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SEMANTIC PRIMING FROM FLANKER WORDS: SOME LIMITATION TO AUTOMATICITY

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We explore under which conditions words flanking a centrally presented digit in the prime display can elicit semantic priming on the lexical decision to a subsequent letter string appearing at fixation about 1 sec later. No significant priming is found when the prime display requires an immediate odd/even classification of a digit (Experiment 1), a delayed recall of a digit (Experiment 3), or the detection of an infrequent change from the digit 4 to the letter A (Experiment 4). It is only in Experiment 2, in which nothing is presented at fixation during the prime display in positive lexical decision trials, that a positive semantic priming effect is found. These results are discussed in the framework of quantitative and qualitative limitations to processing automaticity.

The literature provides ample evidence that words presented visually within a few degrees from fixation are semantically processed. This is demonstrated with both Stroop-like interference tasks and with priming tasks. A flanker compatibility effect was observed in a modified version of the task devised by Eriksen and Eriksen (1974), in which participants classified a target word presented at fixation into one of four semantic categories, while ignoring simultaneously (Shaffer & LaBerge, 1979) or nearly simultaneously (Broadbent & Gathercole, 1990) presented flanker words belonging to the same or a different semantic category. Semantic priming effects were obtained from flanker words presented near fixation (instead of at fixation as in the standard procedure) in prime displays occurring well before the probe

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displays[1]. Depending on the parameters of visual presentation and on the task performed on the prime display, both positive (e.g., Den Heyer, 1985, 1986; Den Heyer, Goring, & Dannenbring, 1985) and negative (e.g., Fox, 1996; Yee, 1991) semantic priming effects have been observed.

The present study is a follow up of our previous work (Duscherer & Holender, 2002) based on a procedure set up by Fox (1996). On each trial of Experiment 1 of Fox (1996) and of our replication thereof, a prime display consisting of a central target digit flanked by a distractor word appearing twice, once above and once below the digit, was followed after a stimulus onset asynchrony (SOA) of about 950 ms by a probe display consisting of a letter string appearing at fixation. The flanker words in the prime display, which were preceded and followed by plus-sign masks, were presented for 150 ms at a distance of 2.4° from fixation. When the probe letter string was a word, it could be semantically related or unrelated to the flanker word. Participants made two consecutive responses. The first response was based on the outcome of a binary odd/even classification of the target digit in the prime display while ignoring the flanker words; the second response was based on the outcome of a word/pseudoword classification of the probe letter string (i.e., a lexical decision).

Fox's (1996) predictions were that most participants would be unaware of the identity and meaning of the flanker words and, because these 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 her data. However, the observation of strong negative semantic priming effects in three out of four conditions[2] in Fox's Experiment 1 appeared problematic and surprising to us, because the procedure did not fulfil the conditions we thought necessary for negative semantic priming from unconscious distractor words to occur (Duscherer & Holender, 2002). Here follows a brief summary of our argumentation.

Although doubts about the mere existence of negative semantic priming

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[1] In the studies concerned with negative priming, at least one, but generally both successive displays are two-component stimuli in which one component is a relevant *target* that has to be attended to and the other component is an irrelevant *distractor* that has to be ignored. We follow the standard terminology of the negative priming literature in calling the first display a *prime* and the second a *probe*, irrespective of whether both displays, only one display, or even no display at all contain two components (or attributes). The standard terminology of the positive priming literature, which is essentially based on single-component stimuli, is to call the first stimulus a prime and the second a target (see Neely, 1991 for a review).

[2] Strong negative semantic priming effects were found in the two within-language conditions and in one of the between-language condition of Fox's (1996) Experiment 1. Our replication involved only a within-language condition.

were cast by Fox (1995) and Damian (2000), our appraisal including later studies (Duscherer & Holender, 2002) led us to conclude that negative semantic priming should provisionally be taken as a genuine phenomenon. Moreover, it appears that a sufficient condition for negative semantic priming to occur is that a conflicting prime display is followed by a nonconflicting probe display. Therefore, both the persisting inhibition model (e.g., Tipper, 1985; Tipper & Cranston, 1985) and the episodic retrieval model (e.g., Neill & Valdes, 1992; Neill, Valdes, Terry, & Gorfein, 1992) can account for negative semantic priming with conscious prime distractors[3]. However, even a potentially competing distractor would loose its potency if it were presented in perceptually impoverished conditions preventing awareness of its identity and meaning, thereby removing any need for selection. It follows that the only way negative priming from unconscious prime distractors could occur is from a synergy between an act of selection taking place during prime processing and diversion of attention taking place immediately afterwards. As the retrieval process would be disabled in such a case, only the persisting inhibition model can account for negative semantic priming with unconscious distractors. This interpretation is germane to that offered by Tipper (1985) to account for the initial demonstration of negative semantic priming with unconscious prime distractors by Allport, Tipper, and Chmiel (1985).

With respect to the procedure implemented in Experiment 1 of Fox (1996), the crucial question is whether an act of selection is needed during prime processing. We surmised that covert naming is the most probable incipient response that would be automatically activated by the flanker words and that covert naming is competing neither with the binary odd-even classification task performed on the prime target digit, nor with the lexical decision performed on the probe letter string. Therefore, this procedure is inappropriate to generate negative semantic priming in any circumstances. Only positive priming is expected, the magnitude of the effect depending on the degree to which the flanker words are available to consciousness.

The first step in our investigation (Duscherer & Holender, 2002) was to replicate Fox's Experiment 1, while correcting for two methodological inadequacies consisting in an imperfect matching of the small subsets of related and unrelated words used to measure priming and in imperfect balancing of response transitions between the prime and the probe trials. We confirmed

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[3] A third major model of negative priming, the temporal discrimination model of Milliken, Joordens, Merikle, and Seiffert (1998) rests on the fact that a sufficient condition for negative identity priming to occur is that nonconflicting primes are followed by conflicting probes. Whether negative semantic priming can occur in such a condition has not yet been investigated.

that prime words presented 2.4° above and below fixation are mostly unavailable to consciousness, and we failed to get any priming effect, as expected. The second step in our investigation, which is reported in Experiment 1 of the present paper, was to move the prime words closer to fixation, at a distance of 0.8°, thus expecting a substantial increase in the availability to consciousness of these prime words, and the emergence of a significant positive priming effect. The first prediction was borne out by the results of Experiment 1 reported below, but the second was not. This absence of priming is in apparent contradiction with the positive priming effect found by Den Heyer (1985, 1986; Den Heyer et al., 1985) with a procedure somewhat similar to ours.

The aim of the present study is to investigate the reason why reportable prime words may fail to induce reliable positive semantic priming effects. Before proceeding, a few remarks are in order about the assessment of prime distractor availability to awareness. Fox (1996) relied on a surprise question replacing the probe of the last trial of the experiment. The question was whether participants could remember what was presented in the last display. Then, participants were interviewed about whether they had noticed anything above or below the digit in any trial. None of the 19 participants of Fox's Experiment 1 could name the flanker words of the last trial; only one participant reported awareness of words being presented during digit classification. In both the present and the previous study (Duscherer & Holender, 2002), we relied only on a postexperimental interview to assess participants' awareness of the flanker words.

The major advantage of the postexperimental assessment of awareness resides in the fact that it does not modify the economy of the task. The major drawbacks of this method are that it almost certainly underestimates the frequency with which participants are aware of the flanker words (see Holender, 1986), and that it does not allow to estimate accurately the proportion of trials in which participants are aware of the meaning of the flanker words at the time of their presentation. However, it should be noted that assessing awareness on a trial-by-trial basis also poses inextricable problems, especially in situations in which distractor word processing is resource limited (see Holender, 1986, especially Section 3.3 about parafoveal processing). We submit that the postexperimental interview is sufficient to distinguish between cases in which there is negligible awareness of the prime words, like in Fox (1996) and Duscherer & Holender (2002), and cases in which the proportion of trials in which participants are aware of the prime words is substantial enough to wonder why no priming occurs, like in the present study.

In fact, we will argue that flanker words presented 0.8° above and below fixation can loose their priming potency for reasons less trivial than mere perceptual degradation making most of them unavailable to awareness. In addition to sensory limitation due to flanker distance from fixation[4], there is now mounting evidence that both the capacity demands and the nature of a task performed concurrently with the display of the distractor words can affect the semantic processing of these words, or at least their potency to elicit semantic priming. With respect to quantitative limitation in processing, Lavie (1995; Lavie & Tsal, 1994) suggested that distractor processing is automatic only to the extent to which the relevant task performed on the target does not exhaust all the available capacity, a point that will be dealt with in the general discussion. With respect to qualitative limitation in processing due to the nature of the concurrent task, a long series of studies inaugurated by Smith, Theodor, and Franklin (1983) and Henik, Friedrich, and Kellog (1983) shows that positive semantic priming is reduced or eliminated if participants have to search the prime word for a letter (see also Hoffmann & MacMillan, 1985; Stolz & Besner, 1996, 1998; and see Maxfield, 1997; Neely & Kahan, 2001, for reviews). Similarly, colouring only a single letter instead of the whole word can reduce the Stroop effect (e.g., Besner & Stolz, 1999a, 1999b; Besner, Stolz, & Boutilier, 1997). Even more intriguingly, although abolishing semantic priming, the letter search task does not necessarily block conscious access to the meaning of the searched words. Maxfield (1997, p. 215) reported that "217 of 244 (approximately 89%) letter search subjects participating in our experiments have reported an awareness of the word relationships.... Some subjects continued to argue that they must have shown priming effects as they were sure that they were aware of the relationships as they were participating in the experiment" .

The existence of such a dissociation not only challenges the use of the priming paradigm to probe the semantic processing of unattended stimuli, but also the explanations of semantic priming based on a spreading activation process occurring prior to the conscious identification of the prime stimulus. Consequently, it is important to examine in which circumstances consciously identified words would induce either no priming at all, or only small, depleted effects. In Experiments 2 to 4, we investigated the possibility that the absence of semantic priming effect may be due to limitations in the automatic processing of the prime words generated by the task implemented on the target of the prime display.

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[4] Eriksen and Eriksen (1974; see also Driver & Baylis, 1991; Miller, 1991) have shown that distractor letters presented beyond 1° from a letter target induced little or no interference effects on a categorization task on that target. On the other hand, Broadbent and Gathercole (1990) observed semantic interference effects from distractor words presented as far as 2.6° from fixation.

Experiment 1

In our previous study based on Fox's procedure (1996), we (Duscherer & Holender, 2002) used a prime word distance of 2.4° from fixation, creating conditions in which participants were unaware of the flanker words. By using a prime word distance of only 0.8° from fixation in the present experiment, we enhance the sensory quality of the stimulus input, thereby increasing the probability that the prime words could be processed up to a semantic level and access awareness. If this manipulation succeeds, we expect positive semantic priming to occur.

Method

Participants. 32 undergraduate students at Université Libre de Bruxelles participated as part of a course requirement. Three extra participants were replaced: Two because more than 10% of their data were eliminated through the cut-off procedure (see below) and one because his error rate on the lexical decision task exceeded 10%. All participants had normal or corrected-to-normal vision, and for all participants French was their first language. Most of them were in their late teens or early twenties.

Stimuli. The material used in this and all the next experiments consisted of 64 French semantically related word pairs. 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, $p < .001$. The priming effect was slightly larger in the second (52 ms) than in the first (40 ms) half of the experiment, but this difference was not significant[5].

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 colour 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 same responses (Buttons 1 and 5 of the MEL response box) were used for both the prime digit classification and the probe word or pseudoword classification. The response mapping for the word or pseudoword classification was the same for all participants: pseudoword-left, word-right, while the response mapping for the digit classification (odd/even) was counterbalanced between participants. 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 0.8°. 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 grey on a black background, using the uppercase standard font of the computer. At a viewing distance of 60 cm, the visual angles subtended by the entire prime display were 2.2° in height, with each character subtending 0.52° in height in both the prime and the probe displays.

One experimental trial comprised the following consecutive events: (a) A

[5] The more common procedure in the semantic priming literature is to avoid within-participant repetition of any stimulus. However, if no repetition of the probe words is allowed, the set of words to be used in the related trials has to be matched very carefully with the set of words to be used in the unrelated trials, a methodological difficulty which we identified (Duscherer & Holender, 2002) as a potential artefact in Fox's (1996) procedure. Allowing the same words to serve in both the related and unrelated conditions overcomes this difficulty. The reason for avoiding stimulus repetition in priming experiments is partly stemming from the fear that the long-lived repetition priming effect shown in serial lexical decision tasks (e.g., Scarborough, Cortese, & Scarborough, 1977) could eventually hamper the short-lived semantic priming effect. Subsequent studies showed this fear to be little justified because associative priming and repetition priming have additive effects on performance, at least as long as there is only a single repetition of the prime and the probe words (Den Heyer et al., 1985; Durgunoğlu, 1988; Pitarque, Algarabel, & Soler, 1992; Wilding, 1986).

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 pseudorandomization 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 on the probe letter string. After the experiment, participants completed a questionnaire in which they were asked if they had noticed the presentation of the flanker prime words and the existence of any associations between the prime and the probe words.

Data analysis. For each participant, we first computed the mean RT and the standard deviation for all the responses falling in the 1- to 2000-ms time window for both the digit classification and the lexical decision task. 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 made an error neither in the digit classification nor in the lexical decision. Participants having more than 10% of their data eliminated through this cut-off procedure were replaced. Remaining participants having more than 10% of their data unavailable because of errors in either the digit classification, the lexical decision, or both, were also replaced. The data of main interest is the priming effect computed by subtracting the mean RT for related from the mean RT for unrelated trials. If anything, we expect only a positive semantic priming effect to occur. However, in order not to bias the issue, we performed a paired sample *t*-test between priming conditions in a bilateral way. Although the usual $p < .05$ probability of making the Type I error is used as a 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 $1 - \beta = .80$. No analyses were conducted on the error rates as those were generally very low (cf. Table 1).

Table 1. *Mean Reaction Times and Mean Standard Deviations (in ms), and Mean Error Percentages for the Lexical Decision*

	Experiment											
	1			2			3			4		
Trial Type	*M*	*SD*	*E*	*M*	*SD*	*E*	*M*	*SD*	*E*	*M*	*SD*	*E*
Related	615	85	3.5	583	57	1.1	610	53	1.6	577	70	2.2
Unrelated	619	89	3.9	607	47	2.1	615	54	1.6	580	70	2.0
Pseudoword	694	93	4.8	712	67	2.6	715	64	3.9	702	85	3.8
Overall RTs	655	87	4.2	641	53	2.1	663	55	2.8	627	72	3.0
Mean Effect	4			24*			5			3		
SE	3.5			5.1			2.9			2.9		

Note. The priming effect was computed by subtracting the mean reaction time for related from that of unrelated trials.
RTs = reaction times.
* p < .05.

Results and Discussion

The cut-off procedure entailed an overall elimination rate of 3.0% of the trials. Table 1 shows the average and the standard deviation of the individual mean RTs, and the average of the individual error rates for each type of probe display—semantically related, semantically unrelated, and pseudowords—as well as the overall results for the lexical decision task. In the digit classification task, the mean RTs for the odd and the even digits were 593 ms (SD = 122, error rate = 2.0%), and 601 ms (SD = 123, error rate = 2.2%), respectively. The 4-ms (SD = 19.9) positive priming effect computed by subtracting the mean RT for the related (M = 615 ms) from that of the unrelated trials (M = 619 ms) was not significant, $t(31) = 1.20$, $p = .24$. Note that this failure to reach significance was not due to the repetition of the word material, as no significant priming effect was observed either in the first (-2 ms; $t(31) = .03$, $p = .98$) or in the second (8 ms; $t(31) = 1.52$, $p = .14$) half of the experiment. A priming effect of 10 ms in absolute value was needed to reach a power of .80. Out of 32, 19 participants reported they could often read the prime words; 13 of them even noticed that sometimes the prime and the probe words were semantically related.

As expected, the reduction of flanker word distance from fixation increased the availability of the prime words to awareness: While not a single participant had been aware of the flanker words presented 2.4° from fixation in Experiment 1 of our previous study (Duscherer & Holender, 2002), more than half of the participants in this experiment were aware of the fact that flanker words were presented 0.8° from fixation[6]. However, while we succeeded in increasing the availability of the prime words to awareness, we failed to get the expected concomitant positive priming effect.

Why did the reportable flanker words fail to induce a significant positive priming effect? One trivial possibility is that only a very small proportion of these prime words was actually available to awareness. However, the 19 participants who claimed awareness of the flanker words were confident about having read many of them. Yet, neither the subgroup of 13 participants who were also aware of the possible semantic relation between the flanker words and the probe words, nor the subgroup of 13 participants not reporting any awareness of the flanker words, did show significant priming effects (nonsignificant effects of 6 and 8 ms, respectively). Hence, it does not appear that the small,

[6] We want to stress that while extreme caution should prevail for assessing participants' *un*awareness through a postexperimental report (cf. Holender, 1986), we *do* trust our participants when they state to be *aware* of flanker words, and even more so, when they are able to report a large number of them.

nonsignificant priming effects of Experiment 1 can simply be explained by insufficient processing of perceptually impoverished flanker words.

As noted in the introduction, positive semantic priming was obtained by Den Heyer (1985, 1986; Den Heyer et al., 1985) with prime displays similar to ours in terms of the distance from fixation of the flanker words. However, there are two major differences between the two experimental set-ups. In Den Heyer's situation, the flanker words remained visible for more than 1000 ms, first with the central position left vacant for the initial 550 ms, and then concurrently with the central target letter string staying on until the response. In our Experiment 1, the masked flanker words were displayed for only 150 ms, and followed by an unflanked probe letter-string after an average SOA of about 950 ms. In addition, the central position of the prime display was occupied by a digit calling for an overt classification response. As both the nature and the capacity demands of the task performed during the prime display can eventually lead to a dissociation between the identification of the meaning of the distractor words and their potency to induce semantic priming effects (Maxfield, 1997), the following three experiments were aimed at disentangling the reasons why positive semantic priming was obtained by Den Heyer, but not by us in Experiment 1.

Experiment 2

In Experiment 2, we simply suppressed the target digit from most prime displays, which makes our situation more similar to that of Den Heyer, while keeping all the other procedural details identical to those of Experiment 1. However, in order to encourage participants to maintain fixation, we presented a central digit in one third of the pseudoword trials (i.e., in one sixth of the trials, overall) and asked participants to keep fixation in order to be able to report any occurrence of such a digit. The digit recall-prompt always followed the lexical decision on the probe letter-string.

Method

Participants, stimuli, and apparatus. Thirty-two students from the same pool as in the other experiments were selected. None of them were involved in any other experiment. Two extra participants, having more than 10% of their data eliminated through the cut-off procedure were replaced. The same stimuli and apparatus were used as in Experiment 1.

Design and procedure. The only difference with the previous experiment is that no central digit was presented in the prime display except in one sixth of the trials. Digits were never presented in the critical trials leading to a positive lexical decision, but only in one third of the non-critical trials in which the probe was a pseudoword. We used a 1000-ms constant SOA between the prime and the probe because there was never any immediate response required to the prime display. Participants were asked to keep fixation in order not to miss any digit that might appear in the prime display. They had always 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 main data analysis was the same as in Experiment 1, except that the pseudoword data corresponding 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 calling for a negative lexical decision.

Results and Discussion

The cut-off procedure entailed an overall elimination rate of 1.4%. Digit report was nearly perfect, being of 98.9%. The results of the lexical decision task are shown in Table 1. A significant positive semantic priming effect of 24 ms (SD = 29.1), $t(31) = 4.66$, $p = .0001$ was found, the mean RTs being 583 ms and 607 ms for the related and unrelated trials, respectively, with a significant effect emerging both in the first (18 ms; $t(31) = 2.8$, $p = .008$) and in the second (31 ms; $t(31) = 4.9$, $p = .0001$) half of the experiment. A priming effect of 15 ms in absolute value was needed to reach a power of .80. All participants reported that they could have read at least some of the flanker primes and all but three had noticed that sometimes the prime distractor and the probe were semantically related.

We observed a positive semantic priming from flanker words close enough to fixation to be available to awareness. However, this was achieved only by making radical changes in the prime display. In Experiment 1, the prime flanker words were always accompanied by a central digit that had to be attended to. This digit had to be identified and mapped onto a response according to an unfamiliar rule, and the classification response had to be executed. By contrast, in Experiment 2, the fixation position of the prime display was left vacant on all the critical trials in which the probe was a word. Hence, no information had to be processed and no response had to be executed during the prime presentation of these trials. To determine which of these two differences between the critical trials of Experiments 1 and Experiment 2 are responsible for the presence or absence of a significant positive priming effect, we carried out two additional experiments.

Experiment 3

In Experiment 3, a single digit (out of a set of four) was always presented at fixation in the prime display. Participants had to identify and to memorize this digit, as they could be asked to report it later in the trial, after the lexical decision was completed. Hence, in Experiment 3, the prime display was identical to the one used in Experiment 1; still, like in Experiment 2, no overt response had to be executed during the prime display. With respect to the overall incentive of keeping fixation as requested, Experiment 3 is similar to Experiment 2 in that participants had to report the prime digit after completion of one sixth of the trials (i.e., one third of the negative lexical decisions). However, in Experiment 2, the uncertainty was about whether a digit would appear at all, whereas in the present experiment, the uncertainty was about whether recall of the digit would be requested at all.

Method

Participants, stimuli, and apparatus. Thirty-two students were drawn from the same pool as in Experiment 1. None of these students participated in any other experiment based on the same material and procedure. Two extra participants, exceeding 10% of errors in the lexical decision task were replaced. The same stimuli and apparatus were used as in Experiment 1.

Design, procedure, and data analysis. The design and procedure were similar to those of Experiment 1, except that no immediate classification response was required to the central digit. Participants were asked to hold the digit into memory because they could be asked to report it after the lexical decision was completed. This happened in one third of the trials in which the probe was a pseudoword. On those trials, a prompt consisting of the word *rappel* (English 'recall') was shown immediately after the probe response was made. The data analysis was the same as in Experiment 1 (i.e., all the pseudowords were included).

Results and Discussion

The cut-off procedures entailed an overall elimination rate of 1.6% of the trials. Digit recall was nearly perfect, being of 97.1%. The results of the lexical decision task are shown in Table 1. The 5-ms (SD = 16.4) difference between the related (M = 610 ms) and the unrelated trials (M = 615 ms) was not significant, $t(31) = 1.70$, $p = .10$. No significant priming was observed either in the first (5 ms; $t(31) = .95$, $p = .34$) or in the second (6 ms; $t(31) =$

1.38, $p = .17$) half of the experiment. A priming effect of 8 ms in absolute value was needed to reach a power of .80.Twenty-two participants out of 32 reported that they were sometimes able to read the flanker words in the prime display; 16 of them noticed the semantic relatedness existing between some of the prime and probe words.

The results of Experiment 3 are similar to those of Experiment 1 both in terms of the proportion of participants aware of the semantic priming procedure and in showing a small, nonsignificant positive semantic priming effect. Thus, it appears that semantic priming is equally depleted by the execution of a digit categorization response immediately on presentation, like in Experiment 1, and by memorization of this digit for later recall, like in the present Experiment 3.

Experiment 4

Experiment 4 is an attempt to render the prime target task even less demanding. Instead of one out of four possible digits, the same digit *4* was presented at fixation in all the prime displays, except for one third of those preceding a pseudoword probe, in which the letter *A* was presented instead. Participants had to detect these occurrences and to name the letter *A* immediately on presentation while trying not to slow down in their lexical decision to the probe. Like Experiments 1 and 3, Experiment 4 involved a visual event consisting of a single character presented at fixation during all prime stimuli. However the discrimination of *A* from *4* probably requires less processing resources than the identification and memorization of one among four digits. Like in Experiments 2 and 3, no response was required to the prime targets of the critical trials of Experiment 4. Overall incentive to keep fixation was also the same as in Experiments 2 and 3 because the letter *A* occurred in one sixth of the trials overall, that is, in one third of the noncritical trials in which the probe was a pseudoword.

Method

Participants, stimuli, and apparatus. Thirty-two students were drawn from the same pool as in Experiment 1. None of these students participated in any of the other experiments. The same stimuli and apparatus were used as in Experiment 1.

Design and procedure. Instead of one out of four possible digits as in Experiments 1 and 3, only the digit *4* was presented at fixation during the prime display except for one third of the pseudoword trials in which the letter *A* was presented. Participants were instructed to name this letter as fast as possible as soon as it was presented. They were asked to try not to miss any letter and not to slow down on the following lexical decision. No response, either immediate or delayed, was required to the prime displays in which the digit *4* was presented.

Data analysis. The main data analysis was the same as in the other experiments except that, like in Experiment 2, the pseudoword data corresponding to the noncritical trials in which the letter *A* was presented in the prime display were not taken into account. Hence, the mean RT for the pseudowords was estimated from two thirds of trials in which the probe called for a negative lexical decision.

Results and Discussion

The cut-off procedures entailed an overall elimination rate of 1.4% of the trials. 99.2% of the occurrences of letter *A* were detected. The results for the lexical decision are shown in Table 1. The 3-ms (SD = 16.6) priming effect computed by subtracting the mean RT for the related (M = 577 ms) from that of the unrelated trials (M = 580 ms) was not significant, $t(31) = 1.18$, $p = .25$. The first half of the experiment produced a significant priming effect of 8 ms, $t(31) = 2.52$, $p = .017$, whereas the –1 ms-effect of the second half was not significant; $t(31) = .16$, $p = .873$. A priming effect of 8 ms in absolute value was needed to reach a power of .80. Eighteen participants out of 32 reported that they were sometimes able to read the flanker primes; fifteen of them noticed the semantic relatedness existing between some of the prime and probe words.

Again no significant positive semantic priming from flanker words close to fixation is obtained, although, like in Experiment 1 and 3, nearly half of the participants were aware of the semantic relations sometimes existing between the prime and the probe words.

Comparison Between Experiments

The four experiments reported in this article all have a common underlying structure, which corresponds to the standard procedure used in the investigation of semantic priming in the lexical decision task, except that the prime words were presented twice as flanker distractors instead of once under the focus of attention (i.e., at fixation). They differ in terms of the supplementary task performed on a prime target presented at fixation. Table 2 specifies all the important characteristics of the supplementary task in terms

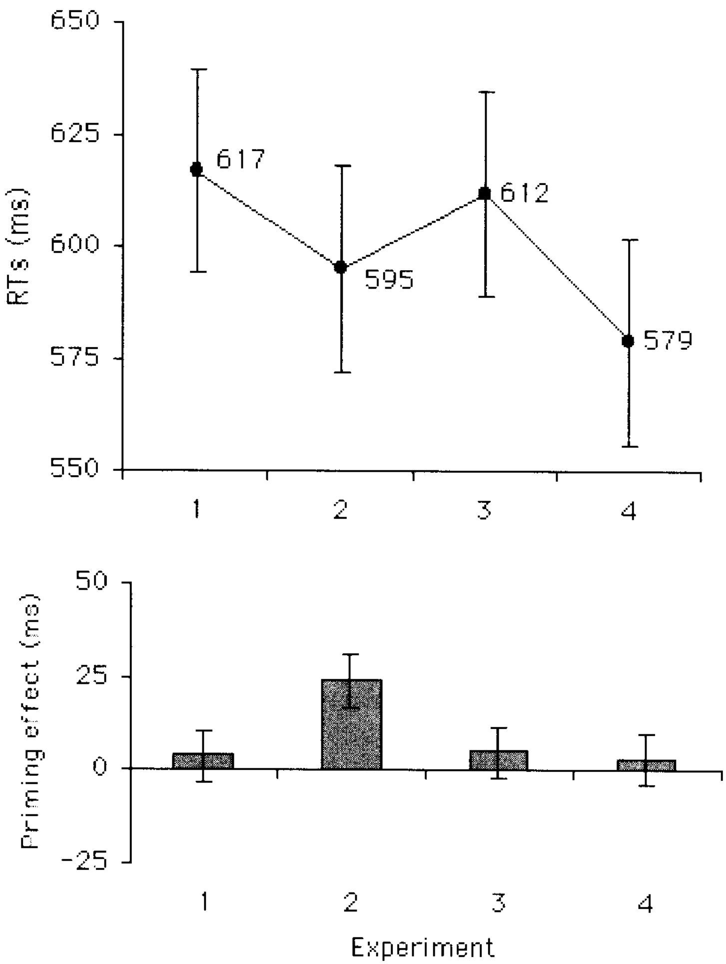

Figure 1. Overall mean RTs for the positive lexical decision (upper part) and mean priming effects (lower part) in each experiment. The error bars indicate the 95% confidence intervals for between-subject designs based on the pooled estimate of the within-condition variance (with 124 *df*).

Table 2. *Type of Prime Target and Type of Task Requirements in each Experiment*

	All trials		Trials with word probes	
Experiment	Type of prime target	Task requirements	Type of prime target	Task requirements
1	*4, 5, 6,* or *7* (100%)	Identification + immediate classification (100%)	*4, 5, 6,* or *7* (100%)	Identification + immediate classification (100%)
2	Blank (83%) vs. *4, 5, 6,* or *7* (17%)	Monitoring (100%) + Identification and delayed recall (17%)	Blank (100%)	Monitoring (100%) for a digit
3	*4, 5, 6,* or *7* (100%)	Identification and memorization (100%) + delayed recall (17%)	*4, 5, 6,* or *7* (100%)	Identification and memorization (100%)
4	*4* (83%) vs. *A* (17%)	Monitoring (100%) + immediate target detection (17%)	*4* (100%)	Monitoring (100%) for an *A*

Note. The percentages in parentheses indicate the frequency with which each type of prime target is presented and the frequency with which each type of process and action are called for in dealing with the prime target.

of (a) which possible stimuli are presented at fixation in the prime display, and (b) which processes and which immediate or differed actions are called for in dealing with the prime target according to the specific instructions given in each experiment. The left part of Table 2 provides this information for the task as a whole; the right part of the table restricts this information to the trials in which the probe is a word, that is, the trials from which the semantic priming effect is computed.

The upper part of Figure 1 shows the average RT obtained by collapsing over the related and unrelated probe words in the four experiments, disregarding the pseudoword trials[7]; the lower part of Figure 1 shows the corresponding mean priming effects. In both graphs, the error bars indicate the overall 95% confidence intervals, computed following Equation 1 of Loftus and Masson (1994) for between-subject designs, which is based on the pooled estimate of the within-condition variance (with 124 *df*).

How do the different prime target tasks affect the absolute level of performance in the subsequent lexical decision on the probe? Examination of the upper part of Figure 1 shows that there is no statistical difference between the mean RTs for the positive lexical decision in Experiments 1 and 3, both experiments requiring the identification of one out of four possible prime target digits, whereas the mean RT is significantly shorter in Experiment 4

[7] We prefer to evaluate the absolute level of performance on trials in which the target is a word instead of on all trials because the negative lexical decision is based on different proportions of pseudowords in different experiments (100% in Experiments 1 and 3 vs. 67% in Experiments 2 and 4), and because priming is assessed on word probes only. In any case, an analysis performed on the overall RTs (including the pseudowords) shown in Table 1, yielded the same results.

requiring a simpler discrimination between one possible digit and one possible letter. Experiment 2, requiring to monitor the empty prime target position for identifying infrequent (17% of the trials) target digits, occupies an intermediate, ambiguous, position in having a mean RT statistically different neither from the slower mean RTs in Experiments 1 and 3, nor from the faster mean RT in Experiment 4.

The grouping of the experiments in terms of priming is, however, different from that based on overall mean RT for the positive lexical decision. As can be seen in the lower part of Figure 1, significant semantic priming is found only in Experiment 2, whereas there is no significant priming in Experiments 1, 3, and 4. It has to be noted that the very same grouping of experiments is also found with respect to awareness of the prime words and of the prime-probe contingency. In Experiment 2, all the 32 participants were aware of the prime flanker words, 29 of them also being aware of the prime-probe contingency. By contrast, only 19, 22, and 18 participants were aware of the prime flanker words in Experiments 1, 3, and 4, in that order, with, respectively, 13, 16, and 15 of them also being aware of the prime-probe contingency. It thus appears that the reduction in processing of the prime distractor is observed in both the slower (Experiments 1 and 3) and the faster (Experiment 4) positive lexical decision, whereas Experiment 2 occupying an intermediate position shows both positive semantic priming and a higher level of awareness of the prime distractor words and of the prime-probe contingency. Hence, we can rule out that the presence or absence of significant priming effects stem from differences in the absolute level of performance for carrying out the lexical decision on the probes.

Before interpreting these results, two remarks are in order about the failure to get significant priming effects in Experiments 1, 3, and 4. First, this is not due to a lack of power. Priming effects of 10 ms in Experiment 1 and of 8 ms in Experiments 3 and 4 are needed to reach a power of .80 (compared to 15 ms in Experiment 2). Second, we do not take this lack of statistical significance as evidence that there is no priming at all. In the complete absence of priming, small effects of both signs would have been found. Rather, we think that the positive effects of 4, 5, and 3 ms found respectively in Experiments 1, 3, and 4 reflect genuine positive priming, the effects being simply too small to reach significance. Actually, in averaging over the 96 participants of Experiments 1, 3, and 4, the 4-ms overall effect was significant, $t(95) = 2.35, p < .05$.

General Discussion

We investigated under which conditions semantic priming could be obtained from prime words presented at a distance of 0.8° from fixation. We observed no significant priming effect in Experiment 1, in which participants had to classify a target digit appearing at fixation in all prime displays. Similarly, no significant priming effects were found in Experiments 3 and 4, which differed mainly from Experiment 1 by requiring no immediate response to the prime target when the probe was a word, but in which a target character (generally a digit, but sometimes a letter in Experiment 4) was always presented at fixation. It was only in Experiment 2, with no target at all presented at fixation in the prime display of the critical trials in which the probe was a word, that we were able to get the expected positive semantic priming effect.

The positive semantic priming effect found in Experiment 2 confirms the results obtained by Den Heyer (1985, 1986; Den Heyer et al., 1985). This result is little unexpected in view of the close similarity between the procedure used in Experiment 2 and that used by Den Heyer and collaborators. Experiment 2 can thus be considered as a baseline showing that our procedure is appropriate for generating positive semantic priming, at least in these specific conditions.

In all other experiments, a supplementary task performed on a prime target presented at fixation seems to impede, or at least to reduce, this priming effect. One tentative explanation of this observation—stemming from the studies centred on qualitative limitations to automatic processing—is that no semantic priming occurs because participants' attention was not directed to the meaning of the prime words at the moment of their encoding (e.g., Smith et al., 1983). An alternate point of view we want to consider is that there may also be quantitative limitations to automaticity, that is, the absence of semantic priming effects from reportable distractor words may be explained by a lack of processing resources during the encoding of the prime words.

In fact, Lavie (1995, Lavie & Tsal, 1994) suggested that distractor processing is automatic only to the extent to which the relevant task performed on the target does not exhaust all the available capacity. As long as target processing leaves spare capacity, processing of the irrelevant information is automatic in the sense of being irrepressible, that is, not under voluntary control. In contrast, if insufficient resources are available to guarantee both the processing of task relevant and task irrelevant information, resources are allocated in priority to the relevant target processing. Until now, Lavie has been mainly interested in testing the impact of *perceptual load* on perceptual processing defined as processing leading to stimulus identification. Her research strategy consists in manipulating the perceptual load of the target in modified versions of the letter flanker task of Eriksen and Eriksen (1974), while keeping all the other task requirements constant. Distractor processing is thus considered more unlikely under conditions of high perceptual load (e.g., with complex stimulus displays or with resource-demanding target tasks) than under conditions of low perceptual load (e.g., with simple stimulus displays or with target tasks requiring only shallow perceptual processing). Indeed, Lavie succeeded in eliminating distractor interference effects by increasing the number of nontarget elements in the attended region of the display, or by varying the processing requirement of the attended target-nontarget discrimination task (Lavie, 1995, 2000; Lavie & Cox, 1997; Lavie & Robertson, 2001; Rees, Frith, & Lavie, 1997; see also Handy, Soltani, & Mangun, 2001; Kumada & Humphreys, 2002).

Both the reportability and the priming potency of the distractor words is increased when less—with no prime target in Experiment 2—rather than more—with digit classification in Experiment 1—processing capacity is diverted by the relevant task in the prime display. More specifically, the comparison between Experiments 2 and 4 provides some evidence for the role of perceptual load in prime processing. As can be seen in the right part of Table 2, both experiments require monitoring the prime display for detecting a target, but differ for the relevant experimental trials (i.e., the word probe trials) in terms of the perceptual load of the prime display: While no stimulus is presented at fixation in Experiment 2, in Experiment 4 the digit *4* is always presented at fixation. Thus, it is tempting to attribute both the presence of positive priming and of a high level of report of the prime to the low perceptual load of the prime display in Experiment 2, whereas both the absence of priming and the depleted level of report of the prime flanker words would be attributed to the higher perceptual load of the prime display in Experiment 4[8]. This tentative account of the results is consonant with other studies from the literature showing that primes that are reportable at the time of their presentation may cause no immediate positive semantic priming (Maxfield, 1997), no delayed repetition priming (Stone, Ladd, Vaidya, & Gabrieli, 1998, Experiment 1), and leave poor episodic memory traces (Stone et al., 1998, Experiments 2 and 3).

By contrast, in our previous work (Duscherer & Holender, 2002) with flanker words farther away from fixation, the manipulation of the capacity

[8] Besides the requirement to process an additional stimulus at fixation, both experiments differ in the specific nature of the prime task. However, it has to be noted that monitoring a blank field for the appearance of a digit (Experiment 2) is probably less capacity demanding than discriminating the presentation of the letter *A* from that of the digit *4* (Experiment 4) and that no significant difference in the overall level of performance for the positive lexical decision is observed between these experiments (see upper part of Figure 1).

that has to be invested on the prime target had no influence on priming, which was null in Experiments 1 and 2, and had little influence on flanker word reportability[9]. Hence, in keeping the other parameters of visual presentation constant (i.e., flanker duration, pre- and postmasking), increasing the distance from fixation of the flanker words from 0.8° (Experiments 1 and 2, present study) to 2.4° (Duscherer & Holender, 2002) suffices to shift the processing of these words from the resource-limited to the data-limited region of the performance-resource function (see Norman & Bobrow, 1975).

Before concluding, we have to discuss two apparent discrepancies between some of our results and some of the results obtained by Marí-Beffa, Fuentes, Catena, and Houghton (2000) in their Experiment 1. Their procedure was similar to that of our Experiment 1, except that both the prime and the probe display consisted of a centrally presented letter string (instead of a digit here) flanked above and below by a distractor word repeated twice, at a distance of 0.95° from fixation (comparable to the 0.8° used here). When the probe target was a word, it could be semantically related or unrelated to either the prime target or the prime distractor. The task on the probe target was a lexical decision; the task on the prime target was a lexical decision in one group of participants and a letter search in the other group. There was a strong 35-ms positive semantic effect stemming from the prime target requiring a lexical decision that was reduced to a non-significant 15-ms effect in the letter search condition. This is just another confirmation of the fact that semantic priming stemming from an attended prime word can be reduced or abolished if this word is searched for a specific letter (see also Hoffman & MacMillan, 1985, Experiments 2 and 3). Turning now to the results we want to discuss, there was a significant 17-ms *negative* semantic priming effect stemming from the prime distractor word when a lexical decision was performed on the prime target, that reversed into a strong positive semantic priming effect of 39 ms when a letter search was performed on the prime target.

The first apparent discrepancy is between the positive semantic priming

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[9] In Experiment 2 of Duscherer and Holender (2002), 11 participants out 32 were aware of the presentation of flanker words, 4 of them also being aware of the prime-probe contingency. However, all these participants attributed their ability to read some prime words to their occasional checking for the parafoveal content through gaze shifting. All of these participants were convinced that without shifting gaze they could not have become aware of the presentation of flanker words. Were it not from these participants' commentaries gathered in the postexperimental interview, and considering that only 17% of the trials involved a to-be-reported target digit, the adoption of such a strategy would probably have passed unnoticed by us. In the present study, with flanker words closer to fixation, no participants in Experiment 2, or in any of the other 3 experiments, ever made such comments for justifying their ability to read some flanker words and to become aware of the prime-probe contingency.

effect stemming from the flanker words when the prime target was searched for a letter in Experiment 1 of Marí-Beffa et al. (2000) and the absence of such priming when the prime target digit was classified as odd or even in our Experiment 1. One possible explanation for this discrepancy lies in the fact that our pairs of words were related only by association whereas those of Marí-Beffa et al. were related both by association and by their semantic category membership. Maxfield (1997, see also Smith, Bentin, & Spalek, 2001) mentioned unpublished data from her own research showing that searching the attended prime for a letter abolishes semantic priming completely when the prime-target relation is exclusively associative, whereas it only reduces semantic priming when this relation is semantic/categorical. Another possible explanation is in terms of the capacity demands of flanker words processing. It is likely that less resources are required for word processing in Experiment 1 of Marí-Beffa et al., in which all the words belonged to four semantic categories used repeatedly, with each individual words repeated 5 or 6 times, whereas disparate words were repeated only twice in our Experiment 1 (see Broadbent & Gathercole, 1990). Moreover, the prime display was easier to process in the experiment of Marí-Beffa et al., because it was presented unmasked until the participants responded to the prime target, than in our experiment, in which it was it was presented for only 150-ms and masked.

The second apparent discrepancy is between the negative semantic priming effect obtained when a lexical decision was performed on the prime target in Experiment 1 of Marí-Beffa et al. (2000) and the positive semantic priming effect found both when the prime target was searched for a letter in Experiment 1 of Marí-Beffa et al. and when the prime target position was monitored for the presence of a digit in our Experiment 2.

To explain this discrepancy, we shall rely on our previous analysis (Duscherer & Holender, 2002) showing that a necessary condition for negative semantic priming to occur is that an act of selection takes place during prime processing, in order to prevent the prime distractor from controlling action. This is clearly demonstrated by the fact that when a prime target word has to be selected from an adjacent distractor, in order to be recalled later, either no priming or negative semantic priming is found (Ortells, Abad, Noguera, & Lupiáñez, 2001; Ortells & Tudela, 1996, Experiment 2), whereas either no priming or positive semantic priming is found when participants simply have to pay attention to the prime word, without being instructed to perform any task on it (Fuentes, Carmona, Agis, & Catena, 1994; Fuentes & Tudela, 1992; Ortells & Tudela, 1996, Experiment 1).

Thus, for explaining negative semantic priming in Experiment 1 of Marí-Beffa et al. (2000) with a lexical decision performed on the prime target, we have to assume that sometimes participants could not help performing the lexical decision on the prime distractor as well[10], which entails that they had to prevent this irrelevant covert "word" decision from controlling the response to the prime target. In contrast, when the prime target had to be searched for a predesignated letter in Experiment 1 of Marí-Beffa et al. or when the prime target position was monitored for the presence of a digit in our Experiment 2, the most probable covert response elicited by the distractor word, if any, would be a naming response. As this incipient naming response is not assumed to compete with the binary decision on the prime target, no negative semantic priming is expected in such conditions. In these conditions, only positive semantic priming is expected, and actually found, provided the perceptual load of either the prime distractor words (in Experiment 1 of Marí-Beffa et al.) or of the prime target position (in our Experiment 2) is not too high. If, however, the task on the prime target is more capacity demanding, while still eliciting no competing covert response from the distractor words, like in our Experiments 1, 3, and 4, only small, nonsignificant, positive priming effects are found.

To conclude, our finding that semantic activation up to conscious identification of a substantial proportion of the prime words (Experiments 1, 3, and 4) does not necessarily cause significant semantic priming effects clearly questions the existence of strong automatic priming processes. Moreover, these results refute an eventual interpretation of the lack of semantic priming with parafoveal prime words or with an additional prime task in terms of an impairment of the visual feature integration process (cf. Neely & Kahan, 2001), as both in the present study and in the experiments discussed by Maxfield (1997), no significant priming effects were obtained with reportable prime words.

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[10] See Holender (1992) and Duscherer, Holender and Molenaar (2003) for some spelling out of the idea that participants covert verbal recoding of the irrelevant aspects of the situation in terms similar to those used in the instructions for defining the task can generate congruity effects (see also Clark, Carpenter, & Just, 1973; and Logan & Zbrodoff, 1999, for related ideas).

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