Published in final edited form as:
J Mem Lang. 2008 May ; 58(4): 907–915. doi:10.1016/j.jml.2007.12.002.

Whole Report versus Partial Report in RSVP Sentences

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Abstract

A sentence is readily understood and recalled when presented 1 word at a time using rapid serial visual presentation (RSVP) at 10 words/s (Potter, 1984). In contrast, selecting just 2 colored letters at 10 letters/s results in easy detection of the first target but poor recall for the second when it appears 200–500 ms later. This attentional blink disappears when all letters must be reported; instead, performance drops more gradually over serial position (Nieuwenstein & Potter, 2006). Would target words in sentences escape an attentional blink? Subjects either reported 2 target words (in red or uppercase) or the whole 10-word sentence. There was a blink for Target 2 in partial report, but that target was easily remembered in whole report. With scrambled sentences whole report dropped but partial report was unaffected, again showing a blink. The attentional blink is not due to memory processing of Target 1, but to target selection, which is incompatible with sentence processing.

Keywords

Sentence processing; Attentional blink; RSVP (rapid serial visual presentation); Target search; Partial report; Sentence memory

Recent research on the role of selective attention in visual processing has focused on a deficit associated with attention that is termed the attentional blink. An attentional blink is the reduced ability to detect a second target presented 200–400 ms after the onset of a first target, in rapid serial visual presentation (RSVP) of targets intermixed with distractors presented at about 10 items/s (e.g., Broadbent & Broadbent, 1987; Chun & Potter, 1995; Raymond, Shapiro, & Arnell, 1992; Weichselgartner & Sperling, 1987). Inasmuch as skilled readers can read normal text at rates of 6 or more words a second, the inability to report the second of two targets arriving within 200–400 ms of each other is surprising. Moreover, viewers have relatively little difficulty comprehending and recalling RSVP sentences presented at 10 words/s (Potter, 1984; 1999; Potter, Kroll, & Harris, 1980; Potter, Kroll, Yachzel, Carpenter, & Sherman, 1986). If viewers can identify and retain 10 or more individual words at 10/s, why do they often miss a target as simple as a letter or digit when it follows shortly after a first target that they have little difficulty reporting?

The studies using RSVP sentences asked subjects to recall the whole sentence, whereas in target search subjects must select targets presented among to-be-ignored distractors. Is selective report responsible for the attentional blink? To address this question Nieuwenstein and Potter (2006) asked subjects to view six unrelated letters with two instructions: either (1)

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report the two letters in a specified color, or (2) report all the letters. The instruction to report only two selected letters resulted in a marked attentional blink for the second target letter when there was one intervening letter of a different color (i.e., when Target 2 appeared at lag 2, where lag 1 is the item immediately following Target 1). In the whole-report condition recall declined over serial position, but the letter corresponding to the lag-2 target was nonetheless reported more accurately than in the selective-report condition. That is, despite having encoded not only the Target 1 letter but also other letters in the sequence, subjects in the whole report condition were better able to report the Target 2 letter (at lag 2) than in the partial report condition in which they had only encoded one previous letter.

Processing in whole report differs from that in partial report not only in what viewers are trying to do, but also in what factors affect performance. For unrelated items in a list (as in Nieuwenstein & Potter's experiments, 2006) whole report is affected by the total number of items in a sequence, whereas partial report is affected only minimally by the total number of items, if only two are to be reported. Selection of a target (even when it is the first item in the sequence) results in a marked lag effect on the second target, with a drop in performance at lag 2 and recovery at longer lags, whereas encoding the first item in whole report does not generate this characteristic attentional blink pattern in report of subsequent items, but instead there is a falloff in accuracy with serial position. Thus, encoding in whole report is limited by memory storage, while partial report and its characteristic attentional blink reflect the limits of attentional selection.

In the present study we examined whether partial and whole report are differentially affected when RSVP sequences consist of sentences or scrambled sentences. Previous work has shown that at rates of RSVP as high as 12 items/s, about 9 words of a 10-word sentence are recalled accurately, whereas when the same words were scrambled only about 6 were recalled, ignoring order errors (Potter et al., 1980; see also Forster, 1970; French, 1981; and Pfafflin, 1974). Thus, the load on encoding processes appears to be substantially reduced for sentences as compared to scrambled sentences. Accordingly, we predicted that whole report performance would be significantly better in the former case.

Our main interest was in whether sentence structure and meaning would benefit partial report. We considered two possibilities: if selecting targets is incompatible with processing the sentence, then embedding the targets in a meaningful sentence should have little or no effect on partial report. On the other hand, the computation of structure and meaning might be so automatic that the target words themselves would be encoded more readily in a normal sentence context than in a scrambled sentence, reducing or eliminating an attentional blink for the second target. This possibility is suggested by work by Juola, Ward, and McNamara (1982), who asked subjects to search for a single word in a specified semantic category, in 9-word sentences or scrambled sentences presented at 10 words/s. Consistent with the possibility that automatic sentence processing can facilitate target selection and encoding, they found a small but significant advantage for a target in the normally ordered sentences; performance was near ceiling in both conditions.

We presented RSVP sentences or scrambled sentences, comparing two tasks: report of the whole sentence and report of just two targets. Accuracy of report of the same two critical words was measured in both tasks. The stimulus onset asynchrony (SOA) between the two critical words was either 187 ms (lag 2) or 467 ms (lag 5); the shorter SOA falls inside the SOA range of the attentional blink, whereas with the longer SOA there should be little or no blink. In Experiment 1 the two critical words in each sentence appeared in red font. In Experiment 2 the sentences were scrambled to disrupt syntax and meaning, leaving the red words in the same relative positions. Experiment 3 replicated Experiment 1, except that the critical words were presented in uppercase font rather than being red.

Experiment 1

The general method in this and the other experiments was to present the two tasks, whole report and selective report, in two blocks, with the order of the blocks counterbalanced between subjects. Within each block, the serial position of Target 1 and the SOA between Target 1 and Target 2 were counterbalanced.

Method

Subjects—The 16 subjects were volunteers from the M.I.T. community who were paid for participating. All were native speakers of English.

Materials—The stimuli were 80 10-word sentences on a wide variety of topics and using diverse syntactic structures; examples are given in Table 1. There were 8 practice sentences, 4 before each block. Words were between one and eight letters in length, and no words in the sentence were repeated. The initial word and all proper names were capitalized. There was no punctuation; the font was Courier, size 22. Words were presented in black on a light grey background, centered on the monitor. The red words were R, G, B 255, 0, 0.

Apparatus—The experiment was programmed using Matlab 5.2.1 and the Psychological Toolbox extension (Brainard, 1997; Pelli, 1997), and was run on a PowerMac G3. The Apple 17″ monitor was set to a 1024 × 768 resolution with a 75 Hz refresh rate and 32-bit colors.

Design—The serial position of Target 1 (first, second, third, or fourth word) and the stimulus onset asymmetry (SOA) between the targets (187 or 467 ms, i.e., lag 2 or lag 5) were counterbalanced within subjects and within sentences across subjects, in each of two 40-trial blocks. The last word in the sentence was never a target. The order of the trials was randomized, and that order was used for all subjects. The two tasks, report of the whole sentence or report of only the two red words, were blocked; the order of the tasks was counterbalanced between subjects. Thus, the 4 × 2 × 2 design was completed with 16 subjects.

Procedure—When the subject pressed the space bar to begin a trial, a black fixation cross appeared for 400 ms, followed by a blank screen for 213 ms and then the sentence, presented for 93 ms/word. After the last word a dialog box appeared: In the whole-report block there was one large entry field; in the selective-report block there were two smaller entry fields. When the subject had typed his or her response and had clicked on a button labelled "OK," the dialog box was replaced by the words "press space bar."

All subjects were told that they would be seeing sentences presented rapidly, one word at a time, and that two of the words would be red. In the partial-report block subjects were instructed to report only the two red words. In the whole-report block they were instructed to "report the whole sentence, regardless of the color of the words." Subjects were asked not to abbreviate words.

Scoring—The initial scoring was done by computer, by searching for the two target words in the response; order of report was ignored. This was followed by a hand check, so that spelling errors could be counted as correct. Aside from obvious spelling mistakes, all letters had to be correct in order for the response to be counted as correct.

Results

The main results, separately for each target, are shown in Figure 1A. In the partial report condition there was a strong attentional blink for Target 2 at an SOA of 187 ms with recovery at 467 ms, whereas in whole report there was no suggestion of a blink. An omnibus analysis of variance (ANOVA) was carried out on the correct responses, with target, serial position of Target 1, SOA, and task (whole versus partial report) as variables. There was a main effect of target, with Target 1 reported correctly on .86 of the trials and Target 2 on .72, $F(1, 15) = 30.06$, $MSE = 0.081$, $p < .001$. There was a significant interaction between target, whole versus partial report, and SOA, $F(1, 15) = 11.68$, $MSE = 0.024$, $p < .001$. The confidence interval for pairwise comparisons of means, calculated from the MSE of this interaction, was .12. For Target 2 partial report, the means at the two SOAs were .44 and .67. This .23 difference was the only SOA contrast that exceeded the confidence interval: clearly, only Target 2 in the partial report condition showed the attentional blink pattern.

Further analyses were carried out separately on the first and second targets. For Target 1, there were significant main effects of whole (M = .94) versus partial report (M = .78), $F(1, 15) = 25.10$, $MSE = 0.070$ $p < .001$, and serial position, $F(3, 45) = 11.39$, $MSE = 0.020$, $p < .001$, with Target 1 reported more accurately when it was the first word in the sentence. These effects interacted, $F(3, 45) = 3.13$, $MSE = 0.014$, $p < .05$, with a greater relative benefit for the first word in the partial report condition. The only other significant effect was an interaction between SOA and task, $F(1, 15) = 5.48$, $MSE = 0.019$, $p < .05$, with less accurate recall of Target 1 with a short SOA in the partial report condition only (see Figure 1A).

In the ANOVA of Target 2 accuracy there was a main effect of whole (M = 89)versus partial report (M = .56), $F(1, 15) = 71.83$, $MSE = 0.100$, $p < .001$, and a main effect of SOA (for 187 ms, M = .68, for 467 ms, M = .77), $F(1, 15) = 32.25$, $MSE = 0.019$, $p < .001$. Crucially, these effects interacted (see Figure 1A), $F(1, 15) = 39.91$, $MSE = 0.029$, $p < .001$, with an attentional blink at the shorter SOA in the partial report condition only. Separate comparisons at each SOA between tasks showed a whole report advantage at both SOAs, $p < .01$ in each case. There was an interaction between task and serial position of Target 1, $F(3, 45) = 4.49$, $MSE = 0.026$ $p < .01$: In the partial report condition Target 2 reports dropped from .65 to .48 as the serial position increased, whereas in whole report there was little change (range .88 to .92).

Finally, an analysis was carried out on accuracy of report of the eight non-critical words in the whole-report condition. The mean proportion reported was .85, compared with .92 of the critical red words. Overall, including the red words, .86 of the words were recalled.

Discussion

The results replicate previous studies in showing that recall of RSVP sentences is generally quite accurate. Selective report of red words was significantly less accurate than whole report and showed a marked attentional blink for the second word at lag 2 (an SOA of 187 ms). Even though the sentences were easily recalled in whole report, presenting sentences did not eliminate the attentional blink when attention was selective, suggesting that subjects could not readily process the sentence at the same time that they were trying to select the red words. Report of the first target in partial report (.78) was also much lower than report of the corresponding word in whole report (.94), showing that selecting and remembering even the first red word was more difficult than simply reading and remembering that word as part of the sentence. In Experiment 2 we disrupted the syntactic structure of the sentences by scrambling the order of the eight non-target words while holding the serial position of the two critical words constant. If subjects in the partial report condition cannot process the sentence, then scrambling should have no effect on partial report, whereas we expected that whole report would be considerably lower with scrambled sentences, perhaps eliminating whole report superiority.

Experiment 2

In Experiment 2 the non-target words in each sentence were randomized, holding the order of the red words constant.

Method

Subjects—There were 16 subjects recruited from the same pool as in Experiment 1. None had participated in Experiment 1.

Design and procedure—The method was the same as that of Experiment 1 except that on each trial the order of the eight non-critical words was randomized; the two red words kept their original serial positions. Examples are shown in Table 1.

Results

The results are shown in Figure 1B, which can be compared with Figure 1A. Scrambling the sentences sharply reduced the ability to recall the critical words in the whole report condition, with the result that partial report was more accurate than whole report except in one critical condition: when Target 2 in partial report was presented at lag 2 (an SOA of 187 ms).

An omnibus ANOVA was carried out with target, task, serial position of the first target, and SOA between targets as the variables. As in Experiment 1, there was a main effect of target, with Target 1 reported correctly on .70 of the trials and Target 2 on .48, $F(1, 15) = 62.54$, $MSE = 0.101$, $p < .001$, and a significant interaction of target with task and SOA, $F(1, 15) = 59.88$, $MSE = 0.028$ $p < .001$. The confidence interval for pairwise comparisons of means, calculated as in Experiment 1, was .13. For Target 2 partial report, the means at the two SOAs were .38 and .66. This .28 difference was the only SOA contrast that exceeded the confidence interval: Again, only Target 2 in the partial report condition showed the blink pattern.

Separate analyses on the first and second targets were carried out. An ANOVA on report of Target 1 showed a significant difference between whole report (M = .65) and partial report (M =. 76), $F(1, 15) = 8.92$, $MSE = 0.076$, $p < .01$, with whole report now worse than partial report, and a main effect of the serial position of Target 1, $F(3, 45) = 16.85$, $MSE = 0.043$, $p < .001$, with better recall of the word that was first in the sentence. These two effects interacted, $F(3, 45) = 4.45$, $MSE = 0.042$, $p < .01$; whereas report of Target 1 in the whole-report condition got steadily worse with increasing serial position, partial report was relatively flat in later serial positions, so that whole report of Target 1 was worse than partial report at later serial positions. No other effects were significant.

In the ANOVA of Target 2 there was no main effect of whole versus partial report, a significant main effect of Target 1 position, $F(3, 45) = 5.85$, $MSE = 0.048$, $p < .01$, and a significant main effect of SOA, $F(1, 15) = 10.43$, $MSE = 0.047$, $p < .01$. Critically, task interacted with SOA, $F(3, 45) = 70.96$, $MSE = 0.035$, $p < .001$. As shown in Figure 1B and noted above, there was a strong attentional blink in the partial report condition at lag 2, similar to that in Experiment 1 (Figure 1A). In contrast, whole report was somewhat better at lag 2 than at lag 5. No other effects were significant. Note that for Target 2 at lag 2, the .13 advantage of whole report over partial report was at the confidence level of .13 calculated earlier.

An analysis of recall of the other eight words in the whole report condition showed that .56 were recalled, compared with .85 in Experiment 1. Of those words that were recalled, order errors were more frequent than in Experiment 1. Altogether, combining reports of the red words (.55) and the other eight words, .56 of the 10 words were reported.

Comparing Experiments 1 and 2—ANOVAs comparing the experiments were carried out separately for Target 1 and Target 2; we report effects in which experiment was a variable. For Target 1, there was a highly significant main effect of experiment, $F(1, 30) = 16.94$, $MSE = 0.185$, $p < .001$, with better report in Experiment 1, and an interaction between experiment and task, $F(1, 30) = 31.61$, $MSE = 0.073$, $p < .001$, with a large negative effect of scrambling for the whole report task only. There was a triple interaction among experiment, task, and serial position, $F(3, 90) = 5.53$, $MSE = 0.028$, $p < .01$, indicating that the advantage of partial over whole report in the scrambled condition was obtained only at the two latest serial positions of Target 1, consistent with an increasing memory load for scrambled (but not normal) sentences later in the sequence. For Target 2, there was a main effect of experiment with better report in Experiment 1, $F(1, 30) = 27.45$, $MSE = 0.270$, $p < .001$, and an interaction between task and experiment, $F(1, 30) = 35.48$, $MSE = 0.147$, $p < .001$, with whole report better than partial report in Experiment 1 and the reverse in Experiment 2. As observed for Target 1, there was also a triple interaction among experiment, task, and serial position, $F(3, 90) = 3.04$, $MSE = 0.039$, $p < .05$, with the overall partial report advantage in the scrambled condition restricted to later serial positions.

Discussion

Clearly, scrambling a sentence made the string of words more difficult to process, with an average of .56 words reported in scrambled whole report compared with .86 when the sentence was presented normally. As predicted, this increase in difficulty reversed the overall whole report advantage. There was still a whole report advantage in one critical condition, however: when Target 2 appeared at a short SOA that produced an attentional blink in partial report (see Figure 1B). Thus, a whole report advantage in this condition is not found only when whole report is robust (as in Experiment 1), but also when whole report overall is worse than partial report

Partial report was unaffected by scrambling the surrounding words, implying that in neither experiment was the sentence structure processed when the task was to select and report just the red words. In Experiment 1 the red words were more accurately reported when the viewer recalled the whole sentence, raising the question of why subjects did not simply encode the whole sentence and then retrieve the words that were red. One possible explanation is that subjects were unable to bind color to specific words at the rate of presentation used in these experiments. In Experiment 3 targets were designated by case, a shape feature that is not only relevant to reading but also is integral to word recognition, and so might be possible to encode while also processing the sentence.

Experiment 3

A possible problem with Experiment 1 and Experiment 2 is that selection required attention to the color of words, a feature that is normally irrelevant to reading. In Experiment 3 the target words were presented in uppercase letters rather than in red; case is a relevant feature in reading, so we speculated that it might be picked up more rapidly than color and might be compatible with sentence processing. If so, the attentional blink in selective report might be reduced or eliminated. Because the uppercase manipulation was irrelevant in the whole report condition, we did not expect any difference between Experiment 1 and Experiment 3 in the whole-report condition, only the partial-report condition.

Method

Subjects—The 16 subjects, recruited from the same pool as in Experiment 1 and Experiment 2, had not participated in those experiments. Two subjects were replaced because of a high error rate, more than 2.5 S.D. lower than the mean.

Design and procedure—The design and procedure were the same as those for Experiment 1 except that the red words in Experiment 1 became uppercase black words in Experiment 3 and we changed capitalized first letters on other words (proper names, the initial word in the sentence) to lowercase. Examples are shown in Table 1. Subjects in the partial report task were instructed to report the two uppercase words.

Results

Figure 1C shows the main results. As in Experiment 1, whole report of the critical words was more accurate than partial report, and there was a marked attentional blink for Target 2 at the short SOA (lag 2) for partial report only.

In an omnibus ANOVA of Target 1/2, task, SOA, and serial position of Target 1, the main effects of target, task, and SOA were all significant. As in the previous experiments, there was a triple interaction among target, task, and SOA, $F(1, 15) = 9.42$, $MSE = 0.032$, $p < .01$. The confidence interval for pairwise comparisons of means, calculated as in Experiment 1, was .13. For Target 2 partial report, the means at the two SOAs were .32 and .55. This .23 difference was the only SOA contrast that exceeded the confidence interval; Again, only Target 2 in the partial report condition showed the blink pattern.

Separate analyses were carried out on the two targets. In the ANOVA of Target 1 only the main effect of task was significant, $F(1, 15) = 77.01$, $MSE = 0.042$, $p < .001$, with whole report (M = .94) more accurate than partial report (M = .72). In the ANOVA of Target 2, the main effect of task was also significant, $F(1, 15) = 163.29$, $MSE = 0.087$, $p < .001$, with whole report (M = .91) better than partial report (M = .44). There was a main effect of SOA, $F(1, 15) = 21.66$, $MSE = 0.040$, $p < .001$, with better performance at the longer SOA, which was qualified by an interaction with task, $F(1, 15) = 10.74$, $MSE = 0.078$, $p < .01$, as shown in Figure 1C. As noted above, the better performance at an SOA of 467 ms than at 187 ms was found only in the partial report task. No other results were significant.

An analysis of correct report of the eight non-target words in the whole report condition showed that .85 were reported, as in Experiment 1. Overall, including the targets (.93), .86 words were recalled.

Comparison of Experiments 1 and 3—ANOVAs were carried out, comparing Experiments 1 and 3, separately for Targets 1 and 2. For Target 1, there was no significant main effect of experiment: red targets, .86; uppercase targets, .83, $F(1, 30) = 1.02$, $MSE = 0.117$, $p = .32$, and no interactions with experiment were significant. For Target 2 there was again no main effect of experiment, $F(1, 30) = 1.53$, $MSE = 0.214$, $p = .23$, and the only significant interaction with experiment was with task, $F(1, 30) = 6.39$, $MSE = 0.093$, $p < .05$, with no Target 2 difference between experiments in whole report (red, .89; uppercase, .91), but with more accurate partial report for red targets (.56) than for uppercase targets (.44). The size of this effect was unaffected by SOA.

Thus, whereas whole report was similar in the two experiments, partial report of Target 2 was more difficult when the targets were in uppercase than when they were red, contrary to our speculation that a sentence-relevant feature such as case would be more readily detected than an irrelevant feature such as color. Evidently the more relevant and hence more normal feature of case was less readily picked out than the less usual feature of color.

Discussion

The main results of Experiment 1 were replicated in Experiment 3, with uppercase rather than red target words. Contrary to the hypothesis that a reading-relevant feature such as uppercase font would be easier to detect than a reading-irrelevant feature such as red font, in the partial report condition uppercase targets were less accurately reported than red targets. In the whole report condition uppercase and red words were equally accurate. Whereas scrambling the words diminished whole report without affecting partial report, making the targets uppercase rather than red diminished partial report without affecting whole report. This double dissociation suggests that whole report and target search are distinct processes. Moreover, there was no hint of a reduction in the attentional blink in Experiment 3, indicating again that processing the sentence was incompatible with selective report, whether of red or uppercase words.

General Discussion

The paradox with which we started is the ease with which RSVP sentences are processed, as contrasted with the difficulty in picking out a second target in a similarly rapid stream. Given the presumed complexity of recognizing individual words, retrieving their meanings, and computing their syntax, it is quite surprising that sentences can be processed so readily, while a second target (even a very simple one, such as a letter) is difficult to pick out in an RSVP stream. The present results deepen rather than dispel this paradox: Even when the sequence consists of a sentence that is easy to report as a whole, selection of two specified words is sufficient to produce an attentional blink for the second, at the relevant lag. The viewer apparently cannot use easy sentence processing to pick out the relevant targets.

Crucially, even when whole report was made more difficult overall than partial report by scrambling the sentences, a target at lag 2 (in the temporal window of the attentional blink) was less accurately reported than the equivalent word in whole report. Although whole report became less accurate, scrambling the sentences had no effect on partial report. Conversely, changing the target-indicating feature from red font to uppercase font increased the difficulty of selecting targets in partial report without affecting the accuracy of those same words in whole report. Thus, different factors affect the difficulty of whole report and selective report, consistent with the difference in processing in the two cases.

What the present study shows, together with that of Nieuwenstein and Potter (2006), is that selection comes at a cost that cannot be explained as the cost of encoding or remembering the selected item, because whole report also requires encoding and remembering those items (together with others). What can be said about this selection cost? It is transient, limited to a period of about 200–400 ms after the onset of the first target, and it usually does not affect items appearing within about 100 ms of the first target, so-called lag-1 sparing (Chun & Potter, 1995; Raymond et al, 1992; Potter et al., 1998; Potter, Staub, & O'Connor, 2002). In addition, the cost that selecting a first target incurs to items that appear 100–400 ms later is only seen when the target is followed by a distractor or by a blank interval of more than 100 ms (Nieuwenstein, Potter, & Theeuwes, in press) and not when it is followed by an unbroken sequence of targets (e.g., Di Lollo, Kawahara, Ghorashi, & Enns, 2005; Olivers, 2007; Olivers, Van der Stigchel, & Hulleman, 2007; for related results, see Kellie & Shapiro, 2004).

As proposed by Wyble, Bowman, and Potter (2007), the sparing of a second target at SOAs of less than 100 ms may reflect the time course of a transient attentional response launched upon detection of the first target (for a related proposal see Nieuwenhuis, Gilzenrat, Holmes & Cohen, 2005). The hypothesized effect is similar to the transient attention produced by a spatial cue to the location of an upcoming target (Nakayama & Mackeben, 1989). In support of this claim, Wyble et al. showed that detecting a categorically defined target amongst distractors elicits a spatio-temporal window of enhanced processing that shares many of the characteristics of the transient attentional response described by Nakayama and Mackeben. Further support for a role of transient attention in sparing can be found in studies that show that sparing still occurs for the second of two targets separated by a distractor, as long as these targets appear at an SOA of less than about 100 ms (Bowman & Wyble, 2007; see also Potter et al., 2002, and Nieuwenhuis et al., 2005).

When the temporal separation between targets is more than 100 ms, a sharp drop in second-target performance is observed. This transition from sparing to blinking occurs when the two targets are separated by a blank interval, or when they are separated by distractor items, but it does not occur when the inter-target interval is filled with additional target items that have to be reported (Nieuwenstein et al., in press). These findings suggest that a key source of difficulty in selecting targets presented during a blink lies in the requirement to rapidly re-engage attention shortly after attention has been disengaged following first-target selection. When target input is continuous rather than temporally discrete, as is the case in whole report and with sequences of successive targets embedded in a sequence of distractors (Di Lollo et al., 2005; Olivers et al., 2007), there is continuous bottom-up target input that allows attention to remain engaged. Consequently, there is no chance for attention to disengage, and thus no need to rapidly re-engage attention when a second target appears. Thus, in this view, the main source of selection delays for targets presented during an attentional blink lies in the time needed to initiate a second episode of attentional engagement shortly after a first (e.g.,Weichselgartner & Sperling, 1987; for evidence that selection is delayed during the AB, see the studies by Nieuwenstein, 2006; Nieuwenstein, Chun, Hooge, & Van der Lubbe, 2005; and Vul, Nieuwenstein, & Kanwisher, in press).

The present findings have two implications for the account outlined above. First, the fact that whole report performance was significantly better with meaningful, structured sentences than with scrambled sentences underscores the role of memory storage limitations in whole report. The ability to sustain attention across a sequence of successive target items (i.e., items that are all to be reported) does not imply that these items can all be encoded and later recalled. Instead, there is indeed a limit to these storage processes. Second, the present results show that whether or not attention can remain engaged following selection of a first target is not governed by purely stimulus-driven factors. Otherwise, the presence of sentence structure in the items trailing the first target in partial report would be expected to facilitate the continued engagement of attention relative to a condition in which no such structure was present. Since the results indicate that there is no effect of sentence structure in a partial report task, the disengagement of attention following a first target appears to be contingent on the fact that these following items do not match the target specification (e.g., being red or uppercase), not on whether or not these items form a coherent structure.

The results have some possible implications for normal reading. Does an extended fixation or refixation on a particular word represent something like the attentional engagement produced by a target? There is evidence that a surprising or emotion-inducing picture in an RSVP sequence can cause an attentional blink (e.g., Most, Chun, Widders, & Zald, 2005). In effect, does a reader of normal text avoid an attentional blink that might be generated by an unexpected word by pausing at such a point until ready to move on? If so, the pattern of eye fixations in reading a given sentence should show some relation to attentional blinks in reading the same sentence in RSVP.

Conclusions

The present experiments show that comprehending and remembering a sentence presented at more than 10 words/s is easy. Selection of two specified words in the sentence, however, leads to an attentional blink for the second word when it appears at a short SOA. The inability of meaningful sentence structure to assist word selection shows that sentence processing and selection (based on color or case) are incompatible, with a double dissociation between factors that affect one process and not the other. The attentional blink observed in partial report cannot be due solely to the need to encode and remember the first target as Chun and Potter (1995) and others have proposed. Instead, selecting the first target (and then withdrawing attention because a distractor or a blank interval follows) is the main requirement for a blink. Whether a surprising or startling word in a sentence could also produce a blink remains to be investigated.

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This work was supported by MH47432. We thank Rijuta Pandav, Winston Chang, and Ravi Gupta for assistance.

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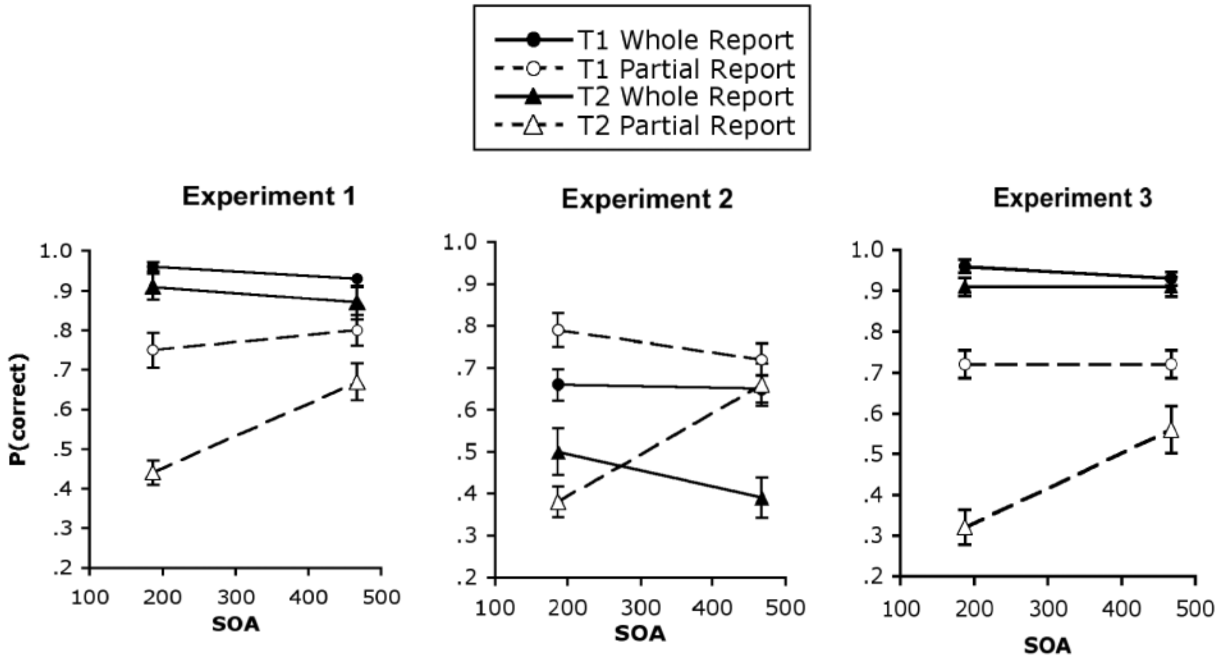

Figure 1.
Correct report of Target 1 (T1) and Target 2 (T2) at SOAs of 187 and 467 ms, separately for whole report and partial report. Error bars depict standard errors of the mean. Experiment 1: Targets are red words. Experiment 2: Sentences are scrambled. Experiment 3: Targets are uppercase words.

Table 1

Examples of sentences in each experiment. The critical words in Experiment 1 and Experiment 2 were red but in the same font as the other words; here they are shown in bold. In Experiment 3 the critical words were uppercase, and no other words were capitalized. Between subjects, the first four words of a given sentence were equally often designated as Target 1, and Target 2 appeared equally often two or five words after Target 1.

Experiment 1
While filming the **movie** Steve had trouble saying **his** lines Several **lions** napped **in** the shade of some tall trees Your children **like** to **play** games without any adults around **Wanda** and Jim are taking **their** vacation in Eastern Europe
Experiment 2
had the saying **movie** While trouble lines filming **his** Steve trees **lions** tall **in** Several some napped the shade to games **like** without **play** Your around any children adults **Wanda** Europe in Eastern taking **their** vacation Jim and are
Experiment 3
while filming the MOVIE steve had trouble saying HIS lines. several LIONS napped IN the shade of some tall trees your children LIKE to PLAY games without any adults around WANDA and jim are taking THEIR vacation in eastern europe