12 Competition for Attention in Space and Time: The First 200 ms

Mary C. Potter

The goal of the research reported in this chapter is to understand how competing stimuli in a temporal stream attract and hold attention in the first 200 ms after onset. In normal circumstances, visual perception is continuous, a cycle of saccades and fixations. Yet, until recently, perception has been studied almost exclusively by presenting a single stimulus array, perhaps preceded by a fixation point and followed by a mask.

In an early study of more continuous perception, my colleague and I tested memory for pictured scenes in a rapid serial visual presentation (RSVP). The goal was to study processing at durations in the range of normal fixations, presenting a different picture on each "fixation" so that we could subsequently measure recognition memory for that fixation. We found that memory for the pictures was excellent at a rate of 1/s, but that more than half the pictures were forgotten at a rate of 3/s, a rate typical of eye movements (Potter & Levy, 1969). Subsequent studies showed that detection of a named target picture (e.g., *small boats on beach*) within an RSVP stream was possible at a presentation rate of 3/s, showing that picture meaning can be extracted much faster than memory for pictures can be consolidated (Intraub, 1980, 1984; Potter, 1975, 1976). Similar experiments using words instead of pictures showed that meaning is extracted even more rapidly from a briefly presented word in an RSVP stream, permitting detection of a target word defined by a category such as *animal* (Lawrence, 1971) at rates of presentation too high for retention of even a short sequence of unrelated words (Potter, 1982, 1993).

These RSVP studies show that words or pictures in a continuous stream can be understood rapidly, but competition from subsequent items leads to forgetting of most of the items. If, however, the items in a stream are words in a meaningful sentence, the sentence (and thus all of the words) can be understood and reported at presentation rates of 12 words/s or even higher (Forster, 1970; Potter, 1984; Potter et al., 1980; Potter et al., 1986). Words in a sentence have meaningful connections to one another that can be computed on the fly, creating an integrated structure that supports reportable memory.

For words presented in a rapid temporal stream, meaningful connections can only be discovered if there is some form of memory for at least the several most recent words. I termed this mediating representation of individual items *conceptual short-term memory* (CSTM) and suggested that CSTM retains meaningful items briefly, permitting integrated structures to be formed (Potter, 1993, 1999). Such structure building requires not only identification of each word in a sentence but also the momentary retrieval of a large number of conceptual associations from which the relevant ones are selected. This process is largely unconscious, as illustrated by our normal lack of awareness that we have selected the context-appropriate meaning of an ambiguous word.

12.1 Competition for Attention Over Time: The Attentional Blink

A limitation on our capacity to process a rapid stream of stimuli leads to competition between items for attention. Although extensive research has been carried out on competition for attention over space, only recently have researchers begun to study competition for attention over time. In these studies investigators have presented RSVP sequences containing two or more items that have been designated as targets the viewer is to report—for example, two letters in a stream of digit distractors. By placing the second target at different serial positions in the sequence, the stimulus onset asynchrony (SOA) between the targets is varied. An early finding was that there is a brief temporal gap in reported perception shortly after attention has been directed to a particular target stimulus, and that if a second target appears during this interval, it is likely to be missed (Broadbent & Broadbent, 1987; Weichselgartner & Sperling, 1987). This transient negative effect on the second target was called an *attentional blink* by Raymond et al. (1992). Raymond et al. showed that the effect was maximal at an SOA between targets of about 200 ms and diminished as the SOA increased, disappearing by about 500 ms. Thus, the *attentional blink* is standardly defined as interference from an initial target (T1) with the processing of a second target (T2) that appears between 200 and 500 ms later. Figure 12.1 shows a typical attentional blink pattern, in an experiment in which viewers attempted to report the two letters in a sequence of digits presented at 10 items/s (Chun & Potter, 1995). Conventionally, performance on T2 is shown conditional on correct report of T1 and is plotted as a function of the lag, or SOA, between T1 and T2.[1]

Raymond et al. (1992; see also Chun & Potter, 1995, experiment 3) found that removing the distractor item immediately following T1 and replacing it with a blank frame reduced or eliminated the attentional blink on T2. This effect of unmasking T1 suggested that the attentional blink is the result of interference produced by an

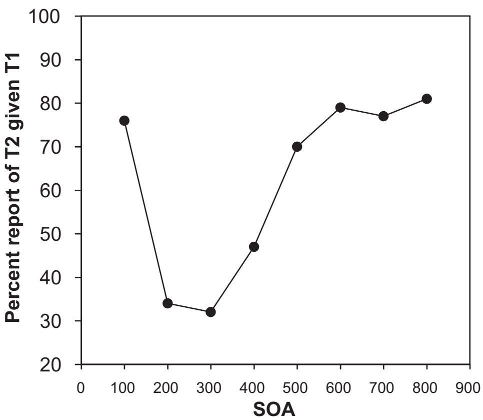


Figure 12.1
A characteristic attentional blink result, in which performance on target 2 (T2) is reported as a function of stimulus onset asynchrony, conditional on correct report of target 1 (T1). (From Chun & Potter, 1995, figure 2) T1 and T2 were letters, and the distractors were digits.

immediate visual event after T1, which slows processing of T1, thus interfering with processing of T2. Another effect noted by Raymond et al. (1992) was that when T2 appeared immediately after T1, T2 was often easier to report than when there was an intervening distractor (see figure 12.1). This effect, termed *lag 1 sparing* because T2 is spared when it lags one step behind T1, is found only when there is no major task shift between T1 and T2 (Potter et al., 1998; Visser et al., 1999).

12.1.1 The Two-Stage Model of the Attentional Blink

Chun and Potter (1995) developed a two-stage model of the attentional blink in which detection and identification of T1 take place in the first stage (lasting about 100 ms). Once identified, T1 is represented in CSTM while a second, serial, stage of consolidation into short-term memory begins (Potter, 1976; Jolicoeur & Dell'Acqua, 1998). This second stage, which is required for report of the item, may take 200–400 ms, so that if T2 appears during this time it will only be processed in stage 1 and will have to wait in CSTM for stage 2 to become available. CSTM is volatile and is subject to interference from subsequent stimuli. Thus, T2 may be momentarily detected and identified but may be forgotten before it can enter stage 2. A number of studies have provided evidence for the claim that an unreported T2 is nonetheless identified (e.g., Luck et al., 1996; Maki et al., 1997; Shapiro et al., 1997).

The Chun–Potter model explains lag 1 sparing as follows. Detection of a target opens an attentional gate, but closure of the gate is inexact or sluggish, and so the immediately following item is also attended (e.g., Weichselgartner & Sperling, 1987;

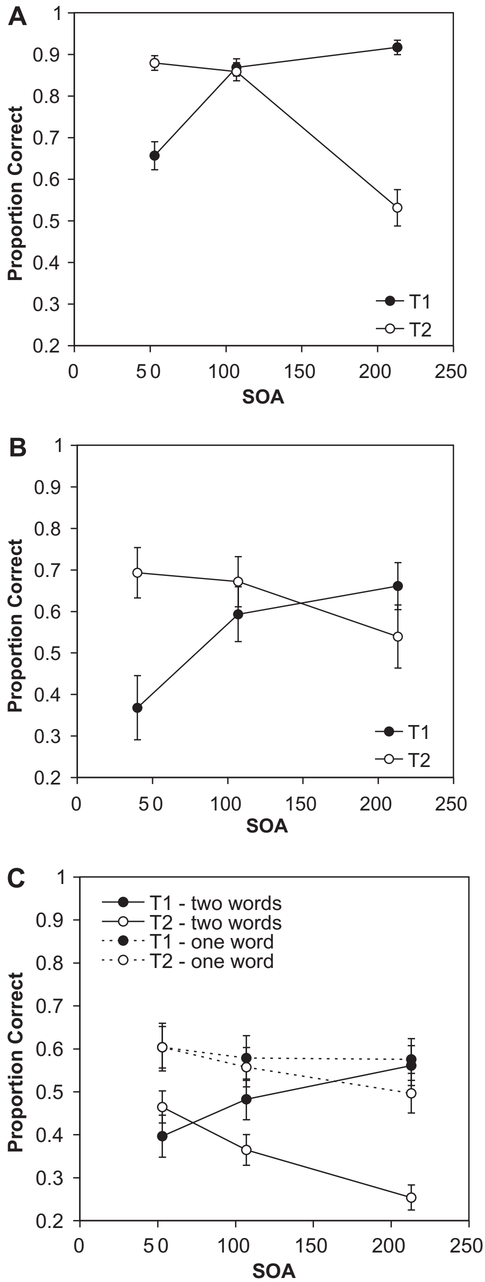
Raymond et al., 1992) and the two items enter stage 2 together. When the following stimulus is a distractor, it must be suppressed, but when it is also a target, the two targets are processed together in stage 2, with some resulting competition. Consistent with this account, performance on T1 was lower at lag 1 than at longer lags (suggesting competition), and the order of report of the two targets was frequently reversed (Chun & Potter, 1995). As will be seen, a different account of lag 1 sparing emerged from studies with shorter SOAs and shorter exposure durations, leading to a modification of the Chun–Potter (1995) model.

12.2 Short SOAs

Until recently, research on the attentional blink used presentation rates of about 10 items/s to ensure that T1 was likely to be perceived. The focus was on T2, and (as noted) performance on T2 was scored conditional on correct report of T1. To investigate performance at SOAs shorter than 100 ms, Potter et al. (2002) used a rate of about 19 items/s (53 ms per item). By approximately doubling the rate of presentation that had been used in most previous attentional blink studies, we were able to disentangle the effects of SOA and of lag. Whereas in earlier studies lag 1 was coincident with an SOA of about 100 ms, in Potter et al.'s studies lag 2 occurred at an SOA of 107 ms, and lag 1 at an SOA of 53 ms. The targets were four- and five-letter words (different on every trial), and the distractors were strings of keyboard symbols.

In our first experiment we presented a single stream of stimuli, and the SOAs between the two targets were 53, 107, or 213 ms. The results are shown in figure 12.2A, which shows performance separately for T1 (the black dots) and T2 (the white dots). Note first that the T2 results for SOAs of 107 and 213 ms were like those in earlier attentional blink studies: At an SOA of 107 ms there was sparing of T2, and at an SOA of 213 ms there was a sizable attentional blink. At an SOA of 53 ms (the actual lag 1 in this experiment) T2 was easily reported. In contrast, at an SOA of 53 ms T1 showed a substantial deficit: There was a marked crossover interaction

Figure 12.2
(*A*) Accuracy in report of each target (T) word (T1 and T2) among symbol strings presented in a single rapid serial visual presentation stream at stimulus onset asynchronies (SOAs) of 53, 107, or 213 ms. Error bars represent standard errors. (From Potter et al., 2002, figure 1) (*B*) Accuracy in report of each target word when targets were presented in separate streams, one above the other, at SOAs of 40, 107, or 213 ms. Error bars represent standard errors. (From Potter et al., 2002, figure 3) (*C*) Accuracy in report of a given word at SOAs of 53, 107, or 213 ms when there were two words on a trial (solid lines) and when there was only one word on a trial (dotted lines). On the one-word trials, T1 and T2 designate target words in the same serial positions as the corresponding words in the two-word trials. Error bars represent standard errors. (From Potter et al., 2002, figure 5)


A
B
C
Proportion Correct
SOA
T1
T2
T1 - two words
T2 - two words
T1 - one word
T2 - one word
0
50
100
150
200
250
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

between target (T1 vs. T2) and SOA. That is, there was not only sparing of T2 at short SOAs but also marked interference with T1.

A possible reason for the poor performance on T1 at lag 1 was that T2 simply masked T1 more effectively than distractors did (a confound at lag 1 that was present in most previous attentional blink studies). In subsequent experiments, Potter et al. (2002) used two streams of stimuli, one directly above the other, with the two targets in separate streams. (The first target appeared randomly in the upper or lower stream.) This method not only avoided the differential masking problem (because the item immediately following each target in its stream was always a distractor) but also allowed for SOAs shorter than 53 ms, including simultaneous presentation. Figure 12.2B shows the results of one experiment with SOAs of 40, 107, and 213 ms. Overall performance was lower with dual streams, but the pattern was similar to that with a single stream. In particular, there was a marked crossover at the shortest SOA, with performance on T1 much lower than on T2. Evidently the masking confound noted in the one-stream experiment was not the sole reason for the crossover.

To show that the pattern resulted from mutual interference between the two targets, in a subsequent experiment with dual streams we omitted one of the two words on a random two thirds of the trials. The results are shown in figure 12.2C. The two lower curves show accuracy for each target when both were presented, with a crossover interaction. The dashed upper curves show the result for each target when only one of the two targets was presented and the other was replaced with a distractor. Overall accuracy in the two-target condition was 42%, compared with 57% in the one-target condition. This difference was significant for every condition except for T1 at an SOA of 213 ms: In that condition T1 performance was the same whether or not a T2 was presented. That is, performance on T1 was immune from interference from T2, presumably because after 213 ms T1 was already in stage 2. Moreover, in the one-target condition there was no evidence for the crossover pattern seen with two targets, showing clearly that the pattern was the result of mutual competition, not serial position or a prior allocation of attention to one of the two streams.

12.3 The Two-Stage Competition Model of Attention

Neither the Chun–Potter (1995) two-stage model nor other models of the attentional blink can account for the crossover between T1 and T2 (i.e., the advantage of T2 over T1) at very short SOAs. Chun and Potter had noted that in their experiments T1 and T2 showed evidence of competition at lag 1 (with an SOA of 100 ms). The two-stage competition model of Potter et al. (2002) was proposed as a modification and extension of the Chun–Potter two-stage model. The main new claim of the competition model is that competition arises in Stage 1 after detection of a potential target (e.g., a string of letters), but before identification of the word. As in the original Chun–Potter model, detection of T1 initiates an attentional response. Whereas the Chun–Potter model proposed that the attentional response ushered T1 into stage 2, in the two-stage competition model the attentional response simply mobilizes processing resources needed for identification of the detected target in stage 1. It takes 50–100 ms to identify T1, and if T2 appears during this time, it competes for these resources. Once one of the targets has been identified, it alone enters stage 2 for consolidation, and then the other target must wait.

Because the attentional response to T1 takes time to reach its maximum (e.g., Shih, 2000; Weichselgartner & Sperling, 1987), T2 may benefit more than T1 when the SOA is short. In effect, T2 steals the attention that T1 activated, creating the crossover pattern that Potter et al. (2002) observed. In this model, "lag 1 sparing" is the result of approximately equal competition between T1 and T2 at an SOA of about 100 ms; with shorter SOAs, T2 tends to dominate T1.

Stage 1, detection and identification, of the two-stage competition model can be summarized as follows:

- A potential target is detected on the basis of some relevant feature (e.g., being alphabetic, when the target is any word among keyboard symbols) and attracts attentional resources required to identify it.
- If a second target appears during this stage, it will compete for resources while both targets are in stage 1.
- At short SOAs, T2 benefits from the prior triggering of attention and may be identified before T1.
- The target that is first identified enters stage 2.
- When one target is occupying stage 2, another target that is left waiting in stage 1 or that enters stage 1 may be identified. If so, it will be represented briefly in CSTM, but it may be be forgotten before it can enter stage 2.

Stage 2, consolidation, of the two-stage competition model can be summarized as follows:

- This stage is serial, capable of processing only one target at a time.
- Consolidation into short-term memory (STM), which can take 200–500 ms, is required for an item to be reported.

12.4 Location Uncertainty

One surprise in Potter et al.'s (2002) results is that the crossover effect, benefiting T2, was obtained even though T1 and T2 appeared in different spatial locations. In other studies (e.g., those reviewed by Visser et al., 1999, and a study by Breitmeyer et al., 1999), a shift in location almost always eliminated lag 1 sparing: That is, T2 showed a large attentional blink deficit at lag 1. Potter et al. always presented the two targets in different streams, so that participants knew as soon as T1 appeared that T2 would be in the other stream; there was no location uncertainty. In most earlier studies using more than one location, the location of T2 remained uncertain.

To test the effect of location uncertainty, Potter and O'Connor (2000) carried out a further experiment in which T2 was equally likely to be in the same or the other stream; the results are shown in figure 12.3. When the targets were in the same stream (see figure 12.3A), the results were like those of Potter et al. (2002) with a single stream (see figure 12.2A) or with two streams when the targets were always in separate streams (see figure 12.2B): There was a crossover interaction between T1/T2 and SOA ($p < .001$). However, when the targets were in separate streams in the uncertain location experiment, the results were very different from the separate-stream results in Potter et al. (2002): T1 was always much better than T2 (see figure 12.3B). There was still a significant interaction with SOA: T1 got better with longer SOAs; T2 got worse ($p < .002$). Clearly, when T2 appeared in the same stream as T1 on half the trials, viewers adopted a conservative strategy of maintaining attention on the T1 stream. As a result, lag 1 sparing at short SOAs was minimal when T2 appeared in the other stream, just as in previous studies with a location shift between T1 and T2.

Thus, the pattern of resource competition is determined in part by expectation, such that there is a bias to maintain attention at the location of the first target at the expense of a target appearing in the other location. Only when the two targets are always presented in different locations is a viewer readily attracted to a second target in the other location, and then only at short SOAs.

12.5 Modifying the Crossover Pattern: Unmasking and Semantic Priming

To test and extend the two-stage competition model, my colleagues and I examined the effects of two other variables on performance at short SOAs, using the same basic procedure of search for two word targets in separate streams of nonalphabetic distractors. The variables we investigated were unmasking (substitution of a blank for the immediate masking stimulus following one or the other target) and seman-

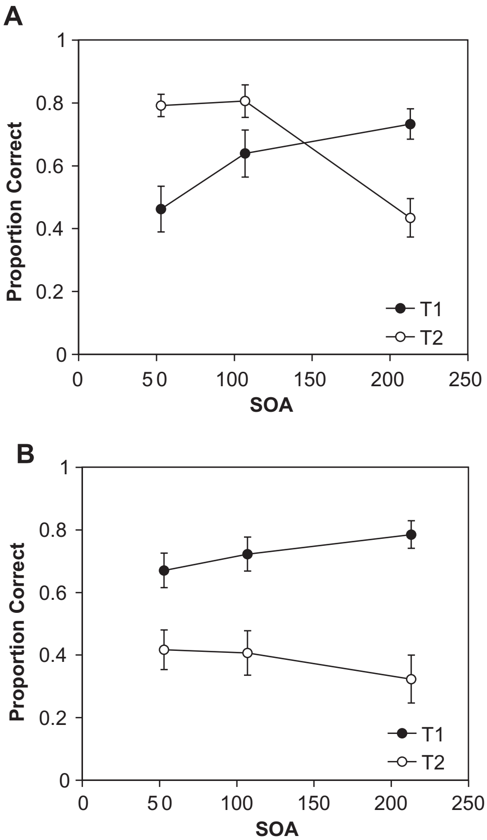


Figure 12.3
(*A*) Accuracy in report of each target (T) word in a two-stream presentation when the targets were in the same stream. Error bars represent standard errors. (*B*) Same, when the two targets were in different streams. SOA, stimulus onset asynchrony.

tic priming of one of the words. These manipulations were expected to boost performance on one of the two targets, allowing us to measure possible competitive effects on the other target.

12.6 Unmasking by Adding a Blank

Earlier work had shown that when a blank follows T1 (instead of a distractor), the attentional blink on T2 is reduced or eliminated (Raymond et al., 1992; Chun & Potter, 1995), presumably because processing of T1 is completed rapidly when there is no immediate visual mask. The presentation duration in those studies was about

100 ms/item, there was only one stream, stimuli were simple (typically, single letters), and performance on T1 was near ceiling even with no blank. In the present research items were presented for about 50 ms, the targets were words appearing in separate streams, and report of T1 was well below ceiling. In these conditions, we asked whether unmasking T1 or T2 would modify the crossover pattern. In particular, would unmasking bias the competition between T1 and T2 at short SOAs, favoring the unmasked target at the expense of the other target? And, at longer SOAs, would unmasking T1 reduce or even eliminate the attentional blink on T2?

12.6.1 Predictions of the Competition Model

We made the following predictions from the competition model:

1. Insofar as T1 and T2 compete in stage 1 at short SOAs (e.g., 53 ms), putting a blank after one or the other target will bias the competition in favor of the blanked target and will decrease the accuracy of reporting the nonblanked target. That is, there would be a benefit for the blanked target at the expense of the other target (a *competition pattern*).

2. At longer SOAs (e.g., 213 ms) unmasking T1 will not only increase report of T1 but will also diminish the attentional blink on T2 (as in earlier studies): That is, unmasking T1 will help both T1 and T2 at longer SOAs.

3. Unmasking T2 at longer SOAs (e.g., 213 ms or longer) will help T2 without a cost to T1.

12.6.2 Method and Results

The experiment (Potter et al., in preparation b) used the general method used by Potter et al. (2002). Presentation duration was 53 ms/item, and there were four SOAs: 53, 107, 213, and 427 ms.[2] Three conditions were intermixed randomly: a blank of 53 ms in the T1 stream immediately after T1, a blank in the T2 stream after T2, or no blank. The results for a blank after T1 and no blank are shown in figure 12.4A. In the no-blank condition we obtained the familiar crossover pattern. When T1 was followed by a blank, performance on T1 was markedly improved, more or less equally at all SOAs. Contrary to our first prediction, however, the competition pattern—a cost to T2—was absent at an SOA of 53 ms. (Similarly, when T2 was followed by a blank, there was no cost to T1—see figure 12.4B.)

Contrary to our second prediction, instead of a blank after T1's helping T2 at longer SOAs, the blank at SOAs of 107 and 213 ms interfered with T2 report, increasing the attentional blink. Thus, the results did not replicate previous studies (with slower presentation rates) in which a blank after T1 helped T2, reducing the attentional blink effect (Raymond et al., 1992; Chun & Potter, 1995). Rather, a blank after

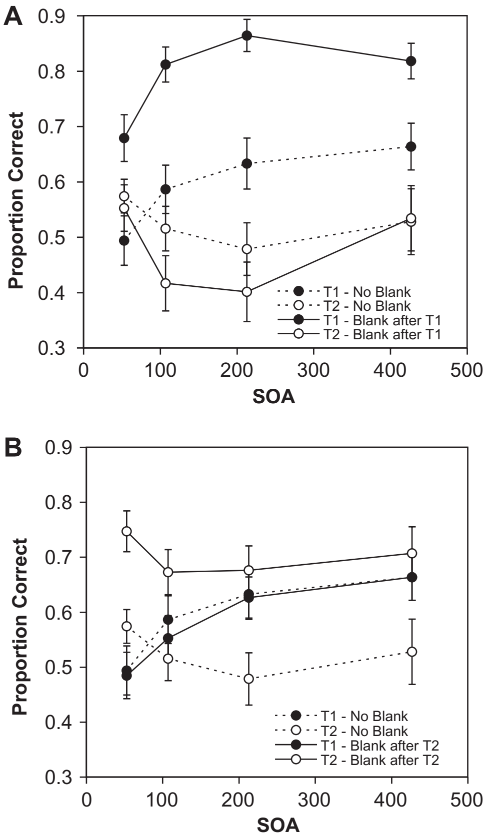


Figure 12.4
(*A*) Report of each target (T) word when T1 was immediately followed by a blank frame of 53 ms (solid lines) and when there were no blanks (dotted lines). Standard error bars are shown. (*B*) Report of each target word when T2 was immediately followed by a blank (solid lines) and when there were no blanks (dotted lines). Standard error bars are shown. SOA, stimulus onset asynchrony.

T1 hurt performance on T2 in the blink range, although not at an SOA of 53 ms nor at 427 ms. Only our third prediction was supported: A blank after T2 at longer SOAs helped T2 without affecting T1 (see figure 12.4B).

12.6.3 Discussion: Unmasking

What do the results say about the competition model? The claim of the model is that competition in stage 1 will only occur at a short SOA. If unmasking one of the targets biases the competition, that should be evident at an SOA of 53 ms, and no such competition pattern emerged. Instead, unmasking either T1 or T2 gave a consistent benefit to the unmasked target at all SOAs, with little effect on the other target except for an increase in the attentional blink on T2 at SOAs of 107 and 213 ms.

A possible explanation is that the unmasking blank came too late to affect competition in stage 1 (at an SOA of 53 ms). Consider the time course of events at an SOA of 53 ms. A blank after T2 began 100 ms after the onset of T1, probably too late to bias competition. However, a blank following T1 began at the onset of T2. If the two words were then processed in parallel, the blank after T1 should have helped it, relative to T2—but that is not what we found. There was no evidence of competition at an SOA of 53 ms, only a benefit for T1 without cost to T2.

12.6.4 A Winner-Take-All Competition in Stage 1?

In our initial competition model (Potter et al., 2002), stage 1 competition meant that resources were shared and that processing continued in parallel until one of the words was identified. A different assumption is that the onset of T2 has a certain probability of attracting all the resources initially accruing to T1. This probability decreases as SOA increases. In other words, the competition is all or nothing: Either attention shifts entirely to T2, or it stays with T1 until it is identified or fails to be identified. If this new hypothesis is correct, then it is not surprising that a T1 blank had no effect at SOAs of 53 ms or greater: At the time the blank began, T2 had appeared and the switch had happened (or not) without influence from the blank.

Why was there a cost to T2 when T1 was unmasked, at SOAs of 107 and 213 ms? In previous studies in which a blank after T1 helped T2, T1 was highly likely to be perceived even without a blank (and, indeed, performance on T2 was analyzed conditional on successful report of T1). Thus, any benefit to T1 would speed up its processing in stage 2 and therefore help T2. In the present experiments T1 was often missed, so a blank after T1 increased the probability that it would be identified and would enter stage 2, thus increasing the likelihood of an attentional blink on T2.

Further discussion of the time course of the unmasking effect is postponed until the results of experiments on semantic priming have been presented.

12.7 Semantic Priming

The second variable we investigated was semantic priming, to discover whether a priming word or phrase modulates the crossover pattern between T1/T2 and SOA. In the first of these studies (Potter et al., in press, experiment 1, $N = 12$) the two target words were either associated in meaning (e.g., *zebra–horse*) or were unrelated. The targets were presented in separate streams as in Potter et al. (2002) and in the unmasking studies just described. Items were presented for 53 ms, and the SOAs between the two target words were 27, 53, 107, and 213 ms. Our predictions were as follows. We assumed that priming benefits flow from the prime to the target, over time, and so most of the priming benefit would be found in report of T2. However, at short SOAs the two targets are hypothesized to be in competition, with T2 at least as likely to be reported as T1. Thus, both T1 and T2 were predicted to show a benefit from priming at short SOAs. Figure 12.5 shows the results: Both predictions were supported.

For the unrelated pairs, although there was no crossover, there was a strong interaction between SOA and target (T1 or T2) as in the earlier studies. For the related pairs, T2 benefited greatly from its relation to T1 at all SOAs, but T1 benefited from T2 only at the shortest SOA, 27 ms. This is consistent with the evidence from the unrelated trials that T1 and T2 were equally likely to be reported at an SOA of 27 ms, but at longer SOAs T1 had an advantage over T2.

A clear implication of these results is that T1 is only semantically primed if T2 is identified first. Potter et al. (in press, experiment 2) also reported an independent experiment carried out in Italian, in which similar results were obtained.

Before considering the processing locus of this priming effect, I will describe two other priming studies in which two word targets were presented, as in the previous experiments. In one study (Davenport & Potter, in press, experiment 1) a prime of one of the target words appeared just before each trial; the target word was an associate of the prime. We predicted that the related word would benefit from the prime in all conditions. The critical question, however, was whether there would be evidence of competition at a short SOA, such that the primed word would benefit at the expense of the unprimed word.

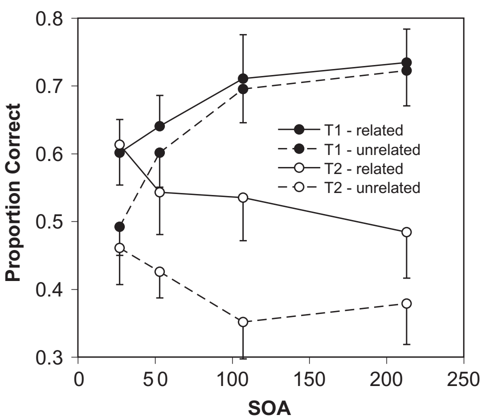


Figure 12.5
Report of each of two semantically related target (T) words (solid lines) or unrelated words (dashed lines). Standard error bars are shown. SOA, stimulus onset asynchrony. (From Potter et al., in press, figure 2)

Figure 12.6A shows the familiar crossover pattern for the unprimed words, and (as predicted) a constant benefit to the primed word, regardless of SOA or T1/T2. Was there, however, a cost to the unprimed word when it accompanied a primed word? In one condition in the experiment the prime word was not related to either of the target words—neither word was primed. If priming one word biases the competition in stage 1, then the other word on that trial should suffer (at a short SOA), compared to the condition in which neither word is primed. As figure 12.6B shows, there was no significant difference between the two ways of not being primed—there was no evidence at any SOA that priming one of two words made report of

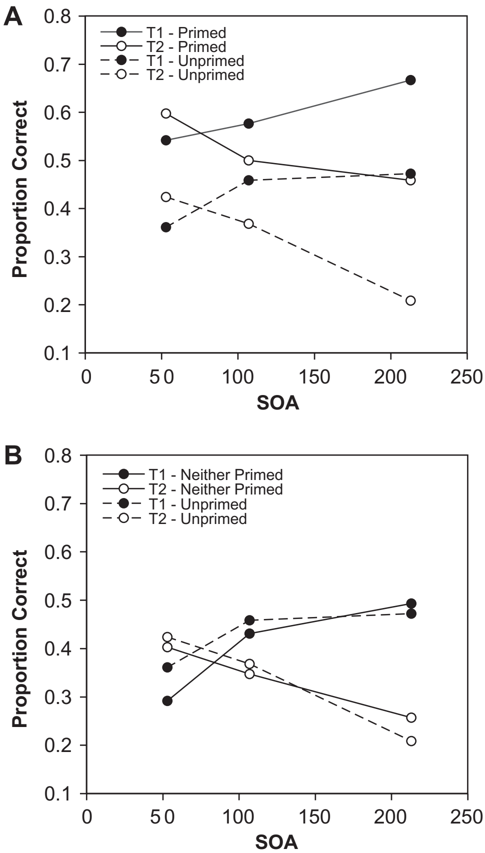


Figure 12.6
(*A*) Report of target (T) words preceded by a semantic prime (solid lines) and words unrelated to the prime (dashed lines) when one word in each pair was primed. SOA, stimulus onset asynchrony. (From Davenport & Potter, in press, figure 2) (*B*) Report of target words preceded by a prime, when neither word was related to the prime (dotted lines) and when one word was unprimed (dashed lines) but the other word was primed. Standard error bars are shown. (From Davenport & Potter, in press, figure 3)

the unprimed word less likely than in the neither-primed condition. (If anything, the result went in the opposite direction.)

We obtained a similar result in the third priming experiment, in which we used short, incomplete sentences as primes (Potter et al., in preparation a). One of the two target words was a good completion of the sentence, although not the most frequent completion that was generated by a norming group of subjects. The words of the sentence were presented at 107 ms/word in RSVP in a single stream, omitting the last word of the sentence (e.g., *She was late for the* . . .). The sentence fragment was followed immediately by two RSVP streams, as in the earlier experiments, with two target words (one of which was *party*, in this example). The SOA between the targets was 27, 53, 107, or 213 ms; the primed word was equally often the first or second word. The t0ask was to report both words; the sentence fragment could be ignored.

Figure 12.7 shows the results, separately for T1 and T2, for the related and unrelated words. Once more, there was a crossover effect for unprimed words, and the priming effect was more or less constant over all conditions. In a replication of these results we included a condition in which neither word was related to the sentence; in that case, performance was almost identical to that of the unprimed word when the other word fit the sentence. That is, again there was no evidence that a priming benefit to one word was at the expense of the other word.

12.7.1 Discussion: Semantic Priming

To sum up the semantic priming results, priming from one target to the other was found only from T1 to T2, with the notable exception that at a very short SOA T2

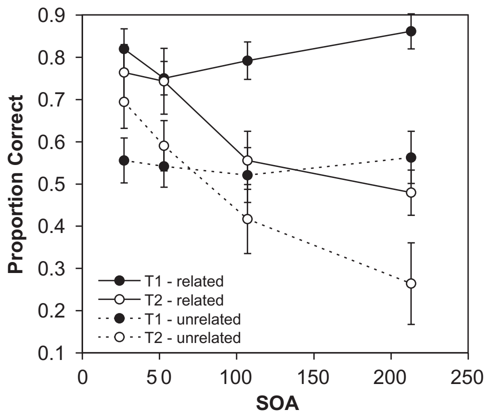


Figure 12.7
Report of target (T) words preceded by an incomplete sentence that was related to the word (solid lines) or unrelated (dotted lines). Standard error bars are shown. (From Potter et al., in preparation a)

was equally likely to prime T1 (Potter et al., in press). When the prime came at the beginning of each trial, preceding both word targets, priming benefited the related target without cost to the unprimed word. For the primed word, the benefit was roughly constant across SOAs. The same pattern was found whether the prime was an associated word (Davenport & Potter, in press) or a sentence fragment (Potter et al., in preparation a).

Semantic priming made it easier to see and report a difficult-to-see, masked word—a stimulus that seems to disappear completely when the mask arrives. Thus, there is reason to think that the semantic effect occurs very early in processing in this set of tasks, rather than reconstructively at the end of a trial. What does this tell us about the probable locus of the semantic priming effect? We can rule out an influence on the competition between T1 and T2 at short SOAs, in that if semantic priming biased this competition, the unprimed word should suffer, and it does not. However, if we assume (as we did earlier in discussing the unmasking results) that the competition consists of an all-or-nothing takeover of resources by T2 when T1 is in stage 1, then the competition stage would be over before either target has been identified. In that case, there would be no reason to expect semantic priming to affect the competition: Any effect would come later.

A likely time for a semantic prime to exert its influence is at the point of identification—that is, lexical access. It seems reasonable that an appropriate semantic context will increase the probability of successful word identification. Thus, even at a long SOA when T1 is likely to be identified first, priming T2 will increase its chances of also being reported.

Could the benefit come still later—for example, at the point of word retrieval at the end of the trial? We considered this possibility in the experiment in which the two target words were related on half the trials (Potter et al., in press). Successful recall of one of the words could have increased recall of the other word because of their semantic relation. In that case, however, the priming benefit would be expected to be similar at all SOAs, whether T1 was recalled first and primed T2, or T2 was recalled first and primed T1. That was the case for the priming benefit to T2: It was found at all SOAs. However, strikingly, the benefit to T1 was only found at the shortest SOA, suggesting that priming effects occurred during presentation rather than at the point of retrieval.

12.8 General Discussion

A question on which I have focused is whether unmasking one of two targets, or semantically priming one target, would bias the competition between the two targets in stage 1, as predicted by the competition model of Potter et al. (2002). Both unmasking and priming had the expected positive effects on the target in question, but neither procedure resulted in a cost to the other target in the earliest stage of processing, contrary to our prediction.

A modification of the competition model's stage 1 has been proposed to account for the failure to find a competitive cost for the other target. Instead of assuming that two targets presented very close in time compete in parallel for resources, my colleagues and I propose that the onset of the second target has a certain probability of shifting all the attentional resources to it, a probability that is greater the shorter the SOA. Thus, with an SOA of 27 or 53 ms, the second target is likely to cause a shift in attention on more than half the trials, whereas at longer SOAs a shift is less likely. In the unmasking condition, the positive effect of unmasking T1 cannot begin until the end of T1's presentation, but at that point T2 has just appeared (when the SOA is 53 ms) and the presumed switch occurs (or fails to occur) before any benefit from the blank following T1. That is, the blank comes too late to affect the probability of an attentional switch. In the case of a blank after T2, the effect begins even later (more than 100 ms after the onset of T1) and could have no effect on stage 1 competition.

For a different reason, the revised interpretation of stage 1 competition as an all-or-nothing switch of attention to T2 predicts that semantic priming (from an advance prime or sentence context) will not bias stage 1 competition. As the shift occurs before either target has been identified, semantic priming cannot bias this decision.

In both sets of experiments we obtained large benefits of unmasking and semantic priming. At what stage or stages of processing did these effects occur? In the case of semantic priming we proposed that the effects occur at the point of lexical access (word identification) at the end of stage 1. Is this also the point where the effects of unmasking occur? Unmasking makes a target easier to process, increasing the probability that it will be identified; this perceptual benefit could affect any stage of processing between the offset of the target and the point of identification. This effect can be expected to be approximately additive[3] with other factors such as SOA and whether the target is T1 or T2. Similarly, semantic priming facilitates lexical identification by increasing the accessibility of a related word, again somewhat independently of other factors. The result in both cases is that the increased accuracy for a primed or unmasked target is roughly additive with the effects of these other factors, as long as accuracy is below ceiling as it was in the present experiments.

12.9 The First 200 ms

The title of this chapter emphasizes the short time period over which competition between two briefly presented targets undergoes the changes shown in the experiments reported here. The competition in the first 100 ms (with an SOA of about

50 ms) favors the second target at the expense of the first; the two targets are more or less equal at an SOA of about 100 ms; and thereafter (at SOAs between 200 and 500 ms) the first target dominates, at the expense of the second target. (At still longer SOAs, not reported here, T2 performance may return to the level of T1 performance.) During the first 200 ms of processing, average accuracy in report of two targets is roughly constant; what changes is which target is more likely to be reported.

Unmasking one target or priming it with a semantically related context improves performance on the primed or unmasked target without otherwise affecting this pattern. Unmasking by inserting a blank frame makes it easier to see the unmasked target, but not in time to affect the competition between the two targets in stage 1 (before identification of either target). Competition once one of the targets has reached stage 2 takes a different form: The target undergoing consolidation monopolizes that stage of processing, forcing the other target to wait in CSTM, so that it is often forgotten before it gains access to stage 2. The fact that semantic priming facilitates target report is consistent with the idea that even under the present conditions, in which target words are very difficult to see, they are close to the point of lexical identification and access to meaning.

In accounting for this pattern of results, the earlier Chun–Potter (1995) two-stage model of the attentional blink was first modified and named the two-stage competition model (Potter et al., 2002) and here has been further modified by the proposal that the competition in stage 1 is not a matter of parallel sharing of limited resources but is instead an all-or-nothing, stochastic switch of attention from T1 to T2 that happens when T2 arrives while T1 is still in stage 1 (see also Davenport & Potter, in press; Potter et al., in press). We know that the probability of such a switch declines as the SOA between T1 and T2 increases. Further research will be required to discover whether other variables (such as contrast or hue) affect the likelihood of a switch in stage 1, producing the competition pattern that proved so elusive in the present studies.

Notes

1. Accuracy of report is measured, not response time, because report of the targets comes at the end of the trial, after both have been presented. Jolicoeur and his colleagues have shown that accuracy measures in an attentional blink paradigm are paralleled by reaction time measures in a modified psychological refractory period paradigm in which two stimuli in a trial are to be reported, but only the response to the second target is speeded (e.g., Jolicoeur & Dell'Acqua, 1998).

2. For 15 of the participants (out of 27), an SOA of 27 ms was included but is not reported.

3. Additivity in the sense of Sternberg's (1969) additive factors applies to measures of reaction time, not accuracy.