Physiological evidence that a masked unrelated intervening item disrupts semantic priming: Implications for theories of semantic representation and retrieval models of semantic priming

Diana Deacon,* Jillian Grose-Fifer, Sean Hewitt, Masanori Nagata, John Shelley-Tremblay, and Chien-Ming Yang

The City College of the City University of New York, 138th Street at Convent Avenue, New York 10031, USA

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Abstract

Event-related potentials were recorded in a paradigm where an unrelated word was interposed between two related words. In one condition, the intervening item was masked and in another condition it was not. The N400 component indicated that priming of the related word was disrupted by the intervening item whether it was masked or not. The data are interpreted to be inconsistent with retrieval models of priming.

Keywords: N400; Priming; Intervening words; Interposition effect; Lag; Distributed representation; Retrieval models

1. Introduction

Responses to a target word are usually facilitated by a semantically related prime. In the intervening item paradigm, however, an unrelated word presented between related primes and targets, decreases the amount of facilitation. This finding has been used to support two rather disparate accounts of semantic priming. The first is that the facilitation by priming occurs at the level of semantic stores, and that these stores are distributed. Masson (1991, 1995) used the intervening item phenomenon to substantiate his model, in which word meanings are represented by a series of nodes, in a Hopfield-like distributed system. Nodes can only be "on" or "off," and as all nodes collectively constitute a single pattern of activation, only one word can be activated at a given time. Although the pattern of nodal activation is unique for each word, related words that share semantic features will activate some of the same nodes. Thus, priming occurs because not all of the nodes comprising the pattern are reset by the related word. When an unrelated item is interposed between two related words, the pattern is reset by the unrelated item, and facilitation is disrupted.[1]

The second account of priming that the intervening item effect is considered to support, is the compound cue retrieval theory (Ratcliff & McKoon, 1988). According to this view, the prime and target form a compound cue that facilitates decisions regarding the target. The compound cue is matched against items in long term memory, and facilitation is proportional to the extent that the elements entering into the compound cue are associated in long term store. The intervening item effect is explained in the context of the compound cue theory as the weakening of the strength of the compound cue due to the inclusion of an unrelated item.

The compound cue model is actually only an explanation of priming effects, and does not, in itself, make predictions about the organization or operation

* Corresponding author.
E-mail address: monterey@bcn.net (D. Deacon).

[1] The effects of the intervening item have been demonstrated to be semantic in nature and not due to the passage of time (Masson, 1988; Ratcliff & McKoon, 1988). Neutral stimuli such as dot matrices or rows of *x*'s interposed between related items had no effect on priming in the latter studies whereas an interposed unrelated word disrupted priming.

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of semantic memory. However, to the extent that virtually all models of semantic memory derive from priming data, the fundamental tenets of the compound cue model and other retrieval models (i.e., Dosher & Rosedale, 1989; Murdock, 1982; Ratcliff & McKoon, 1988, 1997) need to be addressed. Of particular concern is that in the majority of studies that have tested or proposed retrieval models (the compound cue model included), virtually all of the variability in RT and accuracy is accounted for in terms of decision-related, and or post-decision processing. Variability arising from differences in the activation states of semantic stores is interpreted in the context of most retrieval models to be minimal. If these models were adamantly adhered to, the question might thus be raised as to what, if anything, priming data reflect about semantic memory per se.

In advocacy of semantic priming as a manipulation through which semantic memory can be studied, it should be noted that the retrieval models are squarely at odds with a rather large body of physiological data. Priming effects on the N400 component of the human event-related potential (ERP) occur in response to a variety of lexical/semantic manipulations (for a review see Deacon, Hewitt, Yang, & Nagata, 2000, or Deacon & Shelley-Tremblay, 2000). Further, it has been demonstrated in a number of ways that the N400 does not reflect decision or response related processing. For example, it can be recorded and is sensitive to priming even when no decision or response is made regarding the eliciting stimulus (Deacon, Hewitt, & Tamny, 1998; Deacon et al., 2000; Deacon, Mehta, Tinsley, & Nousak, 1995; Kutas & Hillyard, 1989), and can be recorded using masked unidentifiable words (Deacon et al., 2000; Schnyer, Allen, & Forster, 1994). This being so, there is already an abundance of physiological (N400) priming data that could be seen as disproving the compound cue model,[2] because in the compound cue model priming does not affect lexical/semantic processes. The present study attempted to bridge this apparent gap between cognitive scientists ascribing to retrieval models of priming and electrophysiologists investigating similar issues. Assumptions underlying the compound cue model and distributed models were examined using the N400 recorded in an intervening item paradigm that was analogous to those used in the relevant behavioral studies.

One point of divergence in the predictions emanating from distributed models and the compound cue models, is the extent to which masked items might be expected to influence priming. In distributed systems there is no requirement, either stated or implied, that primes be consciously recognizable in order to produce facilitation. By contrast, it seems implausible that a subthreshold prime would enter into compound retrieval cues, which as described by Ratcliff and McKoon would seem to consist largely of amalgamated episodic memories. The compound cue model would predict that masked primes ought not to produce priming, but this is not the case. Words that are masked to below recognition threshold nevertheless produce priming on reaction time (Balota, 1983; Fowler, Wolford, Slade, & Tassinary, 1981; Marcel, 1983) as well as on the N400 (Deacon et al., 2000; Schnyer et al., 1994). These data pose a problem for the compound cue model in its current rendition.

More recently, a retrieval theory termed the "counter" model, has been proposed in order to account for the effects of masked primes (McKoon & Ratcliff, 2001; Ratcliff & McKoon, 2000). In the counter model, a running "count" is kept of the occurrences of any given item. Decision bias towards an item increases as a function of the number of times it is presented. The counter model is largely based upon repetition priming, rather than semantic priming data. Thus, the predictions that could be generated regarding semantic priming are less explicit. As with previous theories of this genre, the counter model assumes the locus of priming to be decision and/or response processing. However, it has already been demonstrated that the N400 (reflecting lexical/semantic processing) is sensitive to repetition priming, even when the first presentation of the word is masked. Although certain other ERP components are affected by manipulations that impact upon decision and response, N400 does not appear to be. Thus, the sensitivity of N400 to masked repetition priming manipulations is evidence against the contention of Ratcliff and McKoon, that repetition priming emanates from bias regarding decision and response processes. Moreover, the N400 data indicate that the counter model does not adequately explain the effects of masked repetition priming.

As it does not explain masked priming, and is restricted in its scope to repetition priming anyhow, the counter model does little to abate previous criticisms of the compound cue model. While the authors of the compound cue theory contend that unrelated intervening items disrupt priming by weakening the compound cue, and use the intervening item effect as evidence of

[2] Data reported in one study were interpreted as demonstrating a post-lexical locus for N400 (Brown & Hagoort, 1993). The grounds for this interpretation were that N400 priming effects were not obtained from masked stimuli. However, several of the studies that we have cited have since reported ample N400 priming effects, using masked primes in similar, but not identical, paradigms. The present study would be more evidence in this regard. Thus, there is no evidence for the post-lexical interpretation of N400. Rather, the extant evidence is consistent with the view that the N400 reflects some aspect of lexical-semantic processing, and is inconsistent with the post-lexical view. This is because the post-lexical processes ascribed to the N400 by Brown and Hagoort cannot operate (according to their own logic) under conditions where the masked words are not recognized.

their theory, the effect of a masked intervening item has never been tested. In the present study, forward and backward masking were employed in order to render the intervening item unidentifiable. It was reasoned that this would prevent rehearsal of the intervening item, would exclude the intervening item from episodic memories formed of each trial, and would prevent it from influencing consciously governed decision and response-related processes. If the intervening item effect were observed under these circumstances it could not be interpreted as a modulation of retrieval processes, because retrieval would be prevented. Moreover, if an intervening item disrupted priming on N400 even though the word could not be identified, this would constitute strong evidence that the locus of semantic priming is lexical/semantic, rather than response related. Even those researchers who have held the view that N400 is of a post-lexical nature (see for example Brown & Hagoort, 1993) would agree that the N400 could not be modulated by post-lexical processing of the intervening item under these conditions. The N400 is smaller (less negative) when words are preceded by a related word than when they are preceded by an unrelated word. If, as Ratcliff and McKoon maintain, the intervening item exerts its effect by diluting the overall semantic relatedness of the stimuli included in the compound cue, then there should be no disruption of N400 priming when the intervening item is masked. The priming effects on masked trials (e.g., CAT-XX-TRUCK-XX-DOG) should be larger than on unmasked trials (e.g., CAT-TRUCK-DOG) where the intervening item (TRUCK) can be identified, and thus enter into, and weaken the retrieval cue. Conversely, if the locus of priming, and its disruption by an intervening item are lexical-semantic, two other predictions would follow. First, in trials where adjacent items are related (e.g., ONION-DOCTOR-NURSE) the third word should produce smaller N400s (greater priming effects) than unprimed trials (e.g., BRICK-PANSY-SHOE), regardless of whether the second word in the triplet is masked. This is essentially what has already been reported by this laboratory and by Schnyer et al. (1994). In addition, the N400 recorded on intervening item trials should be larger (exhibit less priming) than on primed trials, regardless of whether the intervening item is masked. Using the N400 as a dependent measure will allow the amount of priming on masked intervening item trials to be interpreted in terms of the lexical/semantic processes that the N400 reflects, and to be differentiated from the proposed decision and response related effects proposed by retrieval models. In combination, the key features of the present study (masking, the intervening item paradigm, and a physiological measure of lexical/semantic processing) would provide compelling evidence against the compound cue model, if priming were disrupted by the intervening item.

2. Methods

2.1. Participants

Thirteen City College undergraduate and graduate students (6 female, 7 male), who were between 18 and 34 years of age ($M = 27$), participated in the study as paid volunteers. One participant reported being left-handed and the others were right-handed. Each of the participants were native English-speakers, had normal or corrected-to normal vision, and no history of neurological or psychiatric impairment. Informed consent was obtained prior to the participants engaging in the study.

2.2. Stimuli

Common English nouns, presented in black on a gray background in the center of a computer monitor, served as stimuli. The length of words ranged from three to nine characters ($M = 5.81$), and they were, on average, 1-cm high and 4-cm wide. The frequencies of the words used in each condition were equated using the norms of Carroll, Davies, and Richman (1971). A trial was comprised of three sequentially presented words.

Semantic relatedness, established using the Battig and Montague (1969) category norms, was manipulated in order to examine priming effects with and without an intervening item. Words were chosen from the Battig and Montague norms that were generated by at least ten of their volunteers as exemplars of a given category. Category exemplars were then paired on the basis of being associates, as judged by at least three members of the laboratory. Several independent checks were then made to insure that the related words were distributed as equably as possible between conditions, with regard to associative relatedness and category type. One third of the trials served as the Unprimed condition, as they contained a triplet of unrelated words (e.g., BRICK-PANSY-SHOE). One third contained a triplet within which the first word was unrelated to the others, but the second and third words were related to each other (e.g., ONION-DOCTOR-NURSE). Thus, on these (Primed) trials the third word was primed by an adjacent related item. The remaining one third of trials comprised the Intervening item condition. On these trials, related words appeared in the first and third position within the triplet, but were separated by an unrelated item (e.g., CAT-TRUCK-DOG).

The third word in each triplet was followed by a question mark, and then by a probe word, to which the participant responded manually. The critical stimuli, on which ERP data were compared, however, were the third words to appear in each trial. On one half of the trials, the second of the three words was masked to prevent its identification, and on the other half it was clearly visible. Masking stimuli were rows of 10 X's

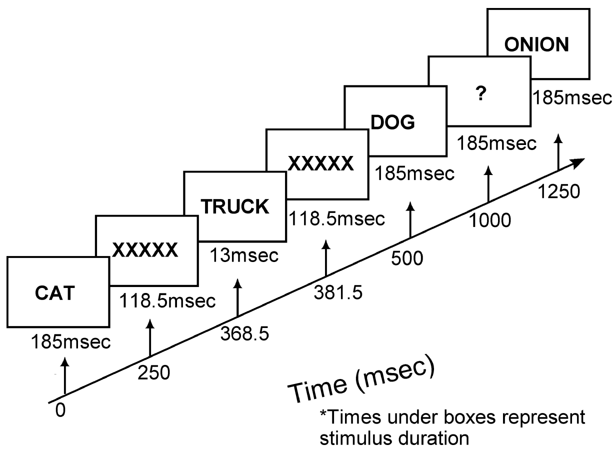

Fig. 1. Methods of stimulus presentation. The example depicts a trial on which two related words are separated by an unrelated masked intervening item. When no word was present, the screen remained gray. For simplicity, these blank screens are not included in the figure.

presented before and after the second word. In both the Masked and Unmasked conditions, 960 words were used; 480 for the primes (the first and second words of each trial); 240 for the critical third word of each trial (80 Unprimed, 80 Primed, and 80 Intervening Item trials); and 240 for probes (124 were repeated and 116 non-repeated items). A practice block was constructed from 48 additional words. None of the words that appeared in the triplets were ever repeated.

2.3. Procedure

The procedure for stimulus presentation in the masked condition is illustrated in Fig. 1. A word was presented for 185 ms, followed, at an SOA of 250 ms, by a row of 10 X's, (the forward mask) displayed for 118.5 ms. The second word appeared for 13 ms[3] as soon as the mask stimulus was erased, and was immediately replaced by another row of 10 X's (the backward mask), the duration of which was also 118.5 ms. Following an SOA of 118.5 ms the third (critical) word appeared for 500 ms. After an SOA of 500 ms, a question mark appeared in the middle of the screen for 185 ms. The purpose of the question mark was to prepare participants to respond to the subsequent probe word. The probe word followed the question mark at an SOA of 250 ms, and was presented for 185 ms. The inter-trial interval, between the probe of one trial and the first stimulus of the next, was 2.5 s.

The intent of this study was to present masked words just below identification threshold. Therefore, prior to recording, participants were asked to read a list of masked words (half of which were primed), using the same masking conditions described above. None of these words were used as stimuli for the ERP recording. Participants who were able to read more than 3 of the 10 masked words were excluded from the study since masking was not judged to be adequate. The task was also repeated after recording to insure that recognition had not improved beyond the criterion level as a result of practice. This procedure is identical to that used by Deacon et al. (2000) and the criteria are similar to those used by others (e.g., Brown & Hagoort, 1993).

The participant's task, during the experiment, was to indicate if the probe word was one of the words in the triplet that they had just seen. A response pad was provided for this purpose with two buttons labeled "yes" and "no." Since participants were unable to identify the masked words, they were told to simply do their best and to guess if necessary. Participants were told that they would find the task easier if they processed the meanings of the words as fully as possible. Even though they could not identify the words, it was expected that the strategy of semantically processing words would promote priming. Prior to recording, a practice session was administered as many times as were necessary for the participant to feel comfortable with the task.

The purpose of presenting the probe after the stimulus triplet, instead of requiring a decision to the critical word, was to avoid ERP component overlap. If participants had been able to make a decision regarding the task when the critical (third) word was presented, then the P3, a positive component elicited by stimulus classification, would have overlapped the N400 and confounded interpretation of the data. In the present paradigm participants did not have all of the information needed to make the decision until the probe was presented. Thus, no decision would be made, and no P3 elicited by the critical stimulus. Nevertheless, the N400 to the critical word of the triplet could be assumed to accurately reflect variability in the strength of the compound cue, since the stimulus triplet would have to be held in memory in order to correctly perform the task.

2.4. EEG recording

The electroencephalograph (EEG) was recorded from eighteen standard 10–20 system scalp locations (FP1, FP2, Fz, F3, F4, Cz, C3, C4, Pz, P3, P4, T3, T4, T5, T6, Oz, O1, O2), referenced to the nose. The horizontal electro-oculogram (EOG) was recorded by electrodes placed lateral to the outer canthi of the left and right eyes. Vertical EOG was recorded by electrodes placed on the supra- and infraorbital ridges of the right eye. Interelectrode impedances were kept below 5 kΩ.

The EEG and EOG data were filtered using bandpass of 0.1–35 Hz. Sweeps of 775 data points were sampled

[3] The short stimulus duration was achieved using software designed to preload stimuli, thus shortening the effective raster rate by eliminating load-time.

from 200 ms preceding the first word in a trial until 1500 ms after the first word (i.e., a total of 1700 ms, that encompassed the first three stimuli of each trial). Baseline correction was performed in relation to the averaged EEG activity in the 200 ms prior to the onset of the third (critical) stimulus. Trials on which EEG or EOG activity exceeded plus or minus 50 μV were automatically rejected from the averaging process. This criterion resulted in the exclusion of approximately 20% of trials.

2.5. Data analysis

Behavioral data were stored for subsequent off-line analysis. The mean reaction times and percentage of correct responses to the probe words were calculated for each participant.

The area (mean amplitude) of the N400 was measured in the 300–500 ms epoch following the onset of critical stimuli for each type. Repeated measures analysis of variance (ANOVA) was performed on the factors of Priming (Primed, Unprimed, Intervening), Masking (Masked, Unmasked), and Electrode (C3, Cz, C4, T3, T4, P3, Pz, P4, O1, Oz, O2). The occipital electrodes and T5 and T6 were not analyzed because priming was less clear in the grand average. The two fronto-polar sites were excluded because of the possibility of contamination by low voltage eye movements. The Greenhouse Geisser Correction was applied where appropriate. The overall ANOVA was followed by Least Squares Difference (LSD) pairwise comparisons between Unprimed and Primed, between Unprimed and Intervening, and between Primed and Intervening conditions (see Table 1).

To establish that the main effect of Priming, reported below was not carried by the unmasked or masked data alone, two-way ANOVAs with factors of Priming (Unprimed, Primed) and Electrode (11) were performed for Masked and Unmasked data separately. Similarly, two-way ANOVAs with factors of Priming (Unprimed, Intervening item) and Electrode (11) were also performed for Masked and Unmasked data separately.

To illustrate this point further, a subtraction analysis was also performed on these data. The Primed condition was subtracted from the Unprimed condition (U − P) and these data were compared to those derived by subtracting the Intervening Item from the Unprimed condition (U − II). Thus, the baseline, Unprimed condition, was incorporated into the dependent measure. These data were submitted to a three-way ANOVA with factors of Masking (Masked, Unmasked), Priming (Primed, Intervening item) and Electrode (11). A two-way ANOVA with factors of Masking (Masked, Unmasked) and Electrode (11) was also performed to compare the subtraction data for the Intervening item trials.

Table 1
Mean amplitudes (in microvolts) of the N400, collapsed across electrodes, for the different experimental conditions

	Unmasked	Masked
Primed adjacent	1.363 (1.05)	2.080 (0.94)
Primed intervening	0.400 (1.00)	1.240 (0.95)
Unprimed	−0.007 (1.16)	−0.006 (0.87)

*SE*s are in parentheses.

3. Results

3.1. Behavioral data

Averaging across conditions, participants responded correctly to approximately 89% of the probes (85% for the masked condition, 94% for the unmasked condition). The mean RT across conditions was 940 ms.

3.2. ERP data

The N400 was largest (more negative, less positive) at central and parietal sites, particularly over the right hemisphere (see Figs. 2 and 3). The overall ANOVA revealed only a main effect of Priming ($F(2,24) = 6.40, p = .01$), there was no Priming by Electrode interaction ($F(20,240) < 1$). There was no significant main effect of Masking ($F(1,12) = 1.43, p = .25$) nor interactions involving Masking and Electrode ($F(10,120) = 1.45, p = .17$), Masking and Priming ($F(2,24) < 1$), or Masking, Priming, and Electrode ($F(20,240) < 1$).

The N400 was largest in the Unprimed condition, second largest in the Intervening condition, and smallest in the Primed condition (see Fig. 4). Differences between conditions of priming (Primed, Unprimed, Intervening) were investigated using LSD comparisons; an alpha level of 0.05 was used. As expected, the amplitude of the N400 was significantly smaller when words were primed than when they were unprimed ($p = .006$). The amplitude of the N400 in the Intervening item condition was found to be significantly larger than that in the Primed condition ($p = .027$), but did not differ significantly from the Unprimed condition ($p = .15$).

To establish that the main effect of Priming, seen above, was not carried by the unmasked data alone, two-way ANOVAs were performed for Masked and Unmasked data separately. There was a main effect of Priming for both the Masked ($F(1,12) = 9.82, p = .009$) and Unmasked ($F(1,12) = 4.90, p = .047$) conditions. There were no interactions between Priming and Electrode in either condition ($F(10,120) < 1$). Similar two-way ANOVAS comparing Unprimed and Intervening item trials showed no main effect of Priming for the Masked ($F(1,12) = 1.73, p = .21$) or Unmasked ($F(1,12) < 1$) conditions. There were no interactions between Priming and Electrode in either condition ($F(10,120) < 1$).

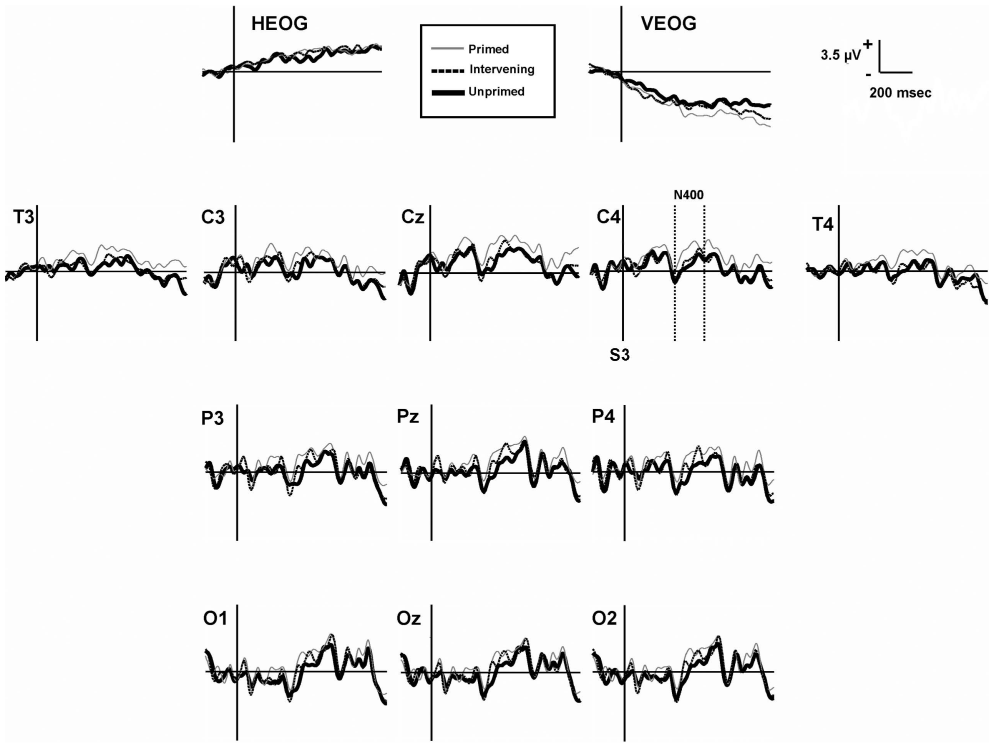

Fig. 2. Topography of the N400 and N400 priming effect in the unmasked condition. This and subsequent figures display the ERP recorded during the presentation of the third stimuli in each trial. The N400 peaked at about 340 ms from the onset of the critical stimulus. In all figures, the ERP printed in the thick black line was recorded on trials where the third stimulus was unprimed. The ERP depicted by the gray line was recorded when the third word was primed by a related item that immediately preceded it. The ERP in the dashed line is from the intervening item condition. Positive is up.

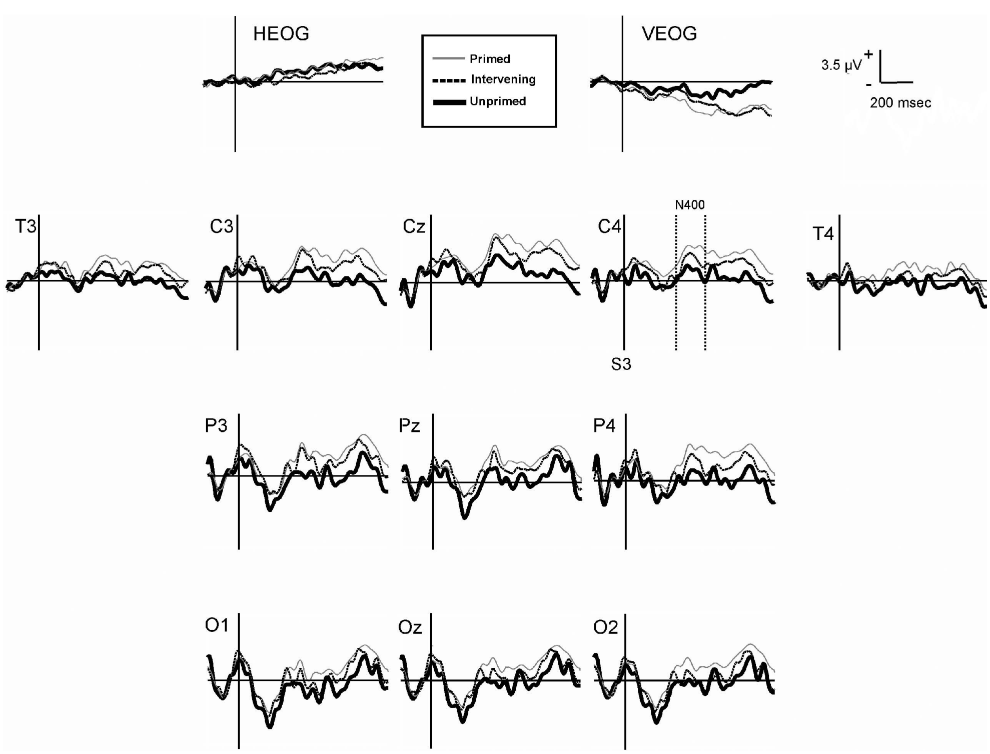

Fig. 3. Topography of the N400 and N400 priming effect in the masked condition.

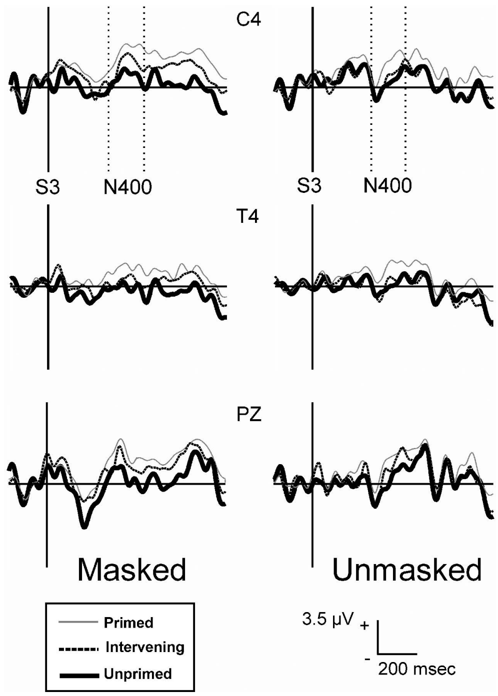

Fig. 4. The effect of experimental conditions, at selected electrodes, displayed at a higher gain.

To illustrate this point further, the three-way ANOVA with factors of Masking (Masked, Unmasked), Priming (Primed, Intervening item) and Electrode (11) for the subtracted data, (U – P) compared to (U – II), revealed only a main effect of Priming ($F(1,12) = 6.33, p = .03$), there was no main effect of Masking ($F(1,12) = 1.09, p = .32$) and no Masking by Priming interactions ($F(1,12) < 1$). The mean subtraction amplitude for the Primed condition (−1.79 μV, ($SEM =$ 0.54)) was significantly more negative than for the Intervening Item condition (−0.88 μV ($SEM = 0.57$)), indicating that there was more priming when related words were adjacent. Additionally, there were no interactions with Electrode ($F < 1$). The two-way ANOVA comparing the subtraction data for the Intervening item trials alone, showed that these were not significantly different, i.e., there was no main effect of Masking ($F(1,12) < 1$) and no Masking by Electrode interaction ($F(10,120) < 1$).

4. Discussion

In all conditions, the analysis of ERP data was limited to the critical (third) word in each trial. The usual priming effect on the N400 was observed, in that related adjacent words (e.g., ONION-DOCTOR-NURSE) produced smaller mean N400 amplitudes than did unrelated words (e.g., BRICK-PANSY-SHOE). In the Intervening item condition (e.g., CAT-TRUCK-DOG), however, the N400 indicated that priming of the third word had been disrupted, in that there was no significant difference between N400 for an unprimed word and for a primed word that followed an intervening item. There were no interactions involving masking. Thus, the intervening item disrupted priming when it was not masked, as in our previous study (Deacon et al., 2000). Moreover, priming was also disrupted when the intervening item was masked.

The finding that an unrelated intervening item disrupts priming even when it cannot be consciously identified is important in several respects. It can be concluded that the intervening item must interfere with the activation of semantic stores directly, as the present study incorporated several design features that precluded the influence of decision or response related processes.

With regard to the predictions that follow from the compound cue theory and distributed models, the data of the present experiment are more amenable to interpretation within distributed models. As laid out in the Introduction, distributed models would predict the usual priming effects from adjacent related primes, whether or not they are masked, and that the intervening item should disrupt priming even when it is masked. The compound cue model, conversely, would predict no priming from adjacent related primes that are masked, and that the intervening item effect would be nullified by masking. Our pairwise comparisons established that priming had occurred from adjacent related words, but not in the intervening item condition. The circumstance that there was priming on the N400, whether or not the word eliciting it was masked is not consistent with the compound cue theory. Further, the finding that an unrelated intervening item disrupted priming, even when the item was masked, is not consistent with the explanation of the intervening item effect that has been offered by Ratcliff and McKoon.

Clarification may be needed at this point, concerning why the intervening item effect is more consonant with distributed models than classic local models, proposed to operate on the basis of automatic spreading activation. There are two aspects to this argument that have been put forth (Masson, 1991, 1995; Ratcliff & McKoon, 1988; McNamara, 1994). One is that truly automatic processes, as they are traditionally defined, should not interfere with each other. Thus, the activation created by the prime, in one portion of semantic memory, should not be interfered with by that created by the intervening item, in another part of semantic memory. The second tenet of the argument is that in some distributed models, such as that proposed by Masson (1991, 1995), only one item can be activated at a time. This is because each item is coded in terms of which "feature" nodes are in the active or inactive state. The pattern of activation encompasses all nodes in the system. When an unrelated (intervening) word with different semantic features is presented after the prime, the pattern corresponding to the prime is effectively "erased" as the feature nodes are reset to reflect the meaning of the unrelated word. The prime will not facilitate processing of a subsequently presented related target because there is no overlap in the feature nodes activated, due to resetting of the pattern by the intervening unrelated word. In this study priming was not significant in the intervening item condition. The data therefore support our previous study (Deacon et al., 2000), which suggested that the locus of the intervening item effect is lexical-semantic and involves the operation of a semantic system, that is, at the very least, partially distributed. The present data also offer strong evidence against the compound cue model, since the intervening item was masked to below recognition threshold. Note that disruption of priming by a masked intervening item would have been strong evidence against the compound cue model in itself, regardless of the dependent measure used.

An anonymous reviewer made the astute comment that there is a considerable body of evidence concerning semantic priming in aphasics that are consistent with our argument against the validity of retrieval models. For example, while Wernicke's aphasics are poor at judging semantic relationships (Goodglass & Baker, 1976; Grober, Perecman, Kellar, & Brown, 1980; Whitehouse, Caramazza, & Zurif, 1978; Zurif, Caramazza, Myerson, & Galvin, 1974), several studies have shown that they demonstrate associative semantic priming (Blumstein, Milberg, & Shrier, 1982; Friedman, Glosser, & Diamond, 1988; Hagoort, 1993; Milberg, Blumstein, & Dworetzky, 1987) albeit at longer response latencies. It has been suggested that although the ability to automatically access and retrieve word meaning is intact, there is an inability to use this information under explicit memory conditions. In the same vein, Coslett and Saffran (1998) have presented data from optic aphasia and pure alexia patients who showed semantic knowledge of items (based upon their ability to categorize them) even though they could not name items correctly. Collectively, these neurological data demonstrate that retrieval of semantic knowledge and representation of semantic knowledge are dissociable phenomenon. Furthermore, semantic priming occurs in some neurological patients in the absence of retrieval.

The compound cue model is, as we have stated, more of an attempt to explain priming than to characterize semantic memory. It has been argued by its proponents, however, to explain several priming phenomena better than other models, that do make claims as to the nature of semantic memory, particularly those that incorporate the concept of automatic spreading activation (Collins & Loftus, 1975; Quillian, 1967). The present data underscore that the compound cue theory is not an appropriate framework within which to examine semantic memory per se. Ratcliff and McKoon (1988) have suggested that the compound cue model and distributed memory models are not necessarily mutually exclusive and might in fact be jointly implemented. Our data suggest, however, that the compound cue model could, at best, only be useful in explaining a portion of priming effects on behavioral data. This is because decision and response processes generally contribute additional variability to behavioral data, that is not reflected by the N400. The present study was designed in such a way that ERPs associated with decision and response processes would not overlap the N400. This aspect of the design was necessary in order for the N400 data to be interpretable, but meant that behavioral data could not be collected to the critical stimulus. Since there was physiological evidence of priming with a lexical/semantic locus, the behavioral data would have been of little interest to us. The physiological data alone are adequate evidence against the compound cue model.

The findings also raise the question of whether retrieval models in general make assumptions that are unwarranted, given the abundance of ERP data that suggests the contrary. Although the present study examined only semantic priming, the same criticism would apply to the "counter model" (McKoon & Ratcliff, 2001; Ratcliff & McKoon, 2000), as it also interprets behavioral data in such a way as to conclude that the locus of facilitation is decision or post-decision related, rather than perceptual or lexical/semantic.

Recent tests of the counter model have produced data that were interpreted as indicating some degree of perceptual facilitation, (Bowers, 1999; Wagenmakers, Zeelenberg, & Raaijmakers, 2000a, 2000b). Nevertheless, decision related processes play a central role in the alternative interpretation that is proposed. Moreover, the authors of the counter model continue to maintain that bias in the decision process can account for even the data suggesting perceptual facilitation (see McKoon & Ratcliff, 2001). The physiological data presented here suggest that retrieval theories of priming that are of the same genre as the compound cue theory and the counter model, may cause the baby to be thrown out with the bath water.

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