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Automatic Semantic Activation and Episodic Memory Encoding

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An experiment was conducted to investigate the influence of a briefly presented pattern-masked stimulus on (1) subjects' latency to make a lexical decision regarding a subsequent letter string and (2) their episodic encoding of that letter string in long-term memory. During the first half of the experiment subjects participated in a primed lexical decision task (LDT). Half of the subjects received the primes at a preexperimentally determined critical threshold, whereas the remaining half received the primes at a suprathreshold level. The primes were either related (*GRAPE*), neutral (*XXXXX*), or unrelated (*BOX*) to the targets (*JAM*). The results of this priming task indicated that subjects responded faster to words which followed a related prime than to words which followed an unrelated prime in both the suprathreshold and, more interestingly, in the threshold condition, where the subjects were actually unable to reliably report the presence of the prime. Subjects were then given an episodic recognition test for the target words which were presented during the LDT. In the crucial conditions, the target was either contextually paired with the same related priming word or a different related word. For example, if the subject received the prime *GRAPE* followed by the target *JAM,* then at recognition the subject either received the pair *GRAPE JAM* or *TRAFFIC JAM,* with the task being to simply recognize the second word in each pair. The recognition results indicated that for the suprathreshold condition there was a large deleterious effect of switching context between study and test, whereas, for the threshold condition, there was virtually no effect of switching context. These results were viewed as indicating that it is possible to produce activation in semantic memory via a threshold stimulus, as indicated by the obtained priming effect; however, this activation does not appear to be useful in directing conscious attention for long-term storage.

One of the more dominant areas of research within the past decade has been concerned with the notion of semantic activation. Such activation has been presumed to underlie semantic priming and sentence verification tasks and is viewed by some theorists to play a role in higher order cognitive processes such as reading (e.g., Kleiman, 1980; Stanovich & West, 1981). In this light, it is interesting that there has been little in the way of research designed to investigate the impact of semantic activation on memory encoding; a processing stage which surely must also be involved in higher order cognitive processing. The present study is an attempt to begin to address this issue.

In order to investigate the impact of semantic activation on memory encoding, an attempt was made to utilize both a task which would allow one to gauge the amount of activation produced at encoding along with an episodic memory task which has been viewed as being sensitive to such activation. A semantic priming task in concordance with an episodic context recognition task appeared to serve the desired purpose. As described below, the results of both of

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these tasks have been viewed as reflecting spreading activation within a conceptual network.

First, with respect to the semantic priming paradigm, the basic result is that response latency to a target word (*yard*) is faster when it follows a related priming word (*inch*) than when it follows an unrelated word (*frog*). A number of theorists (e.g., Neely, 1976, 1977; Stanovich & West, 1981) have suggested that when a priming word is presented, its corresponding semantic memory representation is activated, which in turn causes activation to spread along associative pathways to related concepts in memory. This preactivation of semantically related concepts by the priming word leads to faster recognition of a target word corresponding to one of those related concepts, thereby yielding a semantic priming effect.

A similar spreading activation framework has been utilized to account for recognition context effects. The finding of interest here is that subjects are considerably better able to recognize a target homographic word (*yard*) episodically when it is both studied and tested with the same context word (*inch*) than when the context word is switched between study and test; that is, the subject studies *inch yard* and is tested with *fence yard* (Light & Carter-Sobell, 1970). One account of this finding has been the diffuse spreading activation mechanism presented by Anderson and Bower (1974). According to this notion, words are connected to multiple concepts stored in memory. When a context (*inch*) and target word (*yard*) are presented, activation spreads from the concepts underlying the context and the concepts underlying the target. The point at which there is an intersection between this spreading activation (presumably in this case the concept *measurement*) will determine which sense of the target is encoded in the propositional list structure. Since this same disambiguation process occurs at recognition, a subject may access at recognition a different concept of the same target (*yard*) than that which was encoded, if the context is switched between study (*inch yard*) and test (*fence yard*), thereby accounting for the context effects reported by Light and Carter-Sobell.

Now, with respect to the present study, the question is what should be the relationship between activation produced by primes in a LDT and the impact of that activation on the encoding of a to-be-remembered list of words? At first, the predictions appear to be quite clear. That is, if one finds that subjects are faster to respond to a target (*yard*) when it follows a related prime (*inch*) than when it follows an unrelated prime (*frog*), then one would have evidence that activation has spread from the concepts underlying *inch* to activate a related concept underlying *yard*. This very same activation should also bias the concept of yard referring to *measurement* to be stored in memory, which would be reflected by context effects in later episodic recognition. Unfortunately, however, such a pattern of data would not *necessarily* reflect the impact of semantic activation on the episodic encoding of the target, but rather, may reflect elaborative mnemonic encoding processes between the context and the target (e.g., paired-associate learning) which are totally independent of the activation reflected in the LDT. In this light, it appeared necessary to attempt to utilize a relatively pure measure of activation without the context item being available for episodic encoding.

Recently, a number of studies have apparently indicated that semantic activation can occur, even though the priming stimulus is presented so briefly (and followed by a pattern mask) that it precludes perceptual analysis (e.g., Fowler, Wolford, Slade, & Tassinary, 1981; Humphreys, 1981; Marcel & Patterson, 1978; Marcel, 1980; McCauley, Parmelee, Sperber, & Carr, 1980). Clearly, if one would find evidence of semantic activation of such briefly presented primes then one may also be able to investigate the impact of such activation on later recognition memory performance without the concern that recognition performance is being influenced by encoding effects independent of that activation. Very simply, in this situation the context word should be unavailable for episodic encoding. In the present study an attempt was made to utilize this threshold priming paradigm to investigate the impact of semantic activation on the encoding of long-term memory information.

It is worth noting here that the semantic influence of such briefly presented pattern masked stimuli also has relevance for one of the major theoretical accounts of semantic priming; the Posner and Snyder (1975) and Neely (1977) two-process model. Briefly, these theorists argue that priming involves both an automatic spreading activation process similar to the process described above and a limited capacity attentional process which involves the subject's allocation of attention to the area of memory where the prime word's meaning is represented. Since subjects should not be able to attend to a prime which is unavailable for perceptual analysis, one should find evidence for the spreading activation process only, in the present study. This should be reflected in the pattern of priming effects. That is, if the priming effect reflects spreading activation then one should find primarily evidence for facilitation of a related prime, whereas, if attention is involved then one should find both facilitation of a related prime and inhibition of an unrelated prime, compared to a neutral baseline. Furthermore, within the Posner and Snyder framework if the stimulus onset asynchrony (SOA) between the prime and target is very short one should only find spreading activation effects, whereas at longer SOAs the subject should be able to allocate attention to the prime, thereby producing attentional effects. Clearly, however, if the prime is presented so briefly that it is unavailable for perceptual analysis then one should only find evidence of spreading activation both at the short and long SOAs.

Overview of the Experiment

The experiment entailed two sessions for each subject. During Session 1, each subject's threshold at which he or she could no longer discriminate between a word and a blank field was determined. During Session 2, prime duration (threshold vs suprathreshold) and prime–target SOA (350 milliseconds vs 2000 milliseconds) were factorially crossed to produce four between-subjects conditions. In the first half of Session 2, subjects participated in a primed LDT. The primes in this task were either related (*inch*), neutral (*xxxx*), or unrelated (*frog*) to the targets (*yard*). Also, in order to test for any idiosyncratic effects of polysemous words, half of the targets were homographs and half were nonhomographs. The results of this priming task should provide data regarding (1) threshold priming effects (a phenomenon which has recently led to a considerable controversy, cf. Merikle, 1982), (2) the nature of any obtained threshold priming effects, that is, inhibitory versus facilitative effects, and (3) most importantly, whether there is any activation spreading from the context to the target. With respect to this latter issue, the question is if one finds such threshold priming effects, will the automatic activation reflected by such effects also bias the long-term memory trace of the targets? It seems unlikely that subjects would encode the sense of the word *yard* referring to *backyard* if there is evidence, via the priming task, that the threshold context *inch* has activated the sense of *yard* referring to *measurement*. This prediction was tested in an episodic context recognition test in which each target was either presented with the same context (*inch yard*) that earlier occurred in the LDT or with a different context (*fence yard*).

Method

Subjects

Twenty-four subjects participated in each of the four between-subjects conditions for course credit. No condition was repeated until all four conditions had the same number of subjects.

Apparatus

A four-channel Gerbrands tachistoscope was used for stimulus presentation. Two of the channels and both of the eyepieces were fitted with Polaroid filters. One of the eyepieces was rotated 90 degrees in order to present the stimulus and mask dichoptically to insure central masking. The fixation field was adjusted to a lower luminance than the remaining three fields to prevent forward brightness masking of the prime. Intertrial timing was accomplished by a custom-made controller that presented a 2000-Hz tone every 10 seconds which served as a cue for the subject to press a footswitch to initiate the stimulus sequence.

Materials

Seventy-six homographs were chosen from the Cramer (1970), Kausler and Kollasch (1970), and the Perfetti, Lindsey, and Garson (1971) norms. These words had a median-frequency value of 57/million, as measured by the Kučera and Francis (1967) norms, and a mean length of 4.3 letters. For each homograph, two high associates (each related to a different meaning) were chosen from the above norms and the Schvaneveldt, Meyer, and Becker (1976) and Yates (1978) papers. Also, for each homograph, two unrelated words were selected which approximately matched the related associates to that homograph in both frequency and letter length. The seventy-six nonhomographs were chosen from the Palermo and Jenkins (1964) and the Postman and Keppel (1970) norms. These words had a median frequency value of 101/million and a mean length of 4.5 letters. For each of these nonhomographs, two high associates were chosen from these norms and two unrelated words were selected from the Kučera and Francis norms which again approximately matched the related associates in both frequency and length.

List construction. During the LDT, each subject received a total of 152 trials, the first 24 of which were practice trials. Each test list consisted of 64 word trials and 64 nonword trials. Table 1 displays the different prime–target conditions. As shown in Table 1 each of the homographs and nonhomographs occurred in each of the prime conditions. Since no target was repeated within a particular list, there were eight different lists constructed in order to counterbalance items across the prime conditions. Pronounceable nonwords were produced by changing two letters in each target word. As shown in Table 1, nonwords occurred in the same prime conditions as the word targets. Thus, with this list construction, a particular word or nonword occurred only once in a given list, and across lists each word or nonword (homographs and nonhomographs) served in each of the three priming conditions (related, unrelated, and neutral). Furthermore, across the first four versus second four lists, each prime–target word pair served once in the word target conditions and once as a basis for the nonword target conditions.

The trials across the prime conditions were randomly ordered with the only constraint being that each of the prime conditions occurred equally often during the first and second half of the prime trials. In this way, one could later analyze the first versus second half of the priming trials to test for any changes across time.

Letter strings were printed in Schoolbook face capital letters. The strings subtended 0.28° of vertical and from 0.66° to 2.2° of horizontal visual angle. A pattern mask (produced by scrambling letter pieces of the same type) subtended an area of 0.45° of vertical and 3.6° of horizontal visual angle. The fixation mark consisted of a

TABLE 1
WORD AND NONWORD PRIME CONDITIONS AS A FUNCTION OF HOMOGRAPH VERSUS NONHOMOGRAPH TARGETS

Homographs				Nonhomographs			
Conditions	Prime	Target	Trials	Conditions	Prime	Target	Trials
Word							
Related 1	FENCE	YARD	16	Related 1	MILK	COW	16
Related 2	INCH	YARD	16	Related 2	BULL	COW	16
Neutral	XXXXX	YARD	16	Neutral	YYYYY	COW	16
Unrelated	GLUE	YARD	16	Unrelated	WALL	COW	16
Nonword							
Related 1	FENCE	YOLD	16	Related 1	MILK	CEL	16
Related 2	INCH	YOLD	16	Related 2	BULL	CEL	16
Neutral	YYYYY	YOLD	16	Neutral	XXXXX	CEL	16
Unrelated	GLUE	YOLD	16	Unrelated	WALL	CEL	16

black "+" which subtended a vertical and horizontal visual angle of 0.3°. All stimuli were centered on 5 × 8 inch white cards.

Recognition test construction. The recognition memory test consisted of 128 test items: 64 targets and 64 lures. Half of the targets occurred with a context item at recognition which was the same item that served as a prime during the LDT, e.g., *INCH YARD* during the LDT and *INCH YARD* at recognition. The remaining half of the recognition targets occurred with a context item which was *not* presented earlier as a prime during the LDT. For the words which served in the related condition this *different* context word was the word which served as the prime in the corresponding different list in which that target also occurred in the related condition, e.g., *INCH YARD* during the LDT and *FENCE YARD* at recognition (see Table 1). On the other hand, for the target words which occurred in the unrelated condition, this different context item was simply a different unrelated word which approximately matched the unrelated prime in word frequency and letter length, e.g., *WALL COW* during the LDT and *BOOK COW* at recognition. And finally, for the words which served in the neutral condition this different context item was simply a row of Xs or Ys, e.g., *XXXXX JAM* during the LDT and *YYYYY JAM* at recognition.

The 64 word lures in the recognition test were actually based on the nonword prime–target pairs which occurred in the earlier LDT. For example, if a subject received *YOLD* as a nonword during the LDT, then *YARD* would be presented as a lure on the recognition test. Furthermore, half of the lures occurred with the same context item that earlier served as a prime, and the remaining half occurred with a different context item. This method of recognition lure pair construction was used because: (1) These lure pairs mimicked the target conditions, and therefore, each recognition target had a corresponding recognition lure in the same condition; (2) Subjects could not simply use the recognition context item to make their recognition decision since half of the lures had the same contexts that were presented earlier in the LDT and half did not.

The recognition test was typed in lower case on two pages. At the top of each page appeared a 5-point rating scale which ranged from 5 which meant "I am positive that word occurred on the list" to 1 which meant "I am positive that word did *not* occur on the list" with a rating of 3 meaning "just guessing." For each pair the context item occurred at the left of the underlined target and a space to the right was available for the confidence rating. A total of four different recognition tests were constructed. The same recognition test was used for Lists 1 and 5; 2 and 6; 3 and 7; 4 and 8, since the only difference between these list pairs was whether a given word occurred earlier in the word or nonword conditions. Target and lure recognition pairs were randomly intermixed on the recognition test sheets.

Procedure

Session 1. During Session 1, each subject's threshold was determined by a procedure similar to that described in Fowler et al. (1981). This session lasted approximately 35 minutes including a 10-minute dark adaptation period. Upon their arrival, each subject determined their dominant eye by binocular and monocular alignment of their index finger with a stimulus in the visual background of that finger. Following dark adaptation, each subject was instructed to fixate on the center cross displayed in the tachistoscope and when he or she heard the tone press a footswitch which initiated the following sequence: (a) a word or blank was presented to the nondominant eye for 15 milliseconds; (b) a dark field was initially presented for 250 milliseconds but was adjusted by the experimenter throughout the session; (c) a pattern mask was presented to the dominant eye; (d) return to fixation. The subject's task on each trial was to verbally indicate whether or not a word had been presented. Subjects were told that their response should not be based on the identification of a word or letters of a word but rather they should respond "yes" even if they only saw a flash or blur. The interstimulus interval (ISI) was lowered on each block of six trials in which there were four or more correct responses according to the following sequence: 250 milliseconds; 150 milliseconds; 100 milliseconds; 70 milliseconds; 50 milliseconds. The stimuli were originally presented at these long ISIs in order to allow the subject to become accustomed to the desired discrimination. When the 50-millisecond ISI was reached, there were 5-millisecond decreases in ISI at each block of six trials. The point at which the subject could no longer respond correctly on four or more trials at a particular ISI was initially that subject's threshold. Furthermore, to insure that the subject was at this threshold, the subject received a further 20 trials and if the subject did not respond correctly on at least 12 of these trials, this ISI was used as the subject's threshold. If this criterion was not reached, the ISI was reduced by 5 milliseconds until it was reached. Subjects averaged approximately 120 trials in which these presence/absence judgements were made. Furthermore, in order to determine if this threshold changed across time, those subjects in the threshold group had their thresholds again determined by this same procedure after Session 2 was conducted.

The words used during Session 1 were those primes that a given subject did not receive (because of list counterbalancing) the following day during Session 2. Also, only those primes which were five letters or longer (i.e., those word which should be the easiest to make the presence/absence discrimination) were used to establish a subject's threshold.

Session 2. The second Session lasted about 1½ hours and included 10 minutes for dark adaptation. For those subjects receiving the primes at their threshold, the following stimulus sequence occurred on each trial: (a) the fixation cross was presented; (b) the tone cue to press the footswitch which initiated the stimulus sequence was presented; (c) the priming stimulus was presented to the nondominant eye for 15 milliseconds; (d) a dark field was presented for the critical ISI determined during Session 1; (e) the pattern mask was presented to the dominant eye for 30 milliseconds; (f) a dark field was presented for a duration such that phases (c)–(f) (prime–target SOA) summed to either 350 milliseconds or 2000 milliseconds; (g) the target stimulus was presented binocularly for 2000 milliseconds during which the subject made his or her lexical decision by pressing one of two response keys; (h) return to fixation. This same sequence was used for those subjects receiving the primes at the suprathreshold durations except that (a) the priming stimulus was presented for 300 milliseconds; (b) no mask was presented; (c) the dark field was presented for either 50 or 1700 milliseconds depending upon the prime–target SOA condition. After the subject's response was made, the experimenter recorded the response (word vs nonword) and gave immediate oral feedback regarding accuracy of the response. The intertrial interval was kept constant at 10 seconds across the between-subjects conditions. Subjects were instructed to respond as quickly and as accurately as possible. A 3-minute break occurred between the first and second half of the LDT. Also, an informal inquiry at the end of the LDT indicated that no subject in the threshold condition reported being able to see any of the priming stimuli.

Before participating in the LDT, subjects were told that they would later be asked to try to remember the target words; the nature of the memory test was unspecified. After the LDT, subjects counted backwards by 3 from the number 150 for 1½ minutes to eliminate any recency effects. A short 1-minute break was then given which was followed by the instructions for the forthcoming recognition test. Subjects were told that they should first read the item on the left (the context) and then read the underlined word on the right (the target) and to give a confidence rating to each of the underlined words, independent of whether they thought they had seen the context item during list presentation. It was emphasized that for the present study it was important that the item on the left be read before the word on the right.

Design

For the LDT, the between-subjects factors threshold level (threshold vs suprathreshold) and prime–target SOA (350 vs 2000 milliseconds) and the within-subjects factors prime condition (related, neutral, unrelated), target word class (homograph vs nonhomograph), trials (first half vs second half), and lexicality (word vs nonword) produced a $2 \times 2 \times 3 \times 2 \times 2 \times 2$ mixed-factor design. With respect to the recognition test, the same between-subjects factors threshold level and prime–target SOA and the within-subjects factors prime condition, target word class, context condition (same vs different), and test type (target vs lure) produced a $2 \times 2 \times 3 \times 2 \times 2 \times 2$ mixed-factor design.

Results

Threshold Setting Task

The mean critical prime–target ISIs that were determined for the short SOA threshold condition were 17 and 16 milliseconds for the first (Session 1) and second (after Session 2) testings, respectively. For the long SOA threshold conditions they were 19 milliseconds for both the first and second testings. Thus, there was virtually no change in thresholds across the first and second testings. On a more informal level, as subjects approached their threshold, they reported making their discrimination based on differences in brightness or temporal delay between words and blank fields. Thus, at these short ISIs, subjects did not at least report being aware of basing their presence/absence decisions on letters or letter features.[1]

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[1] Recently, Merikle (1982) has noted a number of difficulties with the past threshold setting procedures utilized in studies that have reported threshold priming effects. One problem that Merikle notes is that there has been an insufficient number of trials utilized (e.g., six at a given threshold) to obtain a reliable estimate of an individual's threshold. In the present study, 26 trials were presented at a given threshold, a substantial increase over past studies. Merikle has also argued that unless one has evidence that subjects are using both responses, it is possible that the chance threshold can be reached simply because subjects have adopted too strict of a criterion for saying "yes" and therefore on most trials respond "no." Thus, it is necessary to

Lexical Decision Task

For each within-subjects cell, a median RT and a mean number of errors were calculated for each subject. These data were submitted to separate 2 (SOA) × 2 (Trials) × 3 (Prime Condition) × 2 (Word Class) mixed-factor ANOVAs. In order to ease the exposition of these results, the suprathreshold and threshold priming data will be discussed separately and then will be followed by a brief overall analysis section.

Suprathreshold priming. There are three general points that should be made from the suprathreshold RT and error data displayed in Table 2. That is, subjects were faster (a) at the short SOA than at the long SOA, $F(1,46) = 29.3$, $MS_e = 121{,}285$, (b) during the second half than during the first half of the priming trials, $F(1,46) = 10.92$, $MS_e = 15{,}459$, and (c) to the word targets following a related prime than neutral or unrelated primes, $F(2,92) = 17.39$, $MS_e = 833$. Also, although word class did not participate in any significant interactions, response latency to homographs (685 milliseconds) was slower than to nonhomographs (661 milliseconds), $F(1,46) = 14.91$, $MS_e = 5694$. Unless otherwise specified, all significant differences have p values at least $< .05$.

The more interesting aspect of the suprathreshold data was a significant interaction between SOA, Trials, and Prime Condition, $F(2,92) = 5.54$, $MS_e = 3668$. The mean facilitation, inhibition, and relatedness effects displayed in Table 3 will aid in interpreting this interaction. As shown in Table 3, at the short SOA, there was more facilitation than inhibition during both the first and second half of the priming trials. A simple effects analysis on the short SOA data indicated that the interaction between Trials and Prime Condition did not reach significance, $F(2,46) = 1.94$, $MS_e = 2267$. Furthermore, post hoc t tests indicated that the facilitation effect at the short SOA was significant, $t(46) = 3.51$, with the inhibition effect not approaching significance, $t(46) = 1.16$. On the other hand, at the long SOA, there is some evidence of facilitation (17 milliseconds) and little evidence of inhibition (2 milliseconds) during the first half of the trials, whereas, during the second half of the priming trials there is a 25-millisecond increase in facilitation and a dramatic 39-millisecond increase in inhibition. The simple effects analysis on the long SOA data did yield a significant interaction between Prime Condition and Trials, $F(2,46) = 4.95$, $MS_e = 5068$. Post hoc t tests yielded nonsignificant facilitation, $t(46) = 1.18$, or inhibition, $t(46) = .12$, effects during the first half of the priming trials, whereas, during the second half, there were both significant facilitation, $t(46)$

TABLE 2

MEAN RT (IN MSEC) AND MEAN PERCENTAGE OF ERRORS[a] FOR THE SUPRATHRESHOLD WORD CONDITIONS AS A FUNCTION OF SOA, TRIALS, AND PRIME CONDITION

	Prime condition		
SOA condition	Related	Neutral	Unrelated
Short SOA			
First half	571 (3.1)	627 (3.6)	636 (6.8)
Second half	553 (2.1)	583 (2.1)	601 (4.2)
Mean	562 (2.6)	605 (2.9)	619 (5.5)
Long SOA			
First half	758 (3.6)	775 (3.1)	777 (2.6)
Second half	693 (3.1)	734 (3.1)	776 (8.3)
Mean	726 (3.4)	755 (3.1)	777 (5.5)

[a] The numbers in parentheses indicate the percentage of errors.

look at the response distributions to insure that subjects are utilizing both responses. Interestingly, in the present study subjects actually overall responded "yes" (52%) slightly more than "no" (48%). The important point to note, however, is that in the present study subjects were clearly using both responses and, in fact, the *most* disproportionate subject responded "yes" 65% of the trials. However, even this measure may be confounded by the fact that subjects expected half absence trials and half presence trials and therefore may have modulated their responses accordingly. Thus, simple response distributions must be considered in accordance with subjects' expectancies regarding the relative probabilities of presence/absence trials. Fortunately, there are other indicants in the present data which suggest that subjects were not reading the primes during the LDT (e.g., the memory data).

TABLE 3
MEAN FACILITATION, INHIBITION, AND RELATEDNESS EFFECTS,[a] IN BOTH RT AND PERCENTAGE OF ERRORS,[b] FOR THE SUPRATHRESHOLD CONDITIONS, AS A FUNCTION OF SOA AND TRIALS

SOA condition	Type of effect: Facilitation	Inhibition	Relatedness
Short SOA			
First half	56 (0.5)	9 (3.1)	65 (3.6)
Second half	29 (0)	19 (2.1)	48 (2.1)
Mean	43 (0.25)	14 (2.6)	57 (2.85)
Long SOA			
First half	17 (−0.5)	2 (−0.5)	19 (−1.0)
Second half	42 (0)	41 (5.2)	83 (5.2)
Mean	29 (−0.25)	22 (2.35)	51 (2.1)

[a] Facilitation = Neutral − Related Prime Conditions; Inhibition = Unrelated − Neutral Prime Conditions; Relatedness = Unrelated − Related Prime Conditions.
[b] The numbers in parentheses indicate the percentage of errors.

= 2.87, and inhibition, $t(46) = 2.85$, effects. Thus, in sum, the suprathreshold RT data indicates that at the short SOA there is primarily evidence for facilitation with little inhibition, whereas at the long SOA there is evidence for both facilitation and inhibition, both of which primarily developed during the second half of the priming trials.

With respect to the error rates (see Table 2), there were three significant effects. First, error rates were higher in the unrelated (5.5%) than either the neutral (3%) or the related (3%) prime conditions, $F(2,92) = 5.69$, $MS_e = 68.9$. Second, an interaction between SOA and Trials, $F(1,46) = 8.13$, $MS_e = 53.4$, indicated that error rates decreased 1.8% for the short SOA during the second half, whereas they increased 1.7% for the long SOA. Third, there were overall more errors for homographs (4.9%) than for nonhomographs (2.8%), $F(1,46) = 9.44$, $MS_e = 66.2$.

Threshold priming. Turning to the threshold RT and error data displayed in Table 4, there are three general points to make. Subjects were faster (a) at the short SOA than at the long SOA, $F(1,46) = 18.0$, $MS_e = 136{,}431$, (b) during the second half than during the first half of the trials, $F(1,46) = 6.47$, $MS_e = 8884$, and most importantly, (c) to the word targets following a related prime than an unrelated prime, thereby suggesting a threshold priming effect, $F(2,92) = 5.71$, $MS_e = 4862$. Post hoc t tests on the main effect of prime condition yielded significant facilitation of the related condition, $t(92) = 2.34$, whereas the inhibition of the unrelated condition did not approach significance, $t(92) = .95$. The overall analysis also indicated that RT to homographs (628 milliseconds) was slower than to nonhomographs (604 milliseconds), $F(1,46) = 25.73$, $MS_e = 3075$, thereby replicating the suprathreshold conditions. No other effect or interaction approached significance (all Fs < 1.8).

TABLE 4
MEAN RT (IN MSEC) AND MEAN PERCENTAGE OF ERRORS[a] FOR THE THRESHOLD WORD CONDITIONS AS A FUNCTION OF SOA, TRIALS, AND PRIME CONDITION

SOA condition	Prime condition: Related	Neutral	Unrelated
Short SOA			
First half	549 (3.1)	572 (2.6)	555 (3.1)
Second half	532 (3.1)	544 (3.1)	550 (5.7)
Mean	541 (3.1)	558 (2.9)	553 (4.4)
Long SOA			
First half	678 (3.1)	696 (3.1)	704 (3.1)
Second half	651 (3.6)	664 (5.2)	694 (3.6)
Mean	665 (3.4)	680 (4.2)	699 (3.4)

[a] The numbers in parentheses indicate the percentage of errors.

TABLE 5

MEAN FACILITATION, INHIBITION, AND RELATEDNESS EFFECTS,[a] IN BOTH RT AND PERCENTAGE OF ERRORS,[b] FOR THE THRESHOLD CONDITIONS, AS A FUNCTION OF SOA AND TRIALS

SOA condition	Type of effect: Facilitation	Inhibition	Relatedness
Short SOA			
First half	23 (−0.5)	−17 (0.5)	6 (0)
Second half	12 (0)	6 (2.6)	18 (2.6)
Mean	18 (−0.25)	−6 (1.55)	12 (1.3)
Long SOA			
First half	18 (0)	8 (0)	26 (0)
Second half	14 (1.6)	29 (−1.6)	43 (0)
Mean	16 (0.8)	19 (−0.8)	35 (0)

[a] Facilitation = Neutral − Related Prime Conditions; Inhibition = Unrelated − Neutral Prime Conditions; Relatedness = Unrelated − Related Prime Conditions.

[b] The numbers in parentheses indicate the percentage of errors.

In Table 5 are displayed the mean facilitation, inhibition, and relatedness effects found for the threshold prime conditions. Interestingly, it appears that (1) the priming effect is larger at the long SOA than at the short SOA and (2) there is some inhibition at the long SOA especially during the second half of the trials. Both of these trends would suggest an attentional factor; however, it is noteworthy that neither the interaction between SOA, Trials, and Prime Condition nor a simple effects interaction between Trials and Prime Condition for the long SOA data approached significance (both Fs < 1). Furthermore, since an attentional factor should produce both facilitation and inhibition, it is unclear why there is not also an increase in facilitation during the second half of the long SOA data, as occurred in the suprathreshold long SOA data. In this same light, however, it is worth noting that although the interaction between SOA and Prime Condition did not approach significance, separate simple effects ANOVAs indicated that the priming effect did not reach significance at the short SOA, $F(2,46) = 2.23$, $MS_e = 3438$, $p = .12$, but was significant at the long SOA, $F(2,46) = 4.58$, $MS_e = 6286$. Interestingly, Fowler et al. have also recently reported an effect of threshold primes at a long SOA but not at a short SOA.

One could argue that the observed threshold priming effect may have been produced by some of the subjects who were not at their threshold. In an attempt to address this possibility, both the long and short SOA groups of subjects were each divided into two further groups depending on whether a given subject's threshold was above (high-threshold group) or below (low-threshold group) the median threshold for that SOA condition. The mean prime–mask critical ISIs for the low-threshold groups were 5 milliseconds for both the long and short SOA conditions, whereas for the high-threshold groups they were 33 milliseconds and 29 milliseconds for the long and short SOA conditions, respectively. This low- versus high-threshold group variable was then added as a factor in an overall ANOVA. The results of this analysis indicated that this factor did not participate in any significant effects. Furthermore, the mean differences between the related and unrelated conditions were actually larger for the low-threshold groups (41 and 14 milliseconds for the long and short SOA groups, respectively) than for the high-threshold groups (29 and 10 milliseconds for the long and short SOA groups, respectively). In light of this analysis, it seems unlikely that the observed threshold priming effects were due to certain subjects with long critical prime–mask thresholds actually being above their thresholds, and therefore, being able to pick up letters or letter features which in turn led to the observed priming effects. Furthermore, it is quite interesting that one would find a 41-millisecond priming effect for a group of subjects whose critical prime–mask ISI was only 5 milliseconds.

Turning to the error data displayed in Table 4, one can see that the error rates are quite consistent across conditions, ranging from 2.6% to 5.7%. The results of the ANOVA on the error data yielded no significant effects for the threshold conditions.

Overall analysis of the priming data. The results of an overall analysis on the word RT data indicated that subjects were faster in the threshold condition (616 milliseconds) than in the suprathreshold condition (647 milliseconds), $F(1,92) = 7.48$, $MS_e =$ 128,858. This effect should, of course, be expected if reading the primes in the suprathreshold conditions demanded capacity, thereby slowing RT compared to the threshold conditions in which subjects were unable to either read or allocate capacity to the primes. This overall analysis also yielded a significant Threshold × Prime Condition interaction, $F(2,184) = 3.48$, $MS_e = 6595$, which indicated that the priming effect was larger for the suprathreshold conditions than the threshold conditions. The corresponding analysis on the error data yielded no significant effects in which the threshold variable participated.

Interestingly, a similar overall analysis of the nonword RT data yielded a significant interaction between Threshold and Prime Condition, $F(2,184) = 5.83$, $MS_e = 7761$. This interaction indicated that there was no effect of prime condition for the threshold conditions, whereas for the suprathreshold conditions, the neutral condition was slower than the related or the unrelated nonword conditions. Neely (1977) also reported word prime nonword target facilitation effects for suprathreshold prime conditions. The important point to note here is that if the primes in the threshold conditions were available for perceptual processing, one would expect a similar pattern of nonword facilitation. However, the present results yielded a 40-millisecond word prime nonword target facilitation effect for the suprathreshold conditions and only 4 milliseconds for the threshold conditions.

Recognition Memory Task

For each within-subjects cell, a mean hit percentage and false alarm rate was calculated, with targets and lures receiving a confidence rating of 4 or 5 being counted as hits or false alarms, respectively. A mean accuracy score was then calculated for each subject/cell based on a high-threshold measure where accuracy = Percentage of Hits − Percentage of False Alarms. Since the homograph versus nonhomograph distinction is of primary interest in the related conditions, this word class variable was collapsed across in the neutral and unrelated conditions.

Table 6 displays the mean accuracy scores and false alarm rates for the suprathreshold conditions. There are three points to be noted in Table 6. First, there was no influence of context for the neutral conditions. This was expected since these items were always either paired with a row of Xs or Ys. In light of this, the related homograph, related nonhomograph, and unrelated conditions will take precedence in the following analyses, and will be referred to as the word–context conditions. Second, recognition accuracy was consistently higher when the target occurred with the same context word that earlier served as a prime than with a different context word. Third, at the short SOA, there is little difference in the effect of switching contexts across the word–context conditions, whereas, at the long SOA, there is a much

TABLE 6
MEAN ACCURACY[a] AND MEAN PERCENTAGE OF FALSE ALARMS[b] FOR THE SUPRATHRESHOLD CONDITIONS AS A FUNCTION OF SOA, CONTEXT TARGET CONDITION, AND CONTEXT

	Context target condition			
	Related			
SOA condition	Homograph	Nonhomograph	Unrelated	Neutral
Short SOA				
Same context	67 (15)	67 (15)	65 (11)	49 (13)
Different context	51 (13)	51 (16)	47 (9)	47 (16)
Mean context effect	16 (2)	16 (−1)	18 (2)	2 (−3)
Long SOA				
Same context	76 (14)	69 (17)	55 (19)	48 (15)
Different context	45 (16)	58 (12)	46 (11)	46 (21)
Mean context effect	31 (−2)	11 (5)	9 (8)	2 (−6)

[a] Mean Accuracy = Percentage of Hits − Percentage of False Alarms.
[b] The numbers in parentheses indicate the false alarm rates.

larger effect of switching contexts for the related homograph than either the related nonhomograph or unrelated conditions.

These observations were supported by a 2 (SOA) × 2 (Same vs Different Context) × 3 (Word–Context Conditions) mixed-factor ANOVA. The main effect of switching context was highly significant, $F(1,46) = 34.65$, $MS_e = 586$. Also, the three-way interaction between SOA, Context, and Word–Context Condition reached significance, $F(2,92) = 3.25$, $MS_e = 327$. Separate simple effects ANOVAs indicated that there was little difference in the context effects across the word–context conditions at the short SOA, $F(2,46) = .09$, $MS_e = 289$, whereas, at the long SOA, there was a significant interaction between Context and Word–Context Condition, $F(2,46) = 4.92$, $MS_e = 367$. Post hoc t tests indicated that the effect of switching context at the long SOA was larger for the related homograph (31%) than for the related nonhomograph (11%), $t(46) = 3.71$, or unrelated conditions (9%), $t(46) = 3.96$.

Turning to the threshold data displayed in Table 7, the important point to note is that there is little evidence for a context effect in either the short or the long SOA conditions. In fact, neither the main effect of Context, the interaction between Context and Word–Context Condition, nor the interaction between SOA, Context, and Word–Context Condition approached significance (all Fs < 1). It is also noteworthy that the overall absolute effect of the context manipulation came remarkably close to zero (−0.5%), thereby clearly indicating that switching context had no effect on recognition memory performance for the threshold prime conditions.

An overall analysis of the recognition data yielded a highly significant interaction between Context and Threshold Condition, $F(1,92) = 25.83$, $MS_e = 414$, indicating that the context effect only occurred for the suprathreshold conditions, i.e., when the context was available for encoding. This analysis also yielded a seemingly spurious Threshold × SOA × Word–Context Condition interaction, $F(2,184) = 3.73$, $MS_e = 324.6$.

DISCUSSION

The major results of the present study are quite clear. In the suprathreshold conditions, there were large semantic priming and episodic recognition context effects, whereas in the threshold conditions there was evidence for semantic priming effects

TABLE 7
MEAN ACCURACY[a] AND MEAN PERCENTAGE OF FALSE ALARMS[b] FOR THE THRESHOLD CONDITIONS AS A FUNCTION OF SOA, CONTEXT TARGET CONDITION, AND CONTEXT

	Context target condition			
	Related			
SOA condition	Homograph	Nonhomograph	Unrelated	Neutral
Short SOA				
Same context	64 (15)	54 (15)	55 (15)	53 (21)
Different context	59 (15)	55 (14)	52 (17)	61 (15)
Mean context effect	5 (0)	−1 (1)	3 (−2)	−8 (6)
Long SOA				
Same context	55 (18)	56 (12)	58 (16)	60 (12)
Different context	55 (14)	62 (11)	61 (12)	58 (13)
Mean context effect	0 (4)	−6 (1)	−3 (4)	2 (−1)

[a] Mean Accuracy = Percentage of Hits − Percentage of False Alarms.
[b] The numbers in parentheses indicate the false alarm rates.

only. In order to ease the discussion of these results, the data obtained in the LDT will be discussed first.

Lexical Decision Task

In the introduction, the Posner and Synder (1975) model was outlined as a useful framework to interpret semantic priming effects. The present suprathreshold results fit quite nicely within this framework. For example, since automatic spreading activation is assumed to be relatively fast acting, one should find evidence of such activation at the short SOA. The present short SOA results supported this notion in two ways. First, automatic activation should primarily yield facilitation with little inhibition, as the short SOA results indicated. Second, because automatic activation should be independent of attentional strategic processes, this facilitation dominance effect should occur both during the first and second half of the priming trials, again as the short SOA results indicated.[2] On the other hand, since the limited capacity attentional mechanism is relatively slower acting one should be more likely to find evidence for this mechanism at the long SOA. The present long SOA results supported this notion also in two ways. First, semantic priming which reflects an attentional mechanism should produce both facilitation and inhibition, as the long SOA results indicated. Second, since attentional priming should reflect the

[2] As shown in Table 3, at the short SOA suprathreshold condition there is some evidence of inhibition (19 milliseconds) during the second half of the priming trials. Although this inhibition did not reach significance, it does suggest that attention may, at least in part, be directed to the primes during a 350-millisecond prime–target SOA. This SOA was 100 milliseconds longer than Neely's (1977) short SOA condition, and therefore may indeed indicate the beginnings of attentional processing. The reason a 350-millisecond SOA was used in the present short SOA condition was because Fowler et al. (1981) found no evidence of threshold priming at their 200-millisecond SOA condition, and therefore, an attempt was made to find such priming at a slightly longer SOA. In fact, the present short SOA threshold condition did show more evidence of priming ($\bar{X}$ relatedness effect = 12 milliseconds) than in the Fowler et al. short SOA threshold condition ($\bar{X}$ relatedness effect = −3 milliseconds). Furthermore, Marcel (1980) has recently found significant threshold priming effects at a 650-millisecond prime–target SOA. Thus, the available literature on threshold priming appears to suggest that threshold priming effects will be found only at moderately long prime–target SOAs (e.g., 500 milliseconds) and will not be found at very short prime–target SOAs (e.g., 200 milliseconds).

development of attentional/strategic processes (e.g., focusing attention on the semantic characteristics of the prime to facilitate target processing), one may expect an increase in both facilitation and inhibition across the priming trials, as the long SOA results also indicated.

In contrast to the suprathreshold data, the threshold data are not completely consistent with the Posner and Snyder framework. That is, since in the threshold conditions subjects should have been unable to attend to the primes, there should have been primarily evidence for facilitation, and moreover this facilitation should have occurred at both the long and short SOAs. Interestingly, however, the threshold priming effect occurred primarily at the long SOA, thereby replicating Fowler et al. Possibly it may take more time for the semantic activation to accrue with a threshold prime simply because the original activation produced by the prime is relatively weaker than a suprathreshold prime. The present results also indicated that at the long SOA there was some evidence of both facilitation and inhibition. At first glance, this pattern would suggest an attentional priming effect. However, it is unclear how subjects could attend to a prime item presented so briefly that they were unable to consistently report whether something was presented. Of course, it is possible that subjects were not actually at their threshold and were able to read the primes. However, if this were the case, then it is unclear why there was no effect of context on later recognition memory performance, as was clearly found when subjects were able to read the primes in the suprathreshold conditions. Thus, the lack of influence of context in recognition performance provides further evidence that the primes during the LDT were truly unattended. In this light, it should be noted that there has been some recent evidence which may reflect an automatic type of inhibition (Antos, 1979; Fischler & Bloom, 1980; Humphreys, 1981). The results of the present long SOA threshold data may also reflect such a mechanism.

The next issue that must be addressed is how a stimulus which the subject cannot report can influence the subject's response latency in a lexical decision task. Recently, Marcel and Patterson (1978) and Allport (1977) have advanced models which are able to account for the present threshold effects. These theorists reject the widely held assumption that if a central mask is presented such that it interferes with the raw visual representation of the stimulus then it will also necessarily interfere with higher-order (e.g., phonological and semantic) processing of that stimulus (cf. Turvey, 1973). Rather, they suggest that central masking simply interferes with one aspect of the stimulus, i.e., its visual record. These theorists argue that when a word is visually presented it automatically activates a series of codes/processes (e.g., a grapheme to phoneme conversion code, a visual code, a semantic/lexical code). These codes are later integrated at a comparator (or "blackboard") stage of processing; the output from which leads to conscious awareness of the stimulus. With respect to the present study, as the threshold primes were presented they activated the codes involved in word recognition. However, when the pattern mask quickly followed the prime, it destroyed or displaced the visual record of the prime item. Now, since awareness of a visual stimulus should be dependent upon an appropriate visual record of that stimulus, once this visual record was lost due to masking the subject was unable to reliably report the presence of the stimulus. However, since the processing codes once activated proceed independently, the stimulus may still have received analysis by the semantic/lexical system if that system was activated. Any activation which reached the semantic system should have spread to related representations, thereby producing a semantic priming effect without the subject's ability to report the priming item. Thus, within this framework, the present results could be viewed as providing evidence for automatic semantic activation of a stimulus subsequent to the central masking of the raw visual input of that stimulus. The question that will now be addressed is to what extent does such activation influence long-term memory storage.

Recognition Memory Performance

Before discussing the threshold context conditions, a theoretically interesting pattern which emerged in the suprathreshold context conditions will be discussed. At the short SOA the size of the recognition context effect was relatively constant across the word context conditions, whereas at the long SOA, the size of the context effect was considerably larger for the related homograph than the related nonhomograph or unrelated conditions. This interaction was particularly puzzling since, as Anderson (1976, p. 387) has argued, one should clearly expect larger context effects for homographs which are studied and tested with different context words (e.g., *river bank* vs *money bank*) than nonhomographs (e.g., *sit chair* vs *table chair*). Very simply, there should be more semantic overlap, and therefore, a decreased likelihood of accessing different context induced senses for nonhomographs than for homographs. However, this pattern was found only at the long SOA.

One solution to this puzzle is to use the priming data as an indicant of "how" the prime semantically influenced the encoding of the target. That is, since at the short SOA the activation appeared to be automatic it may have had less of a semantic influence on the long-term memory trace of the target than the more attentional activation occurring at the long SOA. Possibly, the context effects found in recognition for the short SOA condition reflected a nonsemantic influence of the context. In fact, Hunt and Elliot (1980) have recently demonstrated that nonsemantic information (e.g., orthographic distinctiveness) can play an important role in long-term memory performance (also, see Hunt & Mitchell, 1978; Jacoby, 1974). Although the present study provides insufficient evidence to specify the nonsemantic features underlying the context effects at the short SOA, it does seem reasonable that these context effects were not totally semantic in nature as indicated by the lack of difference between the related homograph and nonhomograph conditions. On the other hand, at the long SOA, since subjects were able to attend to the semantic attributes of the prime during the 2-second prime–target SOA, this attention may have served to semantically disambiguate the encoded memory trace of the homographs. In fact, there is recent evidence (Marcel, 1980; Swinney, 1979) to indicate that disambiguation of homographs does indeed involve attentional allocation. In the present study, this homograph disambiguation at the long SOA, compared to the short SOA, should have served both to increase performance in the same context condition and decrease performance in the different context condition, as the present results indicate (see the Related Homograph Condition in Table 6).

Within the framework outlined above, what should be the effect of a shift in context for the threshold prime conditions? First, it should be noted that since subjects were apparently unable to attend to the priming stimuli, any semantic influence of the primes on the targets should have been automatic in nature. Furthermore, since the pattern mask appeared to have displaced the visual record of the prime, any nonsemantic features of the prime (e.g., orthographic information) should have been unavailable for encoding. Therefore, according to the present arguments, the net memory context effect of an automatic semantic influence of a prime *and* a loss of nonsemantic information due to pattern masking should approach zero, as the results clearly indicated.

It could be objected that the reason no context effects were found in the threshold prime conditions was because the activation produced by the primes was relatively weaker than the activation produced by the suprathreshold primes, as indicated by the smaller priming effect for the threshold conditions. Interestingly, however, if one considers the priming effect for the homographs (those items which should be most influenced in later memory performance by any semantic biasing effects of the primes), one finds that this effect is actually larger (47 milliseconds) for the threshold than for the suprathreshold (31 milliseconds) long SOA conditions. However, turning to recognition memory performance, one finds a dramatically larger context effect for the suprathreshold (31%) than for the threshold (0%) context conditions. In this light, the long SOA data clearly indicate that semantic activation reflected by semantic priming does not necessarily reflect activation which semantically influences the long-term storage of a homographic target.

Implications of the Present Study

This study suggests that although one can provide evidence of pure semantic activation via the presentation of stimuli below the level of subjects' reported awareness, this activation does not appear to direct sufficient attention to enable disambiguation of homographs in long-term memory. Thus, at this level, it does not appear that the spreading activation produced in the present threshold conditions served to direct attention to the activated areas as Anderson (1976, p. 125) and Schvaneveldt, Durso, and Mukherji (1982) have suggested it should. Possibly, such activation may have an influence in an immediate memory task or an episodic task which is more sensitive to semantic activation. On the other hand, it is also possible that there are levels of activation and that the threshold activation produced in the present study is at such a low level that it may have little functional value and is constrained to the lexical decision task. Clearly, if the semantic priming paradigm reflects semantic activation which is similar to the activation that occurs during reading, one must begin to be concerned with how the activation influences the extraction of meaning in complex sentence structures; an extraction process which demands an active working memory (Just & Carpenter, 1980). In this light, the present study should be viewed as a single step in the investigation of the impact of semantic activation on episodic encoding and should serve to emphasize the importance of *empirically* demonstrating the interplay between activation and attentional processing.

References

Allport, D. A. On knowing the meaning of words we are unable to report: The effects of visual masking. In S. Dornic (Ed.), *Attention and performance VI*. Hillsdale, N.J.: Erlbaum, 1977.

Anderson, J. R. *Language, memory, and thought.* Hillsdale, N.J.: Erlbaum, 1976.

Anderson, J. R., & Bower, G. H. A propositional theory of recognition memory. *Memory & Cognition,* 1974, **2**, 406–412.

Antos, S. J. Processing facilitation in a lexical decision task. *Journal of Experimental Psychology: Human Perception and Performance,* 1979, **5**, 527–545.

Cramer, P. A study of homographs. In L. Postman and G. Keppel (Eds.), *Norms of word association.* New York: Academic Press, 1970.

Fischler, I., & Bloom, P. A. Rapid processing of meaning of sentences. *Memory & Cognition,* 1980, **8**, 216–225.

Fowler, C. A., Wolford, G., Slade, R., & Tassinary, L. Lexical access with and without awareness. *Journal of Experimental Psychology: General,* 1981, **110**, 341–362.

Humphreys, G. W. Direct vs. indirect tests of the information available from masked displays: What visual masking does and does not prevent. *British Journal of Psychology,* 1981, **72**, 323–330.

Hunt, R. R., & Elliott, M. J. The role of nonsemantic information in memory: Orthographic distinctiveness effects on retention. *Journal of Experimental Psychology: General,* 1980, **109**, 49–74.

Hunt, R. R., & Mitchell, D. B. Specificity in nonsemantic orienting tasks and distinctive memory traces. *Journal of Experimental Psychology: Human Learning and Memory,* 1978, **4**, 121–135.

Jacoby, L. L. The role of mental contiguity in memory: Registration and retrieval effects. *Journal of*

Verbal Learning and Verbal Behavior, 1974, **13**, 483–496.

JUST, M. A., & CARPENTER, P. A. A theory of reading: From eye fixations to comprehension. *Psychological Review*, 1980, **87**, 329–354.

KAUSLER, D. H., & KOLLASCH, S. F. Word associations to homographs. *Journal of Verbal Learning and Verbal Behavior*, 1970, **9**, 444–449.

KLEIMAN, G. M. Sentence frame contexts and lexical decisions: Sentence-acceptability and word-relatedness effects. *Memory & Cognition*, 1980, **8**, 336–344.

KUČERA, H., & FRANCIS, W. N. *Computational analysis of present day American English*. Providence, R.I.: Brown Univ. Press, 1967.

LIGHT, L. L., & CARTER-SOBELL, L. Effects of changed semantic context on recognition memory. *Journal of Verbal Learning and Verbal Behavior*, 1970, **9**, 1–11.

MARCEL, A. J. Conscious and preconscious recognition of polysemous words: Locating the selective effects of prior verbal context. In R. S. Nickerson (Ed.), *Attention and performance VIII*. Hillsdale, N.J.: Erlbaum, 1980.

MARCEL, A. J., & PATTERSON, K. E. Word recognition and production: Reciprocity in clinical and normal studies. In J. Requin (Ed.), *Attention and performance VII*. Hillsdale, N.J.: Erlbaum, 1978.

MCCAULEY, C., PARMELEE, C. M., SPERBER, R. D., & CARR, T. H. Early extraction of meaning from pictures and its relation to conscious identification. *Journal of Experimental Psychology: Human Perception and Performance*, 1980, **6**, 265–276.

MERIKLE, P. M. Unconscious perception revisited. *Perception & Psychophysics*, 1982, **31**, 298–301.

NEELY, J. H. Semantic priming and retrieval from lexical memory: Evidence for facilitatory and inhibitory processes. *Memory & Cognition*, 1976, **4**, 648–654.

NEELY, J. H. Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited capacity attention. *Journal of Experimental Psychology: General*, 1977, **106**, 226–254.

PALERMO, D. S., & JENKINS, J. J. *Word association norms: Grade school through college*. Minneapolis: Univ. of Minnesota Press, 1964.

PERFETTI, C. A., LINDSEY, R., & GARSON, B. *Association and uncertainty: Norms of associations to ambiguous words*. Univ. of Pittsburgh Press, 1971.

POSNER, M. I., & SNYDER, C. R. R. Attention and cognitive control. In R. L. Solso (Ed.), *Information processing in cognition: The Loyola symposium*. Hillsdale, N.J.: Erlbaum, 1975.

POSTMAN, L., & KEPPEL, G. *Norms of word association*. New York: Academic Press, 1970.

SCHVANEVELDT, R. W., DURSO, F. T., & MUKHERJI, B. R. Semantic distance effects in categorization tasks. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 1982, **8**, 1–15.

SCHVANEVELDT, R. W., MEYER, D. E., & BECKER, C. A. Lexical ambiguity, semantic context, and visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance*, 1976, **2**, 243–256.

STANOVICH, K. E., & WEST, R. F. The effect of sentence context on ongoing word recognition: Tests of a two-process theory. *Journal of Experimental Psychology: Human Perception and Performance*, 1981, **7**, 658–672.

SWINNEY, D. Lexical access during sentence comprehension: (Re) consideration of context effects. *Journal of Verbal Learning and Verbal Behavior*, 1979, **18**, 645–660.

TURVEY, M. T. On peripheral and central processes in vision: Inferences from an information processing analysis of masking with patterned stimuli. *Psychological Review*, 1973, **80**, 1–52.

YATES, J. Priming dominant and unusual senses of ambiguous words. *Memory & Cognition*, 1978, **6**, 636–643.

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