Journal of Experimental Psychology:
Human Perception and Performance
2000, Vol. 26, No. 2, 469–479

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0096-1523/00/$5.00 DOI: 10.1037//0096-1523.26.2.469

Word-Based Grouping Affects the Prime-Task Effect on Semantic Priming

Paloma Marí-Beffa and George Houghton
University of Wales, Bangor

Angeles F. Estévez and Luis J. Fuentes
University of Almería

Semantic priming between words is reduced or eliminated if a low-level task such as letter search is performed on the prime word (the prime task effect), a finding used to question the automaticity of semantic processing of words. This idea is critically examined in 3 experiments with a new design that allows the search target to occur both inside and outside the prime word. The new design produces the prime task effect (Experiment 1) but shows semantic negative priming when the target letter occurs outside the prime word (Experiments 2 and 3). It is proposed that semantic activation and priming are dissociable and that inhibition and word-based grouping are responsible for reduction of semantic priming in the prime task effect.

Skilled reading by adults is a fast and fairly effortless process. However, reading consists of many steps involving different types of information (Posner & Carr, 1992). Most reading researchers agree that early stages of processing (i.e., perceptual features, letters, etc.) can be completed automatically without any attentional involvement. However, there is some debate as to whether attention is involved in the processing of higher level representations, in particular semantic ones (Henik, Friedrich, Tzelgov, & Tramer, 1994; Holender, 1986; Smith, 1979). This is an important issue in reading research, as, for instance, the current leading computational models of reading differ as to whether semantic access is a necessary stage in computing phonology from orthography (Coltheart, Curtis, Atkins, & Haller, 1993; Plaut, McClelland, Seidenberg, & Patterson, 1996; Zorzi, Houghton, & Butterworth, 1998).

One way of exploring the semantic processing of words is the semantic priming procedure. It has been found that if participants have to respond to a word when it has been preceded by a different related word, reaction times (RTs) are faster when compared with a nonrelated control. This facilitation of the response is very robust and may not require focusing of attention on the prime. For example, semantic priming has been found when the prime word is masked in such a way that participants are unaware of its presence (Marcel, 1983); when the prime word is displayed in the parafovea and participants are required to attend an object located in the fovea (Fuentes & Tudela, 1992); and when, during the prime display, attention is engaged in a concurrent task (Fuentes, Carmona, Agis, & Catena, 1994). It has therefore been proposed that the semantic access from words can occur automatically without attention, or the intention to engage in a semantic level task (Neely, 1977).

However, in the last decade some authors have maintained that semantic processing is not totally automatic because it can be voluntarily prevented by allocating attention to some low-level features of the word (Henik et al., 1994; Stolz & Besner, 1996). From this point of view, word recognition is a serial process that begins by computing early perceptual representations and ends with semantic activation. The orienting of attention to low-level features somehow interrupts the flow of processing, and, as a result, the meaning of the word is not accessed. This challenge to the automaticity hypotheses of semantic processing has been mainly based on the observation that the semantic facilitation of a word is attentuated or removed when participants are instructed to attend to some low-level properties of the prime word, in particular when searching for a letter in a word (Friedrich, Henik, & Tzelgov, 1991; Henik, Friedrich, & Kellogg, 1983; Hoffman & MacMillan, 1985; Smith, 1979; Smith, Theodor, & Franklin, 1983). However, the nature of the mechanisms leading to this attenuation of priming remains unclear, even though the idea that the semantic processing of words is not automatic has serious implications for many different areas of research (e.g., the Stroop effect, see MacLeod, 1991, for a review; the computational modeling of word processing, Plaut et al., 1996; and unconscious semantic processing, Marcel, 1983, etc.).

According to Henik et al. (1994; see also Smith, 1979, for a similar explanation), semantic processing of single words is not completely automatic and needs some kind of attentional resource to be dedicated to it. According to this view, the interruption in semantic processing, as indexed by semantic priming, occurs as a direct consequence of the orienting of attention to sublexical features. However, it is clear from other studies that merely orienting attention to these lower levels is not sufficient to eliminate semantic

Paloma Marí-Beffa and George Houghton, School of Psychology, University of Wales, Bangor, United Kingdom; Angeles F. Estévez and Luis J. Fuentes, Departmento de Psicología Experimental y Psicobiología, University of Almería, Almería, Spain.

This research was supported by a grant from Ministerio de Educación y Cultura (Spain). This research was also supported by Grant PM97-0002 from Dirección General de Enseñanza Superior e Investigación Científica. We thank Avishai Henik and two anonymous reviewers for their helpful comments.

Correspondence concerning this article should be addressed to Paloma Marí-Beffa, School of Psychology, University of Wales, Bangor, Gwynedd LL57 2DG, United Kingdom. Electronic mail may be sent to pbeffa@bangor.ac.uk.

priming (Chiappe, Smith, & Besner, 1996; Stolz & Besner, 1996). In particular, semantic priming can be observed when attention is directed to low-level features of words, for instance their color (Chiappe et al., 1996), suggesting that the elimination of semantic priming is tied in particular to attention being directed to the letter level per se. However, even when attending to letters, the effect appears to involve participants' strategies (Stolz & Besner, 1996). These results indicate that the prime task effect is not a general effect consequent on the mere withdrawal of attention from the semantic level. Rather, it seems to involve specific control mechanisms acting within the word-processing system.

In response to such findings, Stolz and Besner (1996; see also Chiappe et al., 1996) have proposed the existence of a mechanism that specifically blocks a feedback loop between the semantic and the lexical representation of words in the interactive activation (IA) architecture (McClelland & Rumelhart, 1981). This activation block constrains attention to the letter level to maximize the allocation of attentional resources. The problem with this proposed mechanism, as we see it, is that it is entirely ad hoc and seems to have no function apart from facilitating letter search. Why should a unique and specific activation blocking mechanism develop between the lexical and semantic levels of the word-processing system?

On grounds of parsimony, it seems unlikely that the control mechanisms allowing flexible processing of written stimuli should be specific to reading. The problem of performing a letter search on a word is an example of the more general situation in which the typical (or prepotent) response associated with a class of stimuli (in this case, reading for meaning) is not the desired one. It is natural to propose that the mechanism permitting letter search (and which is presumably responsible for the observed reduction in semantic priming) must be the same as that engaged in other attention demanding tasks. The mechanisms proposed for the attentional selection of perceptual information, for instance, could be extended to explain results in goal-directed attention. In this context, inhibitory mechanisms of selective control have been widely used to explain the suppression of competing, but task-irrelevant, information, not just in attentional selection (Houghton & Tipper, 1994, 1996) but also in many other cognitive tasks (see Dagenbach & Carr, 1994). We therefore propose that in a letter-search prime, inhibition typically acts to reduce the semantic activation (automatically) caused by the prime word but that this suppression cannot be observed in the standard procedure because perceptual grouping factors occlude it (Marí-Beffa, 1997; Marí-Beffa, Fuentes, Catena, & Houghton, in press). In what follows, we review evidence in favor of the inhibitory suppression of competing features of objects when attention is directed to some task-relevant level.

Semantic Inhibition for the Selection of Perceptual Features

As we said before, one of the main pieces of evidence against the automaticity hypothesis of semantic processing comes from the prime task effect. It is argued that the reduction or elimination of semantic priming when attention is directed to the letter level indicates that semantic access is not taking place under these conditions. Marí-Beffa et al. (in press) pointed out that this kind of argument from the absence of an effect is invalid. That is, though we infer from the observation of priming at a given level that processing has taken place at that level, it does not follow that the failure to observe priming indicates a lack of processing. The semantic priming design does not measure semantic processing of the prime word on-line but rather measures a possibly complex aftereffect on the subsequent processing of related words (Neely, 1991). The chain of processes linking the processing of the prime word with lexical decision on the subsequent probe might be affected at stages after semantic access by the prime word has taken place. Thus, other measures or procedures might detect semantic processing of the prime word even when priming does not take place. For instance, Bentin, Kutas, and Hillyard (1995), using some converging measures of semantic processing, argued that semantic access by the prime word does take place in the absence of semantic priming.

In particular, there is another group of well-known studies in which attention is directed to low-level features of words without any manifest reduction of semantic processing. We refer to the negative priming effect observed in Stroop-like tasks (Dalrymple-Alford & Bundayr, 1966; Lowe, 1979, 1985; Neill, 1977; Neill & Westberry, 1987). Dalrymple-Alford and Bundayr (1966) found, for example, that if the participants were told to name the red color in which the word *GREEN* was printed, RTs to a subsequent word printed in green were slower than to a word printed in any other color. This effect (named *negative priming* years later by Tipper, 1985) has been commonly used to support the idea that selecting against nontarget information can cause it to be inhibited below resting levels (Houghton & Tipper, 1994).

If we consider the activation of every representation and the inhibition of some of them as opponent mechanisms acting on the same representations, then the degree and type of priming consequent on the processing of any stimulus might reflect the balance of these two opposing factors. The different results might depend on both the degree of initial activation and the effectiveness of the inhibitory suppression. Any variable affecting either of these two mechanisms will influence the prime task effect in semantic priming. In fact, if the experimental context is manipulated so that semantic properties of the words are enhanced, positive semantic priming is observed after searching for a letter in the prime task (Stolz & Besner, 1996). Although the converse finding of semantic negative priming is unusual, there is at least one report of this result following a prime letter search task (Besner, Smith, & MacLeod, 1990).

These results suggest that semantic properties of words might indeed be processed automatically whether relevant to the task or not but that this previous activation may not be observed in a priming procedure because inhibition acts to reduce it. We note that in most of the relevant studies, the response to the probe stimulus is made after participants have finished the search for the letter in the prime, and thus inhibitory control processes have time enough to be effective (see, e.g., Friedrich et al., 1991; Henik et al., 1983; Smith et al., 1983).[1]

Perceptual Grouping and Priming

An important variable that seems to bias the direction of priming is the perceptual grouping between the target and distractor information. In the prime task effect, the response-relevant dimension (color, size, letter) and the irrelevant word are perceptually integrated (i.e., are properties of the same object). It is known that perceptual integration has a powerful effect on performance in various paradigms (see Garner, 1974), so it could affect priming as well. For example, Fuentes, Humphreys, Agis, Carmona, and Catena (1998) investigated the effect of target-distractor grouping on negative priming. They found negative priming from two identical distractors when they were both displayed outside a box containing the prime target (i.e., when they were segregated). However, when the two distractors were inside the box with the target, they found positive priming. Importantly, when one distractor was outside and the other was inside the box, no effect of priming was found. In the general context of these findings, it would clearly be absurd to maintain that the absence of any priming effect in the last condition means that in that condition distractors were not processed. A more plausible explanation is that inhibitory attentional mechanisms act more effectively on distractor objects that are perceptually segregated than when they are embedded in the same object as the target. More generally, there is considerable evidence that attention selects whole objects and that perceptual grouping is one of the most powerful sources of object representation (Driver & Baylis, 1998).

In the case of words, the perceptual grouping between words and letters should be particularly strong because the word itself is the hierarchical global property that groups the letters. The advantage of global over local information is a widespread phenomenon, global properties being easier to respond to than local ones (see Kimchi, 1992, for a review). On these grounds, we suggest that to select out a letter within a word we must counteract grouping factors that bias attention toward global properties (i.e., the word level). It is important to reiterate that the prime task effect mainly occurs when there is competition within the word-processing domain. If, instead of looking for a letter in a word, participants are instructed to report the color in which the word is printed, significant positive semantic priming is observed (Chiappe et al., 1996). Selection of stimulus features belonging to different domains of processing (color–word) might not necessarily work in the same way as selection within the same domain of processing (letter–word).

In the present study, we aim to test directly the effect of letter–word (local–global) competition on semantic priming by displaying the target letter and the distractor word in separate objects. With this manipulation, we aim to remove the excitatory binding between the words and the letters that occurs when they are part of the same object. This process should allow any effects of inhibitory mechanisms acting at the word level to emerge more clearly.

Experiment 1

As a general strategy for the spatial segregation between target letter and word, two separate objects need to be displayed. One contains the to-be-attended information and the other the to-be-ignored information. This strategy is used in Experiments 2 and 3, where the participant sometimes has to search for the target letter in a string of characters (e.g., *###R##*) while ignoring a separate word. It is important to notice that to obtain the prime task effect, we need to compare a low-level prime task (e.g., letter search) with a high-level task (e.g., naming). Whereas the letter search can be carried out on any type of display containing letters, naming requires a word as a target. Thus, a comparison between such tasks, using the same displays, is bound to use a condition where the information to be responded to is in the same object as the information to ignore. However, Experiments 2 and 3 were designed to test differences in semantic priming as a function of perceptual segregation. The effect of the prime task itself cannot be addressed in these experiments; hence, we begin with another experiment intended to show that the letter search task still causes a reduction in semantic priming with this two-object design.

One significant change with respect to the standard design was the way in which participants had to search for the letter. In the standard version (see, e.g., Besner et al., 1990; Henik et al., 1994), the target letter is presented simultaneously with the search word and appears repeated in a string above the word, for example, *RRRR* and *CARD*. Participants are instructed to attend to both stimuli and to decide whether they share a letter in common. Note that this procedure requires attention to be directed to two objects in the letter search task. However, in control tasks used in the same experiments (e.g., reading a word aloud), attention is directed to just one object. Hence, the attentional demands of the two prime tasks are not equivalent. In the present study, we wanted to induce the same focused attention state in both the control and experimental conditions. Therefore, in letter-search primes, the target letter was first presented alone, at fixation, followed by the prime display (Figure 1). In both prime task conditions, the prime display contained a second stimulus, apart from the word at fixation, and participants were instructed to ignore it during the whole session. This stimulus was a chain of six characters (#) with one letter located in a random position. For example, *####S#* and *FLOUR*.

The main reason for including the second stimulus is that the later experiments need two objects, one to attend to and

[1] Only Henik et al. (1994) found the prime task effect at short SOA but by using a procedure in which the response to the prime task had to be performed after the response to the probe. It is possible that some sort of interference between the two tasks (the ongoing one to the probe and the one corresponding to the prime that is to be held in memory) may account for the reduction in semantic priming better than the hypothesis of no processing at all.

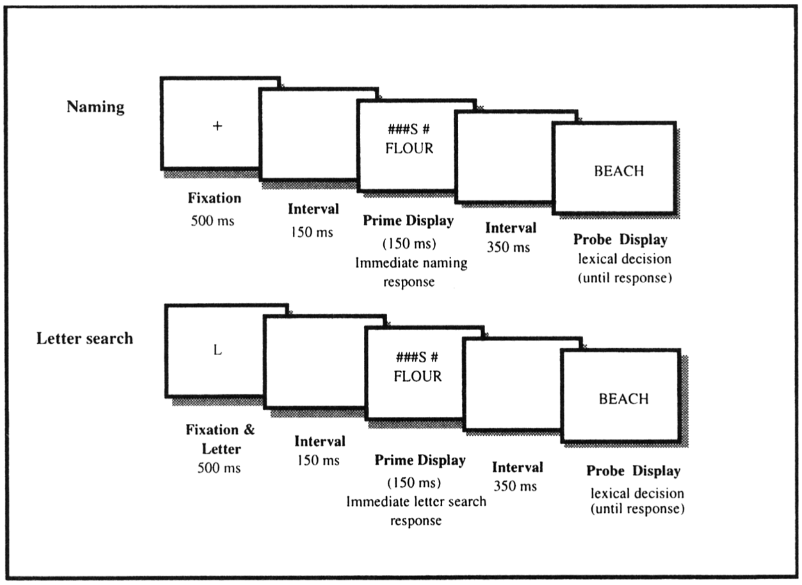

Figure 1. An illustration of the task manipulation, displays, and temporal parameters in Experiment 1. The temporal sequence is represented from left to right in the figure.

another to be ignored. With this procedure we wanted to check that the presence of a second, irrelevant, stimulus in the display does not affect the prime task effect.

Method

Participants. Twenty-four undergraduate students at the University of Almería participated in the experiment in partial fulfillment of a course requirement. They all reported normal or corrected-to-normal vision.

Stimuli and materials. The words consisted of 48 pairs of words in Spanish and 24 nonwords obtained from the word base previously used in Marí-Beffa et al. (in press; see also Fuentes & Tudela, 1992, for similar stimuli). Nonwords were obtained by altering the letters in the words in such a way that the new configuration of letters did not match any real word in Spanish. Each character was 5 mm high and 4 mm wide (.48 and .38° of visual angle, respectively). Stimuli were presented in black with the background in white. The words randomly varied in length from four to seven letters. Each word-like stimulus was accompanied in the prime display by a string of six characters # with a letter in a random position in the string (see Figure 1). This string was randomly presented above or below the word at a distance of 1 cm (.95° of visual angle). In the probe display, a single word appeared in the center of the screen. The screen was located 60 cm from the line of the eyes. Stimuli were presented in a Pentium compatible PC with a VGA card. A computer program controlled the presentation, sequence, and response collection.

Design and procedure. Each trial started with either a cross (for the block of the naming prime task) or a letter (for the block of the letter-search prime task) centered at fixation for 500 ms. After an interval of 150 ms, the prime display was presented for 150 ms. Following the response to the prime, the probe display appeared after an interval of 350 ms and remained on the screen until a response was made (see Figure 1).

A factorial design was used with two within-subject factors: Word Relatedness (related vs. unrelated) × Prime Task (naming vs. letter search). The experimental conditions for the relatedness factor were related, where the prime word was semantically associated to the word in the probe display, and unrelated, where there was no relationship between the prime and the second word. The prime task was manipulated in different blocks of trials, and they were counterbalanced for each participant. Two conditions were designed for the prime task factor: naming and letter search. In both blocks of trials, participants had to decide whether the word-like stimulus in the probe display was a word or a nonword (lexical decision). However, in one of the blocks, participants were instructed to name the prime word, and in the other they had to look for a letter.

As a result of these manipulations, each block of trials contained 96 trials distributed as follows: 24 for each experimental condition (related and unrelated) and 48 extra control trials with nonwords in the probe display for the lexical-decision task. In the experimental trials, the 24 pairs of words from the related condition were always used for the unrelated condition in a different block of trials. We obtained this condition by randomly re-pairing each prime with a new word that did not share any semantic relation with it. As a consequence, none of the pairs of words was repeated in the whole experiment. The related pairs were rotated across blocks on different participants. In these experimental trials (related and unrelated), all stimuli from the probe display were words, and in half of them the search letter was included in the prime display. The target letter in positive prime trials was randomly selected from any of the letters presented in the prime word. The target letter never appeared either in the word of the probe display or in the distractor string of the prime display. We obtained the control conditions by randomly selecting 48 words per block to be displayed as primes. The stimuli in the control conditions were always nonwords. The proportion of word/nonword stimuli was 0.5.

The two blocks of trials (letter search and naming) were counterbalanced for each participant and they were always performed one after the other with a brief resting period. Two additional sets of 16 trials (8 trials per experimental condition plus 8 control trials) served as practice trials before each of the two experimental blocks of trials. Practice trials were randomly selected from the corresponding experimental block.

In the naming block, the prime responses activated a voice key while the computer recorded the RTs. The experimenter recorded any error by immediately pressing a key on the keyboard. After an interval of 350 ms, the probe stimulus was displayed in the center of the screen, and participants were instructed to press the *M* key if the stimulus was a word and the *V* key if it was a nonword. In the letter-search block, the task assigned for the probe display was the same as in the naming block. For the prime task, in contrast, they had to press the *K* key when the target letter was included in the prime word or *F* if it was not present. Participants were asked to respond as quickly and accurately as possible in every block of experimental trials.

The experimenter delivered the instructions before the start of each block of trials.

Results and Discussion

As a general procedure used in every experiment of this article, RT analyses were conducted for trials in which both prime and probe responses were correct. Only those RTs above 200 ms and below 2,000 ms were considered for the analysis. As a result of this trimming, 0.1% of the overall responses were discarded in Experiment 1.

Responses to the prime display. Prime responses were analyzed through a two-way repeated measures analysis of variance (ANOVA) for two factors: relatedness (related, unrelated) and task (naming vs. letter search). Results showed no significant effect among prime responses from any of the mentioned conditions. Errors did not show any significant effect either. The overall RT to the prime display was 640 ms, and the estimated stimulus onset asynchrony (SOA) was 989 ms ($SD = 264$).

Responses to the probe display. Table 1 shows the means of median RTs and error rates (%) per condition and block. A two-way within-subject ANOVA was conducted for the analysis of the medians of RTs per participant and condition. A reliable main effect of prime task was found, $F(1, 23) = 38.64$, $MSE = 22712.35$, $p < 0.0001$, because of an increase in the probe RT in the letter-search condition compared with the naming condition. The factor relatedness also demonstrated a significant semantic positive priming effect (unrelated vs. related), $F(1, 23) = 5.60$, $MSE = 3682.15$, $p < 0.05$. More interesting was the significant effect of prime task on the semantic priming (interaction Prime Task × Relatedness), $F(1, 23) = 5.86$, $MSE = 2506.36$, $p < 0.05$. This interaction was mainly due to the significant semantic priming found in the naming condition (shown by 18 participants from the total 24), $F(1, 23) = 11.98$, $MSE = 2926.52$, $p < 0.005$, that did not reach significance in the letter-search condition (the pattern of semantic positive priming was shown just by 11 out of 24, $F < 1$).

Table 1
Means of Median Reaction Times (in Milliseconds) and Error Rates (%) for Both Naming and Letter Search Groups in the Relevant Conditions (Related and Unrelated) of Experiment 1

	Conditions		Semantic priming
Groups	Related	Unrelated	(Unrelated–related)
Letter search	826	830	+4
%	5	7	
Naming	720	764	+44
%	5	4	

We analyzed error percentages for each participant and each relevant condition by using a two-way ANOVA for the same variables described below. There were no significant effects.

Our results replicated those obtained by Henik et al. (1983): There was a reliable reduction of the semantic priming effect when the prime task involved the search for a letter within the prime word. The most common explanation, as described in the introduction, is that semantic processing does not take place when attention is oriented to low-level features of the words; hence, it is not automatic. However, we propose that this finding can be explained in a different way: The automatic semantic processing does occur, but effects of it are unlikely to be observed with this priming procedure because inhibition acts to reduce it, preventing the processes that lead to priming from taking place. The negative priming that might be expected on this account does not appear because of counteracting effects that are due to letter-word (target-distractor) grouping, as discussed by Fuentes et al. (1998). We test this idea in the following experiment by separating target letter and distractor word into different perceptual objects.

Experiment 2

Experiment 1 showed that the reduction in semantic priming is still observed when the letter search is carried out without perceptual matching between two attended objects displayed simultaneously. If attention is focused on just one object while ignoring a distractor, the same prime task effect is observed. This result is important because this is the procedure to be used in subsequent experiments, and we needed to test that it was effective in showing the reduction in semantic priming. However, as we pointed out before, in Experiment 1 the prime target letter and the prime word shared the same object. Is this source of grouping responsible for the absence of semantic negative priming from the word that would be expected on an inhibitory account of the prime task effect?

In the second experiment, we manipulated the type of grouping between the letter and the word when participants are instructed to look for a particular letter in the object at fixation of the prime display. In every condition, there is a word to be ignored and a letter to be looked for. The main difference between conditions concerns whether the distractor word is within the object at fixation or is located in the distractor one. If the mere orienting of attention to a letter prevents semantic processing of a word from being completed, this should affect the word equally independently of any grouping factor. Alternatively, if inhibitory mechanisms of selective attention cannot work efficiently as a consequence of the existing grouping between the target letter and the word, then semantic negative priming is predicted when we separate the word from the object at fixation.

Method

Participants. Twenty-two undergraduate students at the University of Almería participated in the experiment in partial fulfillment of a course requirement. They all reported normal or corrected-to-normal vision.

Stimuli and materials. The word-like stimuli, temporal, and visual parameters were identical to those used in the previous experiment. The fixation cue was always the target letter, as in the letter-search block of Experiment 1. As in the block of letter-search trials, the prime word appeared at fixation, and the string of characters # with a letter in a random position (always different to the one to be searched for) was randomly presented above or below the word at a distance of 1 cm (0.95 g.v.a.). However, in a separate block of trials, the string of characters with the letter (which could be the same as the target one or not) appeared at fixation while the prime word was above or below the string. The separation between the two objects was the same in every block. Other parameters and materials were kept constant replicating the laboratory conditions of the previous experiment.

Design and procedure. We conducted a factorial design with two within-subject factors: Word Relatedness (related vs. unrelated) × Grouping (grouped vs. segregated). The experimental conditions for the relatedness factor were related, where the prime word was semantically associated to the test word, and unrelated, where there was no relationship between the prime and the probe word. The factor grouping was manipulated in different blocks of trials that were counterbalanced for each participant. Two conditions were designed for the grouping factor: grouped, where the letter to search for belonged to the prime word, and segregated, where the target letter had to be searched for in a random position of the string of #. The grouped block was identical to the letter-search block of Experiment 1.

In these two blocks, participants had to decide whether the letter previously displayed at fixation was present in the prime display (in the word or in the string of # depending on the grouping condition) and decide whether the test stimulus in the probe display was a word or a nonword. The procedure for the responses was identical in both blocks and was the same as those in the letter-search block of Experiment 1.

As a result of this manipulation, each block of 96 trials was created according to the distribution of trials in Experiment 1: 24 for each experimental condition, related and unrelated, and 48 extra control trials with nonwords in the probe display. In both blocks of trials, the search letter only appeared in half of the prime objects, never being displayed in any other stimulus from the prime and probe display. We constructed two blocks of 16 practice trials (one for each grouping condition) by randomly selecting 4 trials from each experimental condition and 8 for control trials. The rest of the control of variables follows the procedure used in the previous experiment.

The two blocks of letter search (grouped and segregated) were counterbalanced for each participant, and they always performed these two blocks one after the other with a rest period between them. The experimenter administered instructions and practice trials in the same way as in the previous experiment.

Results

The procedure used for the trimming, described in the previous experiment, resulted in 0.03% of the responses being discarded.

Responses to the prime display. Prime responses were analyzed through a two-way repeated-measures ANOVA for two factors: relatedness (related, unrelated) and grouping (grouped and segregated). Results indicated no significant effect among prime responses from any of the mentioned conditions. No significant effects on errors were found. The overall RT to the prime display was 670 ms. The estimated SOA was 1,031 ms ($SD = 197$).

Responses to the probe display. Table 2 presents means of median RT and error rates for each condition. A two-way within-subject ANOVA only showed a significant main effect of the interaction between the relatedness and the grouping status, $F(1, 21) = 4.40, MSE = 6991.73, p < 0.05$. This interaction was mainly due to a change in the direction of the semantic priming depending on the grouping. When the word was segregated from the target letter in a different perceptual object, 18 participants showed a reliable semantic negative priming effect, $F(1, 21) = 7.91$, $MSE = 2884.89$, $p < 0.01$. Results did not show any reliable effect when the target letter belonged to the word. Relatedness associated to nonwords that were very similar to real words was also analyzed and did not show any significant effect. No effect concerning the error percentage was significant.

Discussion

The main goal of Experiment 2 was to test semantic priming from prime words when participants performed a letter-search task in the prime display. Two grouping conditions were tested: grouped, where the word was in the object at fixation in which the letter was being looked for, and segregated, when the word was outside that object. In the grouped condition, results replicate the previous experiment because no semantic priming was observed following a letter-search prime task. However, in the segregated condition, negative semantic priming was found from the distractor prime word. This result clearly shows that the mere orienting of attention to letters does not prevent semantic processing of words.

Table 2
Means of Median Reaction Times (in Milliseconds) and Error Rates (%) for Both Variables, Grouping (Grouped Versus Segregated), Manipulated Between Blocks, and the Semantic Relatedness (Related Versus Unrelated), Manipulated Within Block, of Experiment 2

	Condition		Semantic priming
Grouping	Related	Unrelated	(Unrelated–related)
Grouped	757	776	+19
%	5	7	
Segregated	805	760	−45
%	6	10	

The fact that the observed priming was negative was predicted by our suggested inhibitory account. Inhibitory mechanisms of selective attention may act in letter search to reduce the activation of irrelevant semantic features while attending to letters. However, we do not obtain negative priming from the grouped word because attention mainly selects whole objects rather than their features (Fuentes et al., 1998).

Experiment 2 shows a clear change in the priming effect as a function of the object in which the letter is being searched for. However, because the trials for each grouping condition were blocked, participants might have developed different tactics in each block. For example, participants might systematically use the word for locating the letter in the grouped block while tending to ignore the word completely in the segregated condition. Such a strategy might result in less inhibition in the grouped condition when compared with the segregated one. Because these conditions are blocked, different strategies can be built up during the practice trials affecting performance during the whole experimental block. In fact, the prime task effect in semantic priming seems to have a strong strategic component that is based on the adoption of a particular mental set during the task (Stolz & Besner, 1996). The next experiment was designed to test this possibility. To do so, the two trial types (grouped and segregated) were randomly mixed and displayed within each block.

Experiment 3

Experiment 3 is a replication of the previous one except for the distribution of conditions within each block of trials.

Method

In Experiment 2, participants were instructed and tested for each grouping condition separately. However, in the present one, we constructed two blocks of trials in which the word could be either in the object at fixation or in the distractor object with equal probability. No further change was required, other than that the instructions and practice trials were administrated just once at the beginning of the session.

Results and Discussion

The trimming procedure resulted in 0.09% of the responses being discarded.

Responses to the prime display. We analyzed data through a two-way ANOVA with the factors grouping (segregated vs. grouped) and relatedness (related vs. unrelated) as within-subjects factors for a 2 × 2 design. None of the main sources of variance showed any reliable effect. We analyzed errors by using the same procedure without showing any significant result. Participants responded to the prime task with a mean RT of 930 ms. The estimated SOA was 1,283 ms ($SD = 210$).

Responses to the probe display. Table 3 displays the overall priming effects calculated from the arithmetic mean of the medians for each condition for each participant. We analyzed these medians of RTs through a two-way ANOVA with the factors grouping (segregated vs. grouped) and relatedness (related vs. unrelated) as within-subject factors for a 2 × 2 design. The only significant main effect was the interaction between the two factors Grouping × Relatedness, $F(1, 20) = 6.26$, $MSE = 5634.79$, $p < 0.05$. The analysis of the interaction showed a marginally significant effect of semantic negative priming in the segregated condition (showed by 15 from the 21 participants), $F(1, 20) = 4.18$, $MSE = 7558.18$, $p < 0.054$. This effect of priming was not observed in the grouped condition, (positive semantic priming was observed in 10 from the 21 participants, $F < 1$). Error analysis did not produce any reliable difference.

Table 3
Means of Median Reaction Times (in Milliseconds) and Error Rates (%) for Both Variables, Grouping (Grouped Versus Segregated) and the Semantic Relatedness (Related Versus Unrelated) of Experiment 3

Grouping	Condition: Related	Condition: Unrelated	Semantic priming (Unrelated–related)
Grouped	796	823	+27
%	9	6	
Segregated	822	768	−54
%	5	7	

Note. Both variables were manipulated within subjects, randomizing every condition within blocks.

These results reproduce those obtained in the previous experiment. No semantic priming was found when the letter was searched for in the word and negative priming was found when it was searched for in an object outside the word. This dissociation of semantic priming effects seems to depend on the grouping between the to-be-ignored word and the target letter. In addition, the results cannot be explained as due to a particular mental set task adopted for a particular grouping condition (Stolz & Besner, 1996). In the present experiment, participants could not anticipate the type of trial that they were going to receive, and still they showed this differential pattern.

General Discussion

The possibility that nonattended words can be semantically processed has serious implications for both the automaticity of word perception and the role of selective attention on semantic encoding. Although most of the evidence seems to suggest that semantic processing can be completed automatically, or without attentional involvement, there is a growing body of results that seems to contradict the classic point of view. The absence of a semantic priming effect when attention is directed to low-level properties of the word seems to make a strong case against the automatic semantic processing of words. An implicit assumption of this suggestion is that the size of priming directly reflects the amount of automatic processing. We have argued that this is mistaken because the conclusion has not been validated with alternative tests of semantic processing (Bentin et al., 1995) or with different types of procedure. The research reported in this article is an attempt to demonstrate how a simple manipulation (affecting the perceptual integration between word and letter) may offer a different perspective on the prime task effect.

In a series of experiments, we manipulated whether the target prime letter was to be searched for in a word or in a separate object. If the mere allocation of attention to low-level features interrupts semantic processing (Henik et al., 1994), then semantic priming should disappear independently of the location of the letter. However, if the prime task effect is the result of competition between the processing of high- versus low-level features from the same object, then this manipulation may help to disrupt it. Indeed, our experiments have shown that if the letter is searched for in a separate object, the distractor word produces semantic negative priming (Experiments 2 and 3).

This effect can be modeled as the result of a general inhibitory mechanism of attentional selection. In the model of Houghton and Tipper (1994), perceived stimuli are represented as distributed bundles of activated features in different feature dimensions, for example, color, shape, location, semantic features, etc. Inhibition is generated if a stimulus mismatches an internally maintained description of the to-be-attended item and can spread throughout the features that compose the representation of the stimulus. If a subsequent stimulus shares features with the inhibited representation, as we assume semantically related items do, then the activation of this input will be temporarily slowed, relative to a novel input. In order for this to produce an effect on a probe lexical-decision task, we must assume that lexical decision can be based on the activation of semantic representations (words produce familiar patterns of semantic activation, nonwords do not).

The important question is whether this inhibition also produces the reduction of semantic priming in the prime task effect. We suggest that it is and that, in the regular search-in-a-word procedure, the superior activation of the word over the letter may counteract its inhibition with the result that no semantic priming, positive or negative, is finally observed. However, we must acknowledge that the present experiments do not decisively demonstrate this, as we have not directly shown effects from the ignored word in the grouped condition. Thus, it is still possible to argue that, although semantic processing during letter search has been demonstrated in these experiments, the inhibitory effect is entirely limited to the distractor word in the segregated condition. In the grouped condition, semantic activation is simply being blocked in some quite different manner.

How likely is this, and how could it be occurring? We first note that there seems little doubt that lexical activation (activation of orthographic word nodes) occurs during letter search on words. For instance, if the probe word is identical to the prime word, then letter search on the prime produces facilitation (Friedrich et al., 1991). If lexical activation can be clearly shown to be taking place during letter search in words, then this is only one step away from some form of semantic activation (according to all accounts of semantic access that we are aware of). What then could stop it from happening? As stated in the introduction, our view is that there is no independent evidence for a dedicated blocking mechanism lying uniquely between the lexical and semantic levels of representation (as required by the proposal of Stolz & Besner, 1996). It is difficult to imagine what function such a mechanism would ordinarily serve, or why it would develop, given that all our experience with words is for the purpose of extracting meaning.

If this is accepted, then the explanation of the prime task effect on semantic priming must involve processes acting subsequent to the initial activation of the meaning of the prime word that attenuates the further activation on which the semantic priming of lexical decision presumably depends. It is clearly more parsimonious to propose that this mechanism is that invoked in many other discussions of cognitive control, namely, the inhibition of activated but task-irrelevant information. The results from the segregated condition in our experiments clearly show that such inhibition can be acting at the semantic level during letter search tasks. Nevertheless, this line of reasoning would be more persuasive if converging evidence could be found for semantic activation from the prime word during letter search. Fortunately, such evidence does exist.

Semantic Priming From Letter-Search Tasks

Our argument is that inhibition is acting to attenuate irrelevant semantic activation from the prime word in letter search, but that, given the relevance of the prime word itself, this inhibition does not result in a net negative priming effect. It follows from this that, if the prime word is made more relevant semantically, then the semantic inhibition might decrease, allowing semantic facilitation from letter search targets to be seen. Henik et al. (1994) manipulated the contextual semantic salience of the letter-search target word by varying the proportion of related prime-probe pairs in prime task study with a lexical-decision probe task. When the relatedness proportion was low (20%), the standard prime task effect was obtained. However, when it was high (80%), positive semantic priming was obtained from the letter-search prime task.

On our account, the increased semantic relevance of the prime word in this study (as a semantically informative cue for the probe) would have attenuated the task-based inhibition normally applied at the semantic level during letter search, allowing the automatic processes that lead to semantic priming to proceed. However, it could be argued that in the high-relatedness condition participants simply adopt new strategies that have nothing to do with what otherwise happens during the letter search. It is especially important, therefore, to note that Henik et al. (1994) found semantic priming from letter search at both long (840 ms) and short (240 ms) SOAs. It is generally believed that such short SOA semantic priming can only be due to automatic spreading activation, not to the imposition of ad hoc strategies (Neely, 1977). The inhibition account has the advantage that, in the high-relatedness situation, it predicts the attenuation of a process acting during letter search (suppression of irrelevant semantic activation) rather than the addition of one.

Further evidence for semantic activation during letter search is provided by studies described in Maxfield (1997). Maxfield reports results showing that differences in the semantic relationship between prime-probe word pairs affect letter-search priming. When the relationship is primarily associative (e.g., DOG–BONE) no priming from letter search is found. In contrast, when the semantic relationship involves both association and similarity (or category membership, e.g., DOG–CAT), then letter-search priming is found (though it is still smaller than the priming produced by silent reading). This is a striking finding. The null result for associative pairs such as DOG–BONE could be used to support the idea that the prime (DOG) had not been processed semantically during letter search. But this conclusion is hardly tenable given the results for word pairs of the DOG–CAT type. The primes, and the attentional demands of the prime task, are identical in the two conditions. If some form of semantic activation is occurring in one case, there are no grounds for supposing it is not happening in the other.

Prepotent Representations and Inhibitory Control

The above findings support the idea that automatic semantic activation is occurring during letter search on words. According to our account, whether semantic priming is found, and whether it is positive or negative, depends on the prepotency of whole-word processing (grouping) and the inhibition of lexical properties for the selection of low-level features.

Regarding the prepotency of the word level, it is well known that under some conditions it can take longer to identify a letter when it is alone than when it belongs to a word (Reicher, 1969). Moreover, under masking conditions participants seem to identify the meaning of a word more accurately than they do its low-level features (Marcel, 1983). Finally, to-be-ignored words interfere more with the action of naming their color than the to-be-ignored color interferes with the reading of a word (MacLeod, 1991). This asymmetry can also be observed with other types of object. Conflicting information between global and local object properties interferes with identification of the local property but not with the identification of the global one (Navon, 1977). In all of these cases, it is difficult to claim from the absence of interference effects on global processing that the low-level features are not processed. Low-level features of the objects do not normally influence behavior as they are typically used in the computation of high-level properties required for the control of responses. Indeed, action is important in defining what an object is, or in other words, in determining the global property that defines an object representation. In the case of words, the common action is reading for meaning, and therefore these meaningful words are the prepotent objects.

However, it is sometimes necessary to access low-level properties of objects that are normally analyzed for their global features. Hence, control mechanisms are needed to avoid attention becoming captured by the more practiced task. In the present article, we have argued that this control can be performed by inhibitory mechanisms that may be related to the type studied in the negative priming procedure (Houghton & Tipper, 1994). This led us to predict that semantic negative priming might be found following a letter-search task, if the prime word were not grouped with the search string.

There is independent evidence of inhibitory suppression of irrelevant words when attention is directed to their low-level properties, mostly from Stroop tasks in which participants name the print color and ignore the meaning of colored words (Dalrymple-Alford & Bundayr, 1966; Neill, 1977). Also, negative priming from global properties has been reported as a consequence of selecting local features with Navon-like stimuli (Briand, 1994). In both cases, response competition seems to be a major determinant of negative priming from distractor information that is grouped with target information (see also Fox, 1998). If response competition is not occurring, either positive or no priming is typically found (Fuentes et al., 1998; Henik et al., 1994). Only Besner et al. (1990) have reported semantic negative priming from words when the task required the processing of letters.

In the present studies, the global information, the word, does not compete within a specific class of responses but rather competes at the level of task. Negative priming can be found as long as the word-level competitor is segregated from the letter stimuli. When the letters form part of the competing word (the grouped condition), word-level processing can still be suppressed to permit responding to letters. However the fact that attention is operating within the same object (the word is not ignored) means that there is no word-level negative priming effect.

Conclusions

Experimental psychology depends on reliable behavioral effects from which we infer the presence of hypothetical events, processes, and mechanisms. Finding such effects can be a difficult business, and there is a great temptation to use any effect as an infallible index of a suggested process, and thus to interpret any absence of the effect as indicating an absence of the process. However, this is only logically valid if the underlying process is known to be both a necessary and sufficient condition for the effect. Unfortunately things are rarely so straightforward. Parallel processing of perceptual inputs can lead to interference and response competition, producing costs in the reaction times. Simple failure to observe such costs has been taken as evidence against parallel processing of unattended stimuli (Francolini & Egeth, 1980), but other measures show the conclusion to be mistaken (Driver & Tipper, 1989). Ignoring distractors can produce RT costs when they are re-presented as targets, suggesting a lingering effect of a distractor suppression mechanism. Failure to observe this cost is often taken to mean that no distractor suppression took place. Again, such a conclusion is not generally valid (Houghton & Tipper, 1994; Fuentes et al., 1998). In this article, we have argued that another cause-effect pair, semantic processing and semantic priming, are dissociable. The latter is not an inevitable consequence of the former but may depend on the balance of a number of competing, task-related, factors. Absence of semantic priming is not therefore a reliable indicator of lack of semantic processing.

References

Bentin, S., Kutas, M., & Hillyard, S. A. (1995). Semantic processing and memory for attended and unattended words in dichotic listening: Behavioral and electrophysiological evidence. *Journal of Experimental Psychology: Human Perception and Performance, 21,* 54–67.

Besner, D., Smith, M. C., & MacLeod, C. M. (1990). Visual word recognition: A dissociation of lexical and semantic processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16,* 862–869.

Briand, K. A. (1994). Selective attention to global and local structure of objects: Alternative measures of nontarget processing. *Perception & Psychophysics, 55,* 562–574.

Chiappe, P. R., Smith, M. C., & Besner, D. (1996). Semantic priming in visual word recognition: Activation blocking and domains of processing. *Psychonomic Bulletin and Review, 3,* 249–253.

Coltheart, M., Curtis, B., Atkins, P., & Haller, M. (1993). Models of reading aloud: Dual-route and parallel-distributed-processing approaches. *Psychological Review, 100,* 589–608.

Dagenbach, D., & Carr, T. H. (Eds.). (1994). *Inhibitory processes in attention, memory, and language.* San Diego, CA: Academic Press.

Dalrymple-Alford, E. C., & Bundayr, B. (1966). Examination of some aspects of Stroop color-word test. *Perceptual and Motor Skills, 23,* 1211–1214.

Driver, J., & Baylis, G. C. (1998). Attention and visual object segmentation. In R. Parasuraman (Ed.), *The attentive brain* (pp. 299–325). Cambridge, MA: MIT Press.

Driver, J., & Tipper, S. P. (1989). On the nonselectivity of the 'selective' seeing: Contrasts between interference and priming in selective attention. *Journal of Experimental Psychology: Human Perception and Performance, 15,* 304–314.

Fox, E. (1998). Perceptual grouping and visual selective attention. *Perception & Psychophysics, 60*(6), 1004–1021.

Francolini, C. M., & Egeth, H. E. (1980). On the nonautomaticity of automatic activation: Evidence of selective seeing. *Perception & Psychophysics, 27,* 331–342.

Friedrich, F. J., Henik, A., & Tzelgov, J. (1991). Automatic processes in lexical access and spreading activation. *Journal of Experimental Psychology: Human Perception and Performance, 17,* 792–806.

Fuentes, L. J., Carmona, E., Agis, I. F., & Catena, A. (1994). The role of anterior attention system in semantic processing of both foveal and parafoveal words. *Journal of Cognitive Neuroscience, 6,* 17–25.

Fuentes, L. J., Humphreys, G. W., Agis, I. F., Carmona, E., & Catena, A. (1998). Object-based perceptual grouping affects negative priming. *Journal of Experimental Psychology: Human Perception and Performance, 24,* 664–672.

Fuentes, L. J., & Tudela, P. (1992). Semantic processing of foveally and parafoveally presented words in a lexical decision task. *Quarterly Journal of Experimental Psychology, 45A,* 299–322.

Garner, W. R. (1974). *The processing of information and structure.* Hillsdale, NJ: Erlbaum.

Henik, A., Friedrich, F. J., & Kellogg, W. A. (1983). The dependence of semantic relatedness effect upon prime processing. *Memory & Cognition, 11,* 366–373.

Henik, A., Friedrich, F. J., Tzelgov, J., & Tramer, S. (1994). Capacity demands of automatic processes in semantic priming. *Memory & Cognition, 22,* 157–168.

Hoffman, J. E., & MacMillan, F. W. (1985). Is semantic priming automatic? In M. I. Posner & O. S. M. Marin (Eds.), *Attention & performance XI* (pp. 585–599). Hillsdale, NJ: Erlbaum.

Holender, D. (1986). Semantic activation without conscious identification in dichotic listening, parafoveal vision, and visual masking: A survey and appraisal. *Behavioral & Brain Sciences, 9,* 1–66.

Houghton, G., & Tipper, S. P. (1994). A model of inhibitory mechanisms in selective attention. In D. Dagenbach & T. Carr (Eds.), *Inhibitory processes in attention, memory and language* (pp. 53–112). San Diego, CA: Academic Press.

Houghton, G., & Tipper, S. P. (1996). Inhibitory mechanisms of neural and cognitive control: Applications to selective attention and sequential action. *Brain and Cognition, 30,* 20–43.

Kimchi, R. (1992). Primacy of wholistic processing and global/local paradigm: A critical review. *Psychological Bulletin, 112,* 24–38.

Lowe, D. G. (1979). Strategies, content, and the mechanism of response inhibition. *Memory & Cognition, 7,* 382–389.

Lowe, D. G. (1985). Further investigations of inhibitory mechanisms in attention. *Memory & Cognition, 13,* 74–80.

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: An integrated review. *Psychological Bulletin, 109,* 163–203.

Marcel, A. J. (1983). Conscious and unconscious perception: Experiments on visual masking and word recognition. *Cognitive Psychology, 15,* 197–237.

Marí-Beffa, P. (1997). *La naturaleza de la tarea previa affecta el procesamiento del distractor en un procediminto de priming negativo* [The nature of the prime task affects distractor processing in a negative priming procedure]. Unpublished doctoral dissertation, University of Almería, Spain.

Marí-Beffa, P., Fuentes, L. J., Catena, A., & Houghton, G., (in press). Semantic priming in the prime task effect: Evidence of automatic semantic processing of distractors. *Memory & Cognition.*

Maxfield, L. (1997). Attention and semantic priming: A review of the prime task effects. *Consciousness and Cognition, 6,* 204–218.

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: Part 1. An account of basic findings. *Psychological Review, 88,* 315–407.

Navon, D. (1977). Forest before trees: The precedence of global features in visual perception. *Cognitive Psychology, 9,* 353–383.

Neely, J. H. (1977). Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. *Journal of Experimental Psychology: General, 106,* 226–254.

Neely, J. H. (1991). Semantic priming effects in visual word recognition: A selective review of current findings and theories. In D. Besner & G. W. Humphreys (Eds.), *Basic processes in reading. Visual word recognition* (pp. 264–336). Hillsdale, NJ: Erlbaum.

Neill, W. T. (1977). Inhibitory and facilitatory processes in attention. *Journal of Experimental Psychology: Human Perception and Performance, 3,* 444–450.

Neill, W. T., & Westberry, R. L. (1987). Selective attention and the suppression of cognitive noise. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13,* 327–334.

Plaut, D. C., McClelland, J. L., Seidenberg, M. S., & Patterson, K. E. (1996). Understanding normal and impaired word reading: Computational principles in quasi-regular domains. *Psychological Review, 103,* 56–115.

Posner, M. I., & Carr, T. H. (1992). Lexical access and the brain: Anatomical constraints on cognitive models of word recognition. *American Journal of Psychology, 105,* 1–26.

Reicher, G. M. (1969). Perceptual recognition as a function of meaningfulness of stimulus material. *Journal of Experimental Psychology, 81,* 274–280.

Smith, M. C. (1979). Contextual facilitation in a letter search task depends on how the prime is processed. *Journal of Experimental Psychology: Human Perception and Performance, 5,* 239–251.

Smith, M. C., Theodor, L., & Franklin, P. E. (1983). The relationship between contextual facilitation and depth of processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 9,* 697–712.

Stolz, J. A., & Besner, D. (1996). Role of set in visual word recognition: Activation and activation blocking as nonautomatic processes. *Journal of Experimental Psychology: Human Perception and Performance, 22,* 1166–1177.

Tipper, S. P. (1985). The negative priming effect: Inhibitory effects of ignored primes. *Quarterly Journal of Experimental Psychology, 37A,* 571–590.

Zorzi, M., Houghton, G., & Butterworth, B. (1998). Two routes or one in reading aloud: A connectionist dual-process model. *Journal of Experimental Psychology: Human Perception and Performance, 24,* 1–31.

Received October 26, 1998
Revision received April 20, 1999
Accepted September 7, 1999 ■

Correction to Isaak et al. (1999)

The article "The Attentional Blink Reflects Retrieval Competition Among Multiple Rapid Serial Visual Presentation Items: Tests of an Interference Model" by Matthew I. Isaak, Kimron L. Shapiro, and Jesse Martin (*Journal of Experimental Psychology: Human Perception and Performance,* 1999, Vol. 25, No. 6, pp. 1774–1792) contained an error. On p. 1778, the correct Figure 1 was inadvertently replaced in the production process with an erroneous figure. The correct figure appears below.

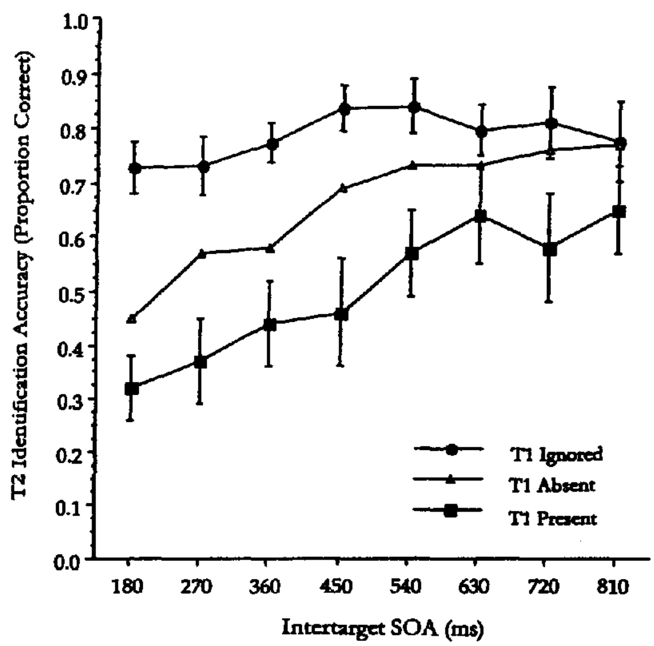

Figure 1. Second target (T2) identification accuracy (proportion correct) in Experiment 1 as a function of the intertarget stimulus onset asynchrony (SOA; in milliseconds) and the first target (T1) task. Error bars represent ± 1 standard error. Error bars have been omitted in the T1-absent condition to facilitate comparison between the ignore-T1 and T1-present conditions.