ERP Evidence for an Interaction between Phonological and Semantic Processes in Masked Priming Tasks

Caroline Jacquier (jacquier@isc.cnrs.fr)
Aïcha Rouibah (rouibah@isc.cnrs.fr)
Institut des Sciences Cognitives, 67 boulevard Pinel
69500 Bron, France

Michel Hoen(hoen@isc.cnrs.fr)
Laboratoire Dynamique Du Langage, 14 avenue Berthelot
69007 Lyon, France

Abstract

Two masked priming experiments investigated the time-course of phonological and semantic processes implicated in visual word recognition as well as their possible interaction, using event-related brain potentials (ERPs). Participants read target words which were phonologically related, semantically related, both phonologically and semantically related or unrelated to a masked prime word. In experiment 1, participants performed a phonological task (decide whether targets rhymed with a previously heard rhyme). The phonological relation elicited a frontal negativity whereas the semantic relation elicited a left anterior negativity, both followed by an N400 at centro-parietal sites. In experiment 2, participants performed a semantic task (decide whether targets belonged to a previously presented semantic category). In contrast to experiment 1, phonological and semantic relations elicited an N400 over frontal sites. Together, these results demonstrate that phonological and semantic processes interact during visual word recognition.

Keywords: Word Recognition; Masked Priming; Phonology; Semantic; Event-Related brain Potentials (ERPs).

Introduction

Phonology: an Obligatory Stage

Although many studies were interested in the determining of cognitive processes implicated in printed word recognition, there have yet been few studies dedicated to phonological information processing and its potential interaction with semantic information processing. For a long time, phonological processing was considered as an optional stage during word recognition.

But recent studies (Berent & Perfetti, 1995; Van Orden, 1987; Hillinger, 1980) have shown much clearer that phonology might well be an obligatory stage during the processing of visual words. For instance, Berent and Perfetti (1995) have observed that non-word primes, phonologically related to target words, induced better identification rates than non-word primes that were orthographically related to target words. Moreover, phonological processing seems unavoidable because it appears even if phonological manipulations are unconscious and alter subject's performance (Tanenhaus, Flanigan, & Seidenberg, 1980). Thus, phonological processing would be both automatic and obligatory during visual word recognition.

Phonology: a Mediator to Meaning Access

Over the past 20 years, the direct access view has been strongly called into question.

Van Orden (1987) has reported clear evidence for phonological mediation during meaning access. In a semantic decision task, homophones of words belonging to a semantic category (e.g., *MEET the homophone of MEAT*), were more often incorrectly classified as belonging to the category *FOOD* than orthographically similar but non homophone words (e.g., *MELT*). The false-positive responses suggest that phonological information was activated and used to access meaning.

Lesch and Pollatsek (1993) and Lukatela and Turvey (1994) have extended this homophone effect in the context of masked priming paradigms. They have reported that the phonological facilitation effect appeared at short prime exposure durations. And they concluded: "The data thus provide support for a model of word recognition in which meaning is rapidly and automatically accessed through a phonological code" (Lesch & Pollatsek, 1993, p.291). Perfetti, Bell, and Delaney (1988) have suggested that the phonological form of a word is activated automatically and at a very early stage in processing.

According to Plaut, McClelland, Seidenberg, and Patterson (1996), an orthography-phonology (OP) and an orthography-semantic-phonology (OSP) pathways would exist. It is generally accepted that at least two pathways exist for reading words, but their exact nature and their mode of interaction are still actively discussed.

Interaction between Phonology and Semantic

As such, phonological priming effects should generally be observed in masked priming experiments, for tasks such as naming or lexical decision. Thus, the question is whether the same is true in a task for which phonological processing of the target is completely irrelevant.

Rouibah, Tiberghien and Lupker (1999) have shown that priming effects based on phonological similarity can be obtained even when the task itself does not require the retrieval of phonological information. They have also tested the hypothesis that phonological and semantic processes may interact. They reported phonological priming effects in a semantic task, but also semantic priming effects in a phonological task. Thus, their results are in accordance with the hypothesis of an interaction between phonological and semantic processing.

More recently, Farrar, Van Orden and Hamouz's (2001) results substantiated this conclusion. Indeed, they observed phonological priming effects mediated by semantic processing (e.g., *the prime SOFA facilitates the processing of the target TOUCH via COUCH which is semantically related to SOFA*). This facilitation effect underlines the fact that semantic processing can take part in the access to phonological representations. However, mediation does not seem to be the adequate relation between the two processes. It seems clear then that semantic and phonological processes interact during printed word recognition even unconsciously.

However, the exact nature and the mode of this interaction are still actively discussed. The lack of information on the nature of processes which take part in visual word recognition and the bad-known organization of the processing units in lexical representation constitute two aspects decreasing the truthfulness of a cognitive conceptualization of reading models. That is, in the current study, we attempted to provide some information on phonological and semantic information processing interactions using event-related potentials (ERPs).

Indeed, reaction times, used in behavioral studies, only display a final picture of cognitive events. Thus, ERPs may help identify electrophysiological markers which correspond to particular cognitive processes and the modulation of markers may correspond to interactions between different experimentally manipulated processing stages.

Phonological and Semantic Priming Effects in ERP Studies

In this article, we focused on phonological and semantic markers. Electrophysiological correlates of phonological processing have been studied by a large amount of authors in different tasks (Bentin, Mouchetant-Rostaing, Giard, Echallier, & Pernier, 1999; Niznikiewicz & Squires, 1996). A negative wave was reported in a time window lasting from 200 to 350 ms which would reflect early phonological processing. For instance, Bentin et al. (1999) in a phonological decision task observed a left temporal negative wave peaking at 320 ms (N320). This marker was elicited by pronounceable but not by unpronounceable letter strings. In a phonological priming experiment, Connolly, Service, D'Arcy, Kujala, and Alho (2001), have reported a phonological mismatch negativity (PMN) peaking around 330 ms. They suggested that the PMN would reflect subprocesses preceding contextual integration as indicated by the manifestation of the N400.

Thus, this early negative wave is elicited in priming condition and would reflect an early stage of phonological processing during word recognition.

In the domain of semantic processing, most of the electrophysiological studies on language processing have reported a negative wave peaking at 400 ms (N400) after word onset that is sensitive to semantic variations.

Kutas and Hillyard (1980) have shown that the evoked potential to semantically incongruent sentence final words elicited a negative wave peaking around 400 ms relative to words providing a semantically congruent ending. However, the N400 is also elicited in non semantic violation contexts, for modulations in semantic expectancy of correct words (see for review: Kutas & Federmeier, 2000).

Brown and Hagoort (1993) have reported that no N400 priming effect was obtained in a masked priming situation. According to these authors, the mask would prevent conscious identification of the prime and therefore, no semantic expectancy strategy would be possible. The N400 would reflect a post-lexical process. But, Deacon, Hewitt, Yang, and Nagata (2000), have reproduced Brown and Hagoort's experiment and observed an N400 priming effect in non masked conditions as well as in masked conditions. Hence, these authors concluded that the N400 does not reflect post-lexical processes and is modulated even unconsciously. Interestingly, the N400 wave was shown to be sensitive to semantic priming effects, both in the visual and auditory modalities (Radeau, Besson, Fonteneau, & Castro, 1998) as well as for cross-modal presentation of prime and target. Others studies (Perrin & Garcia-Larrea, 2003; Kramer & Donchin, 1987) have demonstrated that the N400 is not only sensitive to semantic modulation but also to phonological modulations. For instance, Kramer and Donchin (1987) reported that the N400 amplitude was lower for rhyming words than for non rhyming words in a rhyme matching task.

To sum up, the N400 component can be observed in masked priming conditions and it can be modulated by semantic but also by phonological processing.

Paradigm and Hypothesis

In the aim of supplying some information about the nature and the mode of interaction between phonological and semantic processes, we performed two complementary masked priming tasks (a phonological and a semantic one) in which prime-target relations (phonological, semantic, phonological and semantic or unrelated word pairs) were tested. The first one consisted in a rhyme matching task which *a priori* did not require any semantic processing and the second one a semantic categorization task which *a priori* did not require any phonological processing.

If phonological and semantic processes are early, automatic, and if they interact, phonological and semantic priming effects should be observed in both tasks on reaction times. For ERPs, phonological and semantic processes should elicit two distinct electrophysiological markers. Their time course as well as their spatial distribution should vary. An early negativity should reflect phonological processing and the classical semantic marker N400 should be also observed. N400 should be modulated by phonological and semantic relationships.

Method

Experiment 1: Rhyme Matching Task

Subjects Sixteen right-handed volunteers participated in the experiment. They were all native French speakers with normal or corrected-to-normal vision and without any established hearing disorder.

Stimuli We selected 144 prime-target word pairs. The nature of the relationship between prime and target defined the four experimental conditions: (1) phonologically related[1], (2) semantically related (e.g., "tortue/bélier" (turtle/ram)), (3) both phonologically and semantically related (e.g., "action/mission" (action/mission)) and finally (4) unrelated word pairs (e.g., "secours/cosmos" (help/cosmos)).

Procedure Participants sat in a dimly lit room facing a computer monitor. The screen was at a distance of approximately 70 cm from subject's eyes. First, a sound (rhyme) was emitted that lasted for 2500 ms. Second, a fixation point appeared at the center of the screen for 500 ms, after which the screen remained blank for 250 ms. The mask (##########) was then presented for 500 ms and the prime appeared immediately after and lasted for 60 ms. Finally, the target was presented until the subject's response. Figure 1 illustrates this procedure. The list was divided in two blocks (72 trials) so that subjects could take a break. Subjects performed a training list before beginning the experimental list.

Subjects had to decide whether targets rhymed, or not, with the previously heard rhyme. Volunteers were asked to make this decision as fast and as accurately as possible. They gave their responses by pressing a key on the computer keyboard with one hand when the response was "yes" and a different key with the other hand when the response was "no". Keys were switched over for 50% of subjects to avoid motor biases in ERPs.

Experiment 2: Semantic Categorization Task

Subjects Sixteen right-handed volunteers participated in the experiment. They were all native French speakers with normal or corrected-to-normal vision. None of them was included in experiment 1.

Stimuli The same 144 prime-target word pairs that were used in Experiment 1 were used again. However, target words were listed in 22 semantic categories (e.g., "tortue" (turtle) as belonging to the semantic category "ANIMAL").

[1]In order to avoid well-known orthographic priming effects, 50% of the pairs were orthographically similar to the rhyme (e.g., "accueil/cercueil" (reception/coffin)) and 50% of the pairs were orthographically dissimilar to the rhyme (e.g., "chimie/fourmi" (chemistry/ant)).

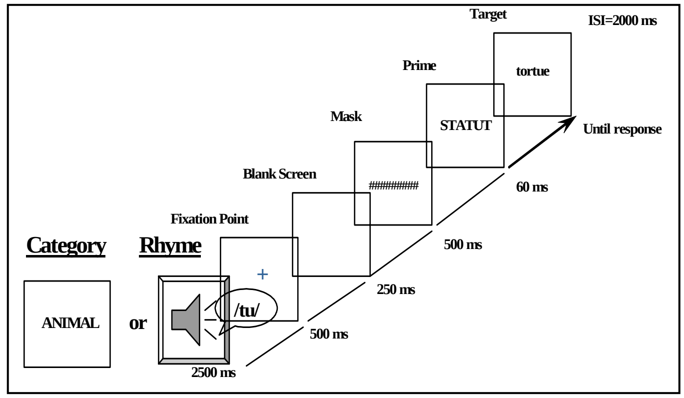

Figure 1: Illustration of both experimental procedures.

Procedure The experimental procedure was generally the same as the one in Experiment 1. The main exception was that, at the beginning of each trial, subjects saw the name of a semantic category instead of hearing a sound. Subjects' task was to decide whether targets belonged to the category they previously saw on the screen (Figure 1).

ERP Recording

The electroencephalogram (EEG) was continuously recorded from 65 scalp sites using Ag/AgCl electrodes mounted on a geodesic net and the electrode Cz was used as reference. Scalp voltages were amplified with a high input impedance amplifier (200 MΩ, Net AmpsTM, Electrical Geodesics Inc.). Amplified analogue voltages (0.1-200 Hz bandpass) were sampled at 500 Hz. Electrode impedance was kept below 30 kΩ during complete recording (Tucker, 1993).

Data Analysis

EEG recordings were segmented from 100 ms before to 900 ms after the onset of the prime. Segments were then filtered by a low-pass filter of 30 Hz, re-referenced to an average reference, and a baseline correction was applied based on the first 100 ms. Computerized artifact rejection was performed before averaging and trial contaminated by eye movements, eye blinks or transient amplitude shifts were rejected from further analyses. ERPs were averaged within each condition for each participant. In order to facilitate statistical analyses of scalp effects, three different locations were defined (frontal, left anterior and centro-parietal), each composed of six electrodes corresponding to the 10–20 coordinates AF2/AF4, F1/F2, FCz, Fr (frontal); F7, FC5, C3, C5, FT7, T7 (left anterior); and CP1/CP2, P1/P2, Cz, CP (centro-parietal), respectively. For all analyses in both tasks, scalp voltages were obtained in a time window lasting from 350 to 450 ms after the onset of the prime. ERP amplitudes were analyzed by repeated-measures ANOVAs. Factors were experimental conditions, electrode sites, spatial domains and tasks. For all repeated measures with more than 1 degree of freedom, the Greenhouse-Geisser correction was applied (Greenhouse & Geisser, 1959).

Results

Behavioral Results

Prime/Target Relation × Task within-subject ANOVA performed on mean reaction times showed two significant main effects for factors task and experimental conditions ($F(1, 15) = 9.55$, $MSE = 22476.18$, $p < 0.01$, and $F(3, 45) = 90.25$, $MSE = 214.03$, $p < 0.01$). The second level interaction was also significant ($F(3, 45) = 5.84$, $MSE = 345.83$, $p < 0.01$). Reaction times in the semantic categorization task were longer (mean: 762.88 ms) than the ones observed in the rhyme matching task (mean: 680.88 ms).

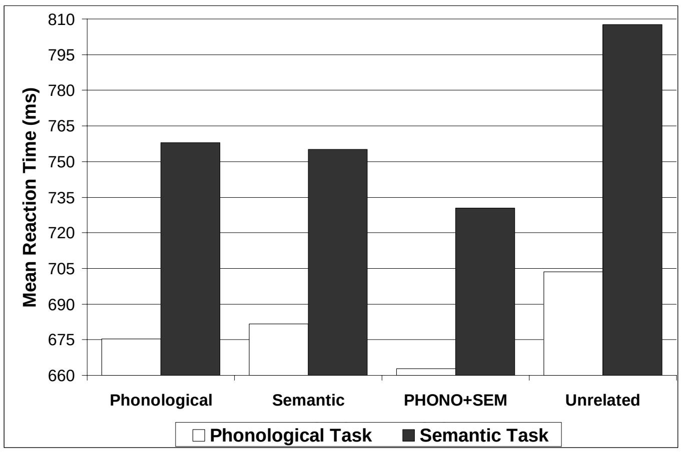

Figure 2: Mean reaction time (ms) for each condition in each task. Note phonological, semantic and phonologico-semantic priming effects in both tasks ($p < 0.05$).

Moreover, reaction times were faster when primes and targets had a relation than when they were unrelated and reaction times were also faster when primes and targets had a combined relation (phonological and semantic) than when they had a simple relation (Figure 2).

Thus, we observe phonological and semantic priming effects and also a stronger combined priming effect in both tasks.

Electrophysiological Results

Average scalp voltage amplitude were calculated between 350 and 450 ms. Visual inspection of grand average waves (Figure 3) showed two distinct negative components that differed in peak latency, spatial distribution and manifestation according to the nature of the task. In the phonological task, an early negative wave peaking at about 320 ms (N320) is observed at central sites, followed by a negative wave peaking around 400 ms (N400). In the semantic task, the N320 is not distinguished but the N400 is highly observed at centro-parietal sites.

First, we compared scalp distribution and conditions effect across tasks. Then, we focused on spatial domains for each task.

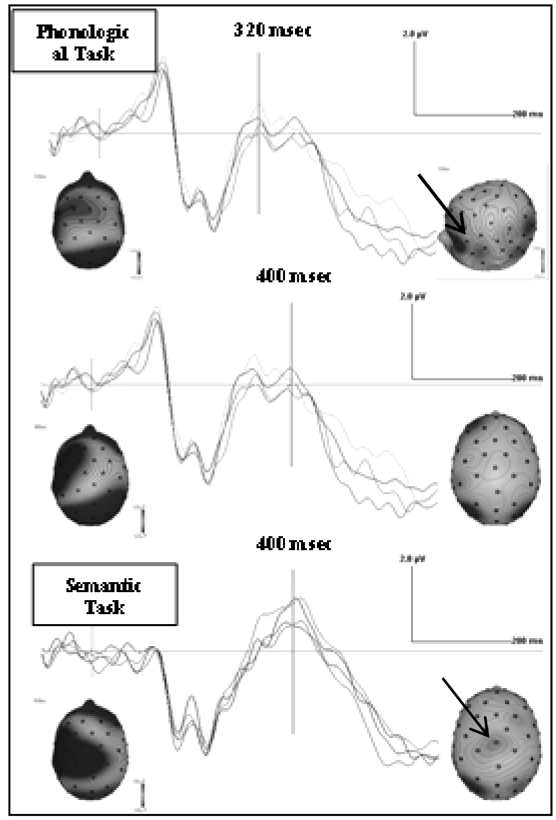

Figure 3: Grand-averaged voltage data (*n = 16*) from central electrode as a function of task: phonological task (in top part) and semantic task (in bottom part).
The components are indicated by the long vertical line. The 3D interpolations show amplitude maps (left) and current source (right). Negative potentials are plotted upwards.

Task Comparison ERPs data were analyzed in a 4-way repeated-measure ANOVA including factors Task (2), Spatial Domain (3), Prime/Target Relation (4) and Electrode (6). The analysis revealed a significant main effect for Spatial Domain ($F(2, 30) = 10.24$, $MSE = 16.76$, $p < 0.01$), average scalp voltages in the left anterior domain being globally more negative than in other domains. The main effect for Task remained at the level of a tendency ($F(1, 15) = 3.62$, $MSE = 13.44$, $p = 0.076$). No significant main effect for experimental conditions was observed ($F(3, 45) = 1.03$, $MSE = 1.13$, $p = 0.39$). Though, a Task × Domain interaction and a Task × Experimental Conditions interaction effects were significant ($F(2, 30) = 7.94$, $MSE = 15.14$, $p < 0.01$ and $F(3, 45) = 3.24$, $MSE = 1.02$, $p < 0.05$), suggesting that the effects of spatial location and experimental conditions were highly depending on the task considered.

In the phonological task, the peak of amplitude was observed at around 320 ms over the left anterior domain whereas in the semantic task, the peak of the negative component was observed around 400 ms over the centro-parietal domain. Thus, these two electrophysiological markers would correspond to phonological and semantic processes involve in visual word recognition. The N320 component seems to reflect a phonological effect whereas the N400 seems sensitive to the semantic expectancy.

A triple Task × Domain × Experimental Conditions interaction was also significant. In order to break down this interaction, Electrode × Experimental Conditions ANOVAs were performed for each spatial domain in each task.

Conditions Effect In the phonological task, a significant main effect for factor condition was observed ($F(3, 45) = 2.64$, $MSE = 0.74$, $p = 0.061$) in the left anterior area. N320 amplitude for the semantic condition was significantly more negative than for the phonologico-semantic and control conditions. But the semantic condition did not differ from the phonological condition. The centro-parietal area's analysis also showed a significant main effect for condition ($F(3, 45) = 2.76$, $MSE = 0.72$, $p = 0.053$). In this area, the N400 amplitude of the phonological condition was significantly less negative than the ones observed for the semantic and control conditions. Finally, over the frontal domain, a significant main effect for condition was also observed ($F(3, 45) = 3.34$, $MSE = 2.18$, $p < 0.05$). In this domain, the N320 amplitude of the phonological condition was significantly more negative than for mixed and control conditions.

In the semantic task, the only domain for which a significant main effect for conditions was observed is the frontal domain ($F(3, 45) = 3.88$, $MSE = 1.43$, $p < 0.05$). For this domain, the N400 mean amplitude for the phonological condition and for the semantic condition were significantly less negative than the ones for mixed and control conditions ($p < 0.05$). In fact, the N400 amplitude was larger for unrelated and totally related pairs than for phonologically or semantically related pairs.

Discussion

In both tasks, behavioral data underline two facilitation effects: phonological and semantic ones. Moreover, a significant facilitation effect is emphasized for the phonologico-semantic double link. These results are in accordance with those observed in former studies (Perrin & García-Larrea, 2003; Rouibah et al., 1999) and are in agreement with the hypothesis of an interaction between phonological and semantic processes during visual word recognition. Masson's distributed memory model (1995) could explain this interaction. According to this model, presentation of a prime automatically creates a pattern of activation across semantic and phonological processing units. If the prime is phonologically or semantically similar to the target, the pattern of activation of the phonological or semantic units is similar to that of the upcoming related target. When the target is presented, activation of its pattern across the phonological and semantic units is then facilitated. This faster activation of the target's phonological and semantic pattern speeds up any response about this target. Besides it, because of the full connection between phonological and semantic processing units, the pattern of activation across the semantic units can help driving the phonological units to the target's pattern and vice versa.

Electrophysiological data in Task comparison have shown no significant effect of task, whereas a Task × Domain effect was observed. Thus, different distributed cognitive processes were implicated during visual word recognition. And, their modulations by conditions were task dependent.

On the one hand, a phonological priming effect was observed in the phonological task over centro-parietal sites, whereas a phonological effect was elicited at frontal sites. Our frontal negativity contradicts the phonological mismatch negativity (PMN) described by Connolly et al. (2001). They have reported a wave more negative for non rhyming than for rhyming words. We observe the opposed modulation. Otherwise, it appears that in the phonological task, an N400, at centro-parietal sites, is essentially sensitive to the phonological processing and that a semantic effect, at left anterior sites, is induced by subject's expectations. Indeed, over left anterior sites, a semantic effect was observed but in the way that semantic condition elicited a more negative wave. Thus, semantic effect would emerge in conditions where this processing is probably automatic and in a phonological task. This last observation highly comforts the hypothesis that semantic information plays a role during phonological access. An alternative explanation is possible according to Hill, Strube, Roesch-Ely, and Weisbrod's (2002) results. They have reported an N310 component sensitive to semantic relations. Contrary to our data, this N310 was more negative for the non-related prime–target condition and could be differentiated from the N400 because of its temporal and spatial pattern. We still observe the opposed modulations.

On the second hand, in the semantic task, a semantic priming N400 effect was observed but also a phonological priming N400 effect over frontal sites. These results suggest that the N400 is sensitive to semantic as well as phonological relations and that meaning access implicates a phonological processing stage. To explain these differences between the two tasks, we refer to Masson's distributed memory model. Indeed, we suggested that semantic processing was not expected in the phonological task thus semantic relation would induce an additional matching over pre-activated semantic units. That is, semantic congruence was not the pertinent information and associated with phonological incongruence induced a more negative potential. However, reaction times were not affected. While in semantic task, semantic processing probably deeper was obligatorily mediated by phonological level thus phonological and semantic priming effect have been established. Explicitly, spreading activation in both tasks would pursue different pathways.

Generally, our results reflect the N400 literature's data (Hill et al., 2002; Deacon et al., 2000; Radeau et al., 1998; Niznikiewicz & Squires, 1996). Deacon et al. (2000) have showed that N400 amplitude was larger for unrelated stimuli than for related stimuli regardless to conditions: masked or not. However, Radeau et al. (1998) have underlined that phonological and semantic priming influenced the N400. Nevertheless, in our rhyme matching task, semantic priming is not highlighted. Perrin and García-Larrea (2003) have suggested that semantic N400 is a powerful N400 appearing also when no explicit instructions was done and when subjects are instructed for a task of a different nature. Furthermore, they have observed a smaller phonological N400 in a mix context. Consequently, we suggest that phonological and semantic processes are in competition. But this hypothesis seems task's dependent.

An explanation for our phonological effect in the phonological task over frontal sites would be that processing of surface would be earlier accomplished and thus would influence also an earlier component like the N320 (Connolly et al., 2001). On the contrary, in the semantic task, phonological processing would be accomplished later and thus would influence the N400.

To sum up, we showed two fundamental points: (i) a semantic processing in the phonological task and (ii) a phonological processing in the semantic task. Thus, we have shown a task independent interaction of phonological and semantic information processing during visual word recognition. Moreover, these processes were reflected by two distinct, automatic, and obligatory electrophysiological markers (N320 and N400).

Acknowledgments

Authors would like to thank Guy Tiberghien that contributed to this study.

References

Bentin, S., Mouchetant-Rostaing, Y., Giard, M. H., Echallier, J. F., & Pernier, J. (1999). ERP manifestations of processing printed words at different psycholinguistic levels: time course and scalp distribution. *Journal of Cognitive Neuroscience, 11(3),* 235-260.

Berent, I., & Perfetti, C. A. (1995). A rose is a REEZ: the two-cycles model of phonology assembly in reading English. *Psychological Review, 102*, 146-184.

Brown, C.M., & Hagoort, P. (1993). The processing nature of the N400: evidence from masked priming. *Journal of Cognitive Neuroscience, 5*, 34-44.

Connolly, J. F., Service, E., D'Arcy, R. C. N., Kujala, A., & Alho, K. (2001). Phonological aspects of word recognition as revealed by high-resolution spatio-temporal brain mapping. *NeuroReport, 12(2)*, 237-243.

Deacon, D., Hewitt, S., Yang, C. M., & Nagata, M. (2000). Event-related potential indices of semantic priming using masked and unmasked words: evidence that the N400 does not reflect a post-lexical process. *Cognitive Brain Research, 9*, 137-146.

Farrar IV, W. T., Van Orden, G. C., & Hamouz, V. (2001). When SOFA primes TOUCH: interdependence of spelling, sound, and meaning in « semantically mediated » phonological priming. *Memory and Cognition, 29(3)*, 530-539.

Greenhouse, S. W., & Geisser, S. (1959). On methods in the analysis of profile data. *Psychometrika, 24*, 95-112.

Hill, H., Strube, M., Roesch-Ely, D., & Weisbrod, M. (2002). Automatic vs. Controlled processes in semantic priming – differentiation by event-related potentials. *International Journal of Psychophysiology, 44*, 197-218.

Hillinger, M. L. (1980). Priming effects with phonemically similar words: the encoding-bias hypothesis reconsidered. *Memory and Cognition, 8*, 115-123.

Kramer, A. F., & Donchin, E. (1987). Brain potentials as indices of orthographic and phonological interaction during word matching. *Journal of Experimental Psychology: Learning, Memory and Cognition, 13*, 76-86.

Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences: brain potentials reflect semantic incongruity. *Science, 207*, 203-205.

Kutas, M., & Federmeier, K. D. (2000). Electrophysiology reveals semantic memory use in language comprehension. *Trends in Cognitive Sciences, 4(12),* 463-470.

Lesch, M. F., & Pollatsek, A. (1993). Automatic access of semantic information by phonological codes in visual word recognition. *Journal of Experimental Psychology: Learning, Memory and Cognition, 19*, 285-294.

Lukatela, G., & Turvey, M. T. (1994). Visual lexical access is initially phonological: 1. Evidence from associative priming by words, homophones, and pseudohomophones. *Journal of Experimental Psychology: General, 123(2),* 107-128.

Masson, M. E. J. (1995). A distributed memory model of semantic priming. *Journal of Experimental Psychology: Learning, Memory and Cognition, 21*, 3-23.

Niznikiewicz, M., & Squires, N. (1996). Phonological processing and the role of strategy in silent reading: behavioral and electrophysiological evidence. *Brain and Language, 52*, 342-364.

Perfetti, C. A., Bell, L., & Delaney, S. (1988). Automatic phonetic activation in silent word reading: Evidence from backward masking. *Journal of Memory and Language, 27*, 59-70.

Perrin, F., & García-Larrea, L. (2003). Modulation of the N400 potential during auditory phonological/semantic interaction. *Cognitive Brain Research, 17*, 36-47.

Radeau, M., Besson, M., Fonteneau, E., & Castro, S. L. (1998). Semantic, repetition and rime priming between spoken words: behavioral and electrophysiological evidence. *Biological Psychology, 48*, 183-204.

Rouibah, A., Tiberghien, G., & Lupker, S. J. (1999). Phonological and semantic priming: evidence for task-independent effects. *Memory and Cognition, 27(3)*, 422-437.

Tanenhaus, M. K., Flanigan, H. P., & Seidenberg, M. S. (1980). Orthographic and phonological activation in auditory and visual word recognition. *Memory and Cognition, 8*, 513-520.

Tucker, D. M. (1993). Spatial sampling of head electrical fields: The Geodesic Sensor Net. *Electroencephalography and Clinical Neurophysiology, 87*, 145-163.

Van Orden, G. (1987). A ROWS is a ROSE: spelling, sound and reading. *Memory and Cognition, 15*, 181-198.