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Semantic Processing of Foveally and Parafoveally Presented Words in a Lexical Decision Task

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Using a lexical decision task in which two primes appeared simultaneously in the visual field for 150 msec followed by a target word, two experiments examined semantic priming from attended and unattended primes as a function of both the separation between the primes in the visual field and the prime–target stimulus-onset asynchrony (SOA). In the first experiment significant priming effects were found for both the attended and unattended prime words, though the effect was much greater for the attended words. In addition, and also for both attention conditions, priming showed a tendency to increase with increasing eccentricity (2.3°, 3.3°, and 4.3°) between the prime words in the visual field at the long (550 and 850 msec) but not at the short (250 msec) prime–target SOA. In the second experiment the prime stimuli were either two words (W–W) or one word and five Xs (W–X). We manipulated the degree of eccentricity (2° and 3.6°) between the prime stimuli and used a prime–target SOA of 850 msec. Again significant priming was found for both the attended and unattended words but only the W–W condition showed a decrement in priming as a function of the separation between the primes; this decrement came to produce negative priming for the unattended word at the narrow (2°) separation. These results are discussed in relation to the semantic processing of parafoveal words and the inhibitory effects of focused attention.

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Semantic processing of unattended information has generally been a crucial point of argument among theories of selective attention. Favoured by late selection theories in the 1960s (Deutsch & Deutsch, 1963) it has been strongly advocated by defenders of automatic processes in human information processing (e.g. LaBerge, 1975; Posner, 1978). Recently, however, new evaluations of the experimental evidence have appeared that cast serious doubts about the contention that stimuli outside the focus of attention undergo semantic processing (e.g. Johnston & Dark, 1986; Kahneman & Treisman, 1984).

Kahneman and Henik (1981) and Kahneman and Chajczyk (1983) have shown that the effect of semantic interference usually found in the Stroop task can be seriously affected by the spatial allocation and intentional direction of attention. Based on these results, Kahneman and Treisman (1984) have interpreted Stroop interference as demonstrating that people do not easily ignore irrelevant properties of an attended object rather than as a failure of selective attention or as evidence that semantic processing can occur automatically (Posner & Snyder, 1975). In Kahneman and Treisman's view, it is essential to distinguish selection of objects from selection of properties; observers may be capable of efficient rejection of irrelevant objects but the irrelevant properties of an attended object cannot be prevented from being processed. It follows from this view that semantic processing of an attended word cannot be avoided, but semantic processing of an unattended word cannot be expected if attention is focused on a different relevant word.

Johnston and Dark (1986) have recently reviewed the experimental literature on selective attention and come to the conclusion that stimuli outside the spatial focus of attention undergo little or no semantic processing. This conclusion stemmed in part from experiments where semantic priming did not obtain when primes were presented at irrelevant locations (e.g. Dark, Johnston, Myles-Worsley, & Farah, 1985). Johnston and Dark (1986) held the view that attention acts as an adjustable-beam spotlight with stimuli outside the spotlight receiving little or no processing, except for the simple physical features.

The present research was initiated to study the semantic processing of unattended words when they are presented parafoveally in the visual field. Two main experimental arrangements of the stimuli can be distinguished in the experimental literature related to this issue. In one of them the "to-be-responded-to" target and the parafoveal prime word(s) are presented simultaneously on the same visual display, and the distance between the prime word(s) and the target is manipulated. In the second, a prime display containing the word(s) is first presented and followed by a second display with a target on it. Under this second arrangement there are two conditions. In one, a single prime word is used, usually presented separated from the fixation point along the horizontal or vertical axis of the display; in the other there are two primes, one presented parafoveally and the other at the fixation point. A short review of the main findings under each of these prototypical experimental conditions will help to frame the present research.

Studies with simultaneously presented target and parafoveal words have employed several different tasks: colour naming in a modified Stroop task (Gatti & Egeth, 1978; Kahneman & Chajczyk, 1983; Merikle & Gorewich, 1979), word naming (Dallas & Merikle, 1976), picture naming (Underwood, 1976), lexical decision (Underwood & Thwaites, 1982; Underwood, Rusted, & Thwaites, 1983), and word categorization (Shaffer & LaBerge, 1979; Underwood, 1981). In all these studies semantic processing of the parafoveally presented words was inferred from the subject's response to the foveal target. To the extent that this response was facilitated or inhibited by the semantic relationship between the parafoveal word and the foveal target, semantic processing of the former was considered as established. Interference is the most commonly reported finding when subjects are instructed to focus on the target and ignore the parafoveal word (Gatti & Egeth, 1978; Merikle & Gorewitch, 1979; Underwood, 1976; Underwood & Thwaites, 1982; Underwood et al., 1983). When semantic facilitation has been found, either distribution of attention was fostered by the experimental procedure (Dallas & Merikle, 1976; Underwood, 1976; 1981), or the stimuli were presented for a time period that allowed for the eye movements of subjects (Shaffer & LaBerge, 1979). Only one study (Kahneman & Chajczyk, 1983) reliably showed both facilitation and interference under a focused attention condition. Apparently the experimental evidence in favour of semantic facilitation by parafoveally presented words when attention is focused on the target is scarce. The bulk of the evidence shows interference.

However, the interpretation of the interference effect found in the above-mentioned experiments is far from clear. One possibility is that parafoveal words automatically activate their lexical representations, and this activation interferes with the subject's task by producing confusion at the lexical or response level (e.g. Shaffer & LaBerge, 1979). A second explanation is that, because the target and parafoveal word are semantically related, the latter may be primed by the former and reach an atypical high level of processing (e.g. Johnston & Dark, 1982). According to this explanation, no automatic activation by the parafoveal words occurs; rather, interference is produced because parafoveal words activated by targets attract attentional resources. It seems difficult to choose between these two alternatives when there is simultaneous presentation of the target and parafoveal word.

Experiments using a successive presentation technique have generally failed to find semantic priming when the prime word was presented on the parafovea. Under distributed attention conditions, Inhoff and Rayner (1980; also Inhoff, 1982) presented ambiguous words in foveal vision and a disambiguating word in the parafovea as prime stimuli. Semantic priming did not obtain in a subsequent forced-choice task requiring some semantic information from the parafoveal word for correct performance. Under focused attention conditions, no priming from words displaced 1.21° from the fixation point was reported by Paap and Newsome (1981) using a lexical decision task. Also, Dark et al. (1985) reported no significant semantic priming from parafoveal primes using a test-word identification task where the target was degraded by a random pattern of dots, which were gradually removed until it was identified. On the other hand, Hoffman and MacMillan (1985), using a lexical decision task in which two prime words were presented, found a small but significant facilitation effect by the uncued word on error rate, but not on reaction time, when subjects had to search for a target letter in the cued word and the ISI between the prime display and lexical decision target was long (1500 msec). No priming was found when subjects had to report just the cued word. Hoffman and MacMillan presented the two prime words above and below the fixation point, with a 1° vertical separation between the centre of the two words, which is approximately the boundary between the foveal and parafoveal regions in vision (Bouma, 1978).

Though it seems appropriate to conclude from the previous review that words presented parafoveally undergo no semantic processing, recent experimental findings point to the possibility that unattended parafoveal primes increase, at least under particular conditions, the time to respond to a target. In their Experiment 8, Allport, Tipper, and Chmiel (1985) presented a prime display containing a drawing to be attended to (the target) and a distractor drawing that was categorically unrelated to the target. Under the easy selection condition the target was always at the centre of fixation and painted in green, whereas the distractor was at a different non-central location and painted in red. Under the difficult selection condition both target and distractor could be at any one of four positions spaced around the fixation point. The priming display was presented for 130 msec and was immediately followed by a pattern mask. Subjects had to attend to and remember the green object and ignore the red one. Following the priming display, a probe display containing two superimposed objects was presented and pattern masked after 130 msec. Subjects were to name the green probe target and ignore the superimposed red figure. The probe target could be categorically related either to the previous attended target (attended categorical condition) or to the previous distractor (distractor categorical condition). A control condition where the probe target was categorically unrelated to the previous display was also included. The time to name the probe target was facilitated under the attended categorical condition both when selection was easy and when it was difficult. However, under the distractor categorical condition the time to name the probe target increased relative to the control condition. This negative priming effect was significant for the easy selection condition but just failed to reach significance for the difficult selection condition.

In light of the Allport et al. findings we can conclude that ignored parafoveal stimuli can influence processing of a subsequent categorically related target. Allport et al. contended that the negative priming effect depends upon both successful selection of the prime target and concomitant successful ignorance of the prime distractor. These authors also required, as a second condition for the occurrence of the effect, that the probe display should contain two stimuli in order to induce a selection process. However, these conditions may be too restrictive; Hoffman and MacMillan (1985) reported a negative priming effect of only marginal significance produced by the ignored prime in a lexical decision task when subjects had to report the attended prime. These authors formulated a *simultaneous encoding hypothesis*, according to which the encoding of information into memory produces inhibition of ignored representations. It is possible that the Allport et al. (1985) results reflect the activity of general inhibitory principles in very constrained selective situations. In any case, it seems reasonable to contemplate the possibility that the general failure to find semantic facilitation from unattended parafoveal words may be partly due to the presence of factors acting in an inhibitory way on their lexical representations (see Yee, 1991, for a very similar explanation).

The purpose of the present research was to analyse the conditions under which semantic facilitation by unattended parafoveal words could occur when there is successive presentation of prime and target. A lexical decision task was used in which a prime display containing two words—one at the fixation point and the other displaced from the fixation point—was followed by a target display containing only one word presented at fixation (see Figure 1). There are several advantages in this type of experimental paradigm. (1) The presentation of two concurrent prime words allows us to compare the semantic processing of unattended words with that obtained of foveal attended words on the basis of their relative semantic-priming potency. (2) The paradigm also allows the manipulation of variables such as the amount of attentional resources invested on each prime, the spatial separation between primes, and the semantic relationship between them.

In the present research the target word could be a member of the same semantic category as the foveal word, the parafoveal word, or it could be a member of a semantic category different from that of both foveal and parafoveal words. The two prime words always belonged to different semantic categories. Other general characteristics of the task were as follows:

1. Attention was manipulated by instructing the subjects to focus on the prime word appearing at the fixation point and to ignore the irrelevant prime word. In order to facilitate focusing on the relevant word, uncertainty about the spatial location of the words was expressly avoided. For a particular subject, words always appeared at the same place.

2. Subjects were engaged in only one task, namely making lexical decisions to targets. No particular task was required on the foveal prime, for two reasons: (1) the absence of a task minimized the presence of any inhibitory factors that could influence the semantic processing of parafoveal words, perhaps due to particular encoding operations of the foveal prime; (2) by eliminating the prime task, subjects should be prevented from conceptualizing the experiment as a dual task. We feared that this possibility could influence the overall level of priming present. Indeed, previous results have shown that, when overt responses to the prime are required, priming may be disrupted (e.g. Carr, Pollatsek, & Posner, 1981; McCauley, Parmelee, Sperber, & Carr, 1980).

3. To prevent eye movements, the exposure of the prime display lasted 150 msec.

EXPERIMENT 1

The first experiment assessed the influence of attended and unattended prime words on lexical decisions when the eccentricity of the unattended word varied along the horizontal axis of the prime display. It was expected that the closer the two prime words were, the less semantic facilitation would be produced by the attended prime word. With respect to the unattended prime words, it was expected that semantic facilitation would decline with increasing eccentricity of the unattended word. Of course, other possible results could occur. For example, Dark et al. (1985, Experiment 2) reported that irrelevant primes, non-adjacent to the relevant stimulus location, produced a 46-msec priming effect, while the effect produced by irrelevant primes adjacent to the relevant stimulus was negative (−56 msec). Though admittedly this difference in priming was not statistically reliable, it nevertheless suggests the possibility that negative priming can be produced by unattended words adjacent to the relevant stimulus. This was tested by manipulating the eccentricity of the unattended word in the prime display. In addition, the stimulus onset asyncrony (SOA) between the prime and target displays was also varied. According to Posner and Snyder's (1975) theory of attention, semantic priming can be produced by two complementary rather than mutually exclusive factors: fast automatic-activation process produced by the presentation of the prime, and a slow process due to the limited-capacity attentional mechanism that can both activate the relevant and inhibit the irrelevant information. The manipulation of the prime–target SOA should provide information about the relative contribution of these two hypothetical sources of priming.

Method

Subjects. One hundred and eight undergraduates from the Psychology Department at the University of Granada were randomly assigned to one of nine experimental groups. Subjects received extra credit towards a higher-class grade for their participation. There were 12 subjects in each group. Care was taken that men and women were equally represented across groups.

Design. There were nine different groups of subjects resulting from crossing three unattended-word eccentricities with three different prime–target SOA values. Subjects were seated approximately 60 cm from the video monitor, and the unattended word was displaced 2.3°, 3.3°, or 4.3° from the fixation point. The SOA between prime and target display was 250, 550, or 850 msec. Within each group of subjects there were three types of prime, depending upon their semantic relation with the target and their attentional condition: attended related, unattended related, or unrelated.

Apparatus and Stimuli. All stimuli were presented on a Toshiba T-100 video monitor, and all stimulus events and timing operations were controlled by a Toshiba T-300 microcomputer system. Words were presented in capital letters, which were on the average 5 mm high and 4 mm wide (equivalent to 0.48° and 0.38°, respectively). They ranged in length from four to six letters and subtended, at a 60-cm viewing distance, a visual angle of 2.4° on the average. Four semantic categories were used: animal, food, body parts, and geographical accidents. For each category 40 members were chosen from the Soto, Sebastián, García, and del Amo (1982) norms. Of the 40 members, 16 were selected as related pairs: 8 members served as prime and 8 as target; the remaining 24 members in each category always served as unrelated primes. There were 32 target words, 8 from each category; from these target words, 32 non-words were created by either changing one vowel letter within a word (e.g. HUEVO changed to HOEVO) or by permutation of two consonant letters of a word (e.g. MANO changed to NAMO). Within each block of trials every target word and non-word was presented twice, one preceded by a related prime, either in the attended or unattended position, and one preceded by primes from different categories. The two prime words always belonged to a different category. Within each block of trials every prime word also appeared twice, one followed by a word, either from the same or from a different category, and one followed by a non-word. In sum, each block contained 128 trials, 64 in which the target was a word and 64 in which it was a non-word; within each of these two 64-trial sets, 16 belonged to the attended related, 16 to the unattended related, and 32 to the unrelated condition.

Procedure. The experimental session consisted of a practice block of 32 trials, followed by two experimental blocks of 128 trials. Presentation of the prime–target combinations was randomized within each block. Figure 1a shows an example of the sequence of stimuli presented in this experiment. A trial was initiated by an asterisk that served as a fixation point presented on a dark background. For half of the subjects in each group the fixation point appeared on the left of the screen during the first block of trials, and on the right of the screen during the second block; for the remaining subjects this order was reversed. The asterisk remained on the screen for 500 msec and was positioned so that it would be centred between the middle two letters of a four-letter word. The asterisk was replaced by a dark field lasting 500 msec and followed by the prime display containing two words on an otherwise dark screen. The prime display was presented for 150 msec and followed by a blank dark screen, which remained so according to the corresponding experimental condition. Targets always appeared at the fixation point and remained in view until the subject responded. For every subject the dominant-hand key was correct for word targets and the non-dominant-hand key was correct for non-word targets.

Subjects were instructed to attend to the fixation point and to the words appearing at the fixation location on both the prime display (attended prime word) and the target display (target word). They also were asked to respond correctly to the target as soon as possible. They were cued about the semantic relation between the attended primes and targets but were told nothing about the semantic relation between unattended primes and targets. With respect to the unattended primes, subjects were encouraged to ignore them and were told that they were presented just to cause distraction from the main task.

Results

Separate analyses were made for the word and non-word targets. No significant effects were found on non-words, and therefore only results related to the word targets will be reported.

For this experiment two analyses were performed, one with subjects as the random variable and another with items as the random variable. Also,

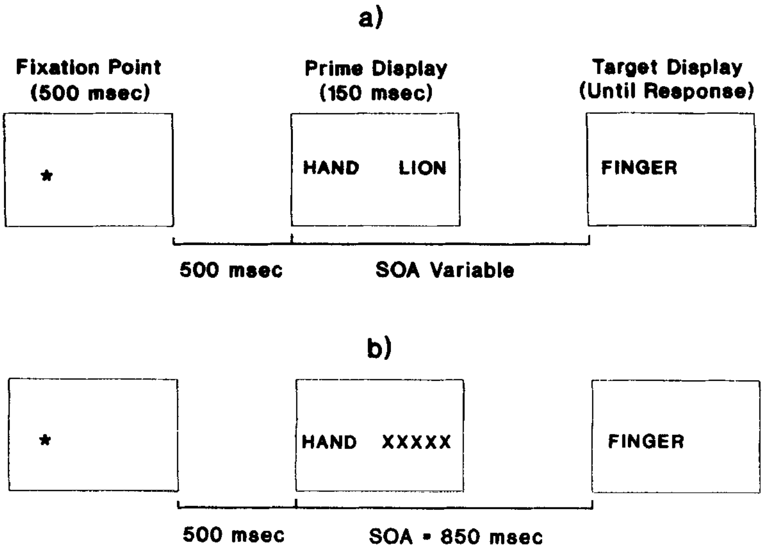

FIG. 1. Sequence of events for trials in Experiment 1 (a), and Experiment 2 (b). Examples shown here have been translated to English.

Fisher's LSDs were calculated for post-hoc comparisons between means, and the 0.05 level was used as criterion for significance in these statistical analyses.

Table 1 presents the mean reaction time and percent error for each prime-type condition under each combination of eccentricity and prime–target SOA value. A 3 (eccentricity) × 3 (SOA value) × 3 (prime type) ANOVA was made on the two dependent variables.

Reaction Time. The main effect of prime type was significant for subjects as random factor, $F1(2, 198) = 117.73$, $p < 0.001$, showing reliable differences among all three conditions (LSD = 6 msec). Thus semantic priming, as measured by the difference in reaction time from the unrelated prime condition, was clearly established for both attended and unattended primes. With items as random factor, prime type was also significant, $F2(2, 62) = 15.08$, $p < 0.001$. Post-hoc tests (LSD = 12 msec) showed that priming was significant for both attended and unattended primes (30 msec and 29 msec of semantic facilitation, respectively), but there was no significant difference between them (the difference was 1 msec).

The Eccentricity × Prime Type interaction was significant for the subject analysis, $F1(4, 198) = 2.47, p < 0.05$. In order to evaluate this interaction, comparisons (LSD = 11 msec) were conducted between the attended related and the unrelated conditions on one hand (priming for attended

TABLE 1
Mean RTs for Prime Type under Three Eccentricities and Three Prime–Target SOA Values

	Eccentricity		
Prime Type	*2.3°*	*3.3°*	*4.3°*
SOA = 250 msec			
Attended Related	681 (4.2)	652 (5.7)	645 (4.2)
Unattended Related	700 (9.6)	677 (11.5)	686 (8.3)
Unrelated	721 (9.5)	692 (9.8)	698 (8.1)
SOA = 550 msec			
Attended Related	624 (5.5)	651 (8.6)	627 (8.6)
Unattended Related	664 (10.4)	697 (10.2)	672 (9.9)
Unrelated	666 (8.7)	706 (9.6)	694 (11.6)
SOA = 850 msec			
Attended Related	664 (6.5)	650 (6.0)	711 (4.2)
Unattended Related	690 (13.3)	686 (7.6)	745 (7.3)
Unrelated	691 (11.7)	693 (6.4)	772 (6.0)

Mean reaction times in msec.
Percentage errors are presented in parentheses.

primes), and the unattended related and the unrelated conditions on the other hand (priming for unattended primes), at each degree of eccentricity.

At 2.3° of eccentricity, priming was significant for attended words (36 msec) but not for unattended ones (8 msec). At 3.3°, priming for both attended and unattended words increased to 46 msec and 10 msec respectively, but was significant only for the former. At 4.3°, priming for attended and unattended words increased again (60 msec and 20 msec, respectively), but now both reached statistical significance. In order to evaluate the statistical significance of priming size increment, *one-df* partial interactions (Keppel, 1982) were carried out for the Eccentricity × Prime Type general interaction. The Eccentricity (2.3° vs. 4.3°) × Prime Type (attended related vs. unrelated) partial interaction was significant, $F1(1, 66) = 8.06$, $p < 0.01$; the Eccentricity (2.3° vs. 4.3°) × Prime Type (unattended related vs. unrelated) partial interaction was marginally significant, $F1(1, 66) = 3.52$, $p < 0.07$. Thus, semantic priming increased with increasing eccentricity from 2.3° to 4.3°, for both attended and unattended prime conditions.

No other main effects or interactions were reliable.

In Figure 2 priming is plotted as a function of eccentricity at each SOA value for the attended and unattended primes. Priming for attended words was obtained subtracting the mean reaction time (RT) for the attended related condition from that for the unrelated one; priming for unattended words was obtained subtracting the mean RT for the unattended related condition from that for the unrelated one. As can be seen, the Eccentricity × Prime Type interaction was mainly due to the pattern followed by longer SOA values. In contrast, when the SOA was 250 msec, the pattern (priming as a function of eccentricity) is rather different from that of both 550 and 850 msec of SOA. Thus, an additional analysis of variance (ANOVA) was performed for just the 250-msec SOA condition. The only effect that reached statistical significance was that of prime type, $F1(2, 66) = 33.5, p < 0.001$. Comparisons (LSD = 11 msec) showed that priming was significant for both attended and unattended primes (45 msec and 16 msec, respectively). The Eccentricity × Prime Type interaction was not significant [$F1(4, 66) < 1$]—that is, priming did not change as a function of eccentricity either for the attended primes or for the unattended ones for an SOA of 250 msec.

The Eccentricity × Prime Type interaction was not significant for the item analysis, [$F2(4, 124) < 1$]. However, as with the subject analysis, semantic priming showed a slight tendency to increase as a function of eccentricity for both attended and unattended primes (24 msec at 2.3°, 28 msec at 3.3°, and 37 msec at 4.3° for attended primes; for unattended ones priming was 25 msec, 28 msec, and 35 msec for each eccentricity, respectively).

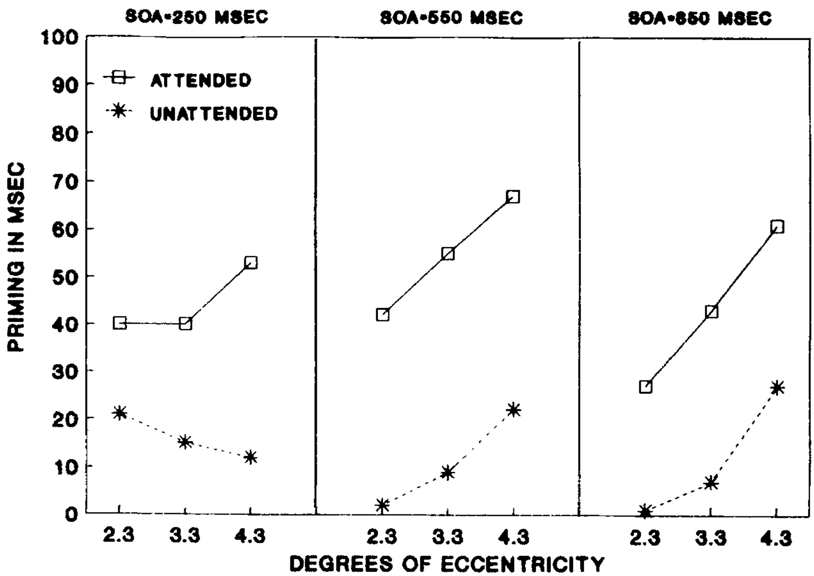

FIG. 2. Semantic priming as a function of eccentricity for each Prime–Target SOA value.

Percent error. Only the main effect of prime type was significant, $F1(2, 198) = 25.99$, $p < 0.001$. Comparisons (LSD = 1.11) showed that the mean percent error for the attended related condition was lower than for both the unattended related and unrelated condition.

Discussion

The attended prime words produced significant semantic priming on both reaction time and error rate measures. In addition, priming showed a tendency to decrease as the distance between primes diminished. This decrement does not seem to be related to the "filtering costs" advanced by Kahneman, Treisman, and Burkell (1983), according to which speeded choice responses to an attended stimulus are delayed by simultaneous occurrence of other events. Filtering costs are eliminated by precuing the position of the to-be-attended stimulus, which was the case in our experiment. It is also unlikely that this decrement can be explained in terms of increasing sensory interaction between primes as a result of their increasing proximity (Bjork & Murray, 1977), because the decremental effect did not appear at the short prime–target SOA condition. Furthermore, this decrement does not seem to be an instance of involuntary processing of the distractor prime as a consequence of its increasing proximity to the attentional focus (Eriksen & Hoffman, 1973); in fact, the priming potency of the unattended distractors was lower the closer the two primes were to each other. A possible explanation for this decrement will have to take into consideration the amount of semantic processing sustained by the simultaneously presented unattended prime.

Given the previous literature, it is of some interest that the unattended, parafoveally presented primes facilitated target RTs. As pointed out in the introduction, some experiments using a successive prime–target presentation have failed to find semantic priming from unattended words (Dark et al., 1985; Inhoff, 1982; Inhoff & Rayner, 1980; Paap & Newsome, 1981). Though these experiments differ in many respects from the present one, at least one of them (Paap & Newsome, 1981) allows some comparison. Paap and Newsome (Experiment 2), using a lexical decision task, presented two simultaneous primes, one at the fixation point and the other to the parafovea. They employed an average prime–target SOA of 630 msec, and the separation between the fixation point and the first letter of the parafoveal prime was 1.21°. No semantic priming produced by the parafoveal primes was found, despite the fact that the very same primes had produced significant priming when presented to the fovea. In the present experiment unattended primes displaced 2.3° from the fixation point (our most comparable eccentricity condition) did not produce significant priming at 550- and 850-msec SOA, but the presence of priming was clear when they were displaced from fixation as far as 4.3°. Thus, it is possible that Paap and Newsome's results are restricted to the particular eccentricity and prime–target SOA combination used in their experiment.

With a short displacement from fixation of parafoveal unattended primes, SOA value seems to be of crucial relevance. For example, Di Pace, Longoni, and Zoccolotti (1991) presented word–non-word pairs as primes in which one member of the pair (the attended) appeared centrally, and the other (the unattended) parafoveally. The prime stimuli were followed by a central target at two interstimulus intervals (ISI), 200 msec (SOA = 320 msec) and 2000 msec (SOA = 2120 msec). In the critical conditions the target could be related to either the foveal or the parafoveal word. The unattended primes were displaced from fixation by 2.3°, just the shortest eccentricity used in our experiment. The authors reported semantic facilitation for unattended words only at short ISI. Part of our results agree with those of Di Pace et al. (1991). As shown in Figure 2, at 2.3° of eccentricity we found significant priming for unattended primes at short SOA (21 msec), but not at the longest SOA (1 msec).

The significant change in priming with changing eccentricity of the parafoveal word rules out an explanation of parafoveal priming in terms of attentional resources shared by both attended and unattended primes. Such explanation should predict a decrease rather than an increase in priming as the separation between primes is enlarged.

Finally, the present pattern of results can be viewed as either a priming decrement as separation between prime words is shortened or a priming increment as the separation between prime words is enlarged. The fact that, contrary to the 250 msec SOA condition, at longer SOA conditions there was a reduction in priming effect when the two prime words were 2.3° and 3.3° apart (see Figure 2) supports the decrement hypothesis. It is interesting to note that this decrement exhibits a similar pattern for both attended and unattended primes, thus suggesting the presence of a common determining factor. The second experiment was designed to further explore the nature of this priming reduction.

EXPERIMENT 2

A possible account for the decrement in priming found at the longest prime–target SOA condition in Experiment 1 might be to consider it a particular instance of the *distractor-suppression effect*. Using a Stroop task, it has been found that when two successive Stroop stimuli are related such that the colour name of the second stimulus matches the distracting word of the first, subjects take longer to respond than when the sequential stimuli are unrelated (Lowe, 1979, 1985; Neill, 1977; Neill & Westberry, 1987). Tipper (1985) also found that the suppression effect can generalize to the semantic category of the ignored stimulus. Following Keele and Neill's (1978) theory of attention, Neill and Westberry (1987) advanced an explanation of this effect in terms of *selective inhibition*, contending that the automatic activation of information in memory must be followed by selection of the activated memory structures appropriate to current task demands. This selection process is accomplished through the inhibition of activated but task-inappropriate memory structures. According to Neill and Westberry, this inhibitory process is time-dependent, and slower than the process of automatic activation of information in memory. Under this account the *distractor-suppression effect* reflects the amount of selective inhibition accumulated on the distracting stimulus.

It is possible that the decrement in semantic priming found in Experiment 1 could be due to an inhibitory process similar to that proposed by Neill and colleagues. To the extent that the ignored unattended primes produced distraction, they would have been inhibited, and subsequently their priming potency would have been reduced. To the extent that selective inhibition is an active process, it might have interfered with attention to the attended primes, thus reducing their primary potency as well. Finally, the finding that semantic priming was significant when the unattended prime was displaced 4.3° from the fixation point, as well as the fact that no decrement in priming as a function of eccentricity was found in the 250-msec SOA condition, would argue in favour of a fast automatic activation of the categorical representation of primes. This activation would be followed by the slower inhibition of the ignored primes responsible for the decrement in priming at the longest prime–target SOA condition. Yee (1991) has reported a finding in agreement with that explanation. In her Experiment 2, subjects were told to attend to a foveally presented object flanked vertically by either a word and a string of symbols or two words (the distractors). After a variable SOA interval a central target (a word or a non-word) was displayed. Subjects were asked to make a lexical decision on target. When distractors were two words, she found positive priming at short, and negative priming at long SOA intervals.

Our Experiment 2 assessed the pattern of semantic priming at 850-msec SOA in the first experiment by comparing a condition in which two prime words were presented (W–W) with one in which only one prime word was presented together with a series of five Xs (W–X). To the extent that selective inhibition may be at work, acting on activated lexical structures, a decrement in priming as a function of the distance between primes would be expected for the W–W condition, but not for the W–X condition.

In addition, the second experiment introduced a few methodological changes. (1) Each target word only appeared once in each block. (2) A chin-rest was used to fix the position of the subject 72 cm from the screen. (3) The fixation point was always located at the position of the left prime stimulus; though in Experiment 1 no difference in semantic priming was found due to the position of the fixation point, we have found in several experiments higher levels of semantic priming when the fixation point was presented on the location of the left prime word.

Method

Subjects. Sixty-four undergraduates from the Psychology Department at the University Campus of Almeria were randomly assigned to each group. Sixteen subjects participated on each group. Subjects received extra credit for participation.

Design. There were four different groups of subjects resulting from crossing two unattended-word eccentricities with two different types of primes. As subjects were seated approximately 72 cm from the video monitor, the parafoveal stimulus was displaced 2° or 3.6° from the fixation point. There were two different configuration of primes: either two words, each from a different semantic category (W–W), or one word and five Xs (W–X; Figure 1b presents an example of this condition). As in Experiment 1, within each group of subjects there were three types of primes, depending upon their semantic relation with the target and their attentional condition: attended related, unattended related, or unrelated.

Stimuli and Apparatus. Fifty-four members of each of the four categories used in Experiment 1 were employed. Eighteen related prime–target pairs were created within each category, which were randomly assigned to either the attended or the unattended condition for each subject. The remaining 18 words from each category served as unrelated primes in both related and unrelated trials, using also a random assignment for each subject. Word frequency estimates were equated for related attended, related unattended, and unrelated trials.

Within each block of trials every target word and non-word was presented once, and every prime word appeared twice, once followed by a word, either from the same or from a different category, and once followed by a non-word.

In sum, each block contained 144 trials, 72 in which the target was a word and 72 in which it was a non-word; within each of these two 72-trial sets, 24 belonged to the attended related, 24 to the unattended related, and 24 to the unrelated condition.

All stimuli were presented on a video monitor model PX-22 controlled by a graphic card model EGA-5145. The video monitor was interfaced to a Tandon computer, which controlled all stimulus events and timing operations.

Procedure. The experimental session consisted of two blocks of 144 experimental trials, each one preceded by one practice block of 24 trials. Between the two blocks of trials there was a rest period. Presentation of the prime–target combinations was randomized within each block.

A trial was initiated by an asterisk that served as a fixation point presented on a dark background. For all subjects the fixation point always appeared on the left of the screen. The asterisk remained on the screen for 500 msec and was followed by a dark field lasting 500 msec. Then the prime display was presented for 150 msec. In the W–W condition, the prime display consisted of two words, each belonging to a different category. In the W–X condition either a word or a five-X set was randomly assigned to the attended or the unattended position, with the proviso that both the word and the five-X set appeared on each position equally often. The SOA between prime and target was 850 msec. Targets always appeared on the left, at the fixation point, and remained on until the subject made the response. For each subject the dominant-hand key was correct for word targets and the non-dominant-hand key was correct for non-word targets.

Instructions were the same as in Experiment 1, except that subjects belonging to the W–X groups were advised about the new configuration of the prime display.

Results

Separate analyses were made for the word and the non-word targets. No significant effect was found on non-words, and therefore only results related to the word targets will be reported.

Table 2 shows the mean RT and percentage error for each prime-type condition (attended related, unattended related, and unrelated) under the two values of eccentricity (2° and 3.6°) and the two prime configurations (W–W and W–X). A 2 (eccentricity) × 2 (prime configuration) × (prime type) ANOVA was made on the two dependent variables.

Reaction Time. The main effect of eccentricity was significant for both subject, $F1(1, 60) = 7.224$, $p < 0.01$, and item analyses, $F2(1, 23) = 395.77$, $p < 0.001$, showing faster responses to targets for the 2° than for the 3.6° prime eccentricity condition. The main effect of prime type was also significant, $F1(2, 120) = 83.01$, $p < 0.001$, and $F2(2, 46) = 88.93$, $p < 0.001$. Post-hoc comparisons (LSD = 8 msec for both analyses) indicated that the attended related primes were reliably faster than both the unrelated and unattended related primes. As in Experiment 1, the latter were also reliably faster than the unrelated primes, thus showing semantic priming produced by the unattended parafoveal primes, though this last difference was only significant with subjects as a random factor.

TABLE 2
Mean RTs for Prime Type under Two Eccentricities and Two Prime Configurations

	Eccentricity	
Prime Type	*2.0°*	*3.6°*
W–W		
Attended Related	573 (4.4)	678 (4.2)
Unattended Related	605 (7.7)	709 (6.6)
Unrelated	594 (7.0)	716 (6.1)
W–X		
Attended Related	613 (3.8)	633 (2.0)
Unattended Related	664 (6.8)	685 (3.5)
Unrelated	684 (8.2)	702 (6.6)

Mean reaction times in msec.
Percentage errors are presented in parentheses.

The Prime Type × Prime Configuration interaction was significant for both subject, $F1(2, 120) = 12.05$, $p < 0.001$, and item analyses, $F2(2, 46) = 10.49$, $p < 0.001$. Partial interactions showed that semantic priming for the attended words was greater for the W–W groups than for the W–X ones: 70 msec vs. 29 msec, $F1(1, 60) = 18.93$, $p < 0.001$; 78 msec vs. 31 msec, $F2(1, 23) = 22.25$, $p < 0.001$. This was also the case for unattended words: 18 msec vs. −2 msec, $F1(1, 60) = 9.06$, $p < 0.01$; 23 msec vs. −11 msec, $F2(1, 23) = 8.98$, $p < 0.01$. In addition, priming was significant for all cases except the −2 msec (−11 msec in the case of item analysis) negative priming effect obtained with the unattended words at W–X condition (LSD = 16 msec for subjects and LSD = 15 msec for items). No other effects were significant.

The absence of the three-way interaction (Prime Type × Prime Configuration × Eccentricity) fails to substantiate the observation made on the basis of Figure 3 that priming changed as a function of eccentricity at the W–W condition. As this effect was predicted on the basis of the results of Experiment 1, the data were explored by further analyses.

For each eccentricity value, the effect of prime type was evaluated in the W–W condition. At 2°, prime type was significant for both subject, $F1(2, 30) = 14.5$, $p < 0.001$, and item analyses, $F2(2, 46) = 13.36$, $p < 0.001$. Post-hoc comparisons (LSD = 12 msec for subjects and LSD = 18 msec for items) indicated that RT was shorter for the attended related than for the unrelated condition (21 msec for both subject and item analyses); also, RT was longer for the unattended related than for the unrelated condition. Although this difference (−11 msec) was only marginally significant ($p < 0.07$) for the subject analysis, it was reliable for the item analysis (−26 msec). Thus, at the near eccentricity we obtained positive priming for attended words, and negative priming for unattended ones. At 3.6°, the effect of prime type was also significant for both analyses, $F1(2, 30) = 13.8$, $p < 0.001$, and $F2(2, 46) = 18.29$, $p < 0.001$, respectively. Post-hoc comparisons (LSD = 15 msec for subjects and LSD = 14 msec for items) showed that RTs were shorter for the attended related than for the unrelated condition (38 msec for subjects and 40 msec for items), but there was no significant difference between the unattended related and the unrelated conditions (7 msec for subjects and 4 msec for items). Thus, at 3.6°, positive priming was obtained only for attended words.

In order to evaluate the change in priming size as a function of eccentricity, partial interactions were evaluated in which eccentricity (2° vs. 3.6°) was one factor and prime type with only two levels (attended related vs. unrelated, or unattended related vs. unrelated) was the other. The increment in priming for unattended words was significant for both subject and item analyses, $F1(1, 30) = 4.9, p < 0.05$, and $F2(1, 23) = 5.52, p < 0.05$, respectively; for attended words the increment in priming at 3.6° was marginally significant, $F1(1, 30) = 2.79$, $p = 0.10$, and $F2(1, 23) = 2.95$, $p < 0.10$, respectively. As in Experiment 1, priming increased with increasing eccentricity for both attended and unattended primes, but only when the prime configuration was word–word.

Percent Error. Only the main effect of Prime Type was significant, $F1(2, 120) = 16.18$, $p < 0.001$. As in Experiment 1, post-hoc tests (LSD = 1.24 msec) showed that the mean percent error for the attended related condition was lower than for both unattended related and unrelated conditions.

Discussion

As in Experiment 1, the attended prime words produced significant semantic priming on both error rate and RT measures. Also, the priming effect on RTs from the attended words was higher than that from the unattended prime words. Unattended parafoveal primes produced significant semantic priming though in the W–X condition. Finally, when the two primes were words, the variation in priming as the distance between primes was changed replicated the pattern of results found in Experiment 1; when the distance between primes was shortened from 3.6° to 2°, semantic priming decreased.

The main purpose of the present experiment was to further evaluate the nature of the decrement in semantic priming with increasing proximity of primes found in Experiment 1 at long prime–target SOAs. The comparison of the priming caused by the W–W and the W–X displays provided at least two pieces of evidence. (1) There was a clear reduction in semantic priming when two words were presented as primes compared with the presentation of a word and five Xs; it appears that the mere presence of a concurrent prime word produces more interference than a concurrent non-meaningful stimulus. (2) As in Experiment 1, the decrement in semantic priming produced by the spatial proximity of the two primes was replicated in the present W–W display. However, no such decrement was found in the W–X display (see Figure 3).

In addition, the present experiment showed that priming produced by the unattended words displaced 2° from the fovea in the W–W display was negative. This result agrees with that reported by Yee (1991; Experiment 2) extending to a lexical decision task an effect that has been found in Stroop-type tasks (e.g. Tipper, 1985) and lends support to the contention that internal representations of distractor objects may be inhibited by an active attentional process (Neill, 1977; Tipper, 1985).

On the whole, the present experiment clearly shows that parafoveal unattended words can be semantically processed. When the W–X display was presented, significant positive semantic priming was produced by unattended prime words independently of the distance from the fovea at which

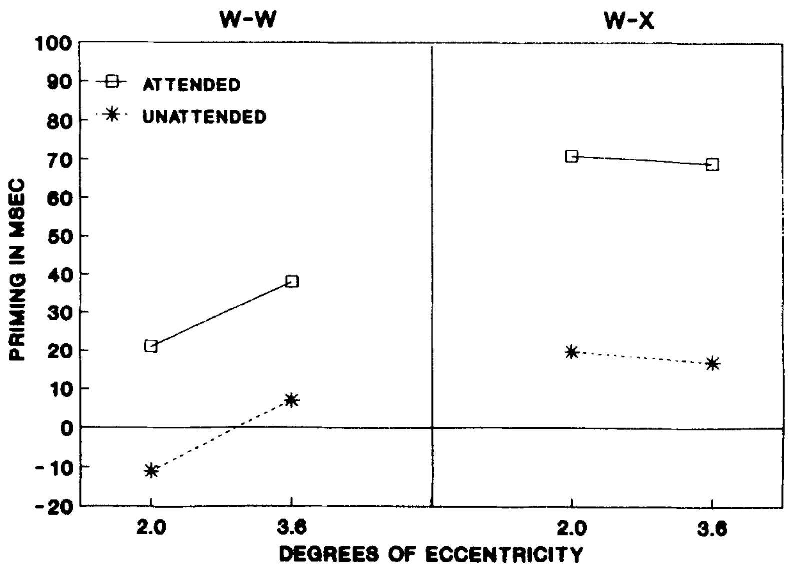

FIG. 3. Semantic priming as a function of eccentricity for the two Prime Configurations. W–W = two prime words; W–X = one word and five Xs.

they were presented. However, when the W–W display was presented, the results indicated that semantic processing is not easily mirrored by positive semantic priming because the presence of inhibitory factors may reduce the level of priming to the point of making it negative.

GENERAL DISCUSSION

Contrary to Kahneman and Treisman's view (1984), the present research showed that semantic priming can occur when the stimulus word is presented outside the focus of attention. The experimental paradigm employed in the present research enabled us to differentiate the relative priming potency of both attended and unattended primes. Moreover, this paradigm allowed a direct measure of the kind and amount of processing sustained by parafoveal unattended primes. From experiments using simultaneous presentation of prime and target, the nature of the processing afforded to parafoveal unattended primes is usually inferred from their effect on responses to foveal attended stimuli. The present paradigm, by introducing two words on a prime display followed by the target display, provided a direct measure of the processing sustained by the unattended parafoveal words, thus allowing a more complete explanation of their effect on the attended stimulus. For example, in the present research a decrement in semantic priming produced by attended words was found when they were in close proximity to an unattended word. A ready explanation for this effect is that the decrement was due to increasing attentional resources being shared by both attended and unattended stimuli as the distance between the two words was shortened. However, this explanation can be ruled out because no concurrent increase in semantic priming due to the unattended words was detected.

The results demonstrated that, at least under the present conditions, significant semantic priming can be produced by unattended words displaced from fixation as far as 4.3°. This priming effect cannot be accounted for by parafoveal word identification for at least three reasons. (1) It is well documented that parafoveal word identification declines as the eccentricity of the parafoveal word increases (Bouma, 1978; Inhoff, 1982; Inhoff & Rayner, 1980); however, the present results show exactly the opposite pattern: semantic priming increased with increasing eccentricity of the parafoveal stimulus. (2) In similar experiments in which subjects were asked to report the parafoveal stimuli, they failed to do so (e.g. Di Pace et al., 1991, Experiment 2; Underwood, 1981, Experiment 2). (3) It seems reasonable to assume that any attempt on the part of the subject to identify the parafoveal word would have produced a decrement in the priming produced by the concurrent foveal word; on the contrary, however, in our data the highest levels of parafoveal priming coincided with the highest levels of attended foveal priming.

Still, one could argue, following Gathercole and Broadbent (1987), that the unattended parafoveal primes were identified, but only after a delay. Thus, at longest SOAs the delayed prime processing may overlap with that of the subsequently presented target. Gathercole and Broadbent (1987), using the task developed by Eriksen and Eriksen (1974), found that interference could arise from stimuli outside the focus of attention when the distractor items were presented shortly before the target. They concluded that distant non-target events are analysed, but produce their effects at a later time than less peripheral events. This hypothesis could certainly explain the priming effect produced by parafoveal unattended stimuli, but not the change in priming as a function of eccentricity that has been found in our experiments.

An alternative explanation is that the source of semantic priming from unattended parafoveal words is independent of word identification and is not related to focal attentional processes.

It is difficult to say why most investigators using a sequential prime–target paradigm have failed to find semantic priming from parafoveally presented words (Dark et al., 1985; Inhoff, 1982; Inhoff & Rayner, 1980; Paap & Newsome, 1981). Experiments by Inhoff (1982) and Inhoff and Rayner (1980) differed in too many aspects from the present experiments to make a comparison possible. They presented their primes under distributed attention instructions and made the location of the parafoveal word uncertain; they also introduced a brightness mask after the primes and used a forced-choice task different from the lexical decision task used here. Any one of these differences may account for the different results. Dark et al. (1985, Experiment 2) did report a tendency for irrelevant primes, non-adjacent to the relevant stimulus location, to produce positive semantic priming; in contrast, the tendency for irrelevant primes, adjacent to the relevant stimulus, was to produce negative priming. Though this difference in priming due to differential proximity of primes was not statistically reliable, the tendency reported by Dark et al. was similar to that found in Experiment 2 for the unattended parafoveal primes in the W–W display. As pointed out in the introduction, the experimental procedure employed by Paap and Newsome (1981) was very similar to ours. In Experiment 1, when the eccentricity of the parafoveal word and the prime–target SOA values employed were close to those used by Paap and Newsome, no significant semantic priming was found. However semantic priming was significant when the eccentricity of the parafoveal word was increased. Thus the results obtained by Paap and Newsome were probably due to the particular experimental conditions employed. In addition, the fact that they required their subjects to respond both to the prime and the target words may have helped disrupt the priming effect (Carr et al., 1981; McCauley et al., 1980).

One finding from the present research that may cast light on the failure to find semantic priming when prime and target are sequentially presented is the decrement in priming observed when the two prime stimuli are words presented in close spatial proximity. In Experiment 2 a significant decrement in priming was found when two words were presented as primes, compared with the situation in which only one word was presented accompanied by a pattern of five Xs. Both in Experiment 1 and 2, there was a tendency for priming to diminish as the distance between the two prime words was reduced. Moreover, in Experiment 2 the priming produced by the unattended parafoveal word displaced 2° from fixation was negative. Hoffman and MacMillan (1985) also reported a similar tendency using a lexical decision task. Thus, it appears that both the presence of more than one word on the prime display (see also Yee, 1991) and the spatial proximity between the words are responsible for the presence of inhibitory effects on semantic priming.

As to the nature of these inhibitory effects, our results extend to a lexical decision task the *distractor-suppression effect* found by other authors in Stroop-type tasks (Neill, 1977; Neill & Westberry, 1987; Tipper, 1985). In general, our results can be explained in terms of inhibitory processes acting on activated representations. Explanations of this kind have been proposed by Hoffman and MacMillan (1985), Neill and Westberry (1987), and Tipper (1985), among others. Both facilitation and suppression effects are observed when two concurrent stimuli are presented and one is to be attended to and the other is to be ignored, but both effects seem to be dependent upon each other. The fact that the highest level of inhibition found in our experiments coincided with the lowest facilitation effect produced by the attended words suggests the possibility of a trade-off between facilitation and inhibition once a selective act has occurred. One could conjecture that attentional resources can be invested to facilitate as well as to inhibit, but the more inhibition the selective act needs, the fewer resources will remain to facilitate the attended stimulus. Although our results fit well with this conception, further work is needed to understand better the nature of the relationship between inhibition and facilitation in word processing.

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