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Knowledge inhibition and N400: A within- and a between-subjects study with distractor words

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ABSTRACT

We tested whether the N400 event-related potential (ERP) indexes the integration of semantic knowledge in the context or whether it indexes the inhibition of activated, but inappropriate, knowledge. A distractor–prime–target word sequence was presented in each trial. Subjects had to make semantic relatedness judgments on prime–target pairs. In the first experiment, subjects had an additional task. They either had to ignore or to attend to distractors. In critical conditions, that is, when distractors were related to targets, the times to make the prime–target semantic relatedness judgments were longer when subjects had to attend to distractors than when they had to ignore them. In accordance with the inhibition hypothesis, the amplitudes of the N400 elicited by distractors were larger in the ignore than in the attend task. In the second experiment, the same distractor–prime–target triplets were used. However, there was no additional task. Subjects only had to make the prime–target semantic-relatedness judgment. They were then split in two subgroups: the good ignorers, who did not take much longer to make the judgment in critical than in control conditions, and the poor ignorers, that is, those who did take much longer. Results were again consistent with the inhibition idea. The amplitudes of the N400s evoked by distractors were larger in the good than in the poor ignorers. The results of these two studies are taken together to support the idea that N400 index a semantic inhibition rather than an integration effort.

1. Introduction

The N400 is a brain potential that is elicited by the presentation of potentially meaningful stimuli in tasks that do not focus on the elementary physical features of these stimuli. Several hypotheses as to the nature of the computations performed by the brain process that are responsible for this potential have been proposed. Recently, some consideration has been given to the possibility that the N400 potential indexes not only activation but also inhibition processes (Barber et al., 2004;

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Barber and Kutas, 2007). However, to the best of our knowledge, only two studies (Debruille et al., 1996; Debruille, 1998) have been specifically built to test the hypothesis that the N400 indexes inhibition (Debruille, in press). In order to account for N400 literature data, these later studies stipulate that this potential indexes the inhibition of semantic knowledge. This inhibition process was included in a theoretical framework where the occurrence of potentially meaningful stimuli, such as word, pseudo-words, faces and objects, triggers two types of processing. The first, probably preconscious, would consist of fast bottom-up activations of item representations as well as of semantic knowledge and representations of global situations. Activated item representations would correspond not only to the item that is presented but also to items that resemble to it. Hence, inappropriate semantic knowledge and inaccurate situational representations would also be activated. Competition between these preconsciously activated representations would occur via reciprocal inhibition. This competition would also include expectancies, that is, representations activated by previous stimuli. The most activated situational representation would 'win' the competition and dampen the level of activation of other situational representations. The second type of processes would then start. They would consist of top-down activations going from the 'wining' situational representation to the lower level representations it subsumes. Hence, corresponding semantic knowledge and item representations would receive an additional amount of activation. This would 'help' them to inhibit concurrent representations at their level. Once concurrent representations are no longer activated, they would no longer be capable of reciprocally inhibiting appropriate representations. These latter representations would then reach their peak level of activation, which could correspond to consciousness.

This latter phenomenon is tentatively proposed to be indexed by one of the component of the late positive complex (LPC), the large positive deflection that immediately follows the N400. Meanwhile, N400 processes would index the inhibitions that precede. This would account for the larger N400s found for unexpected–unprimed items. Unexpectedness would correspond to expectancy of other items and other meanings, the representations of which would be activated. These inappropriate activations would have to be dampened. More information as to how the inhibition idea can provide an account for N400 literature data may be found in another study (Debruille, in press). Meanwhile, two types of literature data can be used to support the theoretical framework in which this inhibition idea is included. First, the finding that ERPs seem to depend on the semantic category of the word as early as 200 ms after the onset of the word (Hauk and Pulvermuller, 2004; Moscoso del Prado et al., 2006). This suggests that the semantic knowledge corresponding to a word is activated no later than 200 ms post onset. It is consistent with the first type of fast bottom-up preconscious processes proposed. Second, the fact that, when studying the N400 elicited by the last word of a paragraph, the global situation depicted by the text seems to have an impact on the N400 that is earlier than that of the content word that immediately precedes (Camblin et al., 2007; Polse et al., 2007). This is consistent with the top-down processes that were proposed to start from the inhibition of situational representations and to continue by the inhibition of semantic knowledge and item representations.

Some results were found to provide support for the N400 knowledge inhibition idea. The amplitude of the N400 elicited by a word was greater when the processing of this word was accompanied by more inhibition, because the presentation of this word could activate inaccurate semantic knowledge via representation of resembling words (Debruille, 1998). Nevertheless, as mentioned in another study (Debruille, in press), these results do not provide unequivocal support for the inhibition idea and cannot either allow the rejection of the idea that the N400 amplitude indexes the efforts at integrating the meaning of the stimulus in its context (Holcomb, 1993).

2. First experiment

2.1. Introduction

The present study capitalizes on the fact that tasks can be used to manipulate the amplitude of the N400. Tasks that focus on semantic properties, such as a semantic categorization task, are known to induce larger N400s than words vs. pseudowords differentiations (e.g., Chwilla et al., 1995; Kounios and Holcomb, 1994; West and Holcomb, 2000). The amplitude is smallest when subjects have to focus on the physical properties of the words, as when they are asked to decide whether words are in written in upper or in lower case letters. This 'strategy' effect means that N400 processes, whether they are attempts at integrating appropriate knowledge or at inhibiting inappropriate knowledge, are boosted by tasks that require semantic processing. Along the same line, if N400 processes were of an inhibitory nature, they could be boosted by a task requiring subjects to ignore the meaning of words they just processed. If greater N400s were observed in a task in which activated knowledge had to be ignored than in a task in which this knowledge has to be attended to, it would provide strong support for the inhibition hypothesis. In addition, such results would contradict the integration hypothesis (Holcomb, 1993). According to this hypothesis greater N400s should be found in the 'attend' task, in which subjects would be expected to generate more integration.

The present study therefore uses the fact that strategy modulates the amplitude of the N400 to test the integration and inhibition hypotheses. Strategies were imposed by means of explicit instructions of attending or ignoring distractor words. We first measured the effect of these strategies on the amplitudes of the N400s elicited by distractor words. Meanwhile, we also assessed the impact of these distractors upon a subsequent semantic judgment. This judgment had to be made for two words, a prime and a target word, which immediately followed each distractor.

The experiment was designed such that the capacity to ignore distractors, if present, rested on an active process rather than on a lack of attention. To achieve this goal, a fixation cross appeared just before each distractor in order to elicit the subject's attention. Moreover, the prime word and target word followed the distractor in quick succession. This was done in order to prevent the possibility of a change of strategy within each trial and to maximize the odds that this strategy would focus on semantic features, even when processing distractors.

Every combination of semantic relationship between distractor, prime and target was included. The critical conditions were those in which the distractor was related to the target: that is, the distractor–target related condition, where only the distractor was related to target, and the all related condition, where distractor, prime and target were semantically related. The other conditions were the no relation condition, which was the control condition for the distractor–target related condition, the prime–target related condition, which was the control condition for the all related condition and the distractor–prime related condition.

Two versions of the experiment were used. In the first version, subjects were explicitly instructed to ignore distractor words and to perform the semantic relatedness judgments on prime and targets words as quickly and as accurately as possible. In the second version, the same judgments had to be made but subjects were explicitly asked, in addition, to pay attention to the distractor words in order to remember them. Assuming that such instructions do indeed influence the subject's strategies, the inhibition hypothesis predicts that distractor words will elicit greater N400s in the 'ignore' than in the 'attend' task. Oppositely, the integration hypothesis predicts greater N400s to distractors in the 'attend' task, as more integration should take place when subjects pay attention to distractors than when they try to ignore them, consistent with the results of McCarthy and Nobre (1993). Our predictions especially pertained to some scalp locations. Indeed, while the classical effect of semantic priming on ERPs, when using written words as stimuli, is widely distributed on the scalp, it has a maximum at centro-parietal electrode and a slightly greater amplitude over the right than over the left hemisphere.

To assess the extent to which the semantic knowledge related to distractors was inhibited, we compared the reaction times (RTs) obtained for the critical conditions in the 'ignore' task to those obtained for these conditions in the 'attend' task. While RTs were expected to be longer in the 'attend' than in the 'ignore' task, two *very* different explanations had to be considered. First, there was the possibility that distractors prime targets. Accordingly, reaction times in the critical conditions should be shorter than in their respective control conditions. In this case, the greater distractor inhibition expected in the 'ignore' task predicts longer RTs in that task than in the 'attend' task because distractors should induce less priming when subjects pay less attention to them. Second, there is the possibility that targets, because they are semantically related to the distractor in critical conditions, remind subjects of the distractor and consequently introduce confusion in the prime–target semantic judgment. Longer reaction times will then be seen in critical conditions than in their respective control conditions. In this case, the greater distractor inhibition induced by the 'ignore' task predicts shorter RTs in that task than in the 'attend' task because targets should be less capable of reminding subjects of the distractors.

The aforementioned RT differences are necessary to verify that the knowledge corresponding to the distractors has been inhibited in the 'ignore' task. However, these RT differences could simply be due to a lesser attention paid to distractors in this task rather than on an active inhibition process. To make sure that this was not the case and that similar amounts of early attentional resources were allocated to the processing of distractors in the 'ignore' and in the 'attend' task, the P100s and N100s elicited by distractors in the two tasks were compared. Indeed, the amplitudes of these ERPs have been shown to be smaller for stimuli to which less attention is being paid (Mangun and Hillyard, 1990). However, these P100 and N100 modulations were found when spatial location was used to define the attended and the ignored stimuli (Mangun et al., 1990). When spatial location does not vary across trials and when attentional selection mechanisms are based on object features (e.g., color, shape, spatial frequency or orientation) it seems that it is rather the frontal selection positivity and the occipital selection negativity (FSP/OSN) that are affected. The FSP/OSN elicited by distractors in the 'ignore' and in the 'attend' task were therefore also examined.

It has to be noted that the ignore instruction was not expected to suppress totally the semantic processing of the distractor. Indeed, this processing occurs even in conditions in which words are presented subliminally (where they induce N400 priming, see for instance Deacon et al., 2000). Thus, given that, in our experiment, the presentation of distractors was clearly supraliminal, the ignore instruction could, at best, *moderate* their semantic processing. Therefore, even in the ignore task, a decrease of the N400s to primes was expected in the conditions in which distractors were related to primes relative to the conditions in which they were not related. On the other hand, in these latter conditions, the integration hypothesis predicts similar prime N400s in both tasks. Indeed, in these unrelated conditions, prime words are not primed, neither in the ignore task nor in the attend task. Thus, prime words should be as difficult to integrate. Meanwhile, in conditions in which distractors are related to primes, the integration hypothesis predicts smaller N400s in the attend than in the ignore conditions. Prime words should be easier to integrate when subjects paid attention to related distractors than when they tried to ignore them. Meanwhile, the inhibition hypothesis leads to different predictions. In both conditions, it predicts larger N400s in the attend than in the ignore task. Indeed, more inhibition would have to be done when subjects paid attention to distractor and therefore activated semantic knowledge more strongly. Only in the case where distractor is the same word as the prime would there be no inhibition required, a case that never existed in the experiment. In conclusion, it can thus be said that while the ERPs to be distractors allow the testing of the inhibition that pertain to semantic knowledge activated by the stimulus itself, the ERPs to the primes allowed the testing of the inhibition of the semantic knowledge activated by prior stimuli.

2.2. Results

2.2.1. *Behavior*

As predicted, subjects appeared to take longer to judge whether the target was semantically related to the prime when they had to attend, rather than ignore, the distractor (Fig. 1). In the no relation condition the means were 942 ms (S.D.: 243) in the 'attend' and 897 ms (S.D.: 228) in the 'ignore' task. In the distractor–target related condition, they were 1051 ms (S.D.: 276) and 969 ms (S.D.: 220). In the distractor–prime related

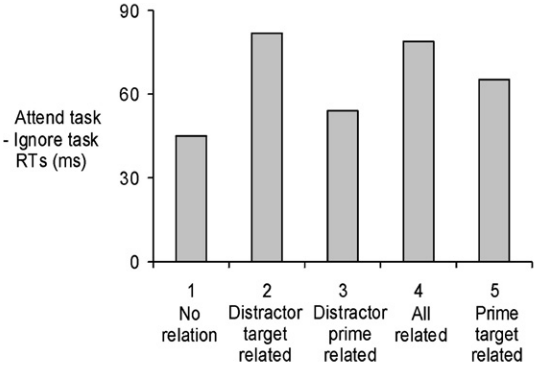

Fig. 1 – Mean reaction times for the prime–target semantic-relatedness judgment in the first experiment: Difference, in each condition, between the task where subjects had to attend to distractors and the task where they had to ignore them.

condition: 881 ms (S.D.: 226) and 827 ms (S.D.: 191). In the all related condition: 925 ms (S.D.: 239) and 846 ms (S.D.: 193). And in the prime–target related condition: 927 ms (S.D.: 232) and 862 ms (S.D.: 201). It should be noted that the RTs across the different conditions cannot be compared within each task since target words in the various conditions could not be perfectly matched in terms of the usual psycholinguistic variables (see Experimental procedures). Only the targets in the critical conditions were matched with the targets in their control conditions. Therefore, the RTs of condition 2 (distractor–target related) can only be compared with the RTs of condition 1 (no relation), while the RTs of condition 4 (all related) can only be compared with the RTs of condition 5 (prime–target related).

RTs were significantly shorter in the ‘ignore’ than in the ‘attend’ task only in the critical conditions, i.e., for condition 2 (distractor–target related) and condition 4 (all related condition) ($F(1, 29)=4{,}93$; $p=.034$). The RT differences were not significant in the other, non-critical, conditions.

The effect of task on error rates was not analyzed. There was no a priori hypothesis for this variable and floor effects could bias analyses. Error rates were all inferior to 10%.

2.2.2. *ERPs*

Fig. 2 shows the grand average of ERPs evoked by distractors in the ‘ignore’ and in the ‘attend’ task, both collapsed across the five conditions. In the time windows of the early components (P100, N100, FSP/OSN), ERPs obtained in the ‘ignore’ task and those obtained in the ‘attend’ task were nearly identical. In contrast, in the N400 time window, ERPs in the ‘ignore’ task appear more negative than those of the ‘attend’ task, and a slight right-hemiscalp preference is observed (e.g., at C4 relative to C3). Fig. 3 illustrates the scalp topography of these differences. For the sagittal montage, the repeated-measure ANOVA with electrode (Fz vs. Fcz vs. Cz vs. Pz) and task (‘ignore’ vs. ‘attend’) as within subject factors revealed an effect of task ($F(1, 29)=4.46$, $p=.043$) and an interaction of task with electrode ($F(3, 87)=3.1$, $p=.04$), in relation to the slightly greater difference observed at Pz and Cz than at Fcz and Fz (Fig. 3). The post hoc one-way ANOVAs performed at Pz and Cz confirmed the effect of task ($F(1, 29)=8.08$, $p=.008$), ($F(1, 29)=4.7$, $p=.042$), respectively. For the parasagittal montage, the ANOVA with electrode (Fp1/2 vs. F3/4 vs. Fc3/4 vs. C4/3 vs. Cp4/3 vs. P4/3 vs. O2/1), hemiscalp (right vs. left) and task as within-subject factors again showed an effect of task ($F(1, 29)=5.8$; $p=.023$) and an interaction of task with electrode ($F(6, 174)=2.20$, $p=.05$,

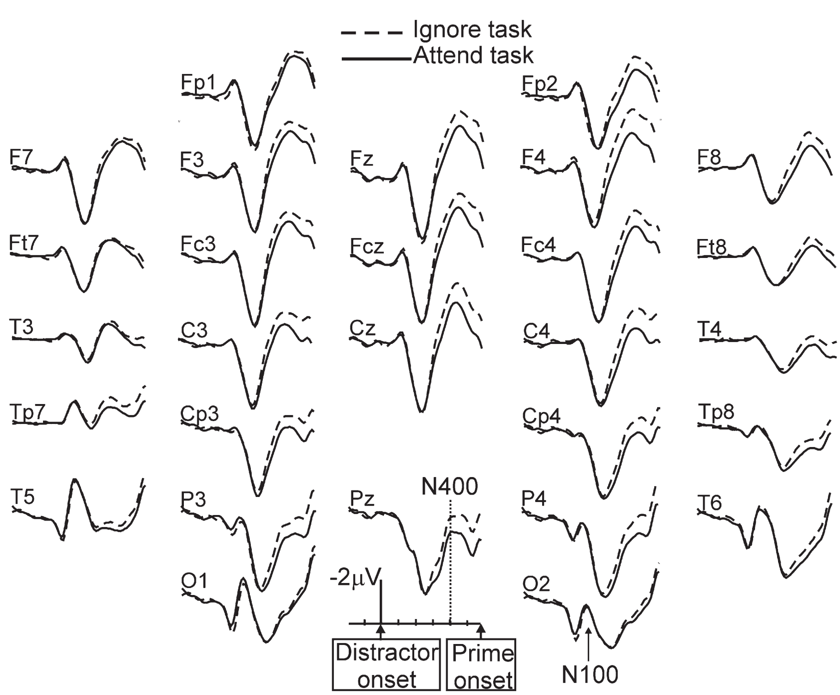

Fig. 2 – First experiment. Grand average of the ERPs ($n=30$) evoked by distractor words when subjects had to attend to them and when they had to ignore them. Negativity is up. Tic marks on the abscissa are placed every 100 ms. The baseline is computed in a −200 to 0 ms pre-stimulus onset time window.

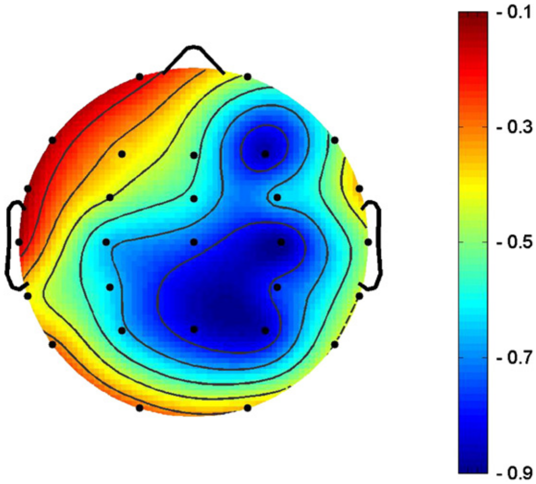

Fig. 3 – First experiment. Spline interpolated maps of the subtraction of the mean voltages obtained for distractors in the attend task in the 350–550 ms time windows from the mean voltages obtained for distractors in the ignore task in that time window. The graduations of the color scale are microvolts.

epsilon=.505). There was also a trend for an hemiscalp× electrode×task interaction (F(6, 174)=1.9, p=.09, epsilon=.801). The post hoc one-way ANOVAs performed at P4, CP4 and C4 confirmed the effect of task (F(1, 29)=13.9, p=.001), (F(1, 29)=5.5, p=.026) and (F(1, 29)=8.0, p=.008), respectively. At the lateral montage, no main effect of task was found and this factor did not interact with either electrode or hemiscalp.

Fig. 4 shows the ERPs elicited by prime words in the attend and in the ignore task according to whether they were related or unrelated to distractors. ERPs were more negative in the N400 time window in the unrelated than in the related condition (F(1, 29)=75, $p \ll$.001) at the sagittal, (F(1, 29)=78, $p \ll$.001) at the parasagittal, and (F(1, 29)=63 $p \ll$.001) at the lateral montage). There was a significant interaction of task with electrode at the sagittal (F(3, 87)=5.33, p=.019), the parasagittal (F(6, 174)=7.94, p=.001) and the lateral montage (F(4, 116)=6.15, p=.003). In the unrelated condition, ERPs in the attend task were more negative than those of the ignore task at P3 and P4 (F(1, 29)=5.44, p=.027) and at CP4CP3 (F(1, 29)=4.48, p=.043). There was no significant interaction of task with relatedness.

Fig. 5 shows the ERPs elicited by targets words in the attend and in the ignore task. ERPs were more negative in the N400 time window in the former than in the latter task ((F(1, 29)=14.5, p=.0006) at the sagittal, (F(1, 29)=11.9, p=.0017) at the parasagittal, and (F(1, 29)=5.9 p=.022) at the lateral montage). This effect of task did not interact with condition.

2.3. Discussion

As expected, RTs for the prime–target semantic relatedness judgments were longer in the task where subjects had to attend to the distractors than in the task where they had to ignore them. These behavioral results were significant in the two critical conditions, that is, in the conditions where distractors were related to targets. On the other hand, the

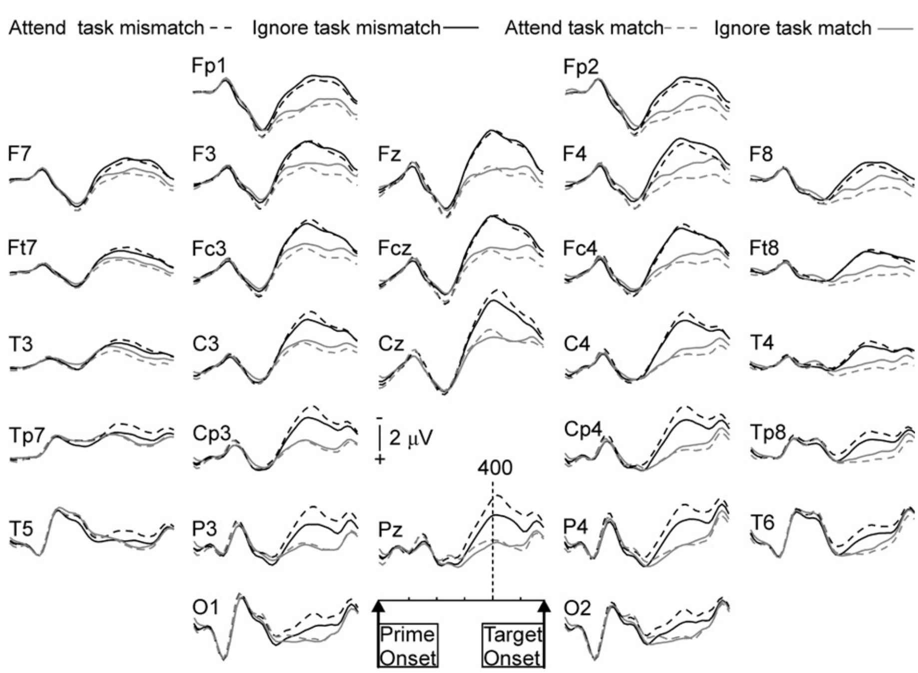

Fig. 4 – First experiment. Grand average of the ERPs (n=30) evoked by prime words in conditions in which prime words were semantically related to the distractors that preceded (i.e., match, in grey) and in conditions in which they were unrelated (mismatch, in black). Dashed lines are for the task where subjects had to attend to the distractor words. Continuous lines are for the task where they had to ignore these distractors. Baselines are computed between 50 and 150 ms post-onset to prevent effects from the different N400s to distractors.

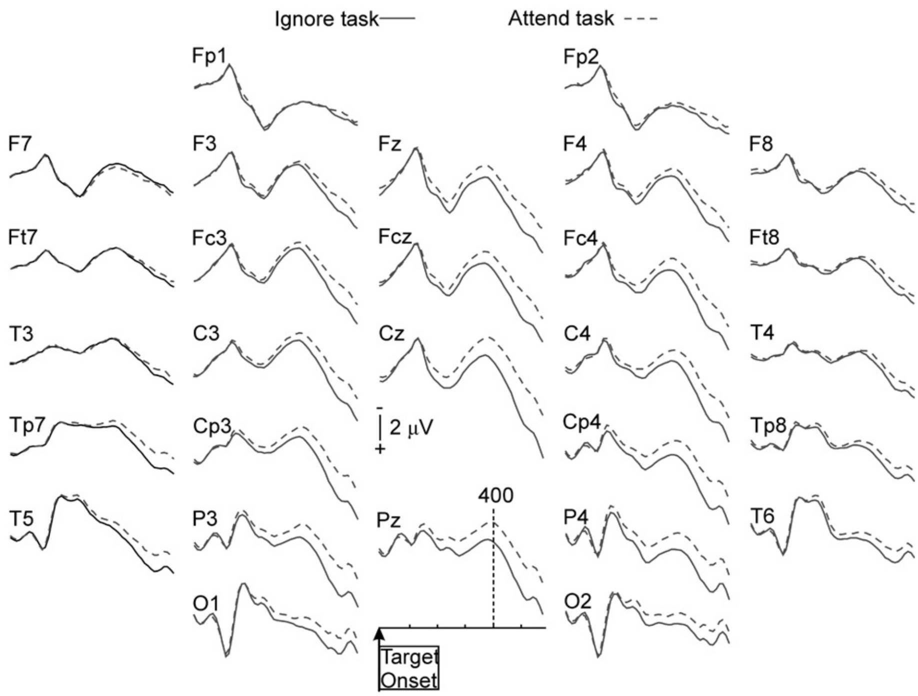

Fig. 5 – Grand average of the ERPs ($n = 30$) evoked by target words when subjects had to ignore distractors (continuous lines) and when they had to ignore these distractors (dashed lines). Baselines are computed between 50 and 150 ms post-onset to prevent effects from different N400 to primes. There was no significant interaction between task (attend vs. ignore) and condition (no relation vs. distractor–prime related vs. all related vs. prime–target related).

ERPs elicited by distractors in the 'attend' task and in the 'ignore' task did not differ in early attention-typical time windows, where they were superimposed. These behavioral and electrophysiological results were prerequisites to test both the integration and the inhibition hypotheses of the N400. As predicted by the second hypothesis, ERPs to distractors were more negative in the N400 time window in the 'ignore' than in the 'attend' task.

2.3.1. *Behavior*

The longer RTs observed in the 'attend' task for both critical conditions suggest that the instruction to either ignore or attend to the distractor was successful in manipulating the extent to which the knowledge activated by the distractor was inhibited. Less inhibition of the distractor knowledge would occur in the 'attend' task, resulting in more interference with the semantic judgement. The fact that RT differences were only significant in the critical conditions is not surprising. In these conditions distractors were related to targets and were therefore more likely to interfere with semantic judgements. The absence of significant effects in the other conditions is also noteworthy. It suggests that the attentional resources allocated to the maintenance of the distractor in the 'attend' condition, where the distractor had to be remembered, were not sufficient to significantly delay the RT of the semantic judgement. On the other hand, these results allow for the rejection of an important possibility: that targets could have been primed by related distractors in the critical conditions. If such a priming had occurred, it would have been greater, and, RTs therefore would have been shorter, in the 'attend' than in the 'ignore' task for the critical conditions.

2.3.2. *Early ERPs to distractors*

The absence of early, attention-typical differences between the ERPs to distractors in the 'ignore' versus the 'attend' task suggests that participants did not pay less attention to distractors in the 'ignore' task than in the 'attend' task. This is important because if they had paid less attention, less knowledge inhibition would have been necessary in the 'ignore' task. The equality in the amount of attention deployed in both tasks was most likely caused by three factors. First, the fixation cross that appeared just before the distractor sent an attention-catching signal. Second, the short delay between the onset of the distractor and the onset of the prime (i.e., 600 ms) may have been too short for subjects to operate a change in their attentional strategies. Longer delays may be necessary for subjects to temporarily dampen their attention to the fixation cross and the distractors in the 'ignore' task and to deploy it fully only in time to process the primes–target pairs. Third, no physical features, such as location in space, color, shape, spatial frequency or orientation, differentiated the distractors of the 'attend' task from those of the 'ignore' task. In contrast, such physical differences are present in classical attention protocols that produce early ERP effects (Hillyard et al., 1998; Mangun et al., 1990).

2.3.3. *Distractor N400s*

ERPs were more negative in the N400 time window in the 'ignore' than in the 'attend' task. These differences appeared to have two maxima, a centro-parietal one, typical of an N400 effect, and a right frontal one at F4 (see Fig. 3). The N400 effect cannot be accounted for by the N400 integration hypothesis (Chwilla et al., 1995; Halgren and Smith, 1987; Holcomb, 1993;

Kutas and Federmeier, 2000; Misra and Holcomb, 2003). According to the integration *effort* version of this hypothesis (see Debruille, in press), it is in the 'attend' task, which most likely is accompanied by greater integration efforts (in order to remember the distractor) that greater N400s should have been seen, in accordance with the greater N400s found by McCarthy and Nobre (1993) for more than for less attended stimuli. Meanwhile, according to the *amount* version of the integration hypothesis, equal N400s should have been found. In contrast, the differences observed in the N400 time window are in line with predictions derived from the knowledge inhibition hypothesis proposed in Debruille et al. (1996) and Debruille (1998). Specifically, the larger N400s obtained in the 'ignore' task reflect a deeper inhibition of the knowledge activated by the distractor than in the 'attend' task.

It should be noted that the component whose amplitude is modulated by the task factor is probably not the one causing the large negative deflection that can be seen on the ERPs waveform, with a maximum at frontal site (i.e., at Fz), around 450 ms post onset. Indeed, the difference observed between the two tasks is not maximal at Fz. The large deflection, because of its scalp distribution and of its late latency, is unlikely to be due to the N400 potential. This type of large anterior deflection has already been observed in semantic categorization tasks (e.g., Grossi, 2006; Alvarez et al., 2003). While its functional significance remains to be specified, it is clearly different from that of the N400 potential, whose maximum is at centro-parietal sites.

The effect of the task on the ERPs in the N400 time window is reminiscent of results obtained by Holcomb (1988) and by Koyama et al. (1992). In each trial of these studies, a prime and a target were serially presented with SOAs of 1150 ms and 1500 ms, respectively. Subjects had to perform a lexical decision task which did not require the processing of the prime. Like the distractors of the present study, primes were also preceded by the occurrence of a fixation stimulus and were therefore hard to miss. In one block, primes were frequently related to targets and were therefore relevant to their processing. This block was labelled the 'attention block' since subjects were probably processing primes more fully. In the other block, primes were rarely related to targets and were therefore less relevant to the processing of targets. This block was labelled the 'automatic block', since subjects were probably processing primes less fully. In both studies, the visual inspection of the ERPs elicited by the primes in the N400 time window reveals greater negativities in the 'automatic' than in the 'attentional' block. Therefore, ERPs to primes display effects similar to those obtained in the present study for distractors: greater negativities in the N400 time region for words that were 'more ignored' relative to words that were 'less ignored'.

In Holcomb (1988) the prime differences obtained were tested using a 300 to 650 ms time window and were found significant. However, they were attributed to a larger amplitude of the P300 component in the 'attentional' than in the 'automatic' block. Although this interpretation is coherent with the larger P300s usually elicited by stimuli that are attended to relative to non-attended stimuli, it cannot be preferred to an N400 effect, neither in their study, nor in Koyama et al. (1992) study or in the present study. The first reason being that inspection of the ERPs elicited by the primes does not reveal a larger N100 to words in the 'attentional' block, neither in (Holcomb, 1988) nor in Koyama et al. (1992) or in the present study for distractors. In both studies, the N100s observed at occipital sites are superimposable across blocks. This contradicts the idea of a greater allocation of attentional resources in the 'attentional' block, and, consequently, goes against the proposed P300 interpretation of the difference found in the N400 time window. The second reason for preferring an N400 effect is that there are no large positive deflections at parietal sites after the P2, meaning no P300 deflection in Holcomb (1988), or in the present study. Third, when such deflections appear, as in Koyama et al. (1992) probably due to the longer SOAs used, they are maximal at 600 ms, like the P600s usually observed when presenting visual word stimuli (see for instance Kutas et al., 1977, for a study focusing on the P300–P600 to words). Therefore, in this kind of protocol, P300s, when they appear, are not maximal during the N400 time window. Moreover, in Koyama et al. (1992) the untested ERP differences between the 'attentional' and the 'automatic' block also appear to be maximal during the N400 time window, not during the P600 time window. Finally, as to the results of the present experiment, it has to be noted that the scalp distribution of the effect is less compatible with a P3 effect than with a N400 effect. The maximum of the P3 effect is known to occur at parietal sites whereas our task effect was as large at Cz as at Pz. Moreover, our effect was slightly larger over the right (at C4) than over the left hemisphere (C3), as the N400 effect to written words often is.

Two other alternative accounts of the ERP differences observed between the tasks could be proposed, based on the idea that inhibition may not be closely tied to stimulus onset, but may rather take place variably over time between the distractor and the prime–target pair, thus not being indexed by the observed effects. First, the more positive ERPs obtained in the 'attend' task in the N400 time window could have been due to a Dm effect. Indeed, this effect consists of more positive late ERPs for items that are better encoded in memory, since they are successfully remembered later (Paller et al., 1987). In the present experiment, encoding could only be boosted by the instructions of the 'attend' task. However, this possibility is unlikely since no Dm effect has been found in the N400 time window for items that are not semantically related to their context of presentation (Neville et al., 1986; Kutas, 1988). In the present study, distractors were not semantically related to the preceding word (i.e., the 'blink' instruction and, prior to that, the target of the preceding trial). Still, as one reviewer pointed out the possibility of a Dm effect in the present experiment cannot be completely cast aside on this basis, since the above-mentioned studies did not contrast conditions that were as different in their memory requirements as those of the present experiment. Also, while the distractors were not preceded by related words, they were followed by a related word in approximately half of the trials. Nevertheless, a Dm effect appears less likely to account for the ERP differences than an N400 effect. One reason is that the similar differences found in the N400 time windows of ERPs to primes in Holcomb (1988) and in Koyama et al. (1992) were present whereas the task was the same in the 'attentional' and in the 'automatic' bloc of the two studies. Secondly, to our knowledge, no impact of following words on the Dm effect in the N400 time window has been demonstrated.

On the other hand, the observed ERP differences could be due to greater contingent negative variations (CNVs) in the 'ignore' than in the 'attend' task. CNVs are negative going potentials that develop when there is a fixed time interval between the onset of two stimuli (Walter et al., 1964; Brunia and van Boxtel, 2001). This happens here between distractors and primes. Nevertheless, three facts warrant against a CNV account. First and foremost is the direction of the effect. In Holcomb (1988) and in Koyama et al. (1992) greater CNVs were observed in the attention block. Accordingly, in the present experiment greater negativities would be expected in the 'attend' than in the 'ignore' task. This was not the case. Second, the 600 ms SOAs used in the present experiment appears a little short for the development of a CNV. This deflection has been discovered with slightly longer (i.e., 1000 ms) intervals and is often studied with 2000 to 4000 ms intervals. Finally, the ERP difference appears to start at about 250 ms, just after the peak of the P2 deflection (e.g., at Pz), which is rather early for a CNV difference. These differences are more likely to start later, maybe as late as 750 ms post onset, as in Holcomb (1988) and in Koyama et al. (1992). Even if we divide this number (750 ms) by two, which is an extreme way of taking into account the fact that our short (i.e., 600 ms) SOAs might have speeded up the occurrence of the effect, we obtain a 375 ms rather than a 250 ms latency. Thus, the 250 ms onset latency of the effect is much more compatible with a N400 effect.

Therefore, since these P300–P600, Dm and CNV accounts of the ERP differences found in the N400 time window appear much less likely than an N400 account, and since neither of the two versions of the integration view explain such an N400 effect, it may be concluded that the ERPs to distractors in the 'ignore' and the 'attend' task support the hypothesis that the N400 indexes inhibition of knowledge. In addition, the present discussion allows us to show that the ERPs to primes obtained by Holcomb (1988) and in Koyama et al. (1992) could also be used to support this inhibition hypothesis.

2.3.4. *Prime and target N400s*

Distractors that were related to prime words induced a significant effect of N400 priming, even in the ignore task. Thus, as mentioned at the end of the Introduction section, the ignore instruction did not totally suppress the semantic processing of the distractors, which, in turn induced a N400 priming effect. At least two reasons may be invoked. First the fact that the presentation of distractors was clearly supraliminal, whereas even subliminal presentation can induce priming (see for instance Deacon et al., 2000). Even when told to do so, it is arguably very difficult not to think about the meaning of a word that is presented *supra*liminally. Second, the prime–target semantic-relatedness judgement about half a second after the onset of the distractor. This has probably oriented subjects strategy towards semantic processing.

When primes were unrelated to distractors, prime N400s were smaller in the ignore than in the attend task at centro-parietal sites. This suggests that the semantic processing of primes was actually easier in the ignore than in the attend task. Together with the shorter RTs in the ignore than in the attend task for the critical (i.e., distractor–target related) condition, these results show that the instruction to either ignore or attend to the distractor had the expected effect.

These larger primes N400s in the attend than in the ignore task were not consistent with the integration hypothesis. According to this hypothesis, when primes were *un*related to distractors, prime N400s should have been equally large in both tasks, since whether attended or ignored, the unrelated distractor could not facilitate the integration of the prime. Moreover, when primes were related to distractors, primes N400s should have been smaller in the attend than in the ignore condition, since, as in Holcomb (1988) and in Koyama et al. (1992), more integration facilitation is induced by a related stimulus when subjects attend to it than when they do not. On the contrary, at parietal sites, prime N400s tend to be a little larger in the attend than in the ignore task. This appears to be in the direction predicted by the inhibition hypothesis. More inhibition have to be done when subjects pay attention to distractor and therefore activate inappropriate semantic knowledge more strongly. Only in the case where distractor is the same word as the prime would there be no inhibition required, a case that never existed in the experiment. It can thus be said that while the ERPs to distractors allow the testing of the inhibition that pertain to semantic knowledge activated by the stimulus itself, the ERPs to the primes allowed the testing of the inhibition of the semantic knowledge activated by prior stimuli.

Target N400s were also studied. They were found to be larger in the attend than in the ignore task in all conditions. This decrease further confirms the idea that the semantic judgment was easier in the ignore task and that task instructions succeeded in manipulating the impact of the distractor. Distractor knowledge would have interfered in the processing of targets to a lesser extent in the ignore than in the attend task. Like the prime N400s, the observed target N400s counter the integration hypothesis. In the conditions in which distractor were unrelated to targets, this hypothesis predicts equally large target N400s, since whether attended or not, unrelated distractors can not facilitate target integration. In the conditions in which distractor were related to targets, it predicts smaller target N400s in the attend than in the ignore task. This was not the case.

Therefore, to conclude, it may be said that a) the ignore task induced only a partial suppression of the semantic knowledge activated by distractors; b) that this partial suppression may be indexed by the additional N400 activity obtained for distractors in the ignore than in the attend task and c) that further partial suppressions may be indexed by the larger N400 activities obtained for primes and targets when subjects attended to distractors relative to when they tried to ignore them. Overall, the results could not be accounted for by the idea that the amplitude of the N400 indexes integration efforts. They provided a coherent support for the idea that it reflects the inhibition of inappropriate knowledge.

3. Second experiment

3.1. *Introduction*

The first experiment was designed to explore the variations in inhibition strength induced by different task instructions. The

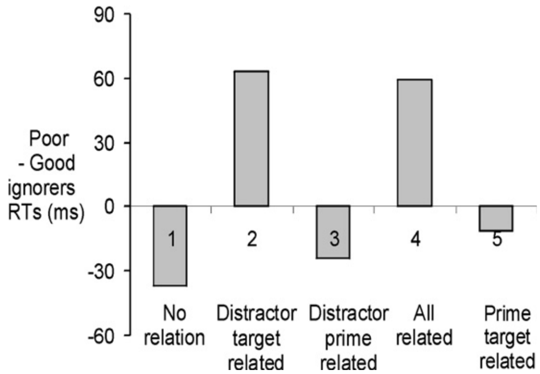

Fig. 6 – Second experiment. Mean reaction times for the prime–target semantic-relatedness judgment: Difference between good and poor ignorers for each condition.

aim of the second experiment was to explore the differences of the strengths in spontaneous inhibition between subjects. To achieve this goal, the distractor–prime–target sequences were thus presented to a new group of subjects. To respect their spontaneous strategies, they were neither told to ignore nor to attend to distractors. These participants were then sorted out into two subgroups: good and poor ignorers. Good ignorers were the subjects who tended not to need longer times to make their semantic judgments in the critical conditions than in their control conditions. Conversely, poor ignorers were subjects who showed much longer RTs in the critical conditions than in their control conditions.

The idea that the N400 indexes inhibition predicted larger N400 amplitudes to distractors in good than in poor ignorers. Meanwhile, the hypothesis that the amplitude of the N400 reflects the amount of efforts deployed to integrate the meaning of the word in its context leads to opposite predictions. Accordingly, it is the poor ignorers who should have the largest distractor N400s since greater integration efforts of distractors can only lead to more interference with the prime–target semantic-relatedness judgement that follows and thus, to longer RTs.

There is no reason to think that subjects classified as good ignorers should be good ignorers only when processing the distractors. They could be such for primes and targets also. Thus, if the N400 inhibition hypothesis is correct, they could have more N400 activities than poor ignorers for prime and target words. However, the contrary could be hypothesized. If these subjects performed a 'good' inhibition of the knowledge activated by distractors, less inhibition of this knowledge would remain to be done at the processing of the prime and at that of the targets. Thus, still according to the inhibition idea, these subjects could have smaller N400s than poor inhibitors. Therefore, in this between-subjects design, no clear prediction can be made from the inhibition hypothesis as to prime and target N400s.

Finally, it was important to measure the attention that was paid to distractors in good and poor inhibitors. Indeed, the best strategy to maximize performance in the semantic judgement was to *not* pay attention to distractors. To check that all the precautions used to prevent such a strategy (see the Stimuli section in Experimental procedure of the second

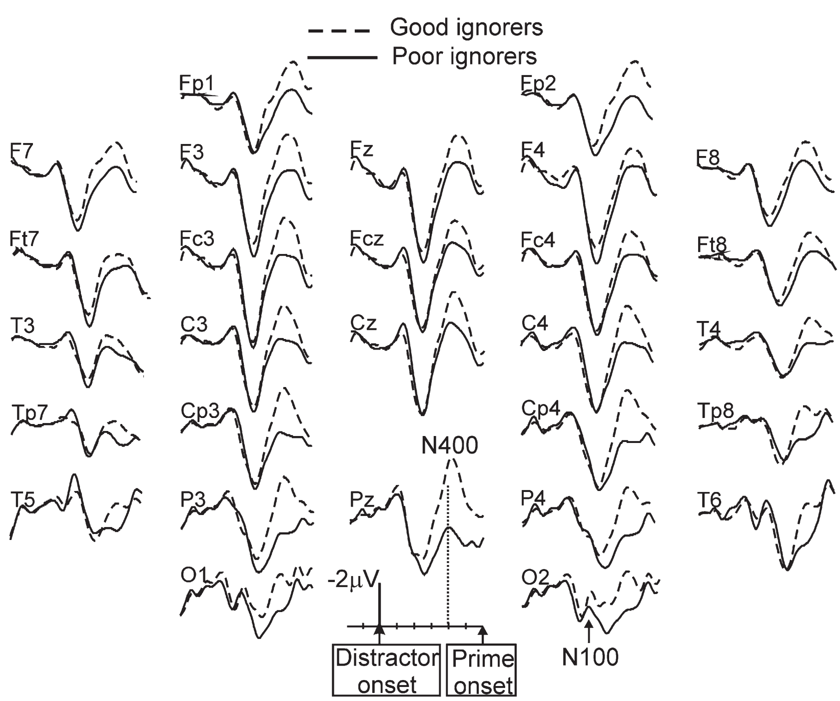

Fig. 7 – Grand average of the ERPs evoked by distractor words in the poor (*n* = 17) and in the good ignorers (*n* = 16) of Experiment 2. Negativity is up. Tic marks on the abscissa are placed every 100 ms. The early negative potential at posterior sites corresponds to the offset of the fixation cross.

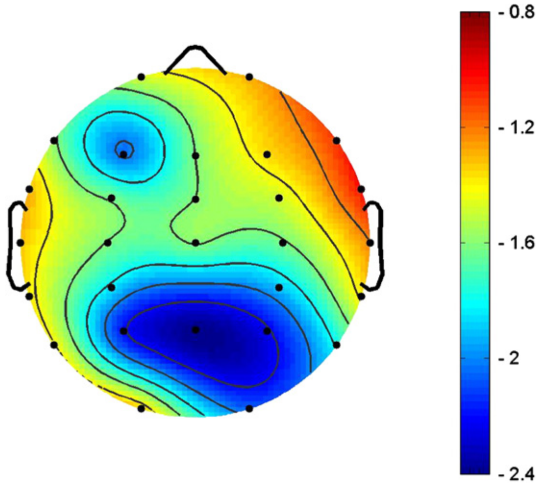

Fig. 8 – Second experiment. ERPS elicited by distractors. Spline interpolated maps of the subtraction of the mean voltages obtained in the subgroup of poor ignorers in the 350–550 ms time windows from the mean voltages obtained in the subgroup of good ignorers in that time window. The graduations of the color scale are microvolts.

experiment) were efficient the P100s and N100s elicited by distractors were assessed in the two groups. Indeed, the amplitudes of these ERPs have been shown to be smaller for stimuli to which less attention is being paid (Mangun et al., 1990; Woods et al., 1992; Salmi et al., 2007). However, these P100 and N100 modulations were found when spatial location was used to define the attended and the ignored stimuli (Mangun et al., 1990). When spatial location does not vary across trials and when attentional selection mechanisms are based on object features (e.g., color, shape, spatial frequency or orientation) it seems that it is rather the frontal selection positivity and the occipital selection negativity (FSP/OSN) that are affected. The FSP/OSN elicited by distractors were therefore also examined.

3.2. *Results*

3.2.1. *Behavior*

The sorting of subjects into good and poor ignorers based on the RT differences observed between the two critical conditions and their respective control conditions was consistent with the data obtained. 94% of the subjects who showed longer RTs in one critical condition (i.e., the all related condition versus its control, the prime–target related condition) also showed longer RTs in the other critical condition (i.e., the distractor–target related condition versus its control condition, the no relation condition). Note that RTs for the other conditions cannot be compared within each group since target words across these conditions could not be perfectly matched for the usual psycholinguistic variables (see Stimuli section in Experimental procedure of the second experiment). The analysis of RTs (Fig. 6) showed that the manner in which good and poor ignorers were sorted led to significant differences between the critical conditions and their controls. In

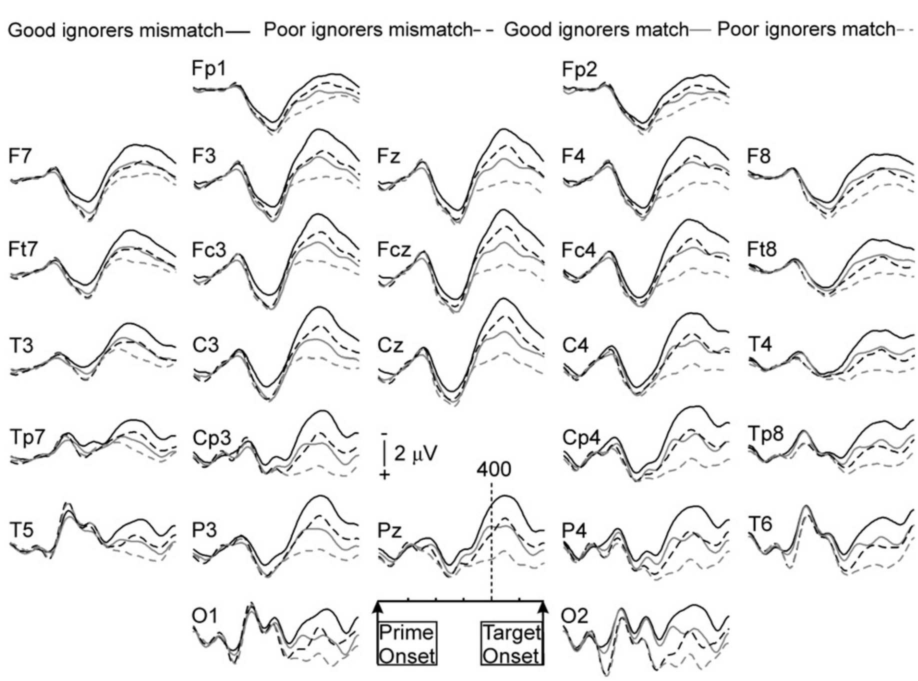

Fig. 9 – Second experiment. Grand average of the ERPs ($n=30$) evoked by prime words in conditions in which prime words were semantically related to distractors that preceded them (i.e., matches, in grey) and in conditions in which they were unrelated (mismatch, in black). Dashed lines are for subjects classified as poor ignorers of preceding distractors. Continuous lines are for good ignorers. Baselines are computed between 50 and 150 ms post-onset to prevent effects from the different N400s to distractors.

poor ignorers, RTs were longer in critical than in control conditions (t=4.83, p=.00018). RT was 1145 ms (S.D.: 188) in the critical distractor–target related condition and 1036 ms (S.D.: 151) in the no relation control condition. It was 993 ms (S.D.: 152) in the critical all-related condition and 949 ms (S.D.: 143) in the prime–target related control condition. Oppositely, in good ignorers, RTs were shorter in critical than in control conditions (t=2.41, p=.029). This difference in the unexpected direction is likely to be due to the way good ignorers were defined, as this was precisely based on having a small, and thus sometimes negative, RT difference between critical and control conditions (see Experimental procedures). RT was 1082 ms (S.D.: 287) in the critical distractor–target related conditions and 1073 ms (S.D.: 193) in the no relation control condition. It was 934 ms (S.D.: 158) in the critical all-related condition and 960 ms (S.D.: 165) in the prime–target related control condition. There was a tendency for good ignorers to show longer RTs than poor ignorers in the non-critical conditions, namely the no relation, the distractor–prime related and the prime–target related conditions (F(2, 62)=2.5, p=.09).

Error rates were smaller than 10% in all conditions for both groups except for the poor ignorers in condition 2, which showed an error rate of 11.2%. Error rates were not analyzed at this point since there were no a priori hypotheses for these variables (but see the Distractor N100s section in the Discussion).

3.2.2. *ERPs*

Fig. 7 shows the grand average of the ERPs evoked by distractors for good and poor ignorers, both collapsed across the five conditions. Visual inspection revealed more negative ERPs in the N100 time window at occipital sites. This was confirmed by the analysis (F(1, 31)=4.62, p=.039). There were no significant differences (F(1, 31)=3.14, p=.085) in the FSP/OSN time window (i.e., 150–300 ms). ERPs appeared much more negative in the N400 time window for good ignorers than for poor ignorers. Fig. 8 illustrates the scalp topography of that difference. At the sagittal montage, there was a group effect (F(1, 31)=4.97, p=.033), together with an electrode × group interaction (F(3, 93)=3.2, p=.025, epsilon=.372). At the parasagittal montage, there was a group effect (F(1, 31)=7.28, p=.011) and an electrode × hemiscalp × group interaction (F(6, 186)=2.61, p=.022, epsilon=.550). There was also a group effect at the lateral montage (F(1, 31)=7.43, p=.01). To locate the source of the interactions and to test the hypotheses at the sites where the N400s to visual words are classically maximal, the group effect was assessed at Pz (F(1, 31)=5.9, p=.021), P4 (F(1, 31)=7.9, p=.008), CP4 (F(1, 31)=5.8 p=.022), C4 (F(1, 31)=4.2, p=.05) and Cz (F(1, 31)=3.13, p=.08).

Fig. 9 shows, for both good and poor inhibitors, the ERPs elicited by prime words that were related to distractors and by prime words that were unrelated. These ERPs were more negative in the N400 time region in good than in poor inhibitors (F(1, 31)=3.96, p=.056) at the sagittal, F(1, 31)=6.16, p=.019) at the parasagittal montage and F(1, 31)=8.34, p=.007) at the lateral montage). This group effect did not interact with conditions (i.e., relatedness).

Fig. 10 shows the ERPs elicited by target words in both good and poor inhibitors. They were similar in the N400 time region (F(1, 31)<1 for all montages).

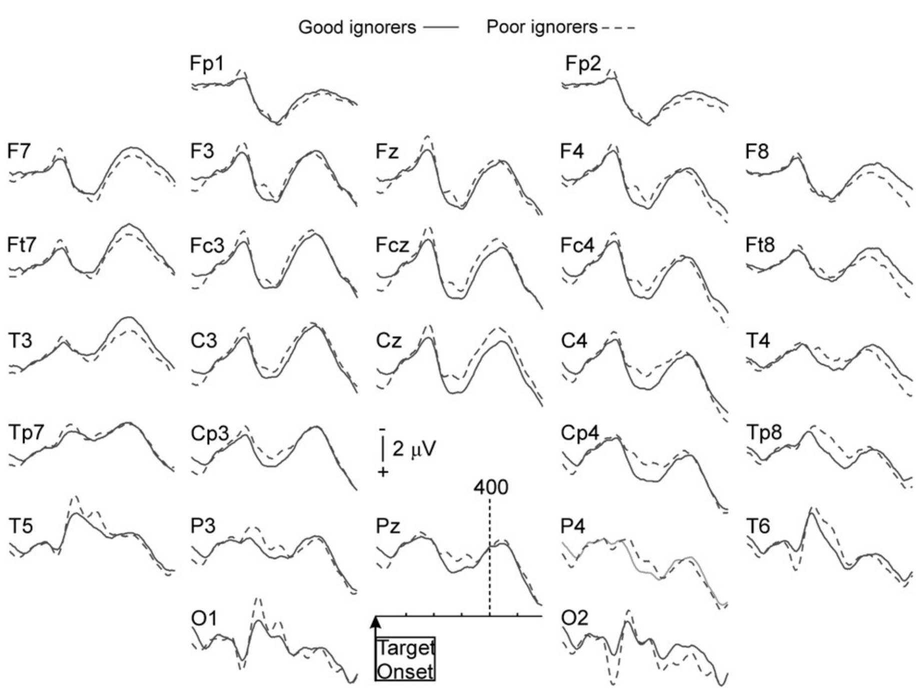

Fig. 10 – Grand average of the ERPs (n=30) evoked by target words in subjects classified as poor ignorers of distractors (dashed lines) and in good ignorers (continuous lines). Baselines are computed between 50 and 150 ms post-onset to prevent effects from the different N400s to primes. There was no significant interaction between 'ignorance' (good vs. poor ignorers) and condition (no relation vs. distractor–prime related vs. all related vs. prime–target related).

3.3. Discussion

Distractor–prime–target word-sequences were presented to subjects who had to judge whether or not the prime was related to the target word. Subjects were then sorted into two subgroups: the good and the poor ignorers. The first subgroup included participants who did not take much more time to make their judgment in trials in which distractors were related to targets relative to trials in which they were not related. The second subgroup included subjects who took much more time. Analyses showed that these RT differences were significant. In these conditions, results matched the predictions drawn from the N400 knowledge inhibition view. The amplitudes of the N400s evoked by distractors were found to be greater in good than in poor ignorers. Still, some results were unexpected: distractor N100s were larger for good than for poor ignorers, prime N400s were larger for good than for poor ignorers. Meanwhile, there was no target N400 difference between these two groups.

3.3.1. Distractor N100s

The greater N100s of good ignorers suggest that these subjects paid more attention to distractor than the poor ignorers. It therefore shows that the experimental design was successful in creating conditions in which ignorance of distractor knowledge was not at all based on a reduced attention, but rather on an active inhibition performed at a later stage of processing, like the one proposed by the N400 knowledge inhibition hypothesis. Although there is no doubt that paying less attention to distractors in order to focus on the semantic judgments would have been a more efficient strategy, this was probably not possible in the present experimental design for three reasons. First, the fixation cross that appeared just before the distractor sent an attention-catching signal. Second, the short delay between the onset of the distractor and the onset of the prime (i.e., 600 ms) may have been too short for subjects to operate a change in their attentional strategies. Longer delays may be necessary for subjects to temporarily dampen their attention to the fixation cross and to the distractors and to deploy it fully only in time to process the primes–target pairs. Third, no physical features, such as location in space, color, shape, spatial frequency or orientation, differentiated the distractors of the 'attend' task from those of the 'ignore' task. In contrast, such physical differences are present in classical attention protocols that produce early ERP effects (Hillyard et al., 1998; Mangun et al., 1990; Woods et al., 1992; Salmi et al., 2007).

If good ignorers paid more attention to stimuli and show stronger inhibition processes, they should therefore make less errors. Although errors were too few to allow analyses free of floor effects, error rates were computed to roughly see whether this could have been the case. Results tend to confirm this idea. On average, across all conditions, good ignorers showed slightly fewer errors (i.e., 5.2%) than poor ignorers (7.2%). As it could have been expected, this was the especially true in critical conditions. In the distractor–target related condition, the mean error rate was 8.4% for good ignorers and 11.2% for poor ignorers. In the all-related condition, the mean error rate was 4.5% for good ignorers and 9.4% for poor ignorers.

Interestingly, the greater attention deployed by good ignorers goes against an interpretation of the differences found in the N400 time window in terms of smaller P3bs for good ignorers. Indeed, greater attention usually corresponds to greater P3bs (Donchin and Coles, 1988).

3.3.2. Distractor N400s

The larger (parietal) N400s of good ignorers could, like the N100s, be due to more attention paid to distractors. Indeed, N400s to attended stimuli are known to be larger than those to unattended stimuli (e.g., McCarthy and Nobre, 1993). However, whatever the reason for large N400s of good ignorers, these results are difficult to reconcile with a straightforward view of the integration hypothesis (Halgren et al., 1987; Rugg et al., 1988; Holcomb, 1993; Kutas et al., 2000; Misra et al., 2003). Indeed, according to this hypothesis, the greater N400s of good ignorers would mean that distractor knowledge was integrated to a greater extent, or that these subjects did more efforts at integrating this knowledge than poor ignorers. This is unlikely since greater interference with semantic judgments should then be seen in the critical conditions. In other terms, for good ignorers, longer RTs should have been observed in critical conditions than in their control conditions. This was not the case.

Alternatively, the integration hypothesis could propose that distractor knowledge was not integrated to a greater extent by good ignorers but these subjects' greater N400s to distractors rather indexes a greater *difficulty* at integrating this knowledge. However, behavioral data do not support the idea that good ignorers had greater difficulties. As mentioned, they did not make more errors than poor ignorers and their mean reaction times for all conditions (i.e., 1010 ms) were not longer than those of poor ignorers (i.e., 1020 ms).

On the other hand, distractor N400 differences were obtained whereas there was no instruction that could have induced greater attention and/or better memorization of distractors as in the first experiment. Therefore, there was no factor that could have led to greater P600 and/or greater Dm effects. It is thus easier to conclude that the ERP differences found in the time window of the N400 are genuine modulations of the amplitude of the N400 potential.

3.3.3. Prime and target N400s

The N400s to the primes were greater for good than for poor inhibitors. These results suggest that there was no circularity with the results of the previous study. Indeed, if there were, prime N400s of good ignorers would have been smaller than those of poor ignorers, like the prime N400s of the previous study were smaller when subjects were asked to ignore distractors than when they were asked to pay attention to them. Target N400s further confirmed this absence of circularity. The amplitudes of these N400s for good ignorers were similar to those of poor ignorers, whereas, in the previous study, they were smaller in the ignore than in the attend task.

In terms of the integration effort hypothesis, the larger N400s to primes found in good relative to poor ignorers may suggest that good ignorers are subjects having greater difficulties at integrating semantic information. However, the same argument as that used for distractor N400 can be used, that is, that if this integration difficulty view was correct, their RTs should have been longer than those of poor inhibitors. This was not the case. To this extent, both distractor and prime N400s go against the integration effort hypothesis. Nevertheless, the larger N400s to distractors and primes of good inhibitors could be understood as showing that these subjects spontaneously deploy more efforts at integrating information, whatever the difficulty. Their shorter RTs in the critical condition of the prime–target semantic-relatedness judgment would thus index the benefit of this strategy. However, target N400s go against this integration interpretation. Indeed, if the strategy of good ignorers was to systematically deploy more integration efforts, this should have been also (and especially) the case for targets. Thus, larger N400s in good than in poor ignorers should have been seen also for targets. This was not the case.

In terms of the inhibition hypothesis, the larger N400s to primes in good relative to poor ignorers suggest that the subjects classified as good ignorers were those inhibiting distractor knowledge not only when processing distractors, but also when processing primes. This is possible since the inhibition hypothesis stipulates that the N400 indexes the inhibition of inappropriate knowledge activated both by the stimulus itself and by preceding stimuli (Debruille, in press). The fact that the amplitude of the N400s of good ignorers were larger than those of poor ignorers 'only' for distractors and primes and not for targets is also consistent with the inhibition hypothesis. If all, or most of, the inhibition of distractor knowledge was done during distractor and prime processing, no or much less of this inhibition remained to be done when processing the target. Thus, the general tendency of these participants to inhibit to a greater extent (as would be suggested by their greater distractor– and prime–N400s) would be counterbalanced by the fact that there would not be much left for inhibition at the level of targets.

4. General discussion

Another alternative account of the larger distractor N400s of good ignorers could be proposed. They could reflect a greater integration of distractor knowledge while the shorter RTs shown by these subjects in critical conditions could in fact be due to a greater *priming* of targets by the related distractors. However, this would be inconsistent with the target N400s of good inhibitors. If there was such a priming, target N400s should have been smaller in these participants than in poor ignorers in the distractor–target related conditions. This was not the case. There was no interaction of the group with condition. Moreover, a priming of targets by distractors is inconsistent with the results of the first experiment. In this experiment, this priming effect, if present, should have been at least as important when subjects had to 'attend' to distractors than when they had to ignore them. This was not at all the case. As mentioned, in the critical conditions, RTs were longer in the 'attend' than in the 'ignore' task. Moreover, this priming perspective does not take into account the fact that, in the distractor–target related condition, the correct response was a rejection, since targets were not related to primes. It is most unlikely that this type of response could be primed in the same way as the detection response that had to be given in the all related condition (see for instance Gernsbacher et al., 1990). The shorter RTs of good ignorers in the critical conditions than in the control conditions are thus much more likely to reflect a smaller interference of target-related distractor information with the prime–target relatedness judgments.

In contrast, the larger N400s to distractors *and primes* in good versus poor ignorers are consistent with the N400 knowledge inhibition hypothesis proposed in Debruille (in press). They may index a greater inhibition of the knowledge activated by the distractor, and therefore the absence of RT delay in the critical conditions relative to their control conditions. This greater inhibition could be due to the allocation of more attentional resources by good ignorers, as suggested by the larger N100s to distractors observed in these subjects.

In conclusion, the results of the present study provide a new support to the idea that N400 index semantic inhibition processes. They also suggest that there are important

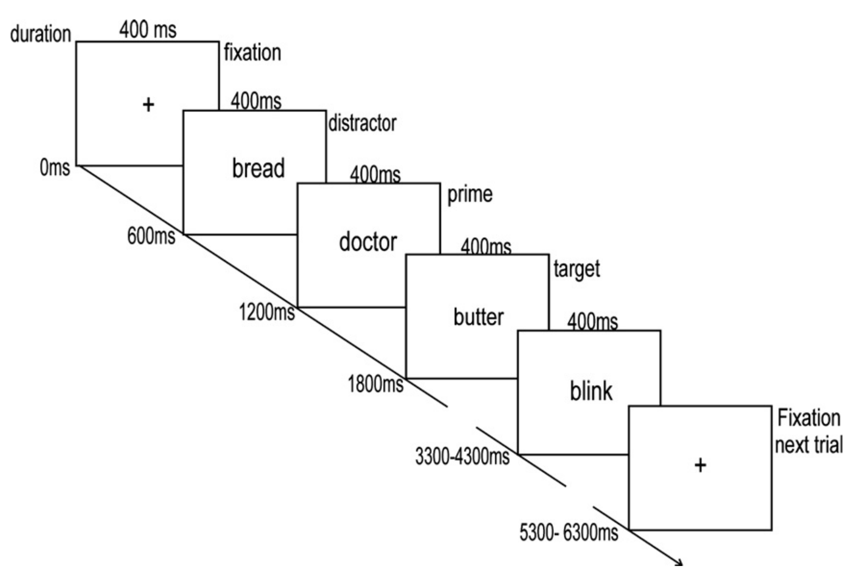

Fig. 11 – Stimulus sequence and timing in each trial. The inter-trial interval was varied randomly between 5300 ms and 6800 ms.

between-subjects differences in the strength of these processes. Finally, it has to be noted that good ignorers could have better suppression mechanisms in general and not only better mechanisms of inhibition of the meanings of distracting items. Further studies should be devoted to further characterize these subjects.

5. Experimental procedure

5.1. First experiment

5.1.1. *Stimuli*

Two sets of 200 trials were used. The first set was used for the 'ignore' task for the first half of the subjects while it was used in the 'attend' task for the second half. Conversely, the second set was used in 'attend' task for the first half of the subjects and in the 'ignore' task for the second half of the subjects. As mentioned, each trial was composed of three words presented serially: the distractor, the prime and the target word. Fig. 11 illustrates the sequence and timing of their presentation. The relatively short (i.e., 600 ms) stimulus onset asynchronies (SOAs) between the distractor, the prime and the target were chosen so that it was difficult for subjects to begin to focus their attention only at the occurrence of the prime. To reinforce attention to distractors, and thus to reinforce the need for inhibition in the 'ignore' task, all three stimuli were presented at the same location and each distractor was immediately preceded by a fixation cross, which announced the beginning of the trial.

The relationship between the words in each of the five experimental conditions, as well as the percentage of trials in each of these conditions, is specified in Table 1. All the possible combinations of semantic relationships were represented so that no biasing strategy could be adopted by subjects. Specifically, there was a condition in which no words were related (condition 1); three conditions in which only two words in the triplets were related, either the distractor and the target (condition 2), the distractor and the prime (condition 3), or the prime and the target (condition 5); and finally, there was the all related condition in which all words of the triplets were related (condition 4). In each set of 200 trials, there were 100 trials for which the response 'no' was required and 100 trials for which the 'yes' response was required. There were 20 trials in condition 2,[1] which was the most difficult, 40 trials in conditions 1 and 3, and 50 trials in conditions 4 and 5. The critical conditions were those in which the distractors were semantically related to the targets, that is, conditions 2 and 4. Words related to each other were semantically related (e.g., prince–child) and/or associated (e.g., king–palace).

All the words were familiar French nouns between 3 to 12 characters long. None of them were repeated. The target words of the distractor–target related condition (cond 2) and of the all related condition (cond 4) were matched in terms of frequency and length with target words of the no relation condition (cond 1) and of the prime–target related condition (cond 5), respectively. Taken together, primes of cond 1 and 5 (i.e., primes unrelated to distractors) were matched to primes of conditions 3 and 4 (i.e., primes related to distractors). For frequency, five ranges of the number of occurrences per million (*F*) computed from the Brulex database (Content et al., 1990) were used: a) $0<F=1$, b) $1<F<10$, c) $10<F<30$, d) $30<F<100$ and e) $F>100$. Frequency match corresponds to similar number of words in each range. For checking that length did not differ, we took the mean number of letters.

Table 1 – English translation of exemplars of the words used

Condition	Distractor	Prime	Target	Correct response	% of trials
(1) No relation	Broom	Airport	Text	No	20
(2) Distractor–target related	Bread	Doctor	Butter	No	10
(3) Distractor–prime related	Farm	Cow	Hair	No	20
(4) All related	Fireplace	Chimney	Flame	Yes	25
(5) Prime–target related	Alcohol	Chair	Table	Yes	25

The proportion of yes- and no-trials were identical.

5.1.2. *Subjects*

Thirty right-handed subjects (19 females) for whom French was the mother tongue were recruited through newspaper advertisements. All subjects had normal or corrected-to-normal vision and no history of neurological or psychiatric disorders. They were aged between 18 and 30 years and were educated at least at the college level. They signed an informed consent form accepted by the Douglas Hospital Research Ethics Board.

5.1.3. *Procedure*

In each trial, subjects had to judge whether or not the meaning of the third word of each triplet (the target) was related to the meaning of the second word (the prime). In addition, in the 'attend' task, they had to pay attention to the first word (the distractor) so as to be able to remember it. To promote attention in this task subjects were asked, at the end of approximately 1 out of 10 trials, to report what the first word of the last triplet was. In contrast, in the 'ignore' task, they were instructed to 'ignore' the distractor. Every subject performed both tasks, the order of which was counterbalanced across participants.

Subjects were seated in a dimly lit, sound attenuated room and were instructed to fixate the center of a computer screen located 0.8 m in front of their eyes. The word stimuli were black on a white background and were between 1 and 3.5 cm long. Following the application of EEG electrodes, subjects were asked to respond as quickly and as accurately as possible by pressing, with their right index finger, the right arrow key of a PC keyboard when the meaning of the target was related to the meaning of the prime and the down arrow key when it was not.

[1] This was done on purpose after pilot experiments that suggested that when there were more trials in that condition, and thus when distractors were more often related to targets, subjects paid too much attention to distractors, even in the ignore task.

5.1.4. *Data acquisition*

The response and the reaction time to each target word were recorded. The EEG was captured with tin electrodes mounted in an elastic cap (Electrocap International) from 28 active points placed according to the extended International 10-20 System. They were grouped in a sagittal (Fz, Fcz, Cz, Pz), a parasagittal (Fp1, Fp2, F3, F4, Fc3, Fc4, C4, C3, Cp4, Cp3, P4, P3, O2, O1) and a lateral (F8, F7, Ft8, Ft7, T4, T3, Tp8, Tp7, T6, T5) montage and were referenced to the left mastoid. Impedances were kept below 5 kΩ. Vertical eye movements were monitored by two electrodes: one above and one below the right eye. Horizontal eye movements were monitored by electrodes placed at the external canthi of the eyes. EEG signals were amplified 20,000 times. High and low pass filter half-amplitude cut-offs were set at .01 and 100 Hz, with an additional 60 Hz electronic notch filter. Starting 200 ms before the onset of the distractor up to 800 ms after the onset of the target, signals were digitized on-line at a sampling rate of 256 Hz and stored along with stimuli and response codes for subsequent averaging.

5.1.5. *Data processing*

Overall, approximately 20% of the trials were rejected prior to averaging due to excessive eye movements (EOG), muscle artefacts (EMG), amplifier blocking, or analog to digital clipping. These rejections were done off-line with a trial rejection program, the thresholds of which were adjusted for individual subjects according to EEG, EMG and EOG characteristics. Average ERPs were calculated for all the distractor words in each of the two tasks. For prime and target words, they were computed for each condition and each task. This was done for each subject by including the correct-response trials that were responded to in less than 2000 ms. Percentages of incorrect responses were computed separately.

5.1.6. *Measures and statistics*

The mean reaction times (RTs) obtained in the 'ignore' task were compared to those obtained in the 'attend' task. These comparisons focused on the critical conditions, those for which the predictions were made. Mean voltage amplitudes of the ERPs to distractors in all conditions were measured relative to a 200-ms pre-stimulus baseline. For the N100s, these mean amplitudes were measured at O1 and O2 within a 100–190 ms time window, centered on the peak of the deflection. For the FSP/OSN, mean amplitudes were measured at prefrontal (Fp1, Fp2) and frontal electrodes (F7, F8, F3, F4, Fz), as well as at posterior electrodes (T5, T6, O1, O2) within the 150–300 ms time window deflection (Hillyard et al., 1998). For the N400s, they were measured within a 350–550 ms time window centered on the peak of the negative deflection observed at Pz on the grand average. For the sagittal montage, a repeated measure ANOVA was run with electrode and task ('ignore' vs. 'attend') as within-subjects factors. For the two lateral montages, the hemiscalp factor (right vs. left) was added as another within-subjects factor. The Geisser and Greenhouse (1959) procedure was used when required to compensate for heterogeneous variances.

For primes and targets, N400s were also measured in a 350–550 ms time windows following the onset of these stimuli. However, these measures were done using a 50–150 ms baseline, since a −200 to 0 ms baseline would have coincided with the N400 elicited by the previous stimulus. For primes, a condition factor with two levels (related vs. unrelated to distractor) was added to the task (attend vs. ignore the distractor) factor. For targets, the condition factor had 4 levels (no-relation vs. distractor–prime related vs. all related vs. prime–target related), given that there were not enough trials in the distractor–target related condition to compute good quality ERPs.

5.2. *Methods of the second experiment*

5.2.1. *Stimuli*

One set of 400 trials was constructed by putting together the two word lists used in the first experiment.

5.2.2. *Subjects*

There were 50 right-handed subjects (32 females) who had the same characteristics and were recruited in the same way as those who participated to the first experiment.

5.2.3. *Subjects' sorting*

The sorting of subjects between good and poor ignorers was based on the results of the first experiment. More specifically, it was based on the longer RTs observed when subject's had to attend to distractors than when they had to ignore them in the two critical conditions (i.e., conditions 2 and 4, where distractors were related to targets). Those subjects that showed much longer RTs in the critical than in the control conditions, like in the 'attend' task of the previous study, were classified as poor ignorers. Conversely, those subjects that showed rather similar RTs in the critical and in their control conditions, like in the ignore condition of the previous study, were classified as good ignorers.

Good and poor ignorers were therefore sorted by using the RT differences between the distractor–target related condition and the no relation condition and between the all related condition and the prime–target related condition. Given the larger proportion of trials in the all related condition (i.e., 25%), a weight of 5 was given to the difference between the RT in this condition (i.e., condition 4) and the RT in the prime–target related condition (i.e., condition 5). Given the smaller proportion of trials of the distractor–target related condition (i.e., 10%), a weight of 2 was given to the difference between the RT in this condition (i.e., condition 2) and the RT in the no relation condition (i.e., condition 1). The compound weighted RT difference used to classify each subject was therefore: 5(RT cond 4 − RT cond 5) + 2(RT cond 2 − RT cond 1). To avoid superimposition between the two groups, subjects close to the median, that is, subjects whose result of the compound weighted RT difference was between 5 and 150 ms, were removed. Good ignorers were therefore subjects in whom this result was smaller than 5 ms and poor ignorers were subjects in whom this result was greater than 150 ms. It should be noted that, within the selected subjects, 94% of those whose the RT in condition 4 was longer than their RT in condition 5 also showed RT in condition 2 that was longer than their RT in condition 1. There were 17 poor ignorers, among whom 7 were males and 10 females. Their mean age was 23.8 years and their mean level of education, 16.2 years. Among the 16 good ignorers, 7 were males and 9 females, their mean age was 24 years, and their mean level of education, 16.8 years.

5.2.4. *Procedure*

The procedure was the same as that of the first experiment except that subjects were neither told to pay attention nor to ignore the first word of each triplet. In each trial, subjects just had to respond as quickly and as accurately as possible by pressing the right arrow key of a PC keyboard when the meaning of the third word was related to the meaning of the second word and the down arrow key when it was not. Stimulus timings were identical to those of the previous study, except for the duration of the fixation cross, which was reduced to 400 ms. This adjustment was done so that the offset of the fixation cross did not coincide with the onset of the first word.

5.2.5. *Data acquisition, data processing, measures and statistics*

Data were acquired, processed, measured and analyzed as in the first experiment except that the task within-subject factor was replaced in all analyses by the group (good vs. poor ignorers) between-subjects factors.

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