contain consonant strings.

**Procedure**

Subjects were tested individually in a single session. In the training phase subjects were presented 20 pairs of normal and 20 pairs of scrambled sentences that did not contain a consonant string (each pair consisting of one critical sentence followed by a filler sentence), and 20 pairs of normal and 20 pairs of scrambled sentences (all filler sentences) that contained one consonant string. Subjects were instructed to search through each rapidly presented series of words to determine whether a string of consonants was present. The fact that meaningful sentences would be presented on half of the trials was not mentioned. The sentences were presented one word at a time, with each word appearing in the center of the monitor for a fixed duration. The duration for each word was 100 ms for half of the subjects and 200 ms for the other half. There was no pause between the two sentences, although the first word of each sentence was capitalized and the last word included a period.

Each trial began with a row of nine + symbols presented for the same duration as the words that would follow and this display was immediately followed by the sequence of words. The last word was immediately followed by a row of nine ? symbols to indicate that the subject was to make a response. The subject pressed an appropriate key on a key pad to indicate whether a consonant string was present in the sequence of words. One key was labeled YES and the other was labeled NO. In the case of trials containing a critical sentence, no consonant string was present so subjects had to attend to the material until the end of the trial. For filler pairs, however, subjects knew what the response would be as soon as the consonant string was detected, although they had to withhold their response until the display ended. After the subject made a response, the monitor was cleared and 500 ms later the next trial began automatically. Subjects were allowed to take a brief rest after every 20 trials.

In the test phase, subjects read all 60 critical and four filler sentences presented one word at a time as in the training phase. Only one sentence was presented on each trial and the subject’s task was to report as many words as possible, in their original order. Half of the subjects were presented the normal version of each sentence and they were told that they would be viewing sentences. The other subjects were shown the scrambled version of each sentence and they were told that they would see series of words. Each trial began with a display at the top of the monitor indicating the trial number and the word READY at the center of the monitor. The subject pressed a key on the key pad to begin the trial. The READY signal was erased and 500 ms
later a row of nine + symbols appeared for 67 ms, followed by the words, each presented for 67 ms. After the last word, a row of nine ? symbols was presented for 67 ms, then the message WRITE DOWN WORDS appeared. The subject then recorded as many words as possible on a printed page containing lines numbered 1-64. The subject’s response on a particular trial was written on the appropriately numbered line. When the subject finished recording the words, she or he pressed a key to erase the monitor and begin the next trial. The first two and last two trials were filler sentences, and the 60 critical sentences were presented in a random order.

Results and Discussion
Performance in the training phase was summarized by computing each subject’s hit and false alarm rate for normal and scrambled sentences. Accuracy on this task logically should not and did not vary reliably as a function of the sentence version to be used in the test phase. Therefore, to simplify presentation of training phase data, the means were collapsed across the two test groups and the analyses reported here did not include test group as a factor. The mean hit and false alarm rates are shown in Table 3. The false alarm rates are based on trials involving the critical items. False alarms were not common, indicating that subjects only occasionally misperceived a word in a critical sentence as a consonant string. To test for differences in the two duration groups, an accuracy measure was derived by subtracting false alarm rate from hit rate. These accuracy scores were analyzed in an ANOVA with duration (100 ms, 200 ms) and sentence version (normal, scrambled) as factors. The analysis indicated that the effect of duration was significant (.86 for the 200-ms condition and .37 for the 100-ms condition), \( F(1, 82) = 316.88, M_{SE} = 0.03 \). The small accuracy advantage for the scrambled over the normal sentences (.63 vs .60) was reliable, \( F(1, 82) = 4.98, M_{SE} = 0.01 \), but the interaction effect did not reach significance (\( p > .15 \)).

The effect of sentence version is consistent with the sentence-inferiority effect in letter search reported by Masson and May (1985). The filler sentences in Experiment 5, however, were not counterbalanced across the normal and scrambled conditions. A systematic difference in either the sentences or the consonant strings in these two sets of materials might have produced the difference in hit rates that was responsible for generating the present sentence-inferiority effect. The most important results of this analysis, however, are not compromised in this way and are that (a) performance on critical sentences, as measured by false alarm rates, was quite accurate, and (b) exposure duration had a large effect on detection accuracy.

Responses in the test phase were scored according to the following criteria. All critical sentences were included in the scoring, regardless of whether the subject made a response error on the trial containing that sentence in the training phase. Word order was not considered when scoring responses from
subjects in the scrambled test condition. For subjects tested with normal sentences, changes of word order that preserved the meaning of the sentence were allowed, otherwise a word reported in an incorrect location was counted as an intrusion. Words that contained spelling errors or changes in pluralization were counted as correct. For subjects in both the normal and scrambled groups, reported words that were not in the sentence (including synonym substitutions) were counted as intrusions. For each subject the proportion of correctly reported words and the proportion of intrusions (based on the total number of words presented in the sentences) were computed as a function of training version of the critical sentences (normal, scrambled, new). The mean proportion of correctly reported words in each condition is shown in Figure 3. The proportion of intrusions, averaged across all conditions, was .06. In an analysis of the intrusion data, none of the effects reached significance.

The proportion correct data were submitted to an ANOVA with test version (normal, scrambled), training version (normal, scrambled, new), and training duration (100 ms, 200 ms) as factors. The group tested with normal sentences reported reliably more words than subjects tested with scrambled sentences (.47 vs .28), $F(1, 80) = 23.27$, $MS_e = 0.080$, and there was a significant effect of training version (.41, .38, and .36 for normal, scrambled, and new, respectively), $F(2, 160) = 23.12$, $MS_e = 0.002$. The only other significant effect was the interaction between training and test form, $F(2, 160) = 5.20$, $MS_e = 0.002$.

The training version effect and its interaction with test version were explored by two further ANOVAs; one compared the normal and scrambled training versions and the other compared the scrambled and new versions. In

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### TABLE 3
Mean Hit and False Alarm Rates and Accuracy in the Training Phase of Experiment 5

<table>
<thead>
<tr>
<th>Duration and sentence version</th>
<th>Hit rate</th>
<th>FA rate</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
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<td></td>
<td></td>
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<td>.09</td>
<td>.35</td>
</tr>
<tr>
<td>Scrambled</td>
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<td>.16</td>
<td>.40</td>
</tr>
<tr>
<td>200 ms</td>
<td></td>
<td></td>
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<tr>
<td>Normal</td>
<td>.89</td>
<td>.04</td>
<td>.85</td>
</tr>
<tr>
<td>Scrambled</td>
<td>.91</td>
<td>.05</td>
<td>.86</td>
</tr>
</tbody>
</table>

*Note. Accuracy equals hit rate minus false alarm rate. The estimated standard deviations of subjects’ accuracy scores, pooled across the two versions, were 0.17 and 0.11 for the 100-ms and 200-ms duration groups, respectively.*
Fig. 3 Mean proportion of correctly reported words in the test phase of Experiment 5. Data in the left panel are from the 100-ms training duration group; data in the right panel are from the 200-ms training duration group. Error bars indicate one standard error of the difference between means, computed separately for each cluster of three training version conditions.

both analyses there was a reliable effect of test version, but the results of interest concern training version. The normal training version produced reliably more correctly reported words than the scrambled version, $F(1, 80) = 13.88, MS_e = 0.002$, but this effect interacted with test version, $F(1, 80) = 9.48, MS_e = 0.002$. From the means in Figure 3, it is clear that the advantage for normal training sentences appeared only when sentences were tested in their normal version, indicating that the advantage bestowed by initial reading was based on the reapplication of comprehension processes rather than enhanced processing of specific words. The scrambled training version, in turn, generated more correct reports than sentences that had not been presented in training, $F(1, 80) = 8.05, MS_e = 0.002$, and this effect did not interact with test version ($F < 1$). The undifferentiated influence of prior reading of scrambled sentences suggests that the benefit of initially reading these sentences derived from more efficient lexical processing, rather than construction of a meaningful message from the randomly ordered words.

The most striking feature of these results is the fact that comprehension processes executed under the highly constrained conditions of rapid serial presentation created a memory representation sufficiently robust to facilitate later comprehension and report of sentences. Despite a large effect of initial
exposure duration on the target detection task, this factor did not influence the effectiveness of reapplying comprehension processes in the test phase. These processes apparently can be executed with as little as 100 ms of processing on each word (see also Masson, 1986a). The aspects of comprehension that contributed to rereading fluency in this study once again appear to be based on the construction of meaningful propositions. If improved identification of individual words were the primary basis for rereading fluency, normal and scrambled sentences ought to have produced equal amounts of improvement. Instead, training with normal sentences produced more enhancement than did scrambled sentences, but only when sentences were tested in normal form—an arena in which proposition-construction processes play a critical role. In keeping with the proposal made by Levy et al. (1991), the actuation of these comprehension processes seems to be impervious to task demands and goes forward even at the cost of reduced performance on the primary task, as indicated by reduced target detection when normal sentences were presented.

Experiment 6

In Experiments 1-5 evidence was obtained to support the conclusion that processing of meaningful propositions that comprise a sentence can be executed more fluently when that sentence is reread. This propositional processing may reflect construction of individual propositions, integration of propositions, or both. Experiment 6 was conducted to test the possibility that integration of causally related propositions contributes to fluent rereading. Integration of propositions can be seen as a conceptual activity of higher order than building the constituent propositions, inasmuch as integration requires inference making to link related propositions (e.g., Fletcher & Bloom, 1988; Singer, Halldorson, Lear, & Andrusiak, 1992; Trabasso & van den Broek, 1985).

Preliminary evidence that integration of propositions or clauses contributes to reprocessing efficiency was provided by Franks, Plybon, and Auble (1980) in a sentence listening task. Two-clause sentences presented against a background of white noise were more accurately reported if the pair of clauses had earlier been heard in the same sentence rather than as components of different sentences. The problem with this result, however, is that when clauses originally appeared in different sentences, those sentences were not comprehensible (e.g., The breakfast was excellent because the needle on the Christmas tree fell). The disadvantage for sentences in the recombined-clause condition could have been due to failed comprehension during training rather than the lack of reinstatement of integration operations.

In Experiment 6 each sentence consisted of a pair of meaningful, causally related clauses. These clauses were constructed so that recombining pairs of clauses would produce new, meaningful sentences. After reading a training set of sentences, subjects reread these sentences either in their original form or
with clauses re-paired to create different sentences. As in Experiment 5, all materials were presented in normal typography. If comprehension procedures that integrate causally related clauses are reapplied during fluent rereading, re-pairing clauses should reduce rereading fluency. Some fluency still should be observed relative to completely new sentences, however, because of improved efficiency with respect to processing individual propositions. Two different sentence processing tasks were tested to determine whether the purported influence of interclause integration would depend on directing attention to the causal relation between clauses. One task required subjects to detect anomalous clause pairings, requiring close attention to causal relation, and the other task involved detection of anomalous words. If interclause integration contributes to fluent rereading only when subjects specifically attend to integration, the re-pairing effect should be obtained only in the anomalous-clause detection task.

**METHOD**

**Subjects**

A sample of 48 subjects was randomly assigned to two groups of 24 subjects each. One group was assigned the task of detecting an anomalous word and the other group was given the task of detecting anomalous clause pairings.

**Materials and design**

A set of 75 critical sentences, each containing two causally related clauses (each ranging in length from 4 to 12 words), was constructed. Sentence (1) is one of the critical sentences.

(1) The presidential candidate had to resign when he was accused of being involved in a scandal.

All 75 critical sentences were shown in the test phase, but for the training phase these items were assigned to three lists of 25 sentences each. For each subject, one list was assigned to each of three training conditions: same clause, different clause, and new (not presented). These assignments were counterbalanced across subjects so that each list was used equally often in each training condition. Sentences in the new condition did not appear in the training phase and sentences in the same-clause condition appeared in the same form in both the training and test phases. Sentences assigned to the different-clause condition did not appear intact in the training phase. Instead, each of the two clauses of a critical sentence was paired with a filler clause to form two different, meaningful sentences that were presented in the training phase. Two filler clauses were written for each critical sentence, to be used when the sentence was assigned to the different-clause condition. For example, the two clauses of sentence (1) were presented in sentences (2) and...
Critical sentences

<table>
<thead>
<tr>
<th>Training phase</th>
<th>Same</th>
<th>Different</th>
<th>New</th>
</tr>
</thead>
<tbody>
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Filler sentences (anomalous-word task)

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Filler sentences (anomalous-clause task)

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<td>(n=8)</td>
<td>(n=8)</td>
<td>(n=8)</td>
<td>(n=8)</td>
<td>(n=17)</td>
</tr>
</tbody>
</table>

Fig. 4 Schematic summary of critical and filler sentences used in Experiment 6. A, B, C, and D indicate clauses; there were two clauses per sentence. Sentence pairs containing interchangeable clauses are indicated by AC DB. An asterisk indicates the presence of an anomaly.

(3) in the training phase when assigned to the different-clause condition (italics indicate the clauses from the critical sentence).

(2) *The presidential candidate had to resign* when it was found out he had bugged the office.

(3) *The TV evangelist denied everything when he was accused of being involved in a scandal.*

Continuing with this example of the different-clause condition, sentence (1) was presented in the test phase and its two clauses had appeared during training, but not jointly, so their integration was novel. The arrangement of the critical sentences is summarized in Figure 4.

Two versions of filler items were constructed, one for each anomaly detection task. The arrangement of the filler items for both tasks is summarized in Figure 4. For the anomalous-word detection task, three sets of filler
sentences consisting of two causally related clauses were constructed. One set of 25 filler sentences appeared in both the training and test phases. These fillers contained an anomaly either during training or test, or on both occasions. In the training phase, 17 of the fillers contained an anomalous word that had been substituted for a content word in one of the clauses (e.g., The doctor ordered some new equipment as he was updating his milk), and the remaining eight contained no anomaly. When these sentences were presented during the test phase, nine of the sentences that contained an anomaly in the training phase contained a different anomaly (e.g., The doctor ordered some new equipment as he was floating his office), and the other eight previously anomalous sentences had the original word put back in place of the anomalous word to create a proper sentence. The eight sentences that were not anomalous in the training phase had an anomaly inserted for the test phase.

The second set of filler sentences used in the anomalous-word task was constructed as 25 pairs of sentences consisting of interchangeable clauses (similar to sentences (2) and (3)). Each pair of fillers appeared in the training phase and was used to construct one new sentence, consisting of one clause from each member of the pair, that was presented in the test phase. As with the first set of fillers, anomalies appeared in these fillers in the training or test phase, or in both phases. Seventeen of the pairs of fillers contained an anomalous word and the other eight pairs containing no anomaly in the training phase. In the test phase, nine of the sentences constructed from the 17 anomalous pairs contained a new anomaly and the other eight contained no anomaly. The eight test fillers constructed from the eight pairs of anomaly-free training sentences were altered to include an anomalous word.

The third set of 25 filler sentences used in the anomalous-word task appeared only in the test phase. In this set, 17 sentences contained an anomalous word and the remaining eight did not.

This arrangement of filler sentences meant that in the test phase, as in the training phase, 51 of the 150 sentences (75 filler and 75 critical) were anomalous. Moreover, considering filler and critical sentences together, there were 50 sentences that had not appeared in any form in the training phase, and 100 that had appeared in training in some form (same- or different-clause pairing). In each of these classes of sentences, 34% were anomalous; thus, the percentage of anomalous sentences was the same among new as among familiar sentences. Of the 34 anomalous test sentences that had appeared in some form in training (same- or different-clause pairing), 16 were not anomalous in training. Finally, of the 100 critical and filler test sentences that had appeared during training, 32 (all fillers) changed their anomalous status between phases. Therefore, familiarity with a sentence was no guarantee of how it should be classified or of whether the classification should be the same as on the initial encounter.
The filler sentences constructed for the anomalous-clause detection task contained an anomaly that was created by pairing two clauses that did not make sense together (e.g., The sleeping baby began to cry as he wanted to continue his corporate law practice). A set of nine anomalous filler sentences were presented unaltered in both the training and test phases. A set of 17 pairs of anomalous filler sentences were presented in the training phase and a new sentence was created from each of these pairs by combining one clause from each sentence. The resulting 17 new sentences, nine anomalous and eight meaningful, appeared in the test phase. For example, sentences (4) and (5) were presented during training, and sentence (6) was presented during test.

(4) The child’s birthday gift arrived late as she did not have any appointments for the afternoon.

(5) The playground became a hive of activity because the mail was delayed.

(6) The child’s birthday gift arrived late because the mail was delayed.

An additional eight pairs of meaningful sentences were shown in the training phase. A new anomalous sentence was created from each of these eight pairs by taking one clause from each sentence in the pair; these eight sentences were presented in the test phase. A further set of eight pairs of sentences, one anomalous and one meaningful sentence in each pair, were presented in the training phase. Clauses from these eight pairs were recombined to produce eight new anomalous and eight new meaningful sentences for use in the test phase. Finally, a set of 17 anomalous and eight meaningful fillers were presented only in the test phase.

The arrangement of filler sentences used in the anomalous-clause detection task ensured that, as in the anomalous-word task, across critical and filler test sentences 34% of completely new and 34% of familiar (clauses that had been read before but not necessarily in the same sentence) sentences were anomalous, and 32% of the familiar sentences changed their anomalous status across phases, rendering familiarity an unreliable cue to a sentence’s classification.

Procedure
Sentences were presented using the same equipment as in the earlier experiments. All materials were shown in normal typography and read silently. Subjects participated in a training session and a test session that were separated by one day. They were instructed to read each sentence as quickly as possible and to classify it as sensible or nonsense. The appropriate characteristic of nonsense sentences (an anomalous word or clause) was explained to the subjects. In the training phase subjects read four practice
sentences (two containing an anomaly), followed by 75 critical and 75 filler sentences in random order. On each trial the sentence was presented in normal typography, left-justified on the middle line of the monitor. The sentence remained in view until the subject pressed one of two response keys on a key pad, one labeled \textit{YES} (to indicate a sensible sentence) and the other labeled \textit{NO}. The sentence was then erased. If the response was correct, the next sentence was presented after a delay of 750 ms; if the response was incorrect, an error message (\textit{ERROR, INCORRECT RESPONSE}) was presented for 1 s before the next trial started. Subjects were allowed to take a brief rest after every 50 trials. At the end of the training phase, subjects were reminded to return for the second session. They returned to the laboratory the next day and were given a review of the instructions from the training phase. Subjects were then given two practice trials, followed by 75 critical and 75 filler trials, all presented as in the training phase.

\textbf{RESULTS}

Any trial on which the response latency exceeded 10 s (0.5\% of the critical trials) was excluded from computation of error rates and response latencies. The overall error rates (combining performance on critical and filler items) were analyzed in an ANOVA with task (anomalous-word, anomalous-clause) and phase (training, test) as factors. The only statistically significant effect was the difference between the two phases (8.9\% and 6.9\% for the training and test phases, respectively), $F(1, 46) = 6.57$, $\text{MS}_e = 15.27$. The error rates on the critical trials in the test phase, conditionalized on a correct response during the training phase, are shown in Table 4. An analysis of these error rates, with task and training version (same pairing, different pairing, new) as factors, revealed only a main effect of training version (0.6\%, 2.3\%, and 3.0\%, respectively), $F(2, 92) = 9.76$, $\text{MS}_e = 7.24$. This effect was explored further by comparing the same- and different-pairing conditions. The error rate in the same-pairing condition was reliably lower, $F(1, 46) = 8.72$, $\text{MS}_e = 7.83$, and the effect held across both tasks as there was no interaction with group.

The mean response latency in the training phase, based on critical trials on which a correct response was made, was 2.98 s and 3.45 s for the anomalous-word and anomalous-clause groups, respectively. This difference was marginally reliable, $t(46) = 1.80$, $\text{SE}_{dm} = 0.26$, $p < .10$. The mean response latencies in the test phase for critical items that were classified correctly in both phases are shown in Table 4. These data were submitted to an ANOVA with task and training version as factors. The effect of task was marginally reliable with shorter latencies on the anomalous-word task (2.51 s vs 2.91 s), $F(1, 46) = 2.91$, $\text{MS}_e = 1.98$, $p < .10$, and the effect of training version was significant (2.57 s, 2.68 s, and 2.88 s for the same, different, and new conditions, respectively), $F(2, 92) = 27.95$, $\text{MS}_e = 0.04$. The interaction was not significant ($F < 1$).
TABLE 4
Mean Response Latency (in seconds) and Percentage Error in the Test Phase of Experiment 6

<table>
<thead>
<tr>
<th>Task</th>
<th>Training version</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Same pairing</td>
</tr>
<tr>
<td>Anomalous word</td>
<td></td>
</tr>
<tr>
<td>Response latency</td>
<td>2.39</td>
</tr>
<tr>
<td>% error</td>
<td>0.54</td>
</tr>
<tr>
<td>Anomalous clause</td>
<td></td>
</tr>
<tr>
<td>Response latency</td>
<td>2.76</td>
</tr>
<tr>
<td>% error</td>
<td>0.67</td>
</tr>
</tbody>
</table>

*Note.* The estimated standard deviations of subjects' mean response latencies, pooled across all three training versions, were 0.60 and 1.01, for the word and clause tasks, respectively. The estimated standard deviations of error percentages were 2.34 and 2.49.

Contrasts between same- and different-pairing conditions and between different-pairing and new conditions were done using two separate ANOVAs including task as a factor. There was a significant advantage of same- over different-pairing, $F(1, 46) = 5.47$, $MS_e = 0.05$, and an advantage of different-pairing over new sentences, $F(1, 46) = 29.88$, $MS_e = 0.03$. In both analyses there was a marginally reliable effect of task ($ps < .10$), and no interaction between training condition and task ($Fs < 1$), indicating that the training effects were consistent across tasks.

**DISCUSSION**

The results of Experiment 6 indicate that interclause integration was accomplished more efficiently when the two clauses comprising test sentences had been presented together in the training phase. The enhancement arose from experience with specific pairs of clauses during the training phase, and did not depend on task demands that required subjects to focus on the causal connection between clauses. Similar effects were found on response latency and error rate measures, ruling out speed-accuracy trade-off as a viable account of the response latency difference between same- and different-pairing conditions. Thus, comprehension processes devoted to integrating causally related clauses appear to be fluently reapplied when the same pair of clauses is encountered up to 24 hours after the initial reading experience. In addition to added fluency associated with integration of clauses, sentences in the different-pairing condition were classified in less time than completely new sentences. This result indicates that even when integration processes are novel, significant enhancement in fluency arises from prior experience with individual clauses or propositions.
General Discussion

The fluent rereading of sentences observed in the experiments reported here clearly reflects the influence of a specific episodic experience that involves comprehension processes. In Experiment 1 it was shown that fluent reading of typographically transformed, meaningful sentences is due to the processing of coherent propositions rather than to syntactic regularity or to the juxtaposition of semantically related words. Experiments 2 and 3 showed that the fluent rereading of a meaningful sentence printed in transformed typography depended in large part upon having processed the sentence's propositions on an earlier reading. Reading a randomly ordered list of words that was later rearranged to form a meaningful sentence did little (Experiment 2) or nothing (Experiment 3) to increase the fluency with which that sentence was read. In Experiment 4 lists of unrelated nouns or nonwords were read twice. It was found that altering the order of items within the lists across the two readings had no measurable effect on rereading fluency. This result indicated that the benefits of earlier reading episodes observed in Experiments 2 and 3 did not stem from a simple repetition of word order. The crucial effect of scrambling word order in Experiments 2 and 3 was to destroy propositional coherence.

These conclusions regarding the role of coherent propositions in fluent rereading were extended to normally printed sentences in the last two experiments. In Experiment 5, meaningful sentences presented using rapid serial presentation were reported more accurately if they earlier had been read in the same form than if the earlier reading involved scrambled versions of the sentences. Integration of propositions was shown in Experiment 6 to contribute to rereading fluency. When test sentences consisted of two causally related propositions that had been read earlier in separate sentences, subjects took longer to comprehend them in comparison to sentences that were held constant across both readings.

PROCEDURAL MEMORY FOR READING EPISODES

A promising way of framing this episodic influence of prior reading is in terms of the fluent reapplication of comprehension processes (Craik, 1991; Kolers & Roediger, 1984; Levy, Di Persio, & Hollingshead, 1992; Levy & Kirsner, 1989; Masson, 1989). In this view, specific reading experiences are encoded in memory as procedures that represent perceptual and conceptual processing operations. The present experiments, in conjunction with earlier work, reveal a number of attributes that this procedural representation must have.

First, the procedural memory is specific to the message conveyed in a sentence. Varying the message by randomly reordering the words results in a representation that is of limited or no value when the sentence is reread in normal word order (Experiments 2, 3, and 5). Thus, comprehension processes that are enhanced by specific prior reading episodes include procedures that
operate at least at the level of phrases or clauses, not individual words. Nor
do these effects arise simply from sensitivity to the visual pattern created by
a particular ordering of words (Experiment 4). Additional support for this
conclusion is provided by the Craik and Gemar study (cited in Craik, 1991)
in which sensitivity to changes in the typographical transformation used on
first and second readings of a sentence was found. This result was apparent
even among words that appeared in different sentences and therefore were
read in both typographies during the training phase. Sensitivity to typography,
therefore, is entwined with comprehension of multiple word units such as
phrases. This view is consistent with the proposal that encoding episodes are
represented and ideally recruited in a wholistic manner (Jacoby et al., 1992;

Second, memory for comprehension processes applied during specific
reading episodes is robust over retention intervals as long as four months
(Experiment 3) or even a year, if Kolers' (1976) result is to be interpreted as
advocated here. Moreover, there was no evidence for a reduction in the
enhancement due to specific prior experience with a meaningful sentence
when test intervals of zero and seven days were compared (Experiment 2 and
its replication). The durability of these fluency effects stands in sharp contrast
to the reliable decrease in recognition memory for previously read sentences
(in either normal or transformed typography) over intervals as brief as one or
two days (Kolers & Ostry, 1974; Masson, 1984).

Third, at least a subset of the comprehension processes that contribute to
rereading fluency have a Stroop-like quality in the sense that these processes
operate even when proscribed by instructions (Carlson et al., 1991) or when
task performance suffers as a consequence of their implementation (Experi-
ment 5; Levy et al., 1991; Masson & May, 1985). These comprehension
processes are assumed to include those proposed by McKoon and Ratcliff
(1992) as responsible for generating the minimal set of inferences encoded
automatically during reading. This feature of the comprehension processes that
contribute to fluent rereading is consistent with a crucial assumption regarding
the reapplication of comprehension processes when a sentence is reread. In
line with other proposals regarding an episodic basis for repetition effects
(e.g., Jacoby & Brooks, 1984; Jacoby et al., 1992; Levy et al., 1992; Levy &
Kirsner, 1989; Logan, 1988; Masson, 1986b; Masson & Freedman, 1990), I
assume that episodic memory for relevant prior experiences is recruited
automatically, under context-specific constraints. Support for this assumption
comes from an aspect of Experiment 3. Episodic memory for normal
sentences read in the training phase was of no significant value in rereading
those sentences in scrambled word order four months later, yet a significant
benefit was derived if those sentences were once again read in normal order.
The opposite pattern of results was obtained for scrambled sentences from the
training phase.
AN EPISODIC BASIS FOR FLUENCY

The characterization outlined here and by others (e.g., Jacoby et al., 1992; Levy, 1993; Levy & Kirsner, 1989; Levy et al., 1992) of the episodic basis for comprehension fluency shares a number of fundamental attributes with the episodic view of repetition effects that has been developed primarily in the arenas of word and object identification (e.g., Jacoby & Brooks, 1984; Roediger et al., 1989). These features include the long-lasting nature of the effects of experience when revealed through fluent reprocessing (e.g., Tulving, Schacter, & Stark, 1982) and robustness across a variety of task demands (e.g., Jacoby & Dallas, 1981). A particularly interesting characteristic is the dissociation between fluent rereading and conscious recollection of text content that has been demonstrated with amnesics (Musen et al., 1990), which parallels the dissociation obtained in word identification tasks (e.g., Graf, Squire, & Mandler, 1984). In both cases, amnesics perform as well as control subjects on tests involving fluent reprocessing or word identification, but are impaired on tests that require intentional remembering. A dissociation of this form involving a linguistic message does not conform to the view that indirect measures of memory reflect the operation of specialized perceptual representation systems (e.g., Tulving & Schacter, 1990). A more accommodating perspective is one that emphasizes memory for procedures that operate on a range of information types, including perceptual and conceptual data carried by a message.

The most fundamental aspect of fluent rereading that also is observed in studies of repetition effects on word and object identification is its basis in memory for a specific encoding episode (Jacoby & Brooks, 1984). Fluent rereading arises in part from a general improvement in reading skill that may reflect accommodation to the particular demands of an experimental procedure or to an unusual typography, but this contribution is clearly separable from the effects of experience with specific sentences. Just as the episodic view of word repetition effects has been placed in contrast to the claim that these effects arise from activation of stable lexical representations (e.g., Jacoby & Dallas, 1981), the characterization of comprehension processes involved in rereading fluency as episodically inspired contrasts with the traditional notion of comprehension processes as constituting a stable, generic rule system (e.g., Miller & Isard, 1963). An interesting question that emerges from this observation is whether skilled comprehension is based on memory for a collection of specific prior experiences. This possibility is also under consideration in the related domain of artificial grammar learning (e.g., Vokey & Brooks, 1992). It is now possible to conceptualize a wide variety of skilled comprehension processes as grounded in a form of episodic memory for specific experiences, and this view may provide a valuable framework for guiding future exploration of language comprehension.
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