The Role of the Anterior Attention System in Semantic Processing of both Foveal and Parafoveal Words

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Abstract

■ This research takes advantage of combined cognitive and anatomical studies to ask whether attention is necessary for high-level word processing to occur. In Experiment 1 we used a lexical decision task in which two prime words, one in the fovea and the other in the parafovea, appeared simultaneously for 150 msec, followed by a foveal target (word/nonword). Target words were semantically related either to the foveal or to the parafoveal word, or unrelated to them. In one block of trials subjects were also required to perform an auditory shadowing task. From PET studies we know that shadowing activates the anterior cingulate cortex, involved in selective attention. If the anterior attention system is always involved in semantic processing, shadowing should reduce semantic priming obtained from both foveal and parafoveal words. In contrast, if semantic priming by parafoveal words is independent of activation in that attention area, priming will not be affected by shadowing. Our results supported the latter hypothesis. A large priming effect arose from foveal primes, which was reduced by shadowing. For parafoveal primes a smaller priming effect arose, which was not affected by shadowing. In Experiment 2 prime words were masked. Semantic priming was reliable for both foveal and parafoveal words but there were then no differences between them. Most important, the size of priming was similar to that obtained from parafoveal words in Experiment 1. We conclude that the anterior attention system increases the potency of processing of consciously perceived stimuli, but there is a component of semantic priming that occurs without both focusing of attention and awareness, involving different cerebral areas to those involved in attention to language. ■

INTRODUCTION

For more than 30 years authors have argued whether attention is necessary for high-level processing to occur, or whether high-level processing can be carried out automatically.

One frequent way of approaching the issue is to present two stimuli, one to the fovea (the attended stimulus) and the other to the parafovea (the unattended stimulus). If the response to the foveal stimulus (the target) is affected by the presence of a related parafoveal one, the processing of the latter is considered as established (Dallas & Merikle, 1976; Fuentes & Ortells, 1993; Merikle & Gorewich, 1979; Shaffer & LaBerge, 1979; Underwood, 1981). However, there are problems with this technique. Since, in the critical conditions, the target and the parafoveal word are semantically related, the "unattended" parafoveal word may itself be primed by the target. According to this explanation, no automatic activation of parafoveal words needs be postulated. Once primed, the parafoveal word may then affect responses to target (Johnston & Dark, 1986).

One way to prevent priming between attended and unattended stimuli is to use successive prime-target presentations (Di Pace, Longoni, & Zoccolotti, 1991; Fuentes & Tudela, 1992). In studies of this form, two unrelated prime stimuli have been briefly displayed, one to fixation (the foveal attended) and the other displaced from it (the parafoveal unattended). After an interval a foveal target is presented to which subjects respond. The target may be related to the attended prime, to the unattended prime, or unrelated to them (see Fig. 1a). Using this technique, studies have shown semantic priming by unattended stimuli presented at different degrees of eccentricity from fixation (Di Pace et al., 1991; Fuentes & Tudela, 1992), and they have been interpreted as evidence in favor of automatic semantic processing of the unattended parafoveal stimuli.

Although the successive prime-target presentation method is not subject to the criticism of priming from the target onto related distractors, the conclusion that parafoveally presented stimuli are semantically processed in an automatic way remains problematic. First, several studies have failed to find semantic priming from unattended parafoveal words (Inhoff, 1982; Inhoff & Rayner, 1980; Paap & Newsome, 1981; although see Fuentes & Tudela, 1992 for an explanation). Second, it is difficult to prove that the parafoveally presented stimuli were really unattended (Holender, 1986; Logan, 1992). Logan (1992) argued that it is not clear whether the small effects of semantic priming from parafoveal words are due to small effects occurring on every trial or to occasional lapses of attention. If so, we expect semantic priming from parafoveal words to decrease (or at least not to vary) with eccentricity. Nonetheless, Fuentes and Tudela (1992) reported just the opposite pattern when long SOA was used: that is, semantic priming from parafoveal words increased with eccentricity.

The issue of whether unattended words are processed semantically can be further explored if we combine behavioral studies with recent cognitive–anatomical analyses of attention. Neuroimaging techniques (e.g., positron emission tomography, PET) provide us with a new framework to address the issue of semantic processing of unattended stimuli.

PET studies have shown two brain areas that are activated when subjects perform semantic tasks (Petersen, Fox, Posner, Mintun, & Raichle, 1988). One lies in the left inferior prefrontal cortex and is linked to semantic processing of verbal (visual or auditory) stimuli. The second is located in the medial frontal lobe (cingulate cortex) and is linked to attention to language. Semantic priming would appear to tap both centers. Primes may automatically activate their representations, as well as those of other related stimuli, even when the relationship between primes and targets is unexpected, and hence unattended (Neely, 1977). As noted above, semantic priming may also occur when primes themselves are unattended. Such effects may be contingent on the left inferior prefrontal cortex. On the other hand, semantic priming can also involve the use of strategic factors (Ratcliff & McKoon, 1988), presumably dependent on the medial frontal lobe (hereafter we refer to this area as the anterior attention system).

The involvement of attention in semantic processing might be assessed if we observe the pattern of interference that a concurrent task, thought to tap the anterior attention system, produces on semantic priming. Several studies have shown that shadowing activates the anterior attention system but not the left prefrontal cortex mediating semantic processing (Petersen et al., 1988; Petersen, Fox, Posner, Mintun, & Raichle, 1989). For instance, Posner, Sandson, Dhawan, and Shulman (1989) reported several experiments on the effects of shadowing on semantic priming. In the focal condition, subjects performed only the visual (e.g., lexical decision) task. In the divided condition subjects performed a shadowing task simultaneously with the visual task. In the divided attention condition of 2 experiments, the secondary shadowing task reduced semantic priming significantly; however, it had smaller effects on the last two experiments. Posner et al. concluded that divided attention can reduce semantic priming but that there may be a component of the priming that is not affected by the secondary task and thus could be considered automatic (Posner et al., 1989, p. 57). In other words, this component would not involve the medial frontal lobe. Unfortunately, no converging evidence was provided that effects were really automatic.

The aim of the present research is to obtain additional evidence regarding the role of the anterior attention system in the semantic processing of both foveal and parafoveal stimuli. Experiment 1 assessed the effect of a secondary shadowing task on semantic priming obtained from both foveally and parafoveally presented words. By using parafoveal words, we aimed to ensure that priming (from these items) was automatic (cf. Fuentes & Tudela, 1992). The following hypotheses can be advanced. If the anterior attention system (i.e., the medial frontal lobe) is always involved in semantic processing, shadowing should reduce semantic priming obtained from both attended (foveal) and unattended (parafoveal) words, and the reduction in semantic priming should be of similar magnitude for foveal and parafoveal stimuli. In contrast, if semantic priming from attended (foveal) words alone uses both the medial frontal and the prefrontal areas, while semantic priming from unattended (parafoveal) words uses only the prefrontal cortex, shadowing may have no effect on parafoveal priming (though it may still reduce foveal strategic priming, which is dependent on the anterior attention system). A similar pattern of results (i.e., reduced semantic priming from foveally presented attended words but not for parafoveally presented unattended ones) should be expected if semantic priming from unattended words involves other different area(s) to the prefrontal cortex (see Conclusions section).

Experiment 2 explored further the nature of the improvement in performance (in this case, in semantic priming) that is usually observed when cognitive tasks involve the anterior attention system (Posner et al., 1989; Experiment 1 of the present study, see Results section). Many PET studies compare conditions where subjects passively receive one kind of stimulus (the control condition) with those where subjects are told to attend actively to the same stimuli (the experimental condition). Substracting neural activity in the experimental condition from that in the control condition reveals the brain area activated by attentional operations. In both the experimental and the control conditions of such studies, the stimuli are presented within the focus of visual attention. The difference between both conditions is that in the experimental condition subjects are told to "focus" on meaning. For instance, in several PET studies (e.g., Chertkow, Bub, Evans, Meyer, & Marret, 1990; Petersen et al., 1989), the activity in the semantic areas has been shown to increase when subjects are told to perform tasks requiring intentional focusing on meaning (e.g., generating verbs or monitoring the category or the words). Results implicating increased semantic processing when subjects focus on the "meaning" of the stimuli have been observed in cognitive studies (e.g., Friedrich, Henik, & Tzelgov, 1991; Smith, Theodor, & Franklin, 1983). Smith et al. (1983) observed an increase in semantic priming when subjects had to determine whether the prime represented a living thing, compared to conditions in which either a phonemic analysis or silent reading of prime was required. Semantic priming disappeared when either visual analysis (determining whether a star preceded the prime) or a letter search task was required. However, Smith et al. (1983) also observed that semantic priming was reliable and of the same magnitude in both the phonemic analysis and the silent reading conditions. This comparison is important because in both Posner et al. (1989) and the present study, the conditions for primes were similar to the silent reading condition of Smith et al. (1983). Yet, shadowing reduced semantic priming in both studies, showing the involvement of the anterior attention system. Thus, we suggest that the anterior attention system must be mediating something more than intentional semantic processing, which we presume is not involved in silent reading.

One possibility is that the anterior attention system is also involved in awareness. That is, attention could mediate the access of stimuli to a conscious representation, allowing intentional semantic processing to take place when focusing on meaning is required by the task. Intentional operations may not be applied unless a stimulus is consciously represented. To prove this conjecture, Experiment 2 included a central masking condition (Fig. 1b shows the sequence of events of this experiment). We used a prime display comprised of two words, one presented at fixation and the other displaced from it by 4.3°. The prime display was followed by a pattern mask that prevented subjects from being aware of the presence of the prime display (see Method). We conject that this might also prevent access of the prime to the anterior attention system. Consequently, the magnitude of priming, under masking conditions, should be reduced as it is expected to occur when access to the anterior attention system is interfered with by a secondary task (shadowing in Experiment 1).

Furthermore, the inclusion of a parafoveal word in the prime display, as in Experiment 1, allowed us to dissociate perceptual from attentional effects on semantic priming, under masking conditions. Here, masked primes presented at the fovea still fall in an attended region of visual field. Masked primes presented to the parafovea fall in an unattended spatial region. This is the case even if subjects are unaware of either type of prime. Kahneman and Treisman (1984) pointed out that studies measuring semantic priming under masking conditions have presented masked words within the focus of attention; consequently, evidence of semantic priming from such words does not prove that perceptual processes operate to a semantic level without attention. As was pointed before, if semantic processing can occur without both focusing of attention and awareness, semantic priming by parafoveal words should be both reliable and unaffected by the pattern mask.

RESULTS

Table 1 shows the mean of median RTs for correct responses, along with percent errors of both experiments. Statistical analyses were performed on RTs for correct responses as well as for percent of errors registered from trials in which targets were words.

Experiment 1

A repeated measures ANOVA was conducted in which prime type (attended related, unattended related, and unrelated) and blocks (single, dual, and single) were within-subject factors. The main effect of prime type proved reliable, $F(2,46) = 27.62$, $p < 0.001$. Pairwise comparisons (Newman–Keuls tests) showed that latencies in the unrelated condition were longer than in both the attended related ($p < 0.01$) and the unattended related conditions ($p < 0.05$). Further, RTs were shorter in the attended related than in the unattended related condition ($p < 0.05$). There was a reliable effect of block, $F(2,46) = 7.16$, $p < 0.01$. Latencies under the dual-task condition were longer than under the single task conditions ($p < 0.05$), but there were no reliable differences between the single-task conditions. The prime type × block interaction was also reliable, $F(4,92) = 3.24$, $p < 0.025$.

Error analyses showed a main effect of both prime type, $F(2,46) = 6.71$, $p < 0.01$, and block, $F(2,46) = 6.47$, $p < 0.01$. The percentage of errors was higher for the unrelated condition than for the attended related one ($p < 0.01$), and block 1 produced more errors than both block 2 and block 3 ($p < 0.01$ and $p < 0.05$, respectively). No other comparisons were reliable.

When only the two blocks of the single task condition were included in the analyses, semantic priming was reliable for both the attended and the unattended primes, $F(1,23) = 65.61$, $p < 0.001$, and $F(1,23) = 6.84$, $p < 0.025$, respectively; however, these conditions did not differ between the two blocks ($F < 1$ in both cases). Thus, to compare semantic priming in the single and dual task conditions, we conducted two additional analyses of variance in which we averaged the data from blocks 1 and 3.

In the first analysis we assessed semantic priming from attended primes. The main effect of prime type (attended

Figure 1. Sequence of events presented in the present experiments. Prime words were displayed for (a) 150 msec in Experiment 1 and (b) 30 msec followed by a pattern mask in Experiment 2. Examples have been translated to English.

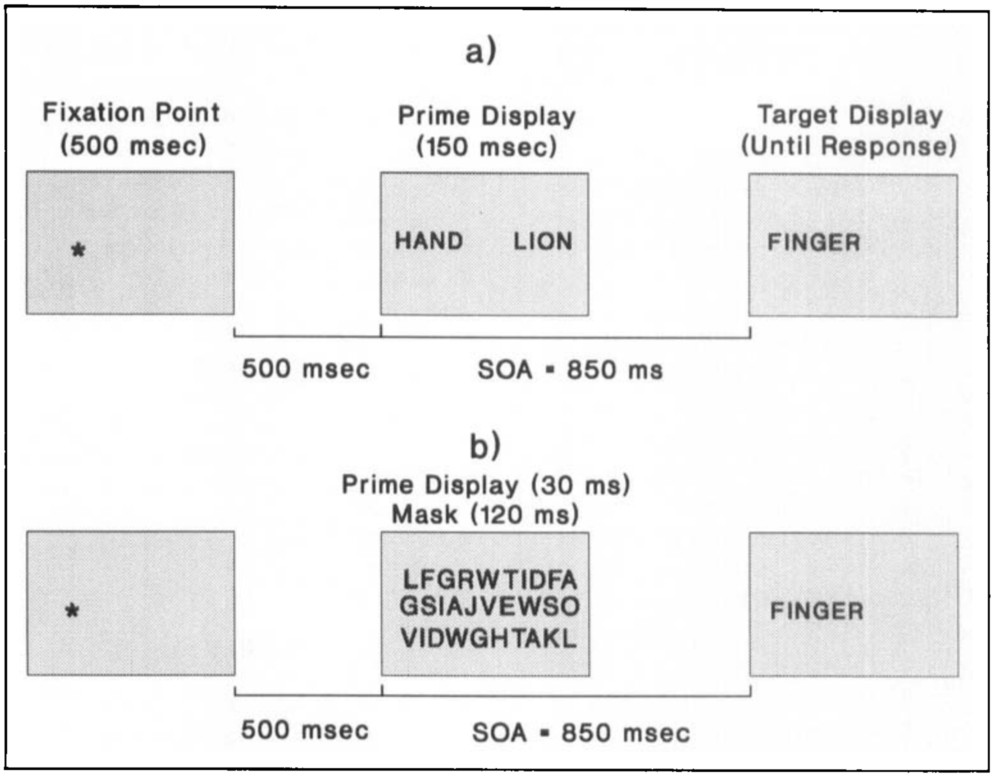

Table 1. Mean of Median Reaction Times for Prime Type under Single (Blocks 1 and 3) and Dual-Task (Block 2) Conditions in Experiment 1, and for the Masking Condition in Experiment 2[a]

	Blocks *Experiment 1*			*Experiment 2*
Prime type	*Single*	*Dual*	*Single*	*Masking*
Attended related	588 (3.8)	644 (3.1)	569 (2.3)	637 (4.9)
Unattended related	632 (6.1)	656 (2.3)	614 (4.9)	632 (6.3)
Unrelated	656 (7.5)	674 (4.7)	627 (4.7)	656 (7.5)

[a]Mean of median reaction times in milliseconds. Percentage errors in parentheses.

related vs. unrelated) was reliable, $F(1,23) = 35.16, p < 0.001$. This shows that semantic priming from attended words (47 msec) was reliable. The prime type × task (single vs. dual) interaction also proved reliable, $F(1,23) = 7.85, p < 0.025$. This shows that priming was reduced by shadowing (from 64 msec in the single, to 30 msec in the dual task). Further, semantic priming was still reliable after the reduction, $F(1,23) = 6.74, p < 0.025$.

In the second analysis we assessed semantic priming from unattended primes. Again, the main effect of prime type (unattended related vs. unrelated) was reliable, $F(1,23) = 9.74, p < 0.01$. This shows that semantic priming from unattended words was reliable (18.5 msec). However, the size of priming was not reduced by the shadowing task (19 msec in the single, and 18 msec in the dual task) (the prime type × task interaction was not reliable, $F < 1$).

Discussion

These results are consistent with the idea of two components in semantic priming (Neely, 1977; Posner, 1978; Posner & Snyder, 1975): one endogenous involving the medial frontal lobe and the other automatic, independent of the anterior attention system. The attentional component is apparent when semantic priming from foveal prime words is observed. Performing a secondary task (shadowing) reduced the size of priming from foveal prime words, but it did not have any effect on semantic priming from parafoveal unattended words. This demonstrates that it is not the semantic content of the secondary task that brought about the reduction in priming (since this should have reduced priming from parafoveal words too), but rather the shared use of the anterior attention system by both priming and shadowing.

The automatic component of semantic priming is observed with parafoveal words. Priming from parafoveal words was both significant (cf. Fuentes & Tudela, 1992) and unaffected by shadowing. This last result is inconsistent with the idea of parafoveal priming being due to occasional attentional slippage to the parafoveal words (Holender, 1986; Logan, 1992).

Finally, the fact that semantic priming from foveal prime words was greater under single than under dual task conditions, and greater than priming from parafoveal words, suggests that one of the functions of the anterior attention system is to increase the potency of semantic processing. The way this may be achieved was further explored in Experiment 2.

Experiment 2

Prime type (attended related, unattended related, and unrelated) was the within-subject factor for the one-way repeated measures ANOVA. The main effect of the factor was reliable, $F(2,46) = 7.14, p < 0.01$.

Pairwise comparisons revealed that latencies in the unrelated condition were longer than in both the attended related and the unattended related conditions ($p < 0.01$), but there were no reliable differences between the last two. Thus semantic priming was obtained from both foveal and parafoveal words, and its size was the same in both cases. The error analysis did not prove reliable, $F(2,46) = 1.39, p > 0.05$, but they followed the pattern of RT data.

In a further analysis, we tested semantic priming from both foveal and parafoveal prime words under comparable masking (Experiment 2) and nonmasking (block 1 of Experiment 1) conditions. Data were entered into a two-way mixed analysis of variance (ANOVA). The condition (masking vs. nonmasking) × prime type (attended related, unattended related, and unrelated) interaction proved reliable, $F(2,92) = 12.02, p < 0.001$. While semantic priming decreased as a consequence of the mask for the foveally presented words, $F(1,46) = 18.43, p < 0.001$, it did not do so for the parafoveally presented ones ($F < 1$).

Discussion

Several aspects of the results deserve comment. First, semantic priming from masked foveal prime words was significant. This is consistent with the idea of semantic processing without awareness, and it replicates the results reported by other similar studies (Balota, 1983; Carr & Dagenbach, 1990; Carr, McCauley, Sperber, & Parmelee, 1982; Dagenbach, Carr, & Wilhelmsen, 1989; Fowler, Woldford, Slade, & Tassinary, 1981; Marcel, 1983; Merikle & Reingold, 1990; Sánchez, 1988).

Second, semantic priming from parafoveal words was also significant. This gives further support to the above contention that semantic priming can occur without awareness. In addition, it allows us to dissociate perceptual from attentional effects on semantic processing under masking conditions (cf. Kahneman & Treisman, 1984). Parafoveal words here were located outside the focus of visual attention, yet they still produced reliable semantic priming. We conclude that perceptual processing to a semantic level can occur with unattended stimuli.

Third, the mask reduced semantic priming from foveal attended words, but it did not affect priming from parafoveal words. We proposed that foveal attended primes in Experiment 1 did not enter into intentional semantic processing. Yet priming from these items was affected by a secondary task that tapped the anterior attention system (Experiment 1), and priming from masked primes (in Experiment 2) was about the same magnitude as priming from unmasked primes when access to the anterior attention system was blocked (either by the secondary task or by primes being presented parafoveally in Experiment 1). We conclude that the anterior attention system is linked to primes being consciously represented, and not solely to intentional semantic processing.

CONCLUSIONS

In the present study we have combined two methods to determine whether semantic processing occurs without attention. The first method is cognitive, and allowed measurements of semantic priming from both foveally and parafoveally presented words in the same procedure (cf. Fuentes & Tudela, 1992). A successive prime-target presentation was chosen to prevent parafoveal unattended stimulus effects from being due to the target priming the distractor (cf. Johnston & Dark, 1986). Experiment 2 used a pattern mask to prevent both foveal and parafoveal words from being detected. In doing so, we could determine whether semantic processing can occur without awareness.

The second method involved shadowing as a secondary task, in a dual task condition. Shadowing was chosen because PET studies have revealed that it requires the anterior attention system. Thus, the pattern of interference on semantic priming produced by shadowing allowed us to determine the role of the anterior attention system in semantic processing of both foveal and parafoveal words.

Semantic priming from foveal and parafoveal words was observed in both experiments, so replicating the findings of previous studies (Fuentes & Tudela, 1992). While both the secondary task and the pattern mask reduced semantic priming from foveal words, priming was still reliable after the reduction and had similar magnitude to that from parafoveal words observed in both experiments. This seems to be strong confirmation that factors that influence semantic priming from foveal words are of two types: one automatic and the other involving conscious attention (Posner & Snyder, 1975). Furthermore, the contribution of these two factors lasted in time, as priming was measured after a rather long interval (SOA was 850 msec).

Contrary to the effects from foveal attended primes, parafoveal priming was not reduced by either the secondary task or the mask (see Fig. 2). These results are important from a behavioral/computational perspective. A traditional way of approaching the issue of whether word recognition is automatic has been to adopt a set of criterion properties that performance must show to be considered automatic. For instance, Neumann (1984) pointed out that performance would be considered automatic if (1) it does not suffer interference from other tasks, (2) it is not influenced by intentions, strategies, or expectations, and (3) it proceeds unconsciously.

Based on these criteria, it could be concluded that the processing of parafoveal words is automatic because (1) it was not interfered with by either shadowing or a pattern mask (criterion #1), (2) it was not affected by intentions, strategies, or expectations, since no action was required on parafoveal words, and in Experiment 2 subjects did not detect their presence (criterion #2), and (3) semantic priming was observed under masking conditions which prevented awareness of primes (criterion #3).

From a neuroanatomic perspective, the findings reported here support the assumption that semantic processing occurs in cerebral areas different from those involved in attention to language, from the shadowing task in this case (Petersen et al., 1988; Posner & Petersen, 1990). It suggests that sites of data processing must be separated from the sources of attention in the brain (Posner & Driver, 1992; Posner & Petersen, 1990). We have shown that an important role of the anterior attention system is to increase the potency of semantic processing of those stimuli that are consciously perceived, but that a second source of semantic priming, that we suppose automatic, exists independent of the anterior attention system mediating shadowing, and independent of subjects' conscious awareness. There may be other brain area(s) involved in automatic semantic processing. A candidate is the prefrontal cortex; however PET studies have shown that activity decreases in both cingulate and prefrontal cortex and increases in temporal and temporal-parietal cortex when a task becomes routinary with practice (cf. Carr, 1992). Because word recognition is practiced, the latter brain areas seem to be the best candidates to mediate automatic semantic processing. Further PET studies would be welcome.

Our results also provide some confirmation regarding the dissociation between attention (to foveated stimuli) and perception in semantic processing. As was indicated in the Introduction, Kahneman and Treisman (1984) pointed out a serious problem with the contention that semantic processing can occur without attention: namely the failure to dissociate perception from attention in visual masking studies. In Experiment 2 parafoveal words produced a similar level of semantic priming to foveal ones. Most important, the potency of priming observed in this experiment was roughly the same as that observed from parafoveal words in Experiment 1 (see Fig. 2). Thus, the present outcomes provide strong support for the

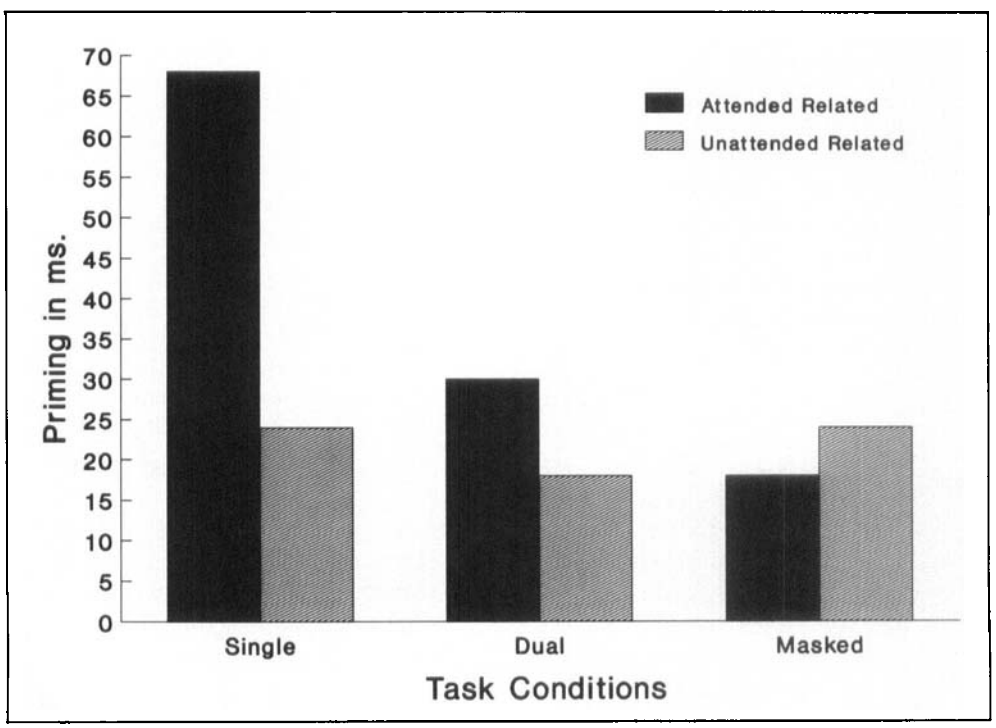

Figure 2. Semantic priming (in milliseconds) for both foveal (attended related) and parafoveal (unattended related) prime words under single-dual task and masking conditions.

claim that semantic priming can occur without both the focusing of attention and without awareness of the presence of stimulation.

An additional aspect of the present study has to do with the nature of the improvement in semantic priming when the anterior attention system is involved. Data from both PET and behavioral studies (e.g., Petersen et al., 1989; Smith et al., 1983) suggest that the anterior attention system mediates intentional semantic processing of attended stimuli. However, shadowing reduced semantic priming from prime words on which no intentional semantic processing was required (Nakagawa, 1991; Posner et al., 1989; Experiment 1, this study). This suggests that the anterior attention system mediates something more than the intentional semantic processing. Results of Experiment 2 showed that semantic priming was reduced by a pattern masking. This suggests that the anterior attention system is an "awareness" system. Thus, once representations of attended information become conscious, subjects can focus intentionally on several semantic aspects of that information, as required by the task.

The contention that the anterior attention system is involved in conscious processing is consistent with other findings. For instance, several studies have shown that attention involves inhibition (Tipper, 1985), depending on the anterior attention system (Nakagawa, 1991). Fuentes and Humphreys (1993) observed negative priming when distractors were presented to the ipsilesional field of a parietal-damaged patient. When they were presented to the contralesional field, facilitation instead of inhibition was then observed. Thus, it seems that awareness is needed for inhibitory processing to take place.

As Posner (1988) pointed out, it is possible that similar to the posterior attention system, the anterior attention system is organized in such a way that cortical and subcortical areas are involved in different operations. The present study has shown that in addition to intentional semantic processing, the anterior attention system is involved in conscious processing.

METHOD

Subjects

In both experiments one group of 24 undergraduates from Campus Universitario de Almeria, aged 19–35 years, participated as experimental subjects. All of them had normal or corrected-to-normal vision.

Stimuli and Apparatus

In Experiment 1 two kinds of verbal material was prepared, one for the visual task and the other for the auditory (shadowing) one. For the former 54 members of each one of 4 semantic categories (animals, food, body parts, and geographical accidents) were chosen from the Soto, Sebastián, García, and del Amo (1982) norms. Eighteen related prime-target pairs were created within each category that 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. Word frequency estimates were equated for related attended, related unattended, and unrelated trials. Nonword targets were formed by either changing one letter within a word [e.g., HUEVO (egg) changed to HOEVO] or by permutation of two consonant letters of a word [e.g., MANO (hand) changed to NAMO]. Every target word/nonword was presented once and every prime word appeared twice, once followed by a word either from the same or a different category, and once followed by a nonword.

Words were presented in capital letters that 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.

For the auditory task a tape was recorded with a fragment of the autobiographic novel "Confieso que he vivido" by Pablo Neruda. The text was pronounced by a female voice.

Visual material was displayed on the color screen of a standard personal computer, which was also used to register both latencies and accuracy responses. Auditory material was presented through professional sound equipment (TASCAM 34) controlled by the computer.

In Experiment 2 subjects performed only the visual task, and the same visual verbal material of Experiment 1 was used.

Procedure

Prime display was comprised of two words, one at fixation and the other displaced from it (always at the right side). Both words always belonged to a different category. Subjects were seated approximately 60 cm from the video monitor, and the parafoveal word was displaced 4.3° from the fixation point. Experiment 1 consisted of three blocks of 144 experimental trials each one preceded by one practice block of 24 trials. In blocks 1 and 3 subjects performed only the visual task; in block 2 they performed both the visual and the auditory tasks. Previously to the experimental blocks, subjects were given training in the shadowing task. They were told to repeat aloud word by word the same text that was used in block 2.

A trial was initiated by an asterisk that served as a fixation point. 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. The SOA between primes and target was 850 msec. Targets always appeared on the left, at the fixation point location, and remained on until the subject made the response. For each subject the dominant-hand key was correct for word targets and the nondominant-hand key was correct for nonword targets.

In Experiment 2, only one block was used. The prime display was presented for 30 msec, followed by a pattern mask lasting 120 msec. The mask consisted of three strings of 22 letters covering the field where prime words appeared (see Fig. 1b). This prime-mask SOA was chosen for the following reasons. Sánchez (1988) carried out four experiments to determine whether semantic priming could occur under objective threshold conditions, measured through different procedures. Using the same equipment as here, he found that SOA for objective thresholds varied from 24.5 to 40 msec in average across the experiments. Yet, even with durations set at these objective thresholds, there was semantic priming in all conditions. Also, Merikle and Reingold (1990) showed that familiar stimuli (i.e., words) that were not detected could be recognized above chance. In their experiments the target-mask SOA interval was 50 msec. Finally, Fuentes and Tudela (1987) showed that in a procedure similar to that used here, not one subject reported having detected any stimulus preceding the mask.

Once the experimental session was over, subjects were asked whether they had detected the presence of any stimulus preceding the mask. Subjects giving an affirmative answer were excluded from the analysis (in fact no subjects reported the presence of any stimuli before the mask).

As in Experiment 1, SOA between the prime and target display was 850 msec.

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