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Processing of attended and ignored words in the parafovea: Inhibitory aspects of semantic processing

Juan Lupiáñez*, María Rosario Rueda, María Ruz
and Pío Tudela

Universidad de Granada

The idea that attentional selection is carried out by means of facilitatory as well as inhibitory mechanisms has gained support in the past few years. With the aim of studying the influence of these mechanisms in language processing, we have used the semantic priming experimental procedure with a parafoveal presentation of two words in the prime display. One of the prime words was to be attended to (attended prime) and the other was to be ignored (distractor). Participants responded with a lexical decision task on the subsequent probe word. In the first experiment we manipulated the SOA between prime and probe at four levels: 250, 450, 650 and 850 ms. At all the SOA levels, we obtained facilitatory effects for probes related to the attended primes. However, inhibitory effects for probes related to ignored primes were only obtained with SOAs of 450, 650 and 850 ms. The facilitatory and inhibitory effects with an SOA of 850 ms were replicated with different experimental conditions in Experiments 2 and 3. The absence of negative priming in the 250 ms SOA supports the idea that the inhibitory mechanism is linked to a controlled and strategic processing. The attentional facilitation, however, can be produced either in an automatic or a controlled way. Moreover, we observed a consistent pattern of lateralization of the effects of facilitation and inhibition, given that the mentioned effects were only produced for primes presented in the right visual field. This pattern of lateralization is discussed in relation to the functional differences between the right and left hemispheres regarding semantic processing.

Key words: Semantic priming, semantic negative priming, time-course, attentional modulation, lateralization.

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*Correspondence to: Juan Lupiáñez Castillo. Facultad de Psicología. Campus Universitario de Cartuja s/n, 18071, Granada, Spain. e-mail: jlupiane@platon.ugr.es .The authors would like to thank the two reviewers, Juan J. Ortells and Jim Juola, and the action editor, Juan Botella, for their comments and suggestions, which greatly improved the original manuscript.

Many situations in our daily lives point to the need for an attentional mechanism which may allow us to select what information to direct our thoughts and actions to. This basic aspect of behavior has generated a great deal of research in the field of Cognitive Psychology and constitutes an entire area of study called *Selective Attention*.

On the other hand, responses to an event are faster and more accurate if we have already had experience with that event. This is the so-called *priming* effect (Scarborough, Cortese and Scarborough, 1977; Jacoby, 1983). Moreover, this processing advantage also occurs even if the previous stimulus is not the same but a semantically-related one (Meyer and Schvaneveldt, 1971). The experimental procedure used to study the priming effect usually involves the presentation of a stimulus (prime) followed by the presentation of a second stimulus (probe) which requires some type of processing in order for a response to be issued. The fundamental manipulation is the relationship between the stimuli. A reduction in reaction time has been consistently observed when the stimuli are the same (repetition priming) or when they are semantically related (semantic priming) compared to the conditions in which prime and probe are not related. In the field of Selective Attention, the priming paradigm has been used to study the influence that the mechanisms of attentional selection on a previous stimulus (the prime) may have upon the processing of a later presentation of the same stimulus (the probe).

A well-accepted interpretation of the priming phenomenon is that the fact of attending to a stimulus activates its representation in memory. This facilitates its later processing, compared to other neutral stimuli which have not previously been attended to. This activation is also transmitted to the representations of the related stimuli, thus producing semantic priming.

The amplification of the internal representation of the attended primes by means of an activation mechanism is an idea shared by the traditional models of selective attention. The distractors, however, are supposed to passively fade away and do not surpass a determined filter to reach posterior stages of processing and/or response (Broadbent, 1958; Deutsch and Deutsch, 1963, Treisman, 1964).

This lack of concern for the ignored information contrasts with the phenomenon of inverted priming that has consistently been obtained in the past few decades. When the stimulus that we must process has been previously ignored, its processing is delayed. This effect, which Tipper (1985) named *negative priming,* has also been obtained for stimuli semantically related to the distractor (*semantic negative priming*). In the same way, negative priming has been described using many experimental procedures and requiring different types of responses to the probe

(Dalrymple-Alford & Budayr,1966, Neill, 1977, and Lowe, 1979, 1985, with a Stroop task; Tipper, 1985, with a picture naming task; Neill, Lissner & Beck, 1990, and DeSchepper & Treisman, 1991, with letter and form matching tasks respectively; Tipper, Brehaut & Driver, 1990, Tipper, Lortie & Baylis, 1992, and Tipper, Howard & Meegan, in press, with spatial localization and *reaching* tasks; Tipper & Cranston, 1985, and Tipper & Driver, 1989, with naming tasks; Fuentes & Tudela, 1992, Ortells & Tudela, 1996, and Yee, 1991, with lexical decision tasks, etc.) See Fox (1995), May, Kane and Hasher (1995) and Neill, Valdes & Terry (1994) for recent reviews on negative priming.

Negative priming and selective attention

The main idea that can be drawn from the selective attention models is that, in order to reach higher levels of processing (e.g., semantic), the internal representation of the information must reach a determined threshold of activation. The function of attention is that of highlighting the representation of the attended information compared to the rest of the stimulation received, thus favoring its processing. Attention is understood to carry out its function by means of a mechanism of activation of the attended representation. However, this differentiation between what is attended to and what is ignored regarding the level of activation could also be achieved by means of a mechanism of inhibition of the irrelevant information, or even better: the combined action of both mechanisms.

The existence of two selective attention mechanisms -the activation of what is relevant and the inhibition of what is irrelevant- was an idea introduced in the study of selective attention at the end of the 1970's (Posner and Snyder, 1975; Neill, 1977). Within this context, the phenomenon of negative priming has been considered as an empirical finding which supports the inhibitory hypothesis, as negative priming is attributed to an active inhibitory mechanism which suppresses the ignored information. Therefore, the state of activation of the representation of irrelevant information lies below the basic activation level that would correspond to neutral conditions. The lower activation level from which the previously ignored information starts off entails that it requires more time to reach the minimum activation threshold to produce a response. This situation causes the increase in reaction time that defines the negative priming effect.

Another important implication, which is directly related to the phenomenon of negative semantic priming, is the fact that it suggests that the meaning is processed even when the stimulus is ignored. This indicates that semantic processing may be carried out automatically. Thus, it is possible to say that the ignored information is processed: its representation is activated but later inhibited in order to avoid interference with the response to the attended information (Driver and Tipper, 1989).

This way of approaching the selective attention process matches more recent ideas related to executive control. Attention is conceived as a central system whose main function is to exert control over the information processing systems by means of mechanisms of activation and inhibition (Tudela, 1992; Posner and DiGirolamo, 1998).

Negative priming and semantic processing

As we mentioned earlier, the effect of negative priming has been obtained with different experimental procedures and with different tasks on the probe. However, our main interest for this research lies in the study of the semantic processing of ignored words. Therefore, we shall focus on procedures that have used verbal material and manipulations regarding the prime-probe semantic relation.

One of these studies was carried out by Fuentes and Tudela (1992). In their experiment they presented two words as primes. The one in the fovea was supposed to be attended to, whereas the one in the parafovea was supposed to be ignored. At this stage, they presented the probe: a word which was situated at the fixation point. The participants were asked to make a lexical decision about it (they were required to say whether it was a word or not). Two manipulations were carried out. First of all, there was the semantic relationship between prime and probe: the probe could be related to the attended prime, the ignored one or neither of the two (control condition). The second manipulation was the distance between the foveal word, which was attended to, and the word presented in the parafovea, which was ignored. They obtained a facilitatory effect (positive priming) in conditions in which the probe was related to the attended primes, compared to unrelated conditions. In the conditions in which the probe was related to the prime ignored word, they found an interference effect (negative priming) with small eccentricity values which became positive as the parafoveal word was presented at a greater distance.

This fact provides evidence of the existence of the semantic processing of non-attended words in the parafovea, just as in other studies which have used semantic manipulations (Yee, 1991; Ortells and Tudela, 1996). Moreover, the interference effect suggests that inhibition is an active process whose function is to avoid the interference of irrelevant stimulation regarding the information which is supposed to be attended to. The closest elements are the ones which interfere the most, and this is why inhibition is needed in small eccentricities. For greater eccentricities inhibition does not take place and the effect becomes facilitatory. In any case, it becomes clear that both the mechanisms of inhibition and facilitation affect the conceptual representation of the stimulus.

Another set of studies coincides in pointing out that, whereas facilitation may be produced automatically, inhibition is a mechanism linked to a strategic or controlled processing. These studies aim at establishing the time course of the appearance of the negative priming phenomenon. As a whole, researchers obtain positive priming effects with SOAs (Stimulus Onset Asynchrony) between prime and probe of about 100 ms. However, negative priming effects require greater SOAs (Lowe, 1985; Yee, 1991; Park and Kanwisher, 1994). The idea is that inhibition is not produced in short SOAs because the strategic processing requires more time to be developed (Posner and Snyder, 1975).

In addition, other variables such as eccentricity or masking, which impede controlled processing, not only eliminate the effect of negative priming but also produce its inversion to positive priming (Allport, Tipper and Chmiel, 1985, and Tipper, 1985, with masking; Fuentes and Tudela, 1992, with manipulation of eccentricity).

On the whole, it seems that the distinction between automatic and controlled processing and the different time courses of the two types of processing may be an effective argument to explain the existing data. On the one hand, automatic processing goes into action immediately after the presentation of the stimulus, which leads to facilitation. Awareness of the stimulus is not necessary for this mechanism to act. Controlled processing, on the other hand, may be facilitatory or inhibitory depending on the strategies derived from the goals of the individual. This is a more complex processing which requires more time to begin to work. Besides, this kind of processing usually leads to awareness of the stimulus. According to this logic, the inhibited representation must be activated automatically at an earlier stage (Houghton and Tipper, 1994). Therefore, the effects of positive priming for ignored information are obtained if the experimental conditions only allow automatic processing.

Using a semantic priming paradigm with a parafoveal presentation of the primes and a lexical decision task (LDT), we attempted to test the foundations of this hypothesis. We used a similar procedure to that used by Ortells and Tudela (1996) in order to make the perceptual characteristics of the attended and ignored information as similar as possible. In this procedure two words were presented parafoveally at the same distance from fixation. One word was situated to the left and the other one was situated to the right. One of the two words was attended to and the other was ignored. The use of this procedure, in which the prime words are lateralized, also allows us to study the lateralization pattern of semantic priming, both positive and negative.

EXPERIMENT 1

The effect of NP has been obtained in different studies with multiple tasks and stimuli, but few studies have used LDT. Therefore, it is important to obtain the effect at a semantic level in order to generalize it to this new paradigm, in which the attended and ignored stimuli are displayed in similar perceptual conditions, as they are both presented in the parafovea. With the aim of studying the time course of the facilitatory and inhibitory effects of the attentional processing, in this first experiment we manipulated the prime-probe onset asynchrony (SOA).

METHOD

Participants. Ninety-six students from the Faculty of Psychology of the University of Granada participated in this experiment. They all received course credits for participating. All of them had normal or corrected-to-normal vision.

Apparatus and Stimuli. The stimuli were presented on an IBM monitor controlled by a VGA graphic card. An IBM PS/433DX computer, assisted by MEL software (Micro Experimental Laboratory; Schneider, 1988), controlled temporization of all events and data collection. The stimuli were presented in white against a dark background. The brightness and contrast were kept constant and at maximum levels of discriminability. The participants responded by pressing the "m" key on the keyboard with the index finger of the right hand or the "x" key with the index finger of the left hand. The assignment of the *yes-no* response to the keys was counter-balanced across participants. Strings of 4 to 7 letters were used as stimuli. They were presented horizontally on the computer screen. The size of each letter was 6mm in height by 3mm in width, which at a distance of 60cm is equal to approximately 0.57 and 0.29 degrees of visual angle (d.v.a.) respectively. The strings of letters took up an average of 2.2 cm (2.1 d.v.a.).

The words used were selected from Soto, Sebastián, García and del Amo's norms of categorization (1982). Four categories were used: geographic features and atmospheric phenomena; food; animals; and body parts. 102 words were selected from each category: 90 for the lexical decision phase and 12 to be used as new words in the recognition phase. Out of the 90 words, 18 were used as stimuli for practice and the remaining words were used as experimental stimuli. Out of these 72 words, 24 related pairs (48 words) were selected to act as related stimuli. The related pairs were selected by judges who were asked to select the most related pairs. In each of them, one word was used as the prime and the other one was used as the probe. The remaining 24 were used as non-related primes. In the same way, for each category the 18 practice words were ascribed to the groups of relevant stimuli, both previously related and not previously related. For each of the words used as probe, its corresponding non-word was constructed, changing only one letter and maintaining its pronounceability and spelling norms.

A different list was constructed for each participant. In this process, the probes were randomly assigned to each experimental condition. Their corresponding related primes were also automatically selected in the conditions in which the probe was related to one of the primes. The remaining words were used as non-related primes. An equal number of words from each category, including that of the probe, were assigned to each condition. This selection process was carried out again using the non-words as probes. This way, each probe would appear only once throughout the experiment, whereas each prime would appear twice: once followed by a word and once followed by a non-word.

Once the lists were constructed, 48 words were randomly chosen to be presented later as signal-stimuli in the recognition phase. 12 words were selected out of each category. 24 of these words appeared on the right and 24 on the left. Half of them were attended to and the others were ignored. These words, together with 48 new words (see above), made up the recognition list .

Procedure. Four experimental groups were used. They corresponded to the four levels of SOA (250, 450, 650 and 850 ms). The participants sat at an approximate distance of 60 cms from the computer screen in a dimly-lit room, with their chins resting on a chin-rest. All of them did two consecutive LD blocks. The first one was for practice and had 48 trials, whereas the second one had 192 experimental trials (96 with a word as probe and 96 with a non-word). In the practice block, the same SOA (850 ms) was used in all the groups. At the end of the two LD blocks, the participants carried out a recognition block which contained some of the stimuli presented in the previous phase and some new stimuli as well.

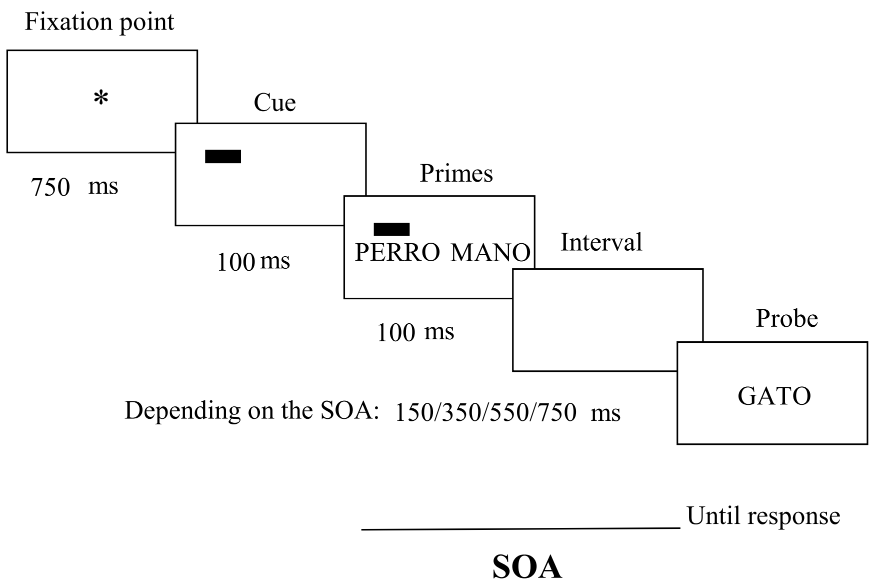


Figure 1. Graphic representation of the course of events that make up a trial in Experiment 1. The events take place from the upper left frame to the lower right. Here we see an example of a trial of the *attended-related* condition, with the signal on the left.

Figure 1 presents the series of events that happened in the LD phase of each trial. It began with the presentation of a fixation point during 750 ms, after which a bar (cue) was presented to its left (left visual field, LVF) or to its right (right visual field, RVF). The cue was 10 mm wide (0.95 d.v.a.) by 4 mm high (0.38 d.v.a.), and appeared at 23 mm (2.2 d.v.a.) from the fixation point at its nearest point. Following the cue, 100 ms later two words were presented in the parafovea. One word appeared at each side of the fixation point, which was replaced by the words. They appeared at 14 mm (1.34 d.v.a.) from their nearest edge to the fixation point. The two words remained on the screen for 100 ms. The interval between the appearance of the cue and the disappearance of the prime words was 200 ms, thus minimizing the possibility of eye movements (Van der Heijden, 1992). One of the 2 primes appeared in the cued position and had to be attended to (target), whereas the other one appeared in the opposite position and had to be ignored (distractor). Participants did not have to respond overtly to any of these words. However, it was emphasized that they had to attend to the target and ignore the distractor. In order to encourage participants to pay attention to the cued words, they were informed that at the end of the experiment they would be required to remember these words.

After the disappearance of the two prime words, the screen remained black for a period of 150, 350, 550 or 750 ms (depending on the SOA). Next, the probe (a word or a non-word) appeared in the center of the screen and remained there until the participant's response. The participants received information about the possible semantic relationship between some of the attended primes and the probe. Just after the participant's response, accuracy feedback was provided. The next trial began with the appearance of the fixation point.

After the lexical decision phase, participants received instructions on the recognition phase. The words were randomly presented one by one in the center of the screen. Participants had to respond by pressing the "1", "2", "3" or "4" computer keys, according to whether 1) they were sure the word had appeared before, 2) they thought it had probably appeared, 3) they thought it had probably not appeared, or 4) they were sure the word had not appeared before in the experiment. In this phase there was no time limit for the response.

Design. Four experimental groups were used. Each of them corresponded to an SOA level (250, 450, 650 and 850 ms). All the participants completed a block of 192 experimental trials, 96 of which had words as a probe and the remaining 96 of which had non-words. For both groups, the preliminary cue appeared in the left visual field (LVF) in half of the trials (48) and in the right visual field (RVF) in the other half. For each of these two conditions, the same number of stimuli were assigned to each of the relatedness conditions (attended-related, ignored-related and unrelated conditions). Each participant randomly received 16 trials from each of the 12 experimental conditions resulting from the factorial combination of the variables Word/Non-word, Location (LVF/RVF) and Relatedness (Attended-related/Ignored-related/Unrelated). Reaction time (RT) and percentage of errors were registered as dependent variables.

RESULTS

In this section we shall only present the results of the LD phase. Given that recognition data did not interact with either experiment or SOA, we will present them collapsed at the end of the section. The average RT values for all the experiments, according to the different experimental conditions, are presented in table 1.

For the analysis of the *trade-off* (see Botella, 1999, pp. 68-69), Pearson's correlation coefficient between the RT and the precision (percentage of correct answers) was computed. A negative correlation, which is not significant though, was found between the two variables: r = -0.05, χ (1, N = 1152) = 2.86, p = 0.091.

For the analysis of the RTs, trials with an RT greater than 2000 ms or lower than 200 ms were eliminated, as well as those with incorrect answers (11% of the trials, 2.44% of them with an RT outside the established range and 8.6% of them with incorrect answers). In this analysis and the following ones, the only trials analyzed were those in which the probe was a word. Averages of the RT of each participant per experimental condition and percentages of errors were introduced in different ANOVAs of 4 (SOA) x 2 (LOCATION) x 3 (RELATEDNESS). Location (LVF/RVF) and Relatedness (Attended-Related/Ignored-Related/Unrelated) were treated as within-participants variables, whereas the SOA (250, 450, 650 and 850 ms) was considered as a between-participants variable. Figure 2 presents the effects of semantic priming depending on the SOA.

Table 1. Trials with response to words. Experiments 1, 2 and 3. Mean median TR (in ms) per experimental condition. Percentage of errors in brackets.

Cue-Relatedness		**Left**			**Right**		
Exp	SOA	Att-Rel	Ig-Rel	Unrel	Att-Rel	Ig-Rel	Unrel
1	250 ms	947 (4.7%)	940 (6.5%)	948 (5.5%)	944 (4.2%)	936 (6.3%)	993 (7.8%)
	450 ms	896 (3.9%)	916 (3.1%)	877 (2.9%)	847 (2.3%)	908 (5.2%)	936 (6.3%)
	650 ms	807 (2.9%)	859 (5.5%)	821 (4.2%)	816 (4.2%)	850 (7.3%)	862 (8.1%)
	850 ms	815 (5.5%)	841 (6.3%)	801 (6.8%)	789 (5.7%)	840 (4.9%)	879 (7.6%)
2	850 ms	767 (4.7%)	812 (6.0%)	775 (3.4%)	756 (4.7%)	771 (5.5%)	810 (9.4%)
3	850 ms	912 (6.8%)	955 (4.9%)	914 (3.9%)	902 (3.4%)	926 (7.3%)	1002 (8.6%)

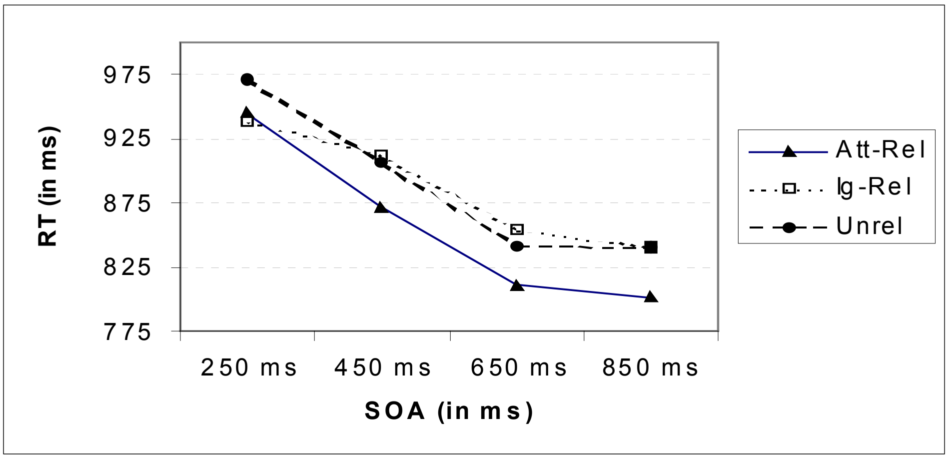


Figure 2. Graphic representation of the average RTs depending on the SOA, for the three Relatedness levels (Attended-Related, Ignored-Related and Unrelated). It should be observed that the facilitatory effect appears from the first SOA level and is maintained, whereas the inhibitory effect of negative priming does not appear until there is an SOA of 450 ms.

Reaction Time: From the general ANOVA analysis, the main effects of the variables Location, $F(1, 92) = 4.113$, $p < 0.05$, and Relatedness, $F(2, 184) = 11.071$, $p < 0.001$ were significant, as well as the Location x Relatedness interaction, $F(2, 184) = 15.03$, $p < 0.001$. The SOA proved to be marginally significant, $F(1,92) = 2.596$, $p = 0.057$. The Relatedness x SOA interaction was not significant. However, when only the 250 and 650 ms SOA levels were introduced into the analysis, the interaction was significant, $F(2, 92) = 3.898$, $p < 0.05$.

Given the interest in the effects of priming depending on the SOA, we analyzed the effects separately for each SOA group:

SOA 250 ms: The effect of Relatedness was marginally significant, $F(2, 46) = 2.58$, $p = 0.087$. Planned comparisons showed a facilitatory effect in the condition of the cue presented in the RVF, both for words related to the previously attended stimulus (49 ms), $F(1, 23) = 4.545$, $p < 0.05$, and for those related to the ignored stimulus (57 ms), $F(1, 23) = 6.526$, $p < 0.05$.

SOA 450 ms: The main effect of Relatedness, $F(2, 46) = 4.217$, $p < 0.05$, and the Location x Relatedness interaction, $F(2, 46) = 7.868$, $p < 0.01$, were significant. Planned comparisons demonstrated a facilitatory effect for attended words with the cue on the right (88 ms), $F(1, 23) = 16.839$, $p <$

0.001, and an increase in the RT for ignored words with the cue on the left (-39 ms), $F(1, 23) = 5.014$, $p < 0.05$.

SOA 650 ms: The main effect of Relatedness proved to be significant, $F(2, 46) = 5.757$, $p < 0.01$. Again, planned comparisons showed a facilitatory effect for attended words with the cue on the right (46 ms), $F(1, 23) = 7.866$, $p < 0.01$, and an increase in the RT for ignored words with the cue on the left (-37 ms), $F(1, 23) = 6.644$, $p < 0.05$.

SOA 850 ms: The effect of Relatedness, $F(2, 46) = 3.623$, $p < 0.05$, and the Location x Relatedness interaction, $F(2, 46) = 6.916$, $p < 0.01$ proved to be significant. The planned comparisons showed a facilitatory effect for attended words with the cue on the right (90 ms), $F(1, 23) = 14.279$, $p < 0.001$. There was a marginally significant increase in the RT for ignored words with the cue on the left (-39 ms), $F(1, 23) = 3.462$, $p = 0.076$.

Percentage of errors: Both the effects of Location and Relatedness, as well as the interaction between both, proved to be significant, $F(1,92) = 5.068$, $p < 0.05$, $F(2, 184) = 7.049$, $p < 0.001$, and $F(2, 184) = 3.04$, $p < 0.05$, respectively. After carrying out the pertinent comparisons for the analysis of the effect of the semantic relation, only a facilitatory effect for related words with the cue on the right (3.9%) proved to be significant, $F(4, 92) = 4.11$, $p < 0.01$. In general, the precision data reflect those of the RTs.

DISCUSSION

Response latency is reduced as the SOA between the primes and the probe increases, mainly between the 250 and the 650 ms SOAs. This result is commonly obtained in different RT tasks, and can be interpreted as a greater preparation for responding to the second stimulus as the SOA increases. The participants took longer to respond when the cue was on the right rather than on the left, although this was shaded by an interaction between the location of the cue and the relationship between prime and probe. The RT was greater in those trials in which the cue appeared on the right rather than on the left, although this increase in the RT for the cue on the right is only produced in the unrelated condition. This may indicate that primes that appear on the right are processed to a greater degree. Thus, when the primes were related to the probe, the corresponding effect appeared. It was facilitatory (PP) or inhibitory (NP) depending on whether the words were attended to or ignored. When there was no relationship, the interference was greater on the right than on the left.

Regarding our initial hypothesis, we can conclude that it is supported in general terms, but only when the primes, be they attended or ignored, are presented in the RVF. Thus, the facilitation or PP effect appeared at 250 ms, whereas the inhibition or NP effect was not present until 450 ms. This result supports our predictions in terms of automatic and controlled processes (Posner and Snyder, 1975), and the need for attentional control in order to obtain the NP effect. However, in the pattern of data, some details do not fit the general explanation. It should be noted that, when the cue is on the right, facilitation is produced for ignored words (presented on the left) in some SOAs (250 and 850 ms). However**,** when the cue is on the left, no facilitation is produced for attended words (presented on the left). This, together with the loss of significance in the NP effect for words presented on the right, led us to think about the convenience of replicating the experiment in the 850 ms SOA. Thus, we replicated the 850 ms SOA condition in the following experiment.

EXPERIMENT 2

The use of long SOAs may increase the experimental noise, given that it allows the use of idiosyncratic strategies by the participants. Therefore, the loss of significance in the 850 ms SOA of Experiment 1 might have been due to a greater variability of the data. The aim of our second experiment was to replicate the 850 SOA group from Experiment 1, making the effect more sensitive to our experimental manipulations by reducing variability. In order to do so, the probe was presented on the screen for only 500 ms, instead of being presented until the participant's response. We expected that the temporal demands due to the limited probe duration would homogenize the response strategies of the participants, and therefore reduce variability.

METHOD

Participants. Twenty-four students from the Faculty of Psychology of the University of Granada participated in the experiment, and received course credits for their participation. All of them had normal or corrected-to-normal vision.

Procedure and apparatus. The procedure and apparatus were the same as those used in Experiment 1, except that the probe was presented for only 500 ms.

Design. The design was the same as that of Experiment 1, except that the SOA variable remained constant at 850 ms.

RESULTS

There were no signs of speed-accuracy *trade-off*, given the negative correlation between the two dependent variables, which was only marginally significant though: r = -0.11, χ (1, N = 276) = 3.482, p = 0.062. To eliminate extreme RTs in the RT analysis, trials with an RT greater than 2000 ms or lower than 200 ms were eliminated (1.2 % of the trials). In the same way, the data from one participant was eliminated because he had a high number of errors compared to the average of the rest (26 % compared to 9 %). For the rest of the trials, the correct RT averages of each participant were computed for each experimental condition. This data and the error percentages were submitted to different 2 (LOCATION) x 3 (RELATEDNESS) repeated measures ANOVAs (see table 1).

Reaction Time: The main effect of Relatedness, $F(2,44) = 3.652$, $p < 0.05$, and the Location x Relatedness interaction, $F(2, 44) = 4.318$, $p < 0.05$, were significant. The analysis of the interaction pattern showed a facilitatory effect for attended words on the right (54 ms), $F(1, 22) = 13.379$, $p < 0.001$, and for ignored words on the left (39 ms), $F(1, 22) = 4.646$, $p < 0.05$. An increase in the RT (-37 ms) proved marginally significant for ignored words on the right (cue on the left), $F(1, 22) = 3.919$, $p = 0.06$.

Percentage of error: The ANOVA revealed the Location x Relatedness interaction, $F(2, 46) = 5.925$, $P < 0.01$ to be significant. The data pattern was similar to that obtained for RT. The main effect of the variable Location proved to be marginally significant, $F(2, 46) = 3.82$, $p = 0.063$. After carrying out the pertinent comparisons for the analysis of the interaction, only facilitation (4.7%) was significant for words presented on the right, $F(1, 23) = 4.283$, $p < 0.05$. The facilitatory (3.9%) effect observed for ignored words on the left proved to be marginally significant, $F(1, 23) = 3.01$, $p = 0.096$.

DISCUSSION

In Experiment 2 we replicated the data obtained in Experiment 1 almost exactly, using an SOA of 850 ms. Once again we observed the effects of PP and NP for attended and ignored words respectively, but only for primes presented in the RVF. The NP effect for ignored words on the right (cue on the left) did not reach significance in Experiment 2 either, although it had once again the same magnitude as that obtained in the 650 ms SOA condition in Experiment 1, where it was significant. However, the effect of facilitation for ignored words on the left (cue on the right) was significant in this second experiment. Hence, the idea that we are dealing with a spurious effect can be ruled out.

It should be noted that the facilitatory effect observed for probes related to ignored primes presented on the LVF disappeared when primes were attended to instead of ignored. When words are ignored on the left, their eccentricity may be functionally sufficient to impede awareness of their corresponding semantic codes. Thus, facilitation may be produced due to automatic activation, as with masking or excessive eccentricity. One tentative explanation might be that the processing of the words presented in the LVF is weaker and therefore more likely to be eliminated or reduced by other factors. The selection key used (a bar over the words to attend to) could mask the cued words when they are presented on the left. This would occur in the condition in which they are attended but not when they are ignored (cue on the right). In order to test this possible explanation, we decided to carry out Experiment 3, in which the primes are selected on the base of a central cue.

EXPERIMENT 3

Although one of the goals of our study was to obtain negative and positive semantic effects depending on the attentional conditions, equaling all the perceptual conditions for attended and ignored words, the use of the bar in the periphery as a cue broke this equality. Therefore, we considered appropriate to reproduce the same pattern of data using a central instead of a peripheral selection cue (Posner, 1988). In this experiment we used an arrow in the center of the screen to indicate which prime should be attended to, thus equalizing the perceptual conditions of the attended and ignored information.

METHOD

Participants. Twenty-four students from the Faculty of Psychology of the University of Granada participated in the experiment. They all received course credits in exchange. All of them had normal or corrected-to-normal vision.

Procedure and apparatus. The apparatus and procedures were the same as those used in Experiment 2, except that the attended prime was cued with a central cue (an arrow presented at the center, pointing either left or right). Thus, participants had to attend to the prime that was pointed by the arrow and ignore the one on the other side. The remaining features of the experiment were exactly the same as those of Experiment 2.

Design. Just as in Experiment 2, each participant randomly received 16 trials from each of the 12 experimental conditions which resulted from the factorial combination of the variables Word / Non-word, Location (LVF / RVF) and Relatedness (Attended-Related / Ignored-Related / Unrelated).

RESULTS

The correlation between precision and RT proved to be negative, although not significant, $r = -0.059$, χ (1, N = 288) = 1, $p > 0.10$. Therefore, the possibility of speed-accuracy *trade-off* is discarded. To avoid including extreme data in the RT analysis, RTs greater than 3000 ms or lower than 200 ms were eliminated (less than 1% of the trials). A higher cut-off was used in this experiment because the average RT was also higher than in previous experiments. For the remaining trials, the averages of the correct RTs for each participant per experimental condition were computed. They were later submitted, together with the error percentages, to separate 2 (LOCATION) x 3 (RELATEDNESS) repeated measures ANOVAs.

Reaction Time: The main effect of Relatedness, $F(2, 46) = 4.736$, $p < 0.05$ proved to be significant, as well as the Location x Relatedness interaction, $F(2, 46) = 9.966$, $p < 0.001$. Planned comparisons showed a facilitatory effect for attended words on the right (100 ms), $F(1, 23) = 13.22$ $p < 0.001$, and for ignored words on the left (76 ms), $F(1, 23) = 7.673$, $p < 0.05$. The increase in RT (-41 ms) for ignored words on the right, $F(1, 23) = 4.934$, $p < 0.05$ proved to be equally significant.

Given the similarity between Experiments 2 and 3 (see table 1), we carried out an ANOVA on the RTs of the two experiments, taking the Experiment as a between-participants variable. In this analysis the Experiment variable was significant, $F(1, 45) = 5.767$, $p < 0.05$. This was due to the greater RT in Experiment 3 (M = 935 ms) than in Experiment 2 (M = 782 ms). However, the Experiment did not interact with any other variable.

Percentage of errors: Only the Location x Relatedness interaction, $F(2, 46) = 5.489$, $P < 0.01$ was significant. The comparisons revealed a significant facilitatory effect (5.2 %) for attended words presented on the right, $F(1, 23) = 11.5$, $p < 0.01$. An interference effect (-2.9 %) for attended words on the left proved to be marginally significant, $F(1, 23) = 3.223$, $p = 0.086$.

DISCUSSION

The average RT in this experiment was greater than in Experiment 2, despite the fact that the only difference between the two experiments was the use of the central cue as a selection key in Experiment 3. The peripheral cue is processed in a more or less automatic way (Rafal and Henik, 1994). However, the central cue must be interpreted, thus implying the involvement of central processing structures whose action requires more time. We replicated the pattern of data obtained in Experiment 2 with a central cue, that is, PP or NP for words presented on the right, depending respectively on whether they were attended or ignored, and facilitation for ignored words on the left. In this experiment, these three pieces of data were significant with a probability of 0.05. Therefore, the effects remain established and the possibility that they may be due to spurious factors is ruled out. Regarding the condition of words attended to on the left, once again no semantic effect is produced at all. It should also be pointed out that the percentage of errors had a marginally significant effect, but in a negative sense.

Recognition Data

Previous analyses related to recognition data showed no main effect of Experiment and SOA, nor did any of the interactions concerning these two factors. We therefore present the data collapsed for the three experiments and the four SOA levels starting from the first experiment.

Hit and False Alarm rates were computed for each experimental condition (Location x Attention). Based on Hit and False Alarms, *d'* was obtained for each experimental condition and participant and introduced in a repeated measures ANOVA of 2 (LOCATION) x 2 (ATTENTION). The main effect of Attention, $F(1, 141) = 51.355$, $p < 0.001$ was significant. This was due to a better performance in the recognition of attended words (d' = 0.91) than that of ignored words (d' = 0.48). Neither the variable Location nor the interaction approached significance, $p > 0.5$. In all conditions the value of d' was significantly different from zero (all ps < 0.001). The Student *t* test was used in this analysis. The results clearly show that the attended words were recognized to a greater extent than the ignored ones. This indicates that participants attended to and ignored the corresponding word in each trial depending on the cue.

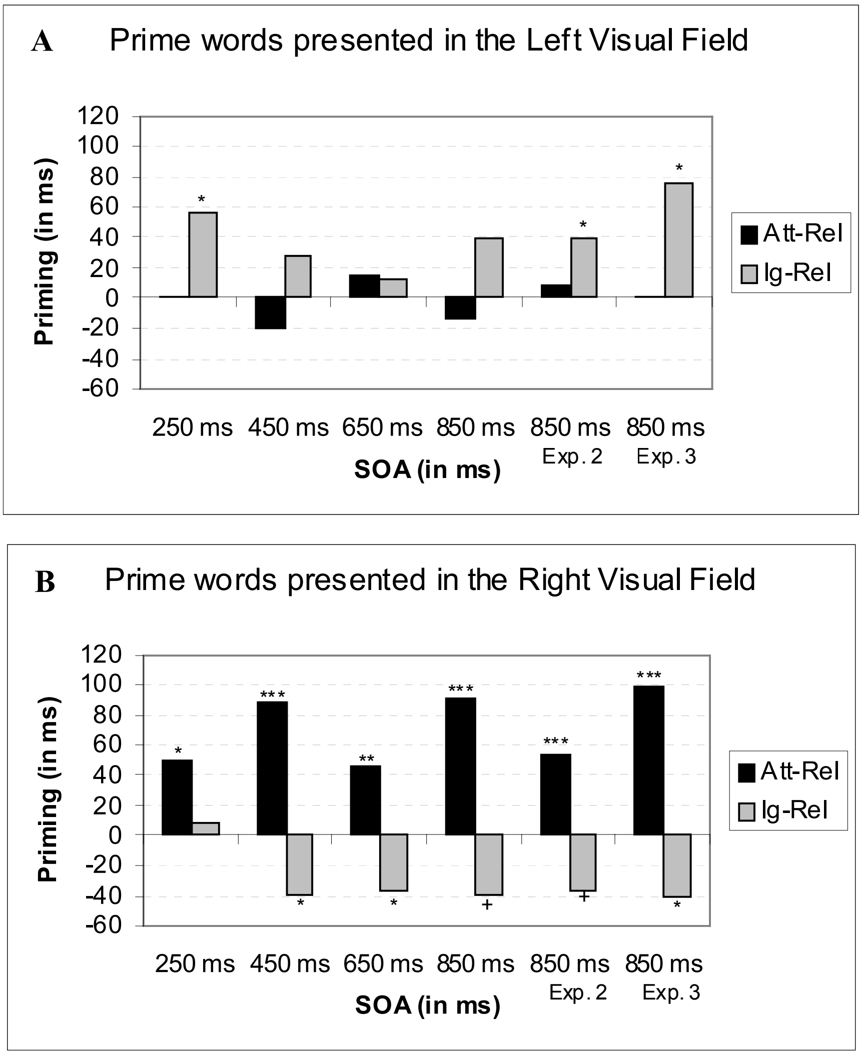
GENERAL DISCUSSION

In the set of experiments presented in this paper we obtained a pattern of positive and negative semantic priming effects based on the manipulation of the SOA which is consistent with the existing literature and the hypothesis presented in the introduction. That is, in the short SOA (250 ms) facilitation occurs for probes related to attended primes as well as for probes related to distractors. Only in longer SOAs is a negative priming effect produced for probes related to distractors, whereas the facilitatory effect for probes related to attended primes is maintained. In addition to that, the effects of positive and negative semantic priming were replicated in Experiments 2 and 3, where we introduced variations in the procedure.

In the light of these results, it seems that the mechanisms involved in selective attention have different time courses, due mainly to their functional characteristics. Whereas the activation of attended information can be done in an automatic way, the inhibition of irrelevant information is the result of a controlled process. Thus, the information presented is automatically processed even at a semantic level from the first moment. If time does not allow for the action of selective attention controlled processes, we obtain facilitatory effects for all the information being presented, that is, what we wanted to attend to as well as what we meant to ignore. This is what occurred in our first experiment when the SOA between probe and prime was only 250 ms. With longer SOAs, there is enough time to develop an attentional inhibition of the information we wish to ignore. As a result, we later observed a delay in responding to probes related to ignored primes, compared to unrelated prime-probe conditions. This semantic negative priming consistently occurs in our experiments in the SOA conditions of 450, 650 and 850 milliseconds.

It is important to point out that the observed effects are semantic in nature. Therefore, we argue that the effects of attentional activation and inhibition of the representations in semantic memory spread to the representations of related concepts, possibly through a mechanism of *spreading activation* (Neumann y DeSchepper, 1991).

However, in our data we consistently observed a clear pattern of hemispheric lateralization of the reported effects (see figure 3, where the effects obtained in the three experiments are shown together). It can be observed that both effects -positive priming for words related to attended primes and negative priming for those related to distractors- are present whenever the corresponding prime word is presented in the RVF (left hemisphere, LH). Interestingly, for prime words presented in the LVF (right hemisphere, RH), we did not observe any effect at all if the prime was attended. In contrast, we observed a facilitatory effect when it was ignored. This effect was significant at least in some cases: Exp.1 with SOA of 250 ms; Exp. 2 and Exp. 3, with SOA of 850 ms.



Figures 3a and 3b: Graphic representation of the effects of *priming* obtained in the three experiments as a function of SOA. When not otherwise specified, the data pertain to Experiment 1. The respective *priming* effects (Att-Rel and Ig-Rel) were computed by subtracting the respective RTs in the conditions of Attended-Related and Ignored-Related from the RT in the Unrelated condition. In Figure 3a the *priming* data are from words (attended and ignored) presented in the Left Hemifield, and in Figure 3b they are from words (attended and ignored) presented in the Right Hemifield. Note that in the Att-Rel condition, the location of the attended word matches the location of the cue. In the Ig-Rel condition, however, the location of the ignored word is the opposite of that of the cue. The symbols (*), (**) and (***) indicate the significance levels, with $p < 0.05$, 0.01 and 0.001, respectively. A (+) indicates that the effect is marginally significant ($p < 0.08$).

Our results are different to the results obtained by other authors and ourselves using similar procedures. Ortells and Tudela (1996) found semantic positive priming for attended words presented in both left and right visual fields, and SNP only from ignored words in the LVF. Ortells, Abad, Noguera and Lupiáñez (in press) have recently obtained a similar pattern of lateralization. Moreover, we have obtained the Ortells and Tudela (1996) pattern of lateralization in our laboratory, and have replicated it in English (Lupiáñez, Tudela, Rueda, Milliken and Ortells, in preparation).

It is not clear why we have obtained a different pattern of lateralization in the experiments reported in this paper: SNP and SPP only from words presented in the RVF. The most important difference between our procedure and that used in the experiments which produced a different pattern of lateralization (Lupiáñez et al., in preparation; Ortells et al., in press; Ortells & Tudela, 1996) concerns the construction of the lists. As noted above in the procedure of Experiment 1, given the way we constructed our lists, in each experimental condition there was the same proportion of unrelated words from each category, including that of the probe word. Therefore, in the procedure used by Ortells and Tudela (1996) the unrelated words of the prime were always from a different category, whereas in our procedure, in 25% of the trials the two prime words were from the same category as the probe. In these trials, in which the three words belong to the same category, one of the prime words (in the attended or ignored related condition) or none of them (in the unrelated condition) were also highly associated to the probe.

In those trials in which the two prime words belong to the same category, a broad coding of the attended prime word is not sufficient to select it. For instance, in order to select "dog" against "camel" we must select the specific meaning of "dog"; coding it as "animal" is not appropriate. However, if the two prime words belong to different categories, coding "dog" as "animal" is sufficient to select it against "camel". As a result, our procedure is likely to emphasize associative, more specific priming, whereas that used by Ortells and Tudela (1996), Ortells et al. (in press) and Lupiáñez et al. (in preparation) measures a combination of categorical and associative priming. As several authors have pointed out, the left hemisphere seems to select the specific meaning of words, whereas the right hemisphere maintains the broader meaning activated (Nakagawa, 1991; Ortells, Tudela, Noguera & Abad, 1998). By using a proportion of trials in which the two prime words were from the same category, our procedure might have emphasized the selection of the specific meaning of the words, thus leading to a semantic priming effect only from words presented in the RVF (processed by the left hemisphere). Unfortunately, we did not code the trials with and without unrelated words from the probe category separately, so we cannot check whether those trials produced a different pattern of lateralization. Nevertheless, the fact that there was only one forth of those trials leads us to think that this effect must be strategic in nature rather than an on-line effect. Further research is necessary to solve this issue.

An alternative explanation to our pattern of lateralization might be related to the asymmetry in the perceptual amplitude of the right and left visual hemifields. For verbal stimuli, the functional eccentricity is greater on the right than on the left of the fixation point (Lupiáñez, Madrid & Rueda, 1999). With this phenomenon as a starting point, we can say that, with the same eccentricity, the words presented in the LVF-RH are processed with less perceptual quality than those presented in the RVF-LH. As we mentioned in the introduction, the factors which deteriorate the controlled processing of the stimulus, mainly those factors related to perceptual quality, eliminate and even invert the effect of negative priming. This is just what occurs in our experiments when the distractor is presented to the left of the fixation point.

However, when a word presented in the LVF-RH is attended to, the effect is not only not facilitatory, but there is instead a certain tendency toward inhibition (negative semantic priming). Regarding this piece of data, Dagenbach and Carr (1994) point out that in situations in which the perceptual quality is deficient, instructions to attend lead to the finding of negative semantic priming (also see Durante & Hirshman, 1994, for similar results). In their opinion, this counterintuitive result occurs because in conditions of poor quality in the perceptual representation of a word, access to its meaning is difficult. In order to facilitate the semantic access of these words, a *center-periphery* attentional mechanism is activated. This mechanism acts boosting the specific concept that the word refers to and inhibiting related concepts, in order to eliminate competitors. This is why the response is slower if the corresponding probe is a related word. This explanation is, nevertheless, merely speculative and must undergo a more thorough experimental process of analysis.

In conclusion, in our three experiments we have consistently shown that the processing of previously presented words influences the processing of a related probe word. Furthermore, we have analyzed the way in which mechanisms of selective attention modulate semantic processing. Our data confirms that, after the presentation of verbal stimuli, their lexical representations are automatically activated in memory from the very first moment. However, when it is necessary to select one word instead of another, the selective attention mechanisms act on the corresponding representations, activating those of attended words and inhibiting those of ignored words. Therefore, the activation of attended words can be implemented in an automatic or controlled way. Attentional inhibition, however, is only linked to controlled type processing. Hence, the effects derived from the inhibitory mechanism are only observed after a time interval which, in our experimental situation, is about 450 ms. Finally, when priming emphasizes specific semantic associations, the effects derived from the action of selective attention mechanisms seem to be lateralized to the left hemisphere.

RESUMEN

Procesamiento de palabras atendidas e ignoradas en la parafóvea. Aspectos inhibitorios del procesamiento semántico La idea de que la selección atencional se lleva a cabo a través de mecanismos tanto de activación como de inhibición ha ganado apoyo en los últimos años. Con el fin de estudiar la influencia de estos mecanismos en el procesamiento del lenguaje hemos utilizado un procedimiento experimental de priming semántico con presentación parafóveal de dos palabras en la presentación previa (EP), una que debía ser atendida y otra ignorada, y tarea de decisión léxica sobre el estímulo objetivo (EO). En un primer experimento manipulamos el SOA entre el EP y el EO a cuatro niveles: 250, 450, 650 y 850 ms. En todos los niveles de SOA se obtuvieron efectos de facilitación para EOs relacionados con el EP atendido. Sin embargo, sólo en los SOAs de 450, 650 y 850 ms se obtuvieron los efectos de inhibición para el EO relacionado con el EP ignorado. Los efectos de facilitación e inhibición con SOA de 850 ms fueron replicados con diferentes condiciones experimentales en los experimentos 2 y 3. La ausencia de priming negativo en el SOA de 250 ms apoya la idea de que el mecanismo inhibitorio está ligado a un procesamiento de tipo controlado o estratégico. La facilitación atencional, sin embargo, puede producirse de forma automática o controlada. Descubrimos, además, un consistente patrón de lateralización de los efectos de facilitación e inhibición, dado que los mencionados efectos sólo se produjeron para EPs presentados en el campo visual derecho. Este patrón de lateralización es discutido a la luz de las diferencias funcionales entre los hemisferios derecho e izquierdo en lo referente al procesamiento semántico.

Palabras clave: Priming semántico, priming semántico negativo, curso temporal, modulación atencional, lateralización.

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