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No Negative Semantic Priming From Unconscious Flanker Words in Sight

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In replicating 1 of the within-language conditions of E. Fox's (1996) Experiment 1, the authors confirmed that unattended words presented 2.4° above and below fixation are mostly unavailable to awareness. However, no negative semantic priming was observed in a lexical decision on a probe letter string appearing about 1 s later, which does not replicate Fox's finding. These results are compatible with the hypothesis underlying the present study, according to which positive semantic priming, if any, rather than negative semantic priming is expected in Fox's situation. The reason is that unavailability to awareness of the parafoveal words is not achieved by means of an act of selective inhibition combined with attentional diversion through masking but is achieved simply by means of perceptual degradation.

The general aim of the present study was to elucidate under which conditions negative semantic priming can be obtained from unconscious prime words. The specific work we present was prompted by Fox (1996), which suggested that negative semantic priming can be elicited by unattended words made unavailable to awareness through brief presentation in a region of reduced visual acuity. This finding deserves close scrutiny and replication, because according to our analysis of the literature, it challenges the conclusions that can be reached about both the conditions needed to generate negative semantic priming and the conditions needed to generate negative priming from unconscious primes.

The primary aim of Fox (1996) was to investigate the organization of lexicosemantic memory in bilinguals while avoiding conscious strategies elicited by participants' awareness of the prime–probe relationship. The prime words were moved outside the focus of attention (at a distance of 2.4° above and below fixation) while participants performed a classification task on a central digit. Under those conditions, Fox predicted that most participants would be unaware of the identity and meaning of the prime words, and because the unconscious words were presented outside the focus of attention, they would exert a negative semantic priming effect on the probe words. Both predictions were borne out by the data. None of the participants reported the flanker word on a surprise question replacing the probe of the final trial of the experiment. Strong negative semantic priming effects were observed in the two within-language conditions and in one of the two cross-language conditions of Experiment 1 (see Table 1).

However, the observation of a negative semantic priming effect in those conditions appears problematic and surprising to us. We argue that if any semantic priming should occur at all with this procedure, it would most probably be positive rather than negative. After briefly describing the early work on negative priming, we try to specify how such a phenomenon could take place with unconscious primes and the necessary conditions for negative semantic priming to occur. Next, we present two experiments based on Fox's (1996) methodology that cast serious doubts on the validity of her results.

Early Work on Negative Priming

After its initial discovery by Dalrymple-Alford and Budayr (1966), the phenomenon of negative priming was more systematically investigated in two sets of studies based on somewhat different procedures. The first set comprises four studies (Lowe, 1979, 1985; Neill, 1977; Neill & Westberry, 1987) in which only negative identity priming was investigated. The main procedural characteristics were that (a) the prime was always an incongruent Stroop color–word stimulus to which participants responded by identifying the color while ignoring the word; (b) participants made two consecutive immediate responses, the first to the prime target and the second to the probe target; and (c) the prime display was presented long enough to enable participants to become fully aware of the identity and meaning of both the target and the distractor.

The second set comprises the study of Allport, Tipper, and Chmiel (1985) and several follow-up studies by Tipper and colleagues (Driver & Tipper, 1989; Tipper, 1985; Tipper & Cranston, 1985; Tipper & Driver, 1988), in which both negative identity and

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Table 1
Mean Reaction Times (RTs; in Milliseconds) for the Unrelated and the Related Trials, and Priming Effects in Studies of Semantic Priming From Ignored Flanker Words Based on a Lexical Decision Task

Experiment and prime reportability	Task on prime target and type of ignored distractors	Distractor duration (ms), mask[a]	Distractor distance from fixation (degrees)	Prime–probe SOA	Mean RT: Unrelated	Mean RT: Related	Priming effect (unrelated − related)
			Yee (1991)				
Experiment 1	Categorize shape						
Nil report	One word	250, none	4.5	circa 626	646	644	+2
	Two different words	250, none	4.5	circa 626	628	664	−36*
Experiment 2	Categorize shape						
NA, probably nil	One word, one string	200, asterisks	4.5	500	757	750	+7
	One word, one string	200, asterisks	4.5	600	736	738	−2
	Two different words	200, asterisks	4.5	500	760	731	+29*
	Two different words	200, asterisks	4.5	600	733	757	−24*
			Fox (1996)				
Experiment 1	Categorize digit						
Nil report	Two identical words[b]	150, plus signs	2.4	circa 953	708	743	−35*
	Two identical words[c]	150, plus signs	2.4	circa 953	726	715	+11
	Two identical words[d]	150, plus signs	2.4	circa 953	767	791	−24*
	Two identical words[e]	150, plus signs	2.4	circa 953	760	795	−35*
			Hoffman and MacMillan (1985)				
Experiment 2	Memorize target word						
NA, indeterminate	One word	64, none	1	714	580	593	−13
	Two words	64, none	1	714	613	616	−3
Experiment 3	Memorize detected letter						
NA, indeterminate	One word	64, none	1	1,564	608	611	−3
	One word	64, none	1	1,564	597	593	+4
			Duscherer and Holender (2001)				
Experiment 1	Categorize digit						
Good report	Two identical words	150, plus signs	0.8	circa 897	619	615	+4
Experiment 2	No target[f]						
Very good report	Two identical words	150, plus signs	0.8	1,000	607	583	+24*
			Marí-Beffa, Fuentes, et al. (2000)				
Experiment 1	Lexical decision						
NA, probably good	Two identical words	RT, none	0.95	circa 1,046	583	600	−17*
	Letter detection						
	Two identical words	RT, none	0.95	circa 1,102	697	658	+39*
Experiment 2	Lexical decision						
NA, probably good	Two identical words	RT, none	0.95	circa 1,000	716	728	−12
	Letter detection						
	Two identical words	RT, none	0.95	circa 1,000	685	657	+28*

Table 1 (*continued*)

Experiment and prime reportability	Task on prime target and type of ignored distractors	Distractor duration (ms), mask[a]	Distractor distance from fixation (degrees)	Prime–probe SOA	Mean RT: Unrelated	Mean RT: Related	Priming effect (unrelated − related)
	Marí-Beffa, Houghton, et al. (2000)						
Experiment 2	Letter detection in word						
NA, probably good	One pound-sign string	150, none	0.95	circa 1,031	776	757	+19
	Letter detection in pound signs						
	One word	150, none	0.95	circa 1,031	760	805	−45*
Experiment 3	Letter detection in word						
NA, probably good	One pound-sign string	150, none	0.95	circa 1,283	823	796	+27
	Letter detection in pound signs						
	One word	150, none	0.95	circa 1,283	768	822	−54*

Note. The probe was always a single-component letter string presented at fixation, except in the study of Marí-Beffa, Fuentes, et al. (2000), in which it was flanked above and below by two identical words. The prime target was always at fixation, except in the study of Hoffman and MacMillan (1985), in which two prime words appeared above and below fixation, with the target position cued by two arrows appearing 96 ms before the prime display. When not assessed, we have guessed the prime reportability from similar conditions in other experiments in which it was assessed (see Footnote 3). NA = not assessed; SOA = stimulus onset asynchrony.
[a] RT in this column means that the prime distractor was present until the response to the prime target. [b] Both the prime and the probe in first language. [c] Prime in second language, probe in first language. [d] Both the prime and the probe in second language. [e] Prime in first language, probe in second language. [f] Except for the presentation of a target digit, to be reported after the lexical decision in one third of the trials in which the probe was a pseudoword.
* $p < .05$.

negative semantic priming were investigated. The procedure used in most of these experiments differs from that of the first set on each of the three procedural characteristics mentioned before: (a) the prime display consisted of an incongruent bicomponent Stroop-like stimulus (i.e., two letters, two pictures, two words, or a picture and a word), with participants having to identify the target component while ignoring the other component specified by a different color; (b) participants had to identify and memorize the prime target, respond to the probe target, and recall the prime target; and (c) the prime display was presented briefly and masked by a pattern after a stimulus onset asynchrony (SOA) adjusted individually, so as to make only the prime target but not the prime distractor fully available to awareness. Participants' awareness of the identity of the prime distractor was further checked through a surprise question replacing the probe on the last trial of the experiment.

This early work revealed three important properties of negative identity priming. First, negative identity priming occurs whether the ignored prime distractor is physically identical to the probe target (e.g., in the letter–letter condition of Tipper & Cranston, 1985) or only nominally identical to it (e.g., in the word–color condition in all the studies using the conventional Stroop stimuli). Second, this negative priming effect vanishes, and even reverses to positive identity priming, with probes that are predictably (i.e., consistently) nonconflicting (Allport et al., 1985, Experiment 9; Tipper & Cranston, 1985, Experiment 3), or not predictably but conspicuously nonconflicting (Lowe, 1979, Experiment 4). Third, availability to awareness of the prime distractor does not seem to be a necessary condition for the effect to occur, because only participants who could not identify the prime distractor above chance in a final catch trial were included in the results of the second set of studies. This third property is shared by negative semantic priming.

To account for this complex pattern of results, Tipper (1985, Tipper & Cranston, 1985) chose to elaborate on the persisting inhibition process already hypothesized by Dalrymple-Alford and Budayr (1966) and by Neill (1977). The initial analysis of both the prime target and the prime distractor is assumed to occur in parallel up to the level of identity and semantic category. After these initial stages of deep processing, the target is selected for action, whereas active inhibition is needed to prevent the execution of the incipient response automatically activated by the distractor. This inhibition persists long enough to impede processing of the ignored distractor of the prime display when it recurs as a probe target calling for an overt response. Note that assuming only shallower levels of processing of the prime distractor would not explain that (a) positive instead of negative priming can be found when the probe is predictably or saliently nonconflicting (Lowe, 1979, Experiment 4; Tipper & Cranston, 1985, Experiment 3; see also Moore, 1994); (b) only the aspects of the ignored prime distractor that conflict with the goal of the task are inhibited, whereas other aspects irrelevant to this goal can facilitate performance on the probe target (Tipper, Weaver, & Houghton, 1994); and (c) negative priming generalizes to probe targets that are categorically or associatively related to the prime distractor.

What remains to be explained is why an act of selection should be needed during prime processing in the case in which the potentially competing distractor is unavailable to awareness. At this point, it is crucial to answer this question within the framework of the persisting inhibition interpretation of negative priming, because both the research of Fox (1996), and the research of Yee (1991) on which it was based, were cast in this framework.

Negative Priming With Unconscious Prime Distractors

Allport et al.'s (1985, Experiments 3–5, 8, and 9) use of a methodology inspired by that of Marcel's (1980) study of unconscious priming from polysemous words (which was based on Schvaneveldt, Meyer, & Becker, 1976), together with partially divergent interpretations of the same research in the simultaneous reports made by Tipper (1985; Tipper & Cranston, 1985), has contributed to make the issue of the role of awareness in negative priming a bit confusing. In Marcel's (1980) experiment, there was no semantic priming stemming from polysemous prime words presented under conditions of severe peripheral energy masking, whereas both meanings of the polysemous prime words facilitated the processing of related probe words under the condition of severe pattern masking. According to Marcel (1980; see also Marcel, 1983), severe energy masking prevents both useful processing and conscious access to the word; severe pattern masking prevents conscious access but preserves the automatic component of lexicosemantic processing, including the spreading activation process responsible for facilitation in probe processing. With an unmasked, fully conscious prime, however, the processing of a probe word was facilitated through automatic spreading activation only when a context word (presented before the polysemous prime word) selectively biased the polysemous word toward the meaning related to the probe word. When the context word suggested a meaning of the polysemous word that was unrelated to the probe word, the processing of the latter was impeded "due to 'negative priming' or inhibition" (Marcel, 1980, p. 453).[1]

When using a prime display that was made fully unavailable to awareness through severe pattern masking, Allport et al. (1985, Experiments 4 and 5) found positive priming stemming from both the unconscious target and the unconscious distractor. Thus, Allport et al.'s results mirrored the results of Marcel (1980) with respect to priming from multiple meanings of polysemous words in a comparable masking condition.

The major condition of Allport et al. (1985) that yielded negative priming with unconscious prime distractors has no exact parallel in Marcel's (1980) work. The procedure of this new condition consisted of two phases. During the first phase, the SOA between the prime and the pattern mask was individually adjusted in such a way as to make only the prime target fully available to awareness, with the goal that the prime distractor would remain completely outside awareness. During the second phase, the individually determined SOA was used in the experiment, in which participants had to select and memorize the red target (while ignoring the green distractor) in the prime display and to recall it after having responded to the probe target. Only the results of the participants who could not report the prime distractor on the last trial of the experiment were taken into account.

There were only two experiments in which the error rates in recalling the prime target were sufficiently high (i.e., 10% and 14% instead of about 2%–3% in all other comparable experiments) to allow a comparison of the priming effects with and without recall of the prime target. In Experiment 3 of Allport et al. (1985; also reported as Experiment 1 in Tipper, 1985), there was a 51-ms negative identity priming effect when participants recalled the prime target, whereas there was a 52-ms positive identity priming effect when participants failed to recall it. A similar result was found in Experiment 2 of Tipper (1985). Allport et al. concluded that negative priming reverses to positive priming when "neither the prime target nor its accompanying distractor can be reported" (p. 117). Although this conclusion seems consistent with the positive priming that stems from both components of the prime being made completely unavailable to awareness through severe pattern masking (Allport et al., 1985, Experiments 4 and 5), one can still object in that there is no direct evidence for the unawareness of the prime distractor in the condition of less-severe masking discussed here. The reason is that except on the last trial of the experiment, participants were instructed to report only the red target and not the green distractor. Hence, an alternative interpretation is that unsuccessful selection of the red target implied that the green distractor was selected instead, which would cause both positive priming and availability for report of the distractor, had this report been requested.

This alternative interpretation is more consonant with Tipper's (1985) description of this research, in which in referring to the prime components, he explicitly stated that "both objects are presented above threshold, thus they are both potentially available to control response" (p. 574) and that "brief exposure durations and pattern masking were employed to reduce the possibility of switching attention to the ignored object after selection of the attended object" (p. 577). Also, following a suggestion made by A. Treisman in a personal communication, Tipper wondered whether participants were not briefly aware of the prime distractor "but that target selection included the suppression of the ignored object from conscious awareness" (p. 587).

It is clear from his description of this research that Tipper (1985) expected negative priming to occur only with SOAs sufficiently long (of the order of 100 ms on average) for the prime to have evaded the masking actions based on early visual processes of prime–mask integration and of interruption of prime feature extraction (Michaels & Turvey, 1979; Turvey, 1973).[2] The only masking mechanism that is still operative with such long SOAs is attentional in nature (Michaels & Turvey, 1979). With this mechanism, attention is drawn from the prime to the mask too early to allow full processing and full phenomenal awareness because of capacity limitation, but the representations already achieved by the prime can eventually exert concurrent and persisting conflicting influences. There is actually some evidence that incongruent primes masked after a 100-ms SOA can generate substantial interference effects in Stroop (Beech, Baylis, Smithson, & Claridge, 1989) and Stroop-like (Tipper & Baylis, 1987) tasks.

[1] This interference was significant only with the 1,500-ms SOA (not with the 600-ms SOA).

[2] The mean SOA was 35 ms in Experiment 3 of Allport et al. (1985), which is the only experiment that resorted to dichoptic masking. With monoptic masking of superimposed pictures, mean SOAs ranging from 74 ms to 118 ms were found (Allport et al., 1985, Experiments 4 and 5; Murray, 1995; Tipper, 1985, Experiment 2; Tipper & Driver, 1988). Superimposed words led to a mean SOA of 125 ms (Tipper & Driver, 1988), whereas a single prime word at the center of a distractor picture needed an SOA of 107 ms in Experiment 3 of Driver and Tipper (1989). In comparison, with monoptic masking, the mean SOAs leading to complete unawareness of the superimposed target and distractor pictures were 21 ms and 23 ms in Experiments 4 and 5, respectively, of Allport et al.

In summary, it appears that within the range of SOAs determined by the threshold setting procedure used by Tipper and colleagues (Allport et al., 1985; Driver & Tipper, 1989; Tipper, 1985; Tipper & Cranston, 1985; Tipper & Driver, 1988; see also Murray, 1995), the prime components are processed deeply enough to compete for action. It is through the combination of a successful act of selection followed by late attentional masking that the prime distractor becomes unavailable to awareness. It cannot be ascertained from the procedure used in the experiments reviewed above whether attentional masking prevents the distractor from ever briefly entering consciousness or whether it is so quickly forgotten as to become almost immediately unreportable (as revealed by the failure to answer the surprise question replacing the probe of the last trial). Whether severe perceptual masking can reliably give rise to positive semantic priming is a moot point that we do not discuss here (see Holender, 1986a, 1986b).

For the present purposes, the only important conclusion is that there is a form of masking that makes the distractor noncompeting, thereby yielding either no priming at all or, eventually, positive priming, and another form of masking that leaves an unreportable, albeit competing, distractor that is able to induce negative priming on a subsequent probe target. It is only in this latter case that the existence of negative priming from unconscious primes is compatible with the persisting inhibition explanation, which constitutes our answer to the question raised at the end of the preceding section.

Evidence for Negative Semantic Priming

The most systematic analysis of the research on negative semantic priming was made by Fox (1995), who pointed out that the phenomenon was not firmly established by the data available up to the time of her review (see also Damian, 2000). However, several recent studies suggest that the phenomenon of negative semantic priming does actually exist. Next, we briefly analyze some of these new studies to specify under which conditions the phenomenon occurs.

Table 1 summarizes the procedures and the results of Experiment 1 of Fox (1996), of the two experiments of Yee (1991), and of several other experiments based on similar overall procedures. Note that in most studies appearing in Table 1, the probe display is a single-component letter string presented at fixation; the only exceptions are the two experiments of Marí-Beffa, Fuentes, Catena, and Houghton (2000), in which the probe target presented at fixation is flanked above and below by two identical distractor words. As negative semantic priming is not confined to these two experiments, one can immediately conclude that the presence of a distractor in the probe display is not a necessary condition for the phenomenon to occur.

Does negative semantic priming then depend on an act of selection taking place during prime processing? Answering this question requires assessing the extent to which the prime distractor is intrusive and the extent to which the processing of the distractor competes with the goal of the task defined on the prime target. Prime reportability constitutes a rather straightforward index of intrusiveness, because deep processing usually results in the availability of information to awareness. Prime reportability allows the partitioning of the experiments summarized in Table 1 into two sets: experiments in which the distractor distance from fixation is relatively large—4.5° and 2.4° in the studies of Yee (1991) and Fox (1996), respectively—and prime report is nil; and experiments in which the prime distractor appears much closer to fixation—1° or less—and the distractor availability for report is much higher (see Table 1).[3]

The evaluation of the extent to which prime distractor processing can potentially compete with the goal of the task is more speculative as it requires formulating some assumptions about which response or action is most probably activated or evoked by the prime distractor. In the subset of studies with prime distractors sufficiently close to fixation to be potentially intrusive, there are four experiments in which the prime distractor could have eventually elicited a decision or a response that conflicted with the goal of the task on the prime target: Experiment 1 of Marí-Beffa, Fuentes, et al. (2000), in which participants had to make a lexical decision to the target while repressing the positive word response potentially elicited by the distractor; Experiment 2 of the same study, in which participants had to avoid categorizing the prime distractor instead of the prime target; and Experiments 2 and 3 of Hoffman and MacMillan (1985), in which participants had to identify the prime target for later recognition while avoiding identifying the distractor instead.

Table 1 shows that in three of these four experiments the trend was toward negative semantic priming, whereas no effect was found in Experiment 3 of Hoffman and Macmillan (1985). However, when participants had to search the target for the presence of a predesignated letter, the negative semantic priming effect reversed to a positive semantic priming effect in Experiments 1 and 2 of Marí-Beffa, Fuentes, et al. (2000), and it simply vanished in Experiment 2 of Hoffman and MacMillan. In a similar manner, in Experiment 1 of Duscherer and Holender (2001), which was a replication of Experiment 1 of Fox (1996), with distractors closer to fixation (0.8° instead of 2.4°), there was no priming at all from a distractor word accompanying an odd or even classification of the prime target digit; positive semantic priming was found in Experiment 2, with no prime target in the trials calling for a positive lexical decision on the probe.

A first important conclusion is that the overall pattern of the results just described is fully compatible with the persisting inhibition account of negative priming. If the distractor is competing with the goal of the task on the prime target, either negative semantic priming or no priming is observed (see also Ortells, Abad, Noguera, & Lupiáñez, 2001; Ortells & Tudela, 1996); if the task on the prime is modified in such a way as to make the distractor noncompeting, either positive semantic priming or no

[3] Nil prime report, as assessed postexperimentally, was found in Experiment 1 of Fox (1996) and in Experiment 1 of Yee (1991). Although not assessed, the availability of the prime distractor should be even more depleted in Experiment 2 of Yee, because of masked instead of unmasked presentation. In contrast, prime report was much better in Experiment 1 of Duscherer and Holender (2001), due mainly to closeness to fixation. The availability for report of the prime distractor was probably even higher in the experiments of Marí-Beffa, Fuentes, et al. (2000) and of Marí-Beffa, Houghton, Estévez, and Fuentes (2000), because of equal or longer unmasked presentations of the prime distractor. There is more uncertainty about prime distractor reportability in Experiments 2 and 3 of Hoffman and MacMillan (1985), as they used no mask but much shorter presentations (64 ms).

priming is observed (see also Fuentes, Carmona, Agis, & Catena, 1994; Fuentes & Tudela, 1992). There is only one study, Marí-Beffa, Houghton, et al. (2000), that yields results that are in apparent contradiction with this rule (see Table 1). We would have predicted no negative semantic priming in the condition in which a central string of pound (#) signs was searched for a letter in Experiments 2 and 3, because processing of the prime distractor word should not have competed with letter search.

A second important conclusion is that the absence of negative priming in our replication of Fox's (1996) procedure with distractors available to awareness (Duscherer & Holender, 2001, Experiment 1) is consistent with the hypothesis that the possible covert naming of these distractors is competing neither with the binary decision on the prime target nor with the lexical decision on the probe letter string. Therefore, less-intrusive distractors appearing 4.5° away from fixation as in Yee's (1991) experiments or 2.5° away from fixation as in Experiment 1 of Fox (1996) should be even less competing. Hence, in these experiments the unavailability to awareness of the prime distractor probably depends only on poor perceptual discriminability due to distance from the fovea, short presentation duration, and masking. In contrast, the negative priming in the experiments with unconscious primes, which were reviewed in the preceding section of this article, depends on the synergy between an act of selection and masking occurring after selection. It follows that, as in the conditions with severe masking used by Allport et al. (1985, Experiments 4 and 5) and by Marcel (1980), no priming or only positive semantic priming is expected in these experiments.

Purpose of the Experiments

Either the negative semantic priming effects found by Fox (1996) and by Yee (1991) are valid and replicable, in which case our analysis needs serious revision, or these results are spurious. Lending credence to the latter possibility, Neill, Valdes, and Terry (1995, p. 229) mentioned a failure to replicate Yee's results, and Fox has noted a failure to replicate her finding (E. Fox, personal communication, January 8, 1998). With respect to the former possibility, we present in the General Discussion an assessment of the extent to which negative semantic priming from unconscious primes can be accounted for in alternative theoretical frameworks not relying on the process of persisting inhibition.

Experiment 1 is an attempt to replicate Fox's (1996) results after having corrected for two methodological inadequacies we identified in her procedure. Experiment 2 is motivated by the fact that we have some evidence found with prime distractor words presented closer to fixation (0.8° instead of 2.4°) that the task load on the prime target limits both the reportability and the priming potency of the distractor words. It was only in leaving the prime target position empty (Duscherer & Holender, 2001, Experiment 2) that the expected positive priming effect was found (see Table 1). Experiment 2 of the present study follows this procedure with flanker words appearing 2.4° away from fixation, as in Experiment 1.

Experiment 1

We replicated the procedure used by Fox's (1996) Experiment 1, except for two important points. First, we used only French native speakers in a within-language priming condition, instead of English–French and French–English bilinguals, with each participant completing two cross-language and two within-language priming conditions. Second, our individual estimates of the priming effect were based on 64 probe words presented twice, preceded once by a related and once by an unrelated prime word; Fox's estimates were based on two different sets of only 15 words, one set being used in related trials and the other set being used in unrelated trials, in each prime–probe language condition.

One difficulty associated with Fox's (1996) procedure is that one needs to match carefully the set of words to be used in the related trials with an equivalent set of words to be used in the unrelated trials. Fox selected two sets of 60 words that could be matched in length and frequency in both the English and the French counterparts of the material. In an unprimed lexical decision task, three native speakers of each language showed overall equivalent median reaction times (RTs) for the matched sets of 60 words. Unfortunately, because Fox's Experiment 1 involved four different language conditions, the two sets of 60 matched words were split into four subsets of 15 words each, without any further check as to whether each paired subset yielded comparable RTs in an unprimed lexical decision. Moreover, each of these paired subsets of words was used in the same language condition by all participants (instead of being rotated between language condition across participants). Therefore, there is no guarantee that the observed difference between the mean RTs of the two subsets of 15 words used in each language condition reflects a true priming effect. Allowing the same words to serve in both the related and unrelated conditions overcomes this limitation.

This problem is further compounded in that two consecutive responses (i.e., one to the prime target digit and the other to the probe letter string) taken from the same response set—a right and a left keypress—had to be made on each trial. In a somewhat comparable situation involving two consecutive lexical decisions, Paap and Newsome (1981, Experiment 1) showed that the facilitation effect (the difference in mean RTs between probes preceded by related and by neutral primes) was modulated by response transition. These results suggest that careful balancing of response transition and type of trial (related and unrelated) is needed to avoid spurious effects. Perfect counterbalancing could not be achieved by Fox (1996), as she was using subsets of 15 words.

It is clear that, after correcting for these methodological inadequacies, we did not expect any negative semantic priming effect in Experiment 1. Although we were more neutral about whether positive or nil priming would take place, we anticipated the latter would be the case. However, even if justified theoretically, the prediction of a nil effect did not fit the logic of the significance-testing decision rule. To circumvent this problem, we supplemented the significance-testing procedure with a power analysis and with the maximum likelihood ratio approach proposed by Dixon (1998; Dixon & O'Reilly, 1999). Both procedures require setting a minimum alternative value for the priming effect. The results of Fox's (1996) Experiment 1 were based on 18 participants. As can be seen in Table 1, one of her conditions yielded an 11-ms positive semantic priming effect that was not significant at the .05 level, and the three other conditions yielded significant negative priming effects, one of 24 ms and two of 35 ms. Consequently, in this experiment we set both α and β at the .05 level for the bilateral test of the null hypothesis of a 0-ms priming effect against an absolute value of a 20-ms priming effect. Because this power could not be reached with a single group of 16 participants, in Experiment 1 we performed two exact replications (Experiment 1A and Experiment 1B).

Method

Participants. Two groups of 16 undergraduate students at the Université Libre de Bruxelles participated as part of a course requirement, one group in Experiment 1A and the other in Experiment 1B. Three extra participants, 1 in Experiment 1A and 2 in Experiment 1B, having produced more than 10% errors in the lexical decision task, were replaced. All participants had normal or corrected-to-normal vision, and French was their first language. Most of them were in their late teens or early twenties.

Stimuli. Sixty-four French semantically related word pairs were used. All words were one to two syllables long, contained between three and seven letters, and were of a relatively high frequency (occurrences per million words) in French according to the BRULEX lexical database (Content, Mousty, & Radeau, 1990). Sixty-four unrelated word pairs were created by repairing randomly the first and the second member of the 64 related word pairs, and by correcting for any remaining association. Two additional sets of 64 French words were selected, one being matched in frequency, number of letters, and number of syllables with the 64 probes, and the other being matched with the 64 primes. The first set was used to generate 64 pronounceable pseudowords by changing one or two letters in each word. The words of the second set were used as primes for the pseudoword probes.

We checked that this material yielded a substantial priming effect in a preliminary experiment that followed the design and procedure described below, except that the prime word was presented only once at fixation instead of twice (once above and once below fixation); and the SOA between the prime and the probe was constant at 1,000 ms, as no response was made to the prime display. We found a positive semantic priming effect of 47 ms ($SD = 27$). This difference between the mean RTs for the related ($M = 555$ ms, $SD = 62$) and unrelated ($M = 602$ ms, $SD = 58$) word pairs was significant, $F(1, 15) = 47.07$, $MSE = 363$, $p < .001$.

Apparatus. The experiments were designed using Micro Experimental Laboratory (MEL; Version 2.01) software (for a descriptive article, see Schneider, 1988). Stimuli were presented on a NEC Multisync XE17 color monitor controlled by a Pentium IBM-compatible computer, which also recorded the RTs in milliseconds via an MEL manual response box.

Design and procedure. Participants performed two successive tasks on each experimental trial: During the prime display they categorized a single-digit target as odd or even; during the probe display they performed a lexical decision task. The prime display was composed of a single-digit target (*4*, *5*, *6*, or *7*) presented at fixation and of a distractor word presented twice, once above and once below fixation. At an average viewing distance of 60 cm, the center-to-center distance between the central digit and either distractor word was 2.4°. The probe display consisted of a centrally presented letter string (a word or a pseudoword). When the probe was a word, it could be either semantically related or semantically unrelated to the parafoveal prime distractor. All stimuli were presented in light gray on a black background, using the uppercase standard font of the computer. The visual angles subtended by the entire prime display were 5.52° in height, with each character subtending 0.52° in height in both the prime and the probe displays. The same responses were used for both the prime digit classification and the probe word or pseudoword classification. Buttons 1 and 5 of the MEL response box were activated by the left and right index fingers, respectively.

One experimental trial comprised the following consecutive events: (a) a 500-ms fixation display, consisting of a central plus (+) sign flanked above and below by a row of seven plus signs that occupied the locations where the prime words would be presented; (b) a black screen for 100 ms; (c) a 150-ms prime display; (d) a 100-ms masking pattern, identical to the initial fixation display; (e) a black screen lasting until the digit classification response, or lasting for 2,000 ms if no response was detected; (f) another black screen for 300 ms after the response to the digit; (g) the probe letter string lasting until the lexical decision, or lasting for a maximum of 2,000 ms; and, finally, (h) a 2,000-ms black screen until the fixation display of the next trial.

The set of 64 related word pairs was split into two subsets of 32 pairs, each subset being matched as closely as possible in terms of letter length, syllable length, and frequency. The split of the set of 64 unrelated word pairs was fully determined by that of the related word pairs, because the probes had to be the same in the corresponding subsets of related word pairs and unrelated word pairs. Four lists of 128 trials were built according to the following rules. List 1 contained one subset of 32 related word pairs, the subset of unrelated word pairs containing the remaining probe words, and the full set of 64 word–pseudoword pairs. List 2 had the other subset of 32 related word pairs, the other subset of unrelated word pairs, and the same full set of 64 word–pseudoword pairs. In each list, half the probes of each type—related, unrelated, and pseudoword—were preceded by an odd digit (equally often *5* and *7*), and the other half were preceded by an even digit (equally often *4* and *6*). An important constraint was that any specific probe word was preceded by the same digit in its two presentations. The same constraint was applied to the two presentations of the pseudoword probes. List 1′ and List 2′ were derived from List 1 and List 2 by crossing the digit–probe pairing. The last stage in list construction was the pseudo-randomization of the 128 stimuli in each list with the constraint that there were never more than three consecutive trials of the same kind in terms of the outcome of either the odd or even digit or the word or pseudoword classification. The resulting sequence of trials in each list was the same for all participants. A practice block of 32 trials containing no related word pairs was also constructed. The words and pseudowords used in this practice block were different from those used in the experiment.

Each participant was tested individually in one session of about 40 min, consisting of one practice block of 32 trials followed by two lists of 128 trials. Each list was divided into two blocks of 64 trials with a rest period between. Two warm-up trials were added at the beginning of each block. The order of the two lists, the order of the two blocks within the lists, and the response mapping for the digit classification (i.e., odd-left, even-right, or vice versa) were counterbalanced between 8 participants. A total of 16 participants were needed to fully balance the design; 8 receiving Lists 1 and 2 and 8 receiving Lists 1′ and 2′. The response mapping for the word or pseudoword classification was the same for all participants: pseudoword-left, word-right. Participants were instructed to respond quickly and accurately on both the prime digit and the probe letter string. After the experiment, participants completed a questionnaire in which they were asked if they had noticed the parafoveal word primes and any associations between the primes and the probes.

Data analysis. For each participant, we first computed the mean RT and the standard deviation for all the responses falling in the 1-ms to 2,000-ms time window for both the digit classification and the lexical decision tasks, disregarding conditions and response accuracy. Then, for each task, RTs exceeding three standard deviations above and below the mean RT were eliminated from further analysis. Error rates for both the digit classification and the lexical decision tasks were computed on the remaining trials in each condition. Mean RTs for each task and each condition were computed only for trials in which participants were correct on both the digit classification and the lexical decision. Participants having more than 10% of their data eliminated by this cutoff procedure were replaced. Remaining participants having more than 10% of their data unavailable because of errors in the digit classification, the lexical decision, or both, were also replaced.

Instead of performing a paired sample *t* test for the difference between related and unrelated trials, we performed a one-factor repeated measures analysis of variance (ANOVA), because the sums of squares from this analysis readily provided the data needed to compute λ, the maximum likelihood ratio in the procedure described by Dixon and O’Reilly (1999).

Although the usual $p < .05$ probability of making the Type I error was used as the criterion of significance, the exact values of p are also reported. In addition, we report the magnitude of the priming effect needed to reach a power $1 - \beta = .95$.

The G•Power software developed by Buchner, Faul, and Erdfelder (1997) was used to make an a posteriori power analysis. For the likelihood ratio, we computed λ, the maximum value of the likelihood ratio favoring Model 2 (in which the magnitude of the effect is at least x, with the absolute value of x being different from zero) over Model 1 (in which there is no effect at all; i.e., x is equal to 0) given the observed value of the priming effect, by using Equation 10 of Dixon and O'Reilly (1999). A likelihood ratio of at least 10:1 is considered evidence in favor of one model over the other. This criterion is roughly equivalent to the $p < .05$ decision rule (Dixon, 1998; Dixon & O'Reilly, 1999), which implies that λ must have a value of at least 10 to conclude in favor of Model 2 (there is a priming effect of at least 20 ms in absolute value) and a value of at most 0.1 to conclude in favor of Model 1 (the 0-ms priming effect). In terms of decisional strategies, intermediate values of λ are considered inconclusive. Once a priming effect is different from zero, only the odds favoring a 20-ms effect of the same sign should be reported, the odds favoring a 20-ms effect of the opposite sign being necessarily smaller.

Results

The cutoff procedure entailed an overall elimination rate of 4.1% and 3.2% of the trials in Experiments 1A and 1B, respectively. Table 2 shows the mean RTs, standard deviations of the means, and mean error percentages for each type of probe display—semantically related, semantically unrelated, and pseudowords—as well as the overall results for the lexical decision task.

Experiment 1A. In the digit classification task, the mean RTs for the odd and the even digits were 584 ms ($SD = 111$; error rate = 0.9%) and 598 ms ($SD = 115$; error rate = 1.6%), respectively. In the lexical decision task, the 0-ms ($SD = 25$) priming effect computed by subtracting the mean RT for the related ($M = 643$ ms) from that of the unrelated ($M = 643$ ms) trials was not significant, $F(1, 15) < 0.01$, $MSE = 323$, $p = .98$. A priming effect of 25 ms in absolute value was needed to reach a power of .95; the actual power for a 20-ms effect was .84. Given the 0-ms observed priming effect, the odds in favor of the 0-ms effect over either the −20-ms or the +20-ms effects were extremely high ($\lambda = 0.001$).

Experiment 1B. In the digit classification task, the mean RTs for the odd and the even digits were 578 ms ($SD = 123$; error rate = 1.1%) and 581 ms ($SD = 124$; error rate = 1.0%), respectively. The −1-ms ($SD = 24$) priming effect, computed by subtracting the mean RT for the related ($M = 637$ ms) from that of the unrelated ($M = 636$ ms) trials, was not significant, $F(1, 15) = 0.07$, $MSE = 292$, $p = .94$. A priming effect of 23 ms in absolute value was needed to reach a power of .95; the actual power for a 20-ms effect was .87. Given the −1-ms observed priming effect, the odds in favor of the 0-ms effect over the −20-ms effect were extremely high ($\lambda = 0.001$).

Experiments 1A and 1B. In the pooled data of Experiments 1A and 1B, the −1-ms ($SD = 24$) negative priming effect, computed by subtracting the mean RT for the related ($M = 640$ ms, $SD = 80$) from that of the unrelated ($M = 639$ ms, $SD = 83$) trials, was not significant, $F(1, 31) < 0.01$, $MSE = 297$, $p = .97$. A priming effect of 16 ms in absolute value was needed to reach a power of .95; the actual power for a 20-ms effect was .99. Given the −1-ms observed priming effect, the odds in favor of the 0-ms effect over the −20-ms effect were extremely high ($\lambda < 0.001$).

There was a trend toward a stimulus–response compatibility effect in the digit classification task. Participants who used the odd-left/even-right mapping were faster ($M = 566$ ms, $SD = 69$) than those who used the odd-right/even-left mapping ($M = 605$ ms, $SD = 106$). Although this 39-ms ($SD = 31$ ms) compatibility effect was not significant, it had strong consequences on the following lexical decision task. We performed a mixed-model ANOVA with compatibility as a between-participants variable (compatible vs. incompatible) and prime target type (odd vs. even) and probe type (related vs. unrelated) as within-participants variables. Both the compatibility and the probe type effects were significant, $F(1, 30) = 6.03$, $MSE = 20{,}175$, $p = .02$; $F(1, 30) = 105.65$, $MSE = 1{,}724$, $p = .0001$, respectively. The Compatibility × Probe Type interaction was not significant, nor was the main effect of prime target type, but the three-way interaction between these variables was significant, $F(1, 30) = 13.25$, $MSE = 656$, $p = .001$. This triple interaction is easily untangled in that response nonrepetitions (left-right or right-left) were faster than response repetitions (left-left and right-right), irrespective of the compatibility of both the digit classification (odd or even) and the probe type (word or pseudoword). This tendency was stronger for pseudowords than for words.

Questioned after the experiment about whether they noticed that words were presented above and below the digit they had to classify, 15 participants in Experiment 1A and 14 participants in

Table 2
Mean Reaction Times (RTs; in Milliseconds), Standard Deviations of the Means, and Mean Error Percentages: Experiments 1 and 2

	Exp. 1A			Exp. 1B			Dummy priming exp.			Exp. 2A			Exp. 2B		
Trial type	*M*	*SD*	% error	*M*	*SD*	% error	*M*	*SD*	% error	*M*	*SD*	% error	*M*	*SD*	% error
Related	643	61	4.7	637	98	2.3	672	76	4.8	600	32	1.6	589	64	1.2
Unrelated	643	68	4.1	636	98	3.6	677	83	5.7	594	32	1.5	596	56	1.9
Pseudoword	722	66	5.0	708	90	3.1	758	80	6.4	716	50	2.5	693	69	4.3
Overall RTs	682	63	4.7	672	90	3.0	715	75	5.8	643	36	1.9	632	61	2.6
Effect	0			−1			5			−6			7		

Note. The priming effect was calculated by subtracting the mean reaction time for related trials from that of unrelated trials. The prime distractor words were removed in the dummy priming experiment. Exp. = experiment.

Experiment 1B gave a negative answer. The remaining three participants noticed some letters appearing with the flanker plus signs but were not sure about whether these letter strings constituted words.

Discussion

In using a procedure similar to that of Fox (1996) in her Experiment 1, we confirmed that parafoveal distractor words presented 2.4° from fixation are mostly unreportable, but we failed to obtain any semantic priming effect, either positive or negative. Three points should be made concerning the strength of the evidence in favor of this nil priming effect. First, the nil priming effect was obtained in two exact replications of the experiment, each involving 16 participants. Second, in both replications the odds in favor of the 0-ms priming effect over either the −20 or the +20 priming effects were extremely high. Third, although the variability of the priming effect was such that a power of .95 for an absolute value of 20 ms could not be reached with the 16 participants involved in each replication, the combined data involving 32 participants reached the power of .95 for a 16-ms effect in absolute value. It thus appears that the nil priming effect of Experiment 1 is both replicable and genuine, and not simply nonsignificant in terms of the conventional significance-testing decision rule. That is, it is not ambiguous because of lack of power or because of insufficient odds in terms of the likelihood ratio approach advocated by Dixon and O'Reilly (1999).

Now we examine the extent to which our data can highlight the possible role of the two inadequacies we identified in Fox's (1996) procedure: imperfect balancing of the response transitions and imperfect matching between the small sets of words used to evaluate priming. Two types of transition effects occurred in Experiment 1. First, there was a high-order compatibility effect between the successive tasks. The 16 participants getting the odd-left/even-right together with the pseudoword-left/word-right stimulus–response assignment were faster than the 16 participants receiving the odd-right/even-left together with the same pseudoword-left/word-right stimulus–response assignment. Second, there was a within-trial response transition effect such that nonrepeated responses were always faster than repeated responses, an effect that was much stronger with pseudowords than with words.

Thus, similar to Paap and Newsome (1981, Experiment 1), we observed that response transition can modulate the priming effect to some extent. However, it is unlikely that an imbalance in response transitions alone could have generated spurious priming effects as large as the 35 ms found by Fox (1996) in two out of four conditions (see Table 1).

To check whether spurious priming effects could arise from the use of small sets of words, we tried to simulate Fox's (1996) conditions by partitioning the data of the first half of Experiment 1, in which no words were repeated, into two sets of matched words. There was no bias in one set of 16 matched probe words, but in the second set one group of participants showed a +14-ms effect, and the other group showed a −16-ms effect. This reversal in the effect can be explained only in terms of differences in the relative speed of responding within each set of matched words, in the absence of any genuine priming effect. This is exactly the point we want to make.

We can conclude that imperfect balancing of response transitions and imperfect matching between small subsets of words can spuriously produce and affect priming effects. However, the only way to ascertain whether Fox's (1996) results were indeed contaminated in that manner would be to perform an exact replication of her Experiment 1. Unfortunately, this cannot be done because the material is no longer available (E. Fox, personal communication, January 8, 1998). In the rest of this discussion, we examine three other potential sources for the discrepancy between our results and those of Fox.

One possible source of discrepancy between the results lies in the differences in data processing in the two studies. Fox (1996) included all the RTs between 200 and 2,000 ms and computed the mean of the median individual RTs for the related and unrelated trials. We included the RTs within plus or minus three standard deviations of the individual mean RTs computed in a 1-ms to 2,000-ms interval, and we computed the average of the individual mean RTs. Here are the results of our Experiments 1A and 1B computed following Fox's procedure: In Experiment 1A, the means of the median RTs were 626 and 625 ms (*SD*s = 57 and 64 ms) for the related and unrelated trials, respectively; the corresponding results in Experiment 1B were 617 and 621 ms (*SD*s = 93 and 83 ms). Less than 1% of the data were eliminated in each experiment instead of the 4.1% and 3.2% that were eliminated with our procedure.

Another difference between the two studies is that the overall level of performance is more than 100 ms faster in our Experiment 1 compared with Fox's (1996) Experiment 1, the latter yielding average median RTs of 708 and 743 ms for the related and unrelated trials, respectively, of the within-language condition, with both the prime and the probe in the participants' first language. We performed a median split on the median RTs collapsed over the related and unrelated trials. For the faster group of 16 participants, the means of the median RTs for the related and unrelated trials were 564 and 568 ms, respectively; corresponding results for the slower group were 680 and 677 ms, respectively.

A further possibility is that the nil priming effect in Experiment 1 might have resulted from antagonistic priming tendencies in two subgroups of participants using different strategies. The reason for formulating such an hypothesis is that there is a fair amount of variability in the individual priming effects, with some participants showing large positive and others showing large negative priming effects. This can be seen in Figure 1, in which the mean priming effects plus or minus two standard deviations are shown. To check for this possibility, we carried out a dummy priming experiment with an additional group of 16 participants. This experiment was based on the procedure of Experiment 1, except that the prime distractor words were removed and replaced by strings of seven *X*s. By computing a dummy priming effect as if the prime words were presented, we can obtain a picture of the natural variability of the difference in mean RTs based on the very same two sets of trials as those used to compute the priming effect in Experiments 1A and 1B. This actually amounts to computing the difference between the mean RT of one presentation of the 64 probe words and the mean RT of another presentation of the same 64 probe words.

The main results of the dummy priming experiment are shown in Table 1 (see also Figure 1). The 5-ms (*SD* = 25) priming effect obtained by subtracting the dummy-related mean RT (*M* = 672

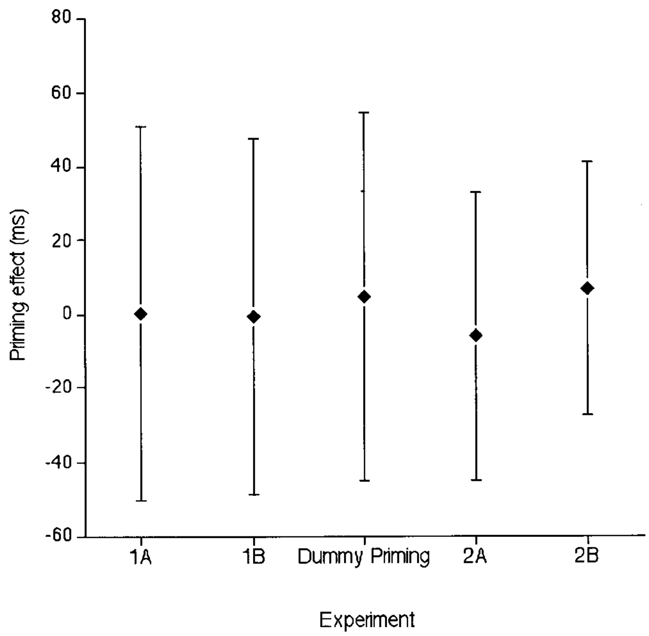

Figure 1. Mean priming effects (in milliseconds) plus or minus two standard deviations in each group of 16 participants, in Experiments 1A and 1B, the dummy priming experiment, and Experiments 2A and 2B.

ms) from the dummy-unrelated mean RT (M = 677 ms) was not significant, $F(1, 15) = 0.61$, $MSE = 310$, $p = .446$. A dummy priming effect of 24 ms in absolute value was needed to reach a power of .95; the actual power was .80. Given the observed +5-ms priming effect, the odds in favor of the 0-ms effect over the +20-ms effect were very high ($\lambda = 0.013$).

As expected, there was no dummy priming effect on average. However, not all individual priming effects were negligible. It is clear from Figure 1 that the range of magnitude of the individual dummy priming effects is similar to the ranges found in Experiments 1A and 1B. Moreover, all the values of the important parameters of the dummy priming experiment (viz., the mean and the standard deviation of the RTs, the mean and the standard deviation of the dummy priming effect, and thereby the minimum value of the priming effect needed to reach the requested power of .95) are not distinguishable from the corresponding values in the real priming situation of Experiments 1A and 1B (see Table 1). In conclusion, the discrepancy between our results and those of Fox (1996) cannot be explained by a difference in the way the data were processed, by a difference in absolute level of performance, or by averaging over two opposite priming tendencies.

Experiment 2

It is tempting to attribute both the complete lack of priming and the almost complete lack of report of the prime words in Experiment 1 to reduced discriminability due to the combination of short duration of presentation (150 ms), distance from fixation (2.4°), and masking through strings of plus signs appearing both before and after the prime words. However, there is now mounting evidence that, in addition to these perceptual limitations, the capacity demands of the task performed on the prime target also contribute to reduce the processing of irrelevant information (Lavie, 1995; Lavie & Tsal, 1994). In using a variant of the letter flanker task devised by Eriksen and Eriksen (1974), Lavie and Fox (2000) found that increasing the perceptual load of the prime target letters decreased both concurrent interference from the prime distractor and subsequent negative priming. We (Duscherer & Holender, 2001) also found some evidence of the role of perceptual and task load in the processing of flanker words close to fixation. A positive semantic priming effect was found only when no prime target was presented during the critical trials in which the probe was a word (see Table 1). Maximum awareness of the prime words and of the prime–probe contingency also occurred in that experiment.

In the present Experiment 2, we explored whether flanker words presented 2.4° away from fixation would become more reportable by reducing the perceptual and the cognitive load of the task to be performed on the prime target. We expected only positive semantic priming, if any, in this situation, as before. We omitted the target digit from most prime displays; however, to encourage participants to maintain fixation, we presented a central digit on one third of the pseudoword trials and asked participants to keep fixation so as to be able to report any occurrence of a digit. The digit recall prompt always followed the lexical decision. As had Experiment 1, Experiment 2 had two exact replications, Experiments 2A and 2B.

Method

Participants, stimuli, and apparatus. Two new groups of 16 undergraduate students at the Université Libre de Bruxelles participated as part of a course requirement, one group in Experiment 2A and the other group in Experiment 2B. Three extra participants, 2 in Experiment 2A and 1 in Experiment 2B, having more than 10% of their data eliminated through the cutoff procedure, were replaced. The stimuli and apparatus were the same as in Experiment 1.

Design and procedure. The only difference between Experiment 2 and Experiment 1 was that the central digit was presented on only one third of the noncritical trials in which the probe was a pseudoword (and on none of the trials in which the probe was a word). We used a 1,000-ms constant SOA between the prime and the probe, because no immediate response was required to the prime display. Participants were asked to keep fixation so as to not miss any digit that might appear in the prime display and to report the digit after the lexical decision was completed. They were asked not to slow down in their lexical decision and to wait until prompted by the experimenter for making their digit report.

Data analysis. The data analysis was the same as in Experiment 1, except that the pseudoword data that corresponded to trials in which a digit was presented in the prime display were not taken into account. Hence, the mean RT for the pseudowords was estimated from two thirds of the trials requiring a negative lexical decision.

Results

The cutoff procedure entailed an overall elimination rate of 1.1% and 1.5% in Experiments 2A and 2B, respectively. Digit report was nearly perfect, being of 99.3% and 99.9% in Experiments 2A and 2B, respectively. The results for the lexical decision task appear in Table 2; Figure 1 shows the variability of the priming effects.

Experiment 2A. The difference of −6 ms (SD = 19) between the related (M = 600 ms) and the unrelated (M = 594 ms) trials was not significant, $F(1, 15) = 1.52$, $MSE = 189$, $p = .237$. A priming effect of 19 ms in absolute value was needed to reach a power of .95; the actual power was .99. Given the observed −6-ms priming effect, the odds in favor of the 0-ms effect over the −20-ms effect were very high ($\lambda = 0.006$).

Experiment 2B. The difference of 7 ms ($SD = 17$) between the related ($M = 589$ ms) and unrelated ($M = 596$ ms) word pairs was not significant, $F(1, 15) = 2.62$, $MSE = 147$, $p = .126$. A priming effect of 16 ms in absolute value was needed to reach a power of .95; the actual power was .99. Given the observed +7-ms priming effect, the odds in favor of the 0-ms effect over the +20-ms effect were very high ($\lambda = 0.006$).

Experiments 2A and 2B. In the pooled data of Experiments 2A and 2B, the difference of 0 ms ($SD = 19$) between the related ($M = 594$ ms) and the unrelated ($M = 594$ ms) word trials was not significant, $F(1, 31) = 0.02$, $MSE = 184$, $p = .89$. A priming effect of 13 ms in absolute value was needed to reach a power of .95; the actual power was .99. The odds in favor of the 0-ms effect over either the −20-ms or the +20-ms effects were very high ($\lambda < 0.001$).

In Experiments 2A and 2B, 6 and 5 participants, respectively, were aware of the presentation of flanker words. Four of these 5 participants in Experiment 2B also noticed some associations between the prime distractor and the probe. The 11 participants who saw some words had a mean priming effect of 5 ms ($SD = 13$); the subset of 4 participants who also noticed the prime–probe relationship had individual priming effects of −1, 3, 10, and 30 ms. The 21 participants who saw no words had a mean priming effect of −2 ms ($SD = 21$).

Discussion

Compared with Experiments 1A and 1B, the absence of a central digit in the prime display of Experiments 2A and 2B increased the reportability of the distractor words to some extent. However, from the participants' comments, it seems that not many of these words were available to awareness provided fixation was kept correctly. Occasionally looking at the parafoveal distractors allowed nearly one third of the participants to notice that words were presented above and below fixation, but this should have been infrequent. Otherwise, the near perfect report of over 99% of the central digit could not have been achieved; some positive priming would have been observed, which was not the case.

The conclusion is clear-cut: With flanker words presented 2.4° from fixation, manipulation of the capacity that has to be invested on prime target processing had no influence on priming (which was nil in both experiments) and little influence on flanker reportability. Hence, in keeping the other parameters of the visual presentation constant (i.e., flanker duration and pre- and postmasking), increasing the distance from fixation from 0.8° (Duscherer & Holender, 2001, Experiments 1 and 2) to 2.4° in the present study sufficed to shift the processing of the flanker words from the resource-limited to the data-limited region of the performance–resource function (see Norman & Bobrow, 1975).

General Discussion

In the two experiments reported in this article, the prime distractor words were presented for 150 ms, at a distance of 2.4° from fixation, and were preceded and followed by masking strings of plus signs. Participants made an immediate odd–even classification of the prime target digit in Experiment 1; they monitored the prime target position for infrequent presentation of a digit in Experiment 2. The results show no semantic priming effect at all in either experiment and little or no awareness of the presentation of prime words, as assessed by interviews taking place after each experiment. The results of our parallel study (Duscherer & Holender, 2001) using prime distractor words closer to fixation (0.8°) were no semantic priming effect with the digit classification task (Experiment 1), for which nearly 70% of participants were aware of the presentation of prime words, and positive semantic priming with the digit monitoring task, for which nearly 100% of participants were aware of the presentation of prime words (Experiment 2).

Taken together, these results are consistent with the idea developed in the introduction that negative semantic priming from unconscious distractor words can occur only if two conditions are conjointly satisfied: An act of selection is needed during prime processing to prevent the distractor from competing with the goal of the task on the prime target, and further processing of the distractor after selection must be prevented through some form of attentional diversion, but not through mere perceptual degradation. As neither condition was fulfilled in Experiment 1, no negative semantic priming was found, as predicted. Yet, although these conditions were fulfilled neither in Experiment 1 of Fox (1996) nor in Experiments 1 and 2 of Yee (1991), substantial negative semantic priming effects were found in some of the conditions of these experiments (see Table 1).

We hypothesize that imperfect matching of the small subsets of related and unrelated words used to measure priming and imperfect balancing of response transitions in Experiment 1 of Fox (1996) are the major determinants of her spurious effects, compared with the absence of effect in our present Experiment 1, in which these methodological inadequacies were corrected. Unfortunately, because of the unavailability of the original raw results and material, it was not possible to check these assumptions further and to carry out an exact replication of Fox's Experiment 1 using the original stimulus sequences. Examination of Yee's (1991) procedure does not reveal the same inadequacies as in Fox's Experiment 1. At present, we can conclude only that the conditions required for generating negative semantic priming were not met and that Neill et al. (1995, p. 229) briefly mentioned a failure to replicate Yee's results.

Alternative interpretations of the negative semantic priming effect have been proposed, but without having been as well spelled out as the interpretation based on persisting inhibition, which is the only one we have discussed so far. With respect to Yee's (1991) results, Milliken, Joordens, Merikle, and Seiffert (1998) wondered whether negative priming that requires probe selection in some experiments but not in others does not implement conditions in which the *temporal discrimination* process is strategically used, and May, Kane, and Hasher (1995) wondered whether negative semantic priming effects in the lexical decision task might be due to a process of *episodic retrieval*. We now examine each of these proposals in turn.

Temporal Discrimination Account of Negative Priming

The temporal discrimination account of negative priming proposed by Milliken and colleagues (Milliken & Joordens, 1996;

Milliken et al., 1998; Milliken, Lupiáñez, Debner, & Abello, 1999) departs in two major respects from the persisting inhibition account and from the episodic retrieval account that is discussed next. First, it builds on the rather unexpected finding that negative identity priming still occurs with nonconflicting primes followed by conflicting probes, which implies that an act of selection during prime processing is not a necessary condition for the phenomenon. Second, the role assigned to attention in generating negative priming occurs through the need to discriminate between the past—the action and/or response automatically retrieved from memory because of a recent episode in which the probe was involved—and the present—the response computed through controlled processing of the probe according to the instructions. Negative priming arises from conditions in which the distinction between the past and the present is made ambiguous by the experimental context. In such conditions, it is much safer to rely on the present (the actual probe target) than on the past (the instance of the target retrieved from memory) for controlling action.

Another unexpected finding is that negative identity priming occurs with severely masked nonconflicting primes of which participants are unaware (Milliken et al., 1998, Experiment 2; see also Neill & Kahan, 1999, for a partial replication). This is an apparent contradiction with the positive priming effect found by Allport et al. (1985), Marcel (1980), and Neill et al. (1995, Figure 8).[4] However, instead of using single-component primes followed by bicomponent probes as in Milliken et al., Marcel used single-component primes, albeit with multiple meanings, followed by single-component probes;[5] Allport et al. and Neill et al. used bicomponent conflicting primes followed by bicomponent conflicting probes. Moreover, the positive identity priming effect found by Neill et al. with masked flanker letters suggests that the finding of Milliken et al. may not generalize to unconscious distractors presented outside the focus of attention. Much empirical work is needed to determine the reliability of these various findings and to specify exactly how they are related to one another.

Not much else can be said about the remark made by Milliken et al. (1998) concerning Yee's (1991) finding (wondering whether the negative priming effect found with probes not requiring selection does not implement conditions in which the temporal discrimination process would be used). The remark was basically meant as an invitation for carrying out more empirical work on the role of probe selection in determining negative priming. Moreover, unless negative semantic priming can be demonstrated with nonconflicting primes followed by conflicting probes, the temporal discrimination process is a poor candidate for explaining a phenomenon that requires conflicting primes but not conflicting probes, as was shown by our analysis of the relevant data in the introduction.

Episodic Retrieval and Dual-Process Accounts

The early form of the episodic retrieval account proposed by Neill (Neill & Valdes, 1992; Neill, Valdes, Terry, & Gorfein, 1992) rests on an act of selection taking place during prime processing and on an automatic retrieval process triggered by the presentation of the probe. Negative priming is caused by a conflict between the automatically retrieved representation of the prime distractor associated with an *ignore* action tag and the positive action called for by the new instance of this distractor now recurring as a probe target.

Some support for the episodic retrieval account can be found in that the magnitude of negative priming depends on the overall structural similarity between the prime and the probe episodes. In Fox and De Fockert (1998) and Neill (1997), the prime distractor was physically identical to the probe target, making the situation optimal for successful automatic retrieval at the time of probe presentation. In fact, episodic retrieval is a form of implicit memory, as it depends neither on participants' deliberate attempt to retrieve the prime nor on an explicit comparison between the relevant target and the retrieved distractor. This has been demonstrated by equivalent negative priming whether participants were aware or unaware of the contingency between the prime distractor and the probe target (e.g., Driver & Tipper, 1989; Malley & Strayer, 1995; Neill & Valdes, 1992; Strayer & Grison, 1999). Implicit memory is heavily dependent on perceptual similarity (e.g., Roediger, 1990; Roediger & McDermott, 1993); it is seldom observed with semantic or categorical relations between the prime and the probe (see Moscovitch, Goshen-Gottstein, & Vriezen, 1994, for a review). In addition, even perceptual implicit memory is dependent on selective attention during prime processing (e.g., Crabb & Dark, 1999; Stone, Ladd, Vaidya, & Gabrieli, 1998) and on awareness of the prime at the time of its presentation (e.g., Hawley & Johnston, 1991).

It thus appears that episodic retrieval is not a likely explanation of negative priming in cases in which (a) the prime distractor and the probe target have different formats (e.g., word–picture, picture–word, and word–ink color), even if they have the same nominal identity; (b) the prime distractor is only semantically related to the probe target, even if both are words as in Fox (1996), Yee (1991), and the present study; and (c) the unattended prime distractor is made unavailable to awareness (see also Kane, May, Hasher, Rahhal, & Stoltzfus, 1997; May et al., 1995; Schooler, Neumann, Caplan, & Roberts, 1997; Tipper & Milliken, 1996; however, see Neill & Mathis, 1998, for a more optimistic view).

The remarks about Yee's (1991) finding made by May et al. (1995), concerning whether negative semantic priming effects were due to episodic retrieval, were cast in the framework of a dual-process theory (see also Kane et al., 1997) in which persisting inhibition plays the major role and episodic retrieval plays a more accessory role in determining negative priming, except in some specific circumstances. According to May et al., one such circumstance is when the probe requires a lexical decision, as is suggested by the work on positive semantic priming. May et al. were alluding to Neely's (1991) retrospective semantic-matching strategy even-

[4] Note that Neill et al. (1995) is a review article in which unpublished data showing a positive priming effect are briefly described.

[5] However, severely masked single-component prime words can generate negative semantic priming in the lexical decision task on a single-component probe letter string (Carr & Dagenbach, 1990; Dagenbach, Carr, & Wilhelmsen, 1989) and can generate negative identity priming (Kahan, 2000) in the naming of probe words, provided participants are induced to pay attention to the meaning of the prime words in the threshold-setting procedure preceding the experiment. Kahan (2000) forcefully argued that participants' deliberate attempt to extract the meaning or the identity of the masked word is crucial for these negative priming effects to occur. Neither Experiment 2 of Milliken et al. (1998) nor the experiments of Yee (1991) and of Fox (1996) satisfy this condition, as participants did not even notice that prime words were presented.

tually used by participants to help their binary decisions in tasks such as a lexical decision. However, the suggestion that the negative semantic priming effect found by Yee (1991) could have arisen from such a process conflicts with May et al.'s assertion that "retrieval induced by aspects of the test trial will be most successful when the prime trial is distinctive and its processing is not otherwise impeded" (p. 48). Clearly, this strategy cannot take place with unconscious primes. It is most probable that the inconsistencies in the position of May et al. stem from their not realizing that processing of the prime words in Yee's study was so severely impeded as to make them completely unavailable to awareness (cf. Table 1 and Footnote 3).

The only remaining question is whether our position should be amended in the light of the most recent theoretical stances on negative priming, other than the temporal discrimination account discussed above. In the dual-process theory proposed by May et al. (1995; see also Kane et al., 1997), and in the comparable position also espoused for a while by Tipper and Milliken (1996), persisting inhibition and episodic retrieval are assumed to have additive effects, with persisting inhibition playing the major role in most situations. For a time, Neill (Neill & Valdes, 1996) conceded that episodic retrieval might not explain all the available data and that persisting inhibition might play a minor role in some situations. Neill (Neill & Mathis, 1998) now suggests that his modified episodic retrieval theory based on the notion of transfer of inappropriate processing fares even better. Tipper (2001) claimed that the persisting inhibition and the episodic retrieval accounts are both inherently based on "forward-acting (encoding) and backward-acting (retrieval) processes" (p. 335). Neither the modified episodic retrieval theory of Neill and Mathis (1998) nor the modified persisting inhibition theory of Tipper (2001) count as dual theories, but they both allow for subtle interactions taking place between prime and probe processing. Yet for each of these revised theories, negative priming still depends on an act of selection taking place during prime processing, at least in most situations.

There are two results that show that our position may not need to be modified: There was no negative priming in Experiment 1 of Duscherer and Holender (2001), with readable primes presented 0.8° from fixation; Experiment 2 of the present article demonstrates that the unavailability to awareness of the prime words presented at a distance of 2.4° from fixation is simply due to perceptual degradation. Both results imply that we do not need to postulate more sophisticated selective processes or more subtle prime–probe interactions to account for the pattern of data observed in both our present and our related study (Duscherer & Holender, 2001).

Conclusions

From our review of the recent literature (see Table 1), it appears that negative semantic priming is found with competing primes followed by noncompeting distractors. Conversely, it was the discovery that nonconflicting primes followed by conflicting probes is sufficient to generate negative identity priming that prompted the development of the temporal discrimination framework (Milliken & Joordens, 1996; Milliken et al., 1998, 1999). Whether negative semantic priming could occur in such conditions is unknown because, to the best of our knowledge, it has not yet been investigated.

The two other explanations of negative priming—persisting inhibition and episodic retrieval—both require that selective attention take place during prime processing; none requires that selective attention take place during probe processing. Hence, both theories can explain negative semantic priming with prime distractors available to awareness. However, only persisting inhibition can account for negative semantic priming with unconscious distractors. If one adopts a dual-process theory based on both persisting inhibition and episodic retrieval, the conclusion would be the same: Both processes could contribute to negative priming with conscious prime distractors, but the episodic retrieval process would be disabled with unconscious distractors.

The pristine form of the persisting inhibition explanation of negative priming is sufficient to account for the results of this and our related study (Duscherer & Holender, 2001); it can also account for most of the results summarized in Table 1 and for the related results discussed in the introduction. Only the results of Yee (1991) and Fox (1996) cannot be explained in this way, but the results' validity and replicability is not yet demonstrated.

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