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Semantic Priming and Retrieval from Lexical Memory: Roles of Inhibitionless Spreading Activation and Limited-Capacity Attention

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SUMMARY

Prior to each visually presented target letter string in a speeded word–nonword classification task, either BIRD, BODY, BUILDING, or XXX appeared as a priming event. When the target was a word, it was (a) a name of a type of bird on most BIRD-prime trials; (b) a name of part of a building on most BODY-prime trials; (c) a name of a part of the body on most BUILDING-prime trials; (d) a name of a type of bird, part of a building, or part of the body equally often on XXX-prime trials. Thus, on BIRD-prime trials the subject expected the word target to be chosen from the same category as the category represented by the word prime itself (Nonshift), whereas on BODY-prime and BUILDING-prime trials the subject's attention was to be shifted because he or she expected the word target to be chosen from a category other than the category represented by the word prime itself (Shift). The word target was an exemplar of either the category the subject expected (Expected) or a category the subject did not expect (Unexpected) and was either semantically related (Related) or semantically unrelated (Unrelated) to the word prime. Thus, there were five different types of word-prime–word-target trials: (a) BIRD–robin (Condition Nonshift-Expected-Related); (b) BIRD–arm (Condition Nonshift-Unexpected-Unrelated); (c) BODY–door (Condition Shift-Expected-Unrelated); (d) BODY–sparrow (Condition Shift-Unexpected-Unrelated); (e) BODY–heart (Condition Shift-Unexpected-Related). The stimulus onset asynchrony (SOA) between the prime and the target letter string varied between 250 and 2,000 msec. At the 2,000-msec SOA, reaction times (RTs) on BIRD–robin type trials were faster than RTs on XXX-prime trials (a facilitation effect), whereas RTs on BIRD–arm type trials were slower than RTs on XXX-prime trials (an inhibition effect). As SOA decreased, the facilitation effect on BIRD–robin trials remained constant, but the inhibition effect on BIRD–arm trials decreased until, at the 250-msec SOA, there was no inhibition. For the Shift conditions at the 2,000-msec SOA, facilitation was obtained on BODY–door type trials and inhibition was obtained on BODY–sparrow type trials. These two effects decreased in magnitude as the SOA decreased until, at the 250-msec SOA, there was no facilitation or inhibition. On BODY–heart type trials, there was an inhibition effect at the 2,000 msec SOA, which decreased as the SOA decreased until, at the 250-msec SOA, it became a facilitation effect. For the nonword targets, the facilitatory effects of the word primes decreased as SOA decreased. These results were regarded as supporting the theory of Posner and Snyder that postulates two distinct components of attention: a fast automatic inhibitionless spreading-activation process and a slow limited-capacity conscious-attention mechanism.

Several recent theories of information processing share the common assumption that retrieval from long-term memory is governed by the operation of two distinct processes. One of these processes operates automatically, is strategy free, and occurs without depleting the resources of a limited-capacity central processor. The second of these processes is an intentional, strategy-dependent mechanism that taps the limited resources of the central processor. Although the relative degree of emphasis given to each of these two processes varies among the different theories, this generic two-process conceptualization of retrieval from long-term memory is instantiated in the recent writings of Anderson and Bower (1973); Collins and Loftus (1975); Keele (1973); LaBerge and his associates (LaBerge, 1973a, 1973b, 1975; LaBerge & Samuels, 1974); Posner and Snyder (1975a, 1975b); Shiffrin and his associates (Schneider & Shiffrin, 1977; Shiffrin, 1975; Shiffrin & Geisler, 1973; Shiffrin & Schneider, 1977); and Turvey (1974).

A further assumption of most of these theories is that the automatic process plays a dominant role in the retrieval of overlearned associations and the retrieval of information from well-established memory structures, whereas the limited-capacity central processor plays a dominant role in the retrieval of less well learned information. (Such an assumption has also been central to earlier theories of skill acquisition, e.g., Fitts, 1964.) Evidence for this assumption has been obtained in experiments reported by LaBerge (1973a, 1975), Schneider & Shiffrin (1977), and Shiffrin & Schneider (1977). These experiments have shown that a mental operation that initially demands attention becomes automated with extended training.

Of those two-process theories mentioned above that are particularly relevant to the present experiments, Posner and Snyder's (1975a) theory of attention is one of the more explicit ones in terms of specifying the properties of each of the two processes and how they operate in isolation and in conjunction with each other. In their theory, an automatic spreading-activation process and a limited-capacity attentional mechanism are involved in the retrieval of information from long-term memory. Posner and Snyder subscribe to Morton's (1970) view that verbal long-term memory contains *logogens*—memory structures containing information stored about events with which a person has had considerable experience. These logogens are fed by banks of visual and auditory feature detectors, and they are activated whenever the number of features feeding into them exceeds some threshold value. In terms of a spatial metaphor, the logogens for semantically related words are assumed to be located nearer one another in long-term memory than are the logogens for semantically unrelated words.

According to Posner and Snyder's (1975a) theoretical treatment of the spreading-activation process, a stimulus *automatically* activates its logogen, and this activation automatically spreads to adjacent, semantically related logogens but not to remote, semantically unrelated logogens. This automatic spreading-activation process has three major properties: (a) It is fast acting; (b) it can occur without intention or conscious awareness; and (c) it does not affect the retrieval of information stored in seman-

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tically unrelated logogens to which it has not spread. Thus, if a word that is to be processed is presented before there has been a complete decay of the logogen activation produced by a previously presented semantically related word, the activation level in the logogen of the to-be-processed word will initially be higher (due to the activation that has spread to it) than it would have been had it been preceded by a semantically unrelated word, and the result will be a facilitation in its processing.

The limited-capacity conscious-attention mechanism of the Posner–Snyder (1975a) theory can also produce a facilitation in processing, with the facilitation occurring for those stimuli that activate logogens upon which attention is being focused. However, the three major properties of the limited-capacity attentional mechanism are opposite to the three major properties of the automatic spreading-activation process. That is, the limited-capacity attentional mechanism (a) is slow acting; (b) cannot operate without intention and conscious awareness, and (c) inhibits the retrieval of information stored in semantically unrelated logogens upon which it is not focused. Indeed, one of the most crucial components of the Posner–Snyder (1975a) theory is the manner in which the conscious-attention mechanism produces inhibition in the retrieval of information from unattended logogens. According to their theory, the conscious-attention mechanism does not inhibit the buildup of activation in unattended logogens but rather inhibits the readout of information from unattended logogens. That is, if a to-be-processed stimulus activates a logogen that is not contained in the subset of logogens upon which attention is focused, the buildup of activation in this unattended logogen proceeds in the same manner it would have if attention had not been misdirected to other logogens; however, before the information stored at the unattended logogen can be analyzed in preparation for response initiation, the conscious-attention readout mechanism must be "shifted" to that logogen. Thus, in terms of the operation of the conscious-attention mechanism, a to-be-processed word will be processed faster when it follows a semantically related word than when it follows a semantically unrelated word because the "distance" that attention must be shifted is shorter when attention is being shifted between semantically related logogens than between semantically unrelated logogens.

To evaluate their two-factor theory of attention, Posner and Snyder (1975b) conducted a letter-matching experiment and an animal-name classification experiment in which the target array about which the subject was to decide was preceded by a priming event to which the subject made no overt response. The subject's conscious attention was controlled by variations in the probability that the priming cue itself would appear as an element in the target array, and the prior automatic activation of the target element was controlled by the presence or absence of that particular target element as a priming cue. A baseline for assessing the conscious-attention and automatic-activation effects produced by the priming cue was provided by a neutral warning-signal prime that did not direct the conscious-attention readout mechanism to a specific set of logogens nor automatically activate any of the logogens activated by the stimulus elements of the target array. If, in comparison to the reaction times (RTs) to respond to the target array when it followed this neutral warning-signal prime, the RTs were shorter following a priming cue, the priming cue was said to have facilitated the processing of the target array; if RTs were longer following the priming cue, the priming cue was said to have inhibited the processing of the target array. The stimulus onset asynchrony (SOA) between the priming event and the target array was varied between 10 and 500 msec to test if the facilitation produced by the fast automatic-activation process would occur at shorter SOAs than would the inhibition produced by the more deliberate commitment of conscious attention.

The data in the Posner and Snyder (1975b) experiments to be considered here first are for trials in which the subject was to respond "yes"—that is, for trials in which the letters in the target array matched in the letter-matching task and for trials in which an animal name appeared in the target array in the animal-name classification task. For the 500-msec SOA, when the priming cue appeared in the target array, the processing of the target array was facilitated regardless of whether the probability that the priming cue would appear in the target array was high or low; but when the priming cue did not appear in the target array, the processing of the target array was inhibited only when the probability that the priming cue would appear in the target array was high enough that the subject's attention would have been misdirected to the priming cue's logogen when the target array appeared. Thus, as predicted, facilitation occurred automatically, regardless of whether the subject was consciously using the priming cue to direct his or her attention to the logogen for a target element, whereas inhibition occurred only when the subject was misdirecting attention in the high-probability condition. Also, as predicted, the facilitation occurred sooner following the presentation of the priming cue than did the inhibition.

Unfortunately, the interpretation of the data from the *yes* trials was complicated by the data for *no* trials—that is, for trials in which the letters in the target array did not match in the letter-matching task and for trials in which an animal name did not appear in the target array in the animal-name classification task. When the prime did not appear in the target array for the *no* trials in the high-probability condition, the prime did not inhibit the processing of the target array, as would be predicted by an unembellished application of the Posner–Snyder (1975a) theory, but rather *facilitated* the processing of the target array. Posner and Snyder (1975b) suggested that this facilitation occurred because of the subject's tendency to respond "no" when the prime was not physically identical to any of the elements in the target array. Therefore, it was unclear whether the inhibition effect for the *yes* trials was being produced by a general inhibition associated with misdirected attention or by a specific physical-match strategy. Posner and Snyder (1975a, 1975b) therefore acknowledged that their theory would be more strongly supported if an inhibition effect were obtained in an experiment in which the priming cue and the target elements were not physically identical.

Of particular relevance to the present research is the manner in which the Posner–Snyder (1975a) theory accounts for a finding commonly obtained in experiments involving a lexical decision task, a task in which the subject must decide as quickly as possible whether a visually presented letter string is a common English word or a nonword. The commonly obtained finding in such experiments (e.g., Meyer & Schvaneveldt, 1971; Meyer, Schvaneveldt, & Ruddy, Note 1) is that subjects are quicker to respond that a target letter string (e.g., NURSE) is a word when the immediately prior target was a semantically related word (i.e., DOCTOR) than when it was a semantically unrelated word (e.g., BREAD). As noted earlier, each of the two mechanisms of the Posner–Snyder (1975a) theory can account for such a semantic-facilitation effect. Responses to NURSE would be faster following DOCTOR than following BREAD because activation would have automatically spread from the logogen for DOCTOR to the logogen for NURSE and because the distance that attention must traverse in shifting from the logogen for DOCTOR to the logogen for NURSE is less than the distance that it must traverse in shifting from the logogen for BREAD to the logogen for NURSE.

As Posner and Snyder (1975a) have pointed out, the automatic spreading-activation and limited-capacity attentional mechanisms of their theory correspond rather closely to the spreading-excitation and location-shifting models proposed by Schvaneveldt and Meyer (1973) to account for the semantic-facilitation effect in the lexical decision task. On the basis of data obtained in a series of experiments designed to distinguish between these two models (Schvaneveldt & Meyer, 1973; Meyer et al., Note 1), Schvaneveldt and Meyer (1973) concluded that the semantic-facilitation effect in the lexical decision task was to be attributed to the spreading-activation process and was not to be attributed to the operation of the limited-capacity attentional mechanism. Since the Posner–Snyder (1975a) theory assumes that spreading-activation and limited-capacity attention are complementary rather than mutually exclusive mechanisms, Posner and Snyder (1975a) have argued that although the Meyer et al. and Schvaneveldt and Meyer data do indeed provide evidence for the involvement of spreading activation in the semantic-facilitation effect, they do not rule out an involvement of the limited-capacity conscious-attention mechanism.

In an experiment designed to evaluate further the role of the limited-capacity attentional mechanism in the semantic-facilitation effect, Neely (1976) adopted the methodology of Posner and Snyder (1975b). The target word to which the subject was to make a lexical decision was preceded by a neutral warning signal on some trials and by either a semantically related word prime or a semantically unrelated word prime on other trials. The RTs to word targets were much faster when the prime was a semantically related word than when the prime was a semantically unrelated word, thus replicating the semantic-facilitation effect. More importantly, in comparison to when a word target followed the neutral warning-signal prime, there was an inhibition in the processing of a word target when it followed a semantically unrelated word prime and facilitation in its processing when it followed a semantically related word prime. Within the framework of the Posner–Snyder (1975a) theory, the fact that a semantically unrelated word prime produced inhibition suggests that limited-capacity attention is involved in the semantic-facilitation effect.

Unfortunately, two other results of the Neely (1976) experiment raised interpretive problems. First of all, the magnitude of the inhibitory effect of the semantically unrelated word prime remained constant over the three SOAs (360, 600, and 2,000 msec), whereas the facilitatory effect of the semantically related word prime was greater at the two longer SOAs than at the shortest SOA. This result is problematic because, contrary to the Posner–Snyder (1975a) theory, the inhibition did not build up as the SOA increased. The second result that argued against limited-capacity attention as the source of the inhibition produced by the semantically unrelated word primes was that the processing of nonword targets was facilitated by the word primes. If the priming word were indeed depleting some of the subject's limited-capacity attention, there should have been an inhibition effect for the nonword targets as well as for the semantically unrelated word targets. Neely (1976) argued that because of the structure of the experiment and the highly stereotyped primary-associative relationship between the priming words and the semantically related target words (e.g., CAT–dog), subjects may have adopted the strategy of generating a primary associate to the priming word (e.g., generating, as the candidate for the target, "dog" to the priming word CAT), matching this self-generated item with the target item and then tending to respond "word" when the two items were the same and tending to respond "nonword" when the two items were different. Such a strategy would have slowed RTs to semantically unrelated words and sped RTs to nonwords.

The purpose of the present research was to provide a more rigorous test of the basic assumptions underlying the Posner–Snyder (1975a) theory by elaborating on the Neely (1976) paradigm so as to permit a further clarification of the roles of limited-capacity attention and automatic spreading activation in the lexical decision task. There were three important features of the present experiment's design. First, the presence or absence of automatic spreading activation was controlled by whether the prime and the target were semantically related or semantically unrelated. Second, the presence or absence of the operation of limited-capacity attention was controlled by whether the prime and target were separated by a long SOA, in which case the subject would be given enough time to engage, focus, and commit limited-capacity attention, or a short SOA, in which case the subject would not be given enough time to engage, focus, and commit attention.

The third, and perhaps most important, feature of the present experiment is that it avoids an as yet unmentioned confounding that has occurred in previous semantic-priming experiments (e.g., Neely, 1976; Posner & Snyder, 1975b; Rosch, 1975). Since these previous experiments were designed so that the priming event that directed the subject's conscious attention to the target's logogen was an event (i.e., the target item itself or a word semantically related to the target word) that should have also produced automatic activation in the target's logogen, these experiments have confounded the facilitatory effects of conscious attention with the facilitatory effects of automatic spreading activation. Thus, it is unclear how much of the facilitation obtained in these experiments was being produced by the subject's having directed his or her conscious attention to the target logogen and how much of the facilitation was being produced by activation having automatically spread to the target logogen. Of course, within the framework of the Posner–Snyder (1975a) theory, a determination of the relative contribution of conscious attention to the facilitation effect can be made by assessing the amount of inhibition accompanying the facilitation effect. However, one need not resort to such an indirect measure, since the two types of facilitation can be unconfounded. The confounding is avoided in the present experiment by using a priming word semantically unrelated to the target word to direct the subject's attention to the area of lexical memory containing the logogen for the target word. As will become clear in the explication of the present experiment's complete design, some novel observations of potential theoretical importance are occasioned when automatic-activation and conscious-attention facilitation effects are unconfounded in this manner.

Design and Theoretical Predictions

Prior to each target letter string about which the subject was to make a lexical decision, the subject saw as a priming event XXX or the priming word BIRD, BODY, or BUILDING. The subjects were instructed as follows:

> When the priming word is BIRD, if the target that follows it is a word, it will be the name of a type of bird on most trials. However, when the priming word is BODY, rather than expecting words that are the names of parts of the human body, you should *shift* your attention to expect that if the target is a word it will be the name of something to do with a building. In fact, when BODY is the priming event, if the target that follows it is a word, it will be the name of something to do with a building on most trials. Likewise, when the priming word is BUILDING, rather than expecting words that are the names of parts of a building, you should *shift* your attention to expect that if the target is a word it will be the name of a part of the human body. In fact, when BUILDING is the priming event, if the target that follows it is a word, it will be the name of a part of the human body on most trials. When XXX is the priming event, if the target is a word it will equally often be chosen from the three semantic categories *bird, body,* and *building.*

In accord with these instructions, when a word target followed the BIRD prime it was a name of a type of bird on two thirds of the trials, a name of a part of the body on one sixth of the trials, and a name of a part of a building on one sixth of the trials. When a word target followed the BODY prime it was a name of a part of a building on two thirds of the trials, a name of a type of bird on one sixth of the trials, and a name of a part of the body on one sixth of the trials. When a word target followed the BUILDING prime it was a name of a part of the body on two thirds of the trials, a name of a type of bird on one sixth of the trials, and a name of a part of a building on one sixth of the trials.

Three main variables are being manipulated by these instructions and these word-target trial types. The first variable is whether the word prime is cuing the subject to focus attention on exemplars of the category represented by the word prime itself, as was the case for the BIRD prime (Nonshift), or cuing the subject to *shift* and focus attention on exemplars of a category other than the category represented by the word prime itself, as was the case for the BODY and BUILDING primes (Shift). (Since,

Table 1
Predicted Processing Effects of Automatic Spreading-Activation (ASA) and Limited-Capacity Attention (LCA) as a Function of Stimulus Onset Asynchrony (SOA)

Condition	No. of test trials/block	Examples	SOA	Processing effects: ASA	Processing effects: LCA	Net effects
Nonshift-Expected-Related	2[a]	BIRD–robin	short	++	0	++
			medium	+	*	+*
			long	0	**	**
Nonshift-Unexpected-Unrelated	1	BIRD–arm	short	0	0	0
	1	BIRD–wall	medium	0	–	–
			long	0	– –	– –
Shift-Expected-Unrelated	2[a]	BODY–door	short	0	0	0
	2[a]	BUILDING–leg	medium	0	*	*
			long	0	**	**
Shift-Unexpected-Unrelated	1	BODY–sparrow	short	0	0	0
	1	BUILDING–canary	medium	0	–	–
			long	0	– –	– –
Shift-Unexpected-Related	1	BODY–heart	short	++	0	++
	1	BUILDING–window	medium	+	–	0
			long	0	– –	– –

Note. Facilitatory effects are represented by + and *, and inhibitory effects are represented by –.
[a] In addition to the two test trials per block, there were also two buffer trials per block for each of these trial types.

in terms of the main variables being manipulated in the present study, each type of BUILDING-prime trial has a functionally equivalent counterpart instantiated in one of the types of BODY-prime trials, only the BODY-prime trials will be used to illustrate the crucial aspects of the design of the experiment.) The second variable is whether the word target following the word prime is an exemplar of the category the subject *expects* on the basis of the word prime (Expected) or is an exemplar of a category other than the category the subject expects on the basis of the word prime (Unexpected). The third variable is whether the word prime and the target are semantically related (Related) or semantically unrelated (Unrelated).

The various combinations of these three variables yielded the five conditions given in Table 1. First consider the two Nonshift BIRD-prime conditions. On BIRD–robin type trials, the target was an exemplar of the category the subject was expecting (i.e., bird names), and the prime and the target were semantically related (Condition Nonshift-Expected-Related). On BIRD–arm type trials, the target was an exemplar of an unexpected category, and the prime and the target were semantically unrelated (Condition Nonshift-Unexpected-Unrelated). Now consider the three Shift BODY-prime conditions. On BODY–door type trials, the target was an exemplar of the category the subject was expecting (i.e., building parts), but the prime and target were semantically unrelated (Condition Shift-Expected-Unrelated). On BODY–sparrow type trials, the target was an exemplar of an unexpected category, and the prime and the target were semantically unrelated (Condition Shift-Unexpected-Unrelated). On BODY–heart type trials, the target was an exemplar of an unexpected category but the prime and the target were semantically related (Condition Shift-Unexpected-Related). Table 1 also presents predictions derived from the Posner–Snyder (1975a) theory for the relative amounts of facilitation and inhibition produced by the automatic spreading-activation process and the limited-capacity attentional mechanism in each of these five word-target conditions as a function of SOA. To clarify the predictions shown in Table 1 it will be necessary to enumerate the assumptions underlying them.

The assumptions underlying the predictions for the automatic spreading-activation effects were as follows:

1. Automatic spreading activation has an effect only when the prime and the target are semantically related. Thus, zeroes appear for all SOAs for all of the Unrelated conditions.

2. Automatic spreading activation produces only facilitatory effects and no inhibitory effects. Thus, all nonzero effects are +.

3. Automatic spreading activation decays unless the subject makes a conscious effort to maintain it via rehearsal. Thus, the facilitatory effect of automatic spreading activation decreases as SOA increases. For present purposes, it will be assumed that the long SOA is sufficiently long that there will have been a complete decay of automatic spreading activation. Evidence supporting the assumption that automatic spreading activation decays has been obtained in experiments by Loftus (1973), Meyer et al. (Note 1), and Warren (1972).

The assumptions underlying the predictions for the effects of limited-capacity attention were as follows:

4. Limited-capacity attention produces a facilitatory effect (designated as $*$ rather than + to distinguish it from the facilitatory effect produced by automatic spreading activation) when the target is an exemplar of the category the subject expects, and it produces an inhibitory effect when the target is an exemplar of an unexpected category. Thus, $*$s are present in the two Expected conditions and −s are present in the three Unexpected conditions.

5. The effects of limited-capacity attention increase with increasing SOA. For present purposes, it will be assumed that the short SOA is sufficiently short that limited-capacity attention has not yet been committed. Thus, there is a zero entry in the limited-capacity attention column for all conditions at the short SOA.

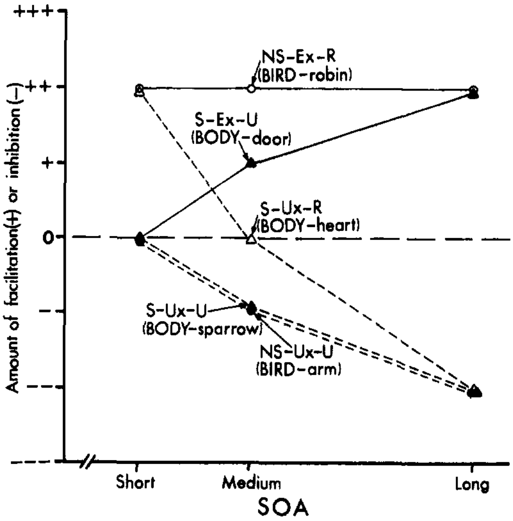

Figure 1. Amount of facilitation (+) or inhibition (−) predicted for word targets in word-prime conditions as a function of stimulus onset asynchrony (SOA). (NS-Ex-R = Nonshift-Expected-Related; NS-Ux-U = Nonshift-Unexpected-Unrelated; S-Ex-U = Shift-Expected-Unrelated; S-Ux-R = Shift-Unexpected-Related; S-Ux-U = Shift-Unexpected-Unrelated.)

The following assumptions were made to compute the net effects:

6. The facilitatory effects produced by automatic spreading activation and limited-capacity attention are additive. To simplify matters, it will be assumed that $+ = *$.

7. The facilitatory effects of automatic spreading activation and the inhibitory effects of limited-capacity attention are additive. To further simplify matters, it will be assumed that + and − exactly cancel each other out in Condition Shift-Unexpected-Related at the intermediate SOA such that the net effect is zero.

Figure 1 presents a graphic display of the net effects predicted by the Posner–Snyder (1975a) theory in conjunction with the simplifying assumptions mentioned above. To permit a direct comparison of these predictions with the obtained results, the short, medium, and long SOAs are given the values used in the experiment.

Of course, to derive predictions for RTs, additional assumptions will need to be made concerning the mapping of various magnitudes of the hidden underlying facilitatory and inhibitory processes into the RTs the experimenter observes. Two further assumptions were made in this regard:

8. The mapping of underlying process into RTs is some unspecified *monotonic* function.

9. The scales underlying the mapping of facilitation into RTs and of inhibition into RTs are not necessarily comparable. That is, when a given prime (e.g., BODY) produces facilitation only through the operation of limited-capacity attention (as in Condition Shift-Expected-Unrelated), the amount of observed facilitation measured in milliseconds for that prime will not necessarily be equal to the amount of observed limited-capacity attentional inhibition measured in milliseconds for that prime (i.e., in Condition Shift-Unexpected-Unrelated). However, under such circumstances, if the pure limited-capacity attentional facilitatory effect for a given prime is statistically significant or nonsignificant, the inhibitory effect for that prime should likewise be statistically significant or nonsignificant, and vice versa.

Given these two assumptions, the most important aspect of Figure 1 is the *pattern* of the facilitation and inhibition effects predicted for the various conditions and not their absolute magnitudes.

The five most important aspects of the predicted pattern of results shown in Figure 1 are the following:

1. The facilitation effect in Condition Nonshift-Expected-Related (BIRD–robin) is flat as a function of SOA, whereas the facilitation effect in Condition Shift-Expected-Unrelated (BODY–door) starts at zero and increases with increasing SOA until it converges with the facilitation effect obtained for the BIRD–robin trials. Of course, the fact that the facilitation effect for BODY–door trials follows a different time course than the facilitation effect for BIRD–robin trials does not necessarily mean that spreading activation is not involved in the facilitation effect obtained for BODY–door trials. When BODY is the prime, the subject most probably uses the attentional mechanism to retrieve the BODY–"building" association, thus activating the "building" logogen. This activation would begin to spread to logogens semantically related to "building", such as "door." Once the "building" logogen has been activated via retrieval of the unautomated BODY–"building" association, the subject probably uses the attentional mechanism to maintain activation in the "building" logogen (and in the "bird" logogen following the BIRD prime) so that it does not decay during the 2,000-msec SOA. However, the important point is that the activation in the "building" logogen would not have *automatically* occurred when BODY was presented because the BODY–"building" association is not a well-learned, automated association like the BIRD–"bird" association.

2. The inhibition effects in Conditions Nonshift-Unexpected-Unrelated (BIRD–arm) and Shift-Unexpected-Unrelated (BODY–sparrow) are equivalent, starting at zero at the short SOA and growing in magnitude with increasing SOA.

3. The BIRD prime produces a facilitation effect for BIRD–robin trials at the short SOA, but this facilitation is not accompanied by an inhibition effect for BIRD–arm trials at the short SOA. On the other hand, the BODY prime produces a facilitation effect for BODY–door trials only if at the same time it is producing an inhibition effect for BODY–sparrow trials. Facilitation in BIRD–robin trials is not necessarily accompanied by inhibition in BIRD–arm trials because the BIRD–robin facilitation is based on an overlearned, automated association. However, facilitation in BODY–door trials is always accompanied by inhibition in BODY–sparrow trials because the BODY–door facilitation is not based on an overlearned, automated association and therefore must involve the commitment of limited-capacity attention.

4. Perhaps the most interesting prediction made by the Posner–Snyder (1975a) theory is that in Condition Shift-Unexpected-Related (BODY–heart), there should be a net facilitation effect at the short SOA because of activation automatically spreading from

the "body" logogen to the semantically related "heart" logogen and because there has not been enough time allowed by the short SOA for limited-capacity attention to begin exerting its counteracting inhibitory influence. However, as the SOA increases, the automatic spreading activation decays, and the limited-capacity attention mechanism begins to exert its inhibitory influence, so that the net effect is inhibitory at the long SOA.

5. The final aspect to note about the predictions shown in Figure 1 is that the curve for the BODY–heart trials is far above the curve for the BODY–sparrow trials at the short SOA because of the facilitation effect produced by automatic spreading activation due to the close semantic relationship between BODY and heart. However, as SOA increases and automatic spreading activation decays because attention is shifted to the "building" logogen, the curve for BODY–heart trials converges with the curve for BODY–sparrow trials.

To the degree that the data obtained for the word-prime–word-target conditions correspond to the five major predictions of the Posner–Snyder (1975a) theory displayed in Figure 1 and outlined above, the basic assumptions of the Posner–Snyder theory will be supported. Any discrepancies between the predicted results shown in Figure 1 and the obtained results will call into question the basic assumptions of the Posner–Snyder theory and will demand that these assumptions be abandoned or modified to account for such discrepancies.

Method

Stimulus Materials

So that enough observations per subject per condition could be obtained without requiring that a word target be repeated in the experiment, word targets were chosen from the exemplars of three large semantic categories given in the Battig and Montague (1969) norms—birds, parts of the body, and parts of a building. The pronounceable nonword targets were matched with the word targets by changing one letter in a word matched to each of the word targets on the basis of frequency of occurrence in the language, number of letters, and number of syllables. Nonword targets were formed in this manner because James (1975) has argued that subjects must access the meaning of a word target in order to make a lexical decision whenever they cannot classify words and nonwords on the basis of structural differences. The set of word targets from each semantic category was split into two sets of equal size according to category dominance in the Battig and Montague norms: a high-category-dominance (HCD) set and a low-category-dominance (LCD) set. Since the nonword targets were matched with the word targets, they too were distinguished by their category membership and category dominance, but for the nonword targets these are pseudodistinctions unless they are confounded with the structural characteristics that formed the basis for the matching of the word and nonword targets (cf. Landauer & Streeter, 1973).

Test-List Construction

To insure that the results could not be attributed to differences in the categories used in a given condition, a base list was constructed for each of three different category-assignment (CA) sets. Across the three CA sets, each of the priming words occurred in the nonshift condition, and each priming word cued each of the two remaining semantic categories when it occurred in a Shift condition. A base list consisted of six blocks of 60 trials: 30 word-target trials (10 from each category) and their 30 matched nonword-target trials. There were 36 word-prime trials per block, with each of the three word primes appearing in 12 trials, and 24 XXX-prime trials. Twelve of the 36 word-prime trials were buffer trials: 6 word-target trials and their matching set of 6 nonword-target trials. As noted in Table 1, the 6 word-prime–word-target buffer trials represented instances of the two different Expected conditions. A block always began with 2 buffer trials, with the remaining 10 buffer trials being randomly scattered throughout the rest of the trials in that block.

In addition to the 12 word-prime buffer trials, each block of 60 trials contained 48 test trials from which the data to be reported here were taken. Twenty-four of these trials were word-prime trials (12 word-target trials and their 12 matched nonword-target trials) and 24 were XXX-prime trials (12 word-target trials and their 12 matched nonword-target trials). The constitution of the 12 word-prime–word-target test trials for each block is represented in Table 1. It can be seen that in each block Condition Shift-Expected-Unrelated was represented in 4 trials, whereas the remaining four conditions were represented in 2 trials each. As a consequence of the nonword-target trials being matched with the word-target trials, there were 8 Shift trials and 4 Nonshift trials for the 12 word-prime–nonword-target test trials. For the 12 XXX-prime–word-target test trials, 4 word targets were chosen from each of the three semantic categories, and their matching nonword targets were used for the 12 XXX-prime–

nonword-target test trials. Across blocks, word targets and nonword targets from each of the three categories were equally divided between HCD and LCD items within each condition. Within and across blocks, the presentation order of the target items was a pseudorandom sequence with the first-order sequential probabilities for condition, target lexicality, and category membership being equated as nearly as possible.

Seven other lists were derived from each of the base lists for each of the three different CA sets by reordering the priming events for the test trials so that the order of presentation of the target events was identical for all lists. Thus, altogether there were 24 different lists, that is, 8 lists × 3 CA sets. Across these 24 lists, the net effect for the test trials was that each word target and each nonword target appeared equally often following a given word prime and the XXX prime, and each word-prime condition involved the three different word primes BIRD, BODY, and BUILDING. Thus, none of the theoretically crucial differences between the various priming conditions can be attributed to item effects.

Practice-List Construction

The targets in both of the two practice lists were words on half of the trials and nonwords on the other half of the trials. For the 40-trial first practice list, there were two different priming events, ANIMAL and XXX, and the target words were selected from the Battig and Montague (1969) categories *animals* and *metals.* The ANIMAL and XXX primes were both equally often followed by word targets and nonword targets, but the word target following the ANIMAL prime was always an animal name, whereas the word target following the XXX prime was an animal name on half of the trials and a metal name on the other half of the trials. The first practice list was constructed in this manner so that the subject would learn that the word prime provides information about the semantic nature of the word target, whereas the XXX prime does not provide such information, and that neither the word prime nor the XXX prime provides information as to the lexicality of the target that follows it.

The stimulus materials for the 36-trial second practice list were comparable to those of the test list. However, only word primes appeared, with each of the three word primes being presented equally often and always being followed by a word target chosen from the expected category on word-target trials.

Subjects

One hundred twenty-two native English speakers in the Yale community were individually tested and received either experimental credits for an introductory psychology course or $4 each for their participation in the 1¾-hr. session. The data from two subjects were discarded because one of them failed to respond on several trials and the other could not describe midway through the session the attention-shifting strategy she was to be adopting.

Procedure

General instructions were read to all subjects prior to the first practice list. Each trial began with the subject pressing down with his dominant hand a home-base key between the two response keys. The response key on the subject's dominant side and nondominant side was always assigned to the "word" and "nonword" response, respectively. Each trial consisted of two slides, the priming slide and the target slide, successively rear projected on translucent Mylar near the center of a 12 × 16 cm aperture. The uppercase priming event and the lowercase target event appeared in identical positions in the aperture. The priming slide was exposed for 150 msec, and the SOA was varied according to the duration of the dark blank interval between the offset of the priming slide and the onset of the target slide, which was displayed for 1,000 msec for all trials. During the 4-sec intertrial interval, the experimenter informed the subject if an error had been made on the previous trial. The exposure durations of the prime and the target slides were controlled by Lafayette shutters and BRS/LVE Digi-Bit solid-state timers. The RTs were measured to the nearest millisecond.

Before the second practice list, the three different instructional sets appropriate to the three CA sets were introduced. In addition to informing the subject explicitly about the attention-shifting strategies that should be adopted with each prime, these instructions emphasized how important it was for the subject to attempt to adopt these strategies on every trial. The SOA was always 2,000 msec for the first two practice lists.

Following the second practice list, the SOA varied between 250 and 2,000 msec both between and within subjects. In the 2,000-alone group, the SOA was held constant at 2,000 msec for all trials. Each of the 24 subjects in the 2,000-alone group received a different one of the 24 lists—8 lists × 3 CA sets—described above. For the three 2,000-mixed groups, the 2,000-msec SOA was randomly intermixed with a shorter SOA. The shorter SOAs were 250, 400, and 700 msec for Groups 250–2,000, 400–2,000, and 700–2,000, respectively. For the three 2,000-mixed groups, the short and long SOAs were superimposed on the stimulus sequence with the constraint that within each block each condition would occur with a short and long SOA and that across blocks both HCD and LCD items would equally often be represented within each condition at the short and long SOAs. A result of these constraints was that a short or long SOA followed itself more often (around 55% of the time) than it followed the opposite SOA. Since preliminary analyses of the data from the 2,000-alone group indicated that the amount of facilitation or inhibition seen in a particular condition was not substantially affected by CA set, subjects in the 2,000-mixed groups were exposed to lists from only two of the three CA sets, and a given list within a CA set was used twice, so that a particular target appeared in a given condition at both SOAs. Thus, each of the 32 subjects in each of the 2,000-mixed groups received a different one of 32 lists: 8 lists × 2 CA sets × 2 SOA orders.

A third practice list, a repetition of the second, was given to the three 2,000-mixed groups but not to the 2,000-alone group, in order to introduce the subjects to the two SOAs they would be receiving in the test series. The long SOA was given on half of the trials and the short SOA was given on the remaining half of the trials, with each priming event and the word and nonword targets occurring equally often at the long and short SOAs. The subjects were told that even though it might be difficult to shift their attention during the short interval, it was extremely important that they make every effort to do so and that, since the order of presentation of the long and short intervals would be randomly determined, they should not try to anticipate what the interval for a given trial would be, and they should try to start shifting their attention as soon as the priming event was shown.

The test series followed either the third practice list for the 2,000 mixed groups or the second practice list for the 2,000-alone group. The subjects were told that on a very few trials they would receive a word target chosen from a category other than the one from which they expected the word targets to be chosen, given the particular priming event, and that when this happened the word target would equally often come from the two different unexpected categories. It was strongly emphasized that they were to try to avoid anticipating whether a given trial would contain a word target chosen from an expected or an unexpected category and that they should fervently try to adopt the appropriate attention-shifting strategy *on every trial.* The subjects were also told to avoid the strategy of responding "nonword" if the target letter string did not belong to the expected category because if they adopted such a strategy they would make too many errors on trials in which the word target was chosen from an unexpected category. A 5-min. rest period occurred between the third and fourth blocks of the test series. Following this break, the subject was asked to review the attentional strategy that was to be adopted for each prime.

Results

Facilitation and Inhibition for Word-Prime–Word-Target Trials

The data for correct responses to the word targets for the various conditions at the 2,000-msec SOA for the 2000-alone group and the three 2,000-mixed groups are displayed in Table 2. Since the xxx-prime trials used to compute a facilitation or inhibition score for a given word-prime condition involved exemplars of only those categories represented by the word targets in that particular word-prime condition, two different xxx-prime control conditions were used to compute the facilitation or inhibition scores for the word-prime conditions.

All reported t values were computed using the appropriate error term from an overall analysis of variance as the error estimate. Unless otherwise specified, all differences referred to as statistically significant were associated with two-tailed p values less than .01. (These two general rules apply to the nonword-target data as well.)

Group 2,000-alone. An inspection of Table 2 reveals that for the 2,000-alone SOA a facilitation effect was obtained in each of the two Expected conditions, an inhibition effect was obtained in each of the three Unexpected conditions, and these facilitation and inhibition effects were substantial and statistically different from zero. It can also be seen in Table 2 that the error rates were very low for the 2,000-alone SOA, that is, only 3.8% averaged across all conditions. Since most errors were made to LCD word targets (6.7%) and virtually no errors were made to HCD word targets (.9%), and since subjects often commented that they made errors to some of the LCD words (e.g., joists, egret, and osprey) because these words were not in their vocabulary, the error data are not particularly informative measures of processing difficulty and will not be considered further.

An analysis of variance with one between-subjects factor, CA, and two within-subjects factors, category dominance and condition, was conducted on the facilitation and inhibition scores for the word-prime conditions. The effect of condition was highly significant, $F(4, 84) = 46.85$, $MS_e = 4414$. However, subsequent t tests revealed that there was no difference in the facilitation scores for the two Expected conditions nor were there differences among the inhibition scores for the three Unexpected conditions (all ts < 1.1). Although the CA × Condition interaction was marginally significant, $F(8, 84) = 2.18$, $MS_e = 4414$, $p = .05$, when the data were broken down according to CA subgroups, the smallest facilitation effect for any Expected condition in any CA subgroup was +33 msec, and the smallest inhibition effect for any Unexpected condition in any CA subgroup was −34 msec. The amount of facilitation or inhibition did not depend on category dominance as is evi-

Table 2
Reaction Times (RTs) (in msec) and Error Percentages to Word Targets in Terms of Mean Facilitation (+) or Inhibition (−) Scores for Word-Prime Conditions and of Mean RTs and Error Percentages for XXX-Prime Conditions for the 2,000-msec Stimulus Onset Asynchrony

	Condition						
	Word prime					xxx prime	
Group	NS-Ex-R	NS-Ux-U	S-Ex-U	S-Ux-U	S-Ux-R	x-a	x-b
2,000-alone							
RT	+47***	−72***	+56***	−72***	−59***	716	718
SE_M	6.9	8.4	7.4	13.6	14.2	—	—
n	23***	23***	24***	23***	19*	—	—
% errors	−.2	−4.6	+.1	−4.6	−2.5	2.4	2.0
N	275	266	553	268	271	1,098	550
250–2,000							
RT	+14	−70***	+30***	−77***	−63***	765	759
SE_M	11.1	13.5	8.4	12.5	17.1	—	—
n[a]	22★	26**	24**	28***	25**	—	—
% errors	+.2	−9.5	−1.6	−1.5	−8.8	4.5	1.3
N	188	165	369	177	169	720	372
400–2,000							
RT	+33*	−56***	+49***	−68***	−43***	749	736
SE_M	13.0	10.3	8.7	14.0	14.4	—	—
n[a]	22★	26**	26**	27***	26**	—	—
% errors	+3.2	−5.2	−2.0	−4.2	−6.6	4.2	1.4
N	186	171	365	175	174	719	372
700–2,000							
RT	+26★	−57***	+48***	−100***	−53***	760	739
SE_M	13.7	12.0	9.9	13.4	11.2	—	—
n[a]	22★	24**	25**	29***	24**	—	—
% errors	+1.6	−6.5	+.6	−2.6	−5.1	2.7	2.7
N	186	171	374	180	176	731	362

Note. Facilitation and inhibition scores were derived by subtracting word-prime RTs (error percentages) from XXX-prime RTs (error percentages). Facilitation or inhibition scores for Conditions NS-Ex-R and S-Ux-U are based on Condition x-a, and facilitation or inhibition scores for Conditions NS-Ux-U, S-Ex-U and S-Ux-R are based on Condition x-b. Word-prime–word-target conditions = Nonshift-Expected-Related (NS-Ex-R), Nonshift-Unexpected-Unrelated (NS-Ux-U), Shift-Expected-Unrelated (S-Ex-U), Shift-Unexpected-Unrelated (S-Ux-U), and Shift-Unexpected-Related (S-Ux-R). n = number of subjects, out of 24, showing the facilitation or inhibition effect. N = total number of correct-response observations remaining after exclusion of errors and shutter-failure trials. Variations in N greater than 30 are due to differences in maximum number of observations possible for different conditions.

[a] Number of subjects, out of 32, showing the facilitation or inhibition effect.
★ $p < .05$, one-tailed.
* $p < .05$, two-tailed.
** $p < .01$, two-tailed.
*** $p < .001$, two-tailed.

denced by the nonsignificant Condition × Category Dominance interaction, $F(4, 84) = 1.36$.

The word-target data for the 2,000-alone SOA provide some useful general information about the present paradigm. First of all, the fact that facilitation was obtained in Condition Nonshift-Expected-Related (BIRD–robin) indicates that in the lexical decision task a semantic-facilitation effect can be produced by a category–exemplar relationship between the priming word and the target word as well as by the previously employed primary-associative relationship between the priming word and the target word (e.g., CAT–dog and DOCTOR–nurse). Furthermore, within the framework of the Posner–Snyder (1975a) theory, the inhibition obtained in Condition Nonshift-Unexpected-Unrelated (BIRD–arm) serves as a source of evidence that conscious attention was partially involved in the facilitation effect obtained for BIRD–robin trials. The facilitation effect obtained in Condition Shift-Expected-Unrelated (BODY–door) and the inhibition effects obtained in the two Shift-Unexpected conditions (BODY–sparrow and BODY–heart) are methodologically important because they verify that the subjects did indeed shift their attention during the 2,000-msec SOA interval. Also, the fact that the magnitude of the inhibition obtained for BODY–heart trials was not significantly smaller than the magnitude of the inhibition obtained for BODY–sparrow trials indicates that the automatic activation spreading from the "body" logogen to the "heart" logogen had decayed during the 2,000-msec SOA.

Groups 2,000-mixed. As can be seen in Table 2, the word-target data for the 2,000-msec SOA showed the same pattern for all three 2,000-mixed groups, that is, facilitation in the two Expected conditions and inhibition in the three Unexpected conditions, and this pattern was very similar to the pattern that emerged in the 2,000-alone data, but with the magnitude of the facilitation and inhibition effects somewhat reduced from that in the 2,000-alone data. This similarity in the pattern of results for the 2,000-msec SOA for all groups is important because it indicates that subjects were adopting similar strategies at the 2,000-msec SOA independently of the presence and duration of the shorter intermixed SOAs. Thus, it would seem to be more parsimonious to attribute any differences in the pattern of results at the shorter SOAs to changes in the operation of attentional mechanisms with time rather than to the subjects' adopting completely different strategies for the different SOAs in the different groups.

An analysis of variance with two between-subjects factors, CA and group, and two within-subjects factors, category dominance and condition, was conducted on the facilitation and inhibition scores for the 2,000-msec SOAs from the three 2,000-mixed groups. The contention that the same pattern of data held true for all three 2,000-mixed groups was supported by the nonsignificant Group × Condition interaction ($F < 1$). The only effect to approach statistical significance was the highly significant main effect of condition, $F(4, 360) = 66.99$, $MS_e = 8750$. Unlike the 2,000-alone data, part of this effect was attributable to there being a larger inhibition effect in Condition Shift-Unexpected-Unrelated (BODY–sparrow) than in Condition Shift-Unexpected-Related (BODY–heart) [$t(360) = 3.01$; sign test, 58 + and 38 −; $p < .05$, one-tailed] or in Condition Nonshift-Unexpected-Unrelated (BIRD–arm) [$t(360) = 2.15$, $p < .05$; sign test, 59 + and 37 −, $p < .05$]. The fact that the inhibition effect was smaller for BODY–heart trials than for BODY–sparrow trials indicates that the automatic activation spreading from the "body" logogen to the "heart" logogen had not completely decayed during the 2,000-msec SOA for the 2,000-mixed groups. The fact that the inhibition effect was smaller for BIRD–arm trials than for BODY–sparrow trials may be attributable to the subjects' paying more attention to the Shift prime than to the Nonshift prime because of the emphasis given to the shifting strategy by the instructions. Further support for the contention that subjects paid more attention to the Shift primes than to the Nonshift prime is provided by the fact that the facilitation effect in Condition Shift-

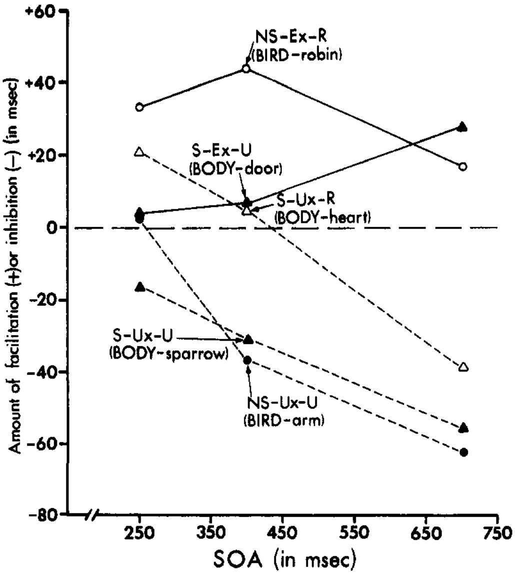

Figure 2. Amount of facilitation (+) or inhibition (−) (in msec) for word targets in word-prime conditions as a function of stimulus onset asynchrony (SOA) (in msec). (NS-Ex-R = Nonshift-Expected-Related; NS-Ux-U = Nonshift-Unexpected-Unrelated; S-Ex-U = Shift-Expected-Unrelated; S-Ux-R = Shift-Unexpected-Related; S-Ux-U = Shift-Unexpected-Unrelated.)

Expected-Unrelated (BODY–door) was marginally larger than the facilitation effect in Condition Nonshift-Expected-Related (BIRD–robin), $t(360) = 1.87$, $p < .05$, one-tailed; sign test, 57 + and 39 −, $p < .05$, one-tailed.

Of course, the most important aspect of the data from the 2,000-mixed groups is the time course of the development of the facilitation and inhibition effects seen for each of the conditions at the 2,000-msec SOA as the SOA was increased from 250 msec to 2,000 msec. Given the design of the present experiment, there are two ways to evaluate changes in facilitation and inhibition with changing SOA. First, in each of the three 2,000-mixed groups, the magnitude of the facilitation or inhibition effect for a given condition at the 2,000-msec SOA can be compared with the magnitude of the facilitation or inhibition effect in the same condition at the short SOA, with SOA as a within-subjects factor. The second method of evaluating the changes in facilitation and inhibition with changing SOA is to compare the magnitude of the facilitation or inhibition effect for a given condition at the 250-, 400-, and 700-msec SOAs, with SOA as a between-subjects factor. Since an analysis of variance conducted on the data from Group 700–2,000 indicated that the amount of facilitation or inhibition in a given condition was the same for the 700- and 2,000-msec SOAs, an adequate picture of changes in facilitation or inhibition as the SOA increases from 250 msec to 2,000 msec is provided by comparisons of the magnitudes of the facilitation or inhibition effects obtained for the various conditions at the 250-, 400-, and 700-msec SOAs. The data for correct responses to the word targets for the various conditions at the 250-, 400-, and 700-msec SOAs are shown in Table 3 in the same format as the data presented in Table 2.

The facilitation and inhibition effects for the RTs are displayed in Figure 2 so that the pattern of the obtained results can be directly compared with the pattern of predicted results displayed in Figure 1. Recall that there were five important aspects of the predictions derived from the Posner–Snyder (1975a) theory. The first prediction was that the facilitation effect for BIRD–robin trials would be flat as a function of SOA and that the magnitude of the facilitation effect for BODY–door trials would start at zero at the 250-msec SOA and increase with increasing SOA until it converged with the facilitation effect for the BIRD–robin trials. As can be seen in Figure 2, this prediction was confirmed by the data. The second prediction was that the magnitude of the inhibition effects for the BODY–sparrow and BIRD–arm trials would be equivalent, with both originating at zero at the 250-msec SOA and increasing with increasing SOA. This prediction was borne out by the data, since the 16-msec inhibition effect obtained for the BODY–sparrow trials at the 250-msec SOA was not statistically significant. (See Table 3.) The third prediction confirmed by the data was that the BIRD prime produced a significant amount of facilitation in BIRD–robin trials at the 250-msec SOA, but at that same SOA it did not produce a significant amount of inhibition in BIRD–arm trials; on the other hand, the BODY prime produced a significant amount of facilitation in BODY–door trials only for that SOA (i.e., 700 msec) at which it also produced a significant amount of inhibition in BODY–sparrow trials. (See Table 3.) The fourth prediction of the Posner–Snyder (1975a) theory, that there should be a facilitation effect in BODY–heart trials at the 250–msec SOA, was also confirmed. The final prediction to be considered is that the curves for the BODY–heart and BODY–sparrow conditions should be far apart at the 250-msec SOA and converge with increasing SOA. This prediction was also verified, since there was a 36-msec difference between these two conditions at the 250-msec SOA and only a 17-msec difference beween them at the 700-msec SOA.[1] In short, then, the data conformed almost perfectly with all five predictions derived from the Posner–Snyder (1975a) theory and the assumptions outlined earlier.

As can be seen in Table 3, the error rates for the 2,000-mixed groups were quite

Table 3
Reaction Times (RTs) (in msec) and Error Percentages to Word Targets in Terms of Mean Facilitation (+) or Inhibition (−) Scores for Word-Prime Conditions and of Mean RTs and Error Percentages for XXX-Prime Conditions for the Short Stimulus Onset Asynchronies (SOAs) in the 2,000-mixed Groups

	Condition						
	Word prime					XXX prime	
SOA	NS-Ex-R	NS-Ux-U	S-Ex-U	S-Ux-U	S-Ux-R	X-a	X-b
250 msec							
RT	+33***	+3	+4	−16	+20★	778	780
SE_M	10.7	11.8	10.7	10.6	11.7	—	—
n	22★	16	15	19	22★	—	—
% errors	+1.8	−4.3	−5.5	+3.8	−2.7	6.4	2.1
N	186	176	351	184	179	715	372
400 msec							
RT	+44***	−36**	+8	−31**	+5	739	722
SE_M	10.3	11.6	9.0	11.8	10.1	—	—
n	27***	22★	20	17	17	—	—
% errors	+2.7	−5.3	−1.6	0.0	−.1	3.2	2.1
N	187	176	365	181	185	736	371
700 msec							
RT	+17	−62***	+28**	−56***	−39***	747	736
SE_M	12.2	13.9	9.5	13.8	11.0	—	—
n	21	25**	22★	26**	23*	—	—
% errors	+2.0	−3.4	−.4	−3.4	−1.4	2.6	1.8
N	188	178	370	174	183	740	370

Note. Facilitation and inhibition scores were derived by subtracting word-prime RTs (error percentages) from XXX-prime RTs (error percentages). Facilitation or inhibition scores for Conditions NS-Ex-R and S-Ux-U are based on Condition X-a, and facilitation or inhibition scores for Conditions NS-Ux-U, S-Ex-U, and S-Ux-R are based on Condition X-b. Word-prime–word-target conditions = Nonshift-Expected-Related (NS-Ex-R), Nonshift-Unexpected-Unrelated (NS-Ux-U), Shift-Expected-Unrelated (S-Ex-U), Shift-Unexpected-Unrelated (S-Ux-U), and Shift-Unexpected-Related (S-Ux-R). *n* = number of subjects, out of 32, showing the facilitation or inhibition effect. *N* = total number of correct-response observations remaining after exclusion of errors and shutter-failure trials. Variations in *N* greater than 30 are due to differences in maximum number of observations possible for different conditions.

★ $p < .05$, one-tailed.
* $p < .05$, two-tailed.
** $p < .01$, two-tailed.
*** $p < .001$, two-tailed.

low, 4.4% averaged across all conditions and all SOAs. Also, as in the 2,000-alone group, there were many more errors made to LCD words (7.4%) than to HCD words (1.2%). Thus, the error data will not be given further consideration.

A single analysis of variance was performed on only the data for the 250-, 400-, and 700-msec SOAs with SOA a between-subjects factor, and separate analyses of variance were conducted for the three different 2,000-mixed groups. In all analyses, CA was a between-subjects variable and category dominance and condition were within-subjects variables. When the data for the 250-, 400-, and 700-msec SOAs were analyzed, the SOA × Condition interaction was significant, $F(8, 360) = 3.41$, $MS_e = 7125$. When the data were analyzed separately for the three different 2,000-mixed groups, the SOA × Condition interaction was significant for Groups 250–2,000 and 400–2,000, $F(4, 120) = 15.63$, $MS_e = 7885$, and $F(4, 120) = 5.60$, $MS_e = 7208$, respectively, but, as noted earlier, it was not significant for Group 700–2,000, $F(4, 120) = 2.23$. In all analyses, the main effects of category dominance and CA were never significant nor did these two factors participate in any statistically significant interactions.[2]

Table 4 presents for each of the five conditions the t values for comparisons of the magnitudes of facilitation or inhibition obtained at the two long SOAs with the magnitudes of facilitation or inhibition obtained at each of the two short SOAs. Table 4 also presents, for each of the five conditions for the within-subjects comparisons involving the 2,000-msec SOA, the number of subjects who showed a facilitation or inhibition effect at the short SOA that was smaller than the facilitation or inhibition effect obtained at the 2,000-msec SOA. Of particular relevance are the differences between the shortest (250-msec) SOA and the two long SOAs. The main conclusion to be drawn from Table 4 is that, with the exception of Condition Nonshift-Expected-Related (BIRD–robin), at least one of the comparisons between the 250-msec SOA and the two longer SOAs was highly significant or approached statistical significance. Thus, these statistical analyses support the statements made above about the changes in the amount of facilitation or inhibition observed in a given condition as the SOA decreased from 700 or 2,000 msec to 250 msec. These analyses also support the con-

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[1] It should be noted that the fact that there was statistically less (i.e., 29 msec less) inhibition in Condition Shift-Unexpected-Related than in Condition Shift-Unexpected-Unrelated for the 2,000-msec SOA in the 2,000-mixed groups is problematic for the interpretation that automatic spreading activation has decayed within 700 msec in the 2,000-mixed groups. However, the decay of spreading-activation interpretation is supported by the fact that there was no statistical difference in the amounts of inhibition obtained for Conditions Shift-Unexpected-Related and Shift-Unexpected-Unrelated for the 2,000-msec SOA in the 2,000-alone group. Given the previously obtained evidence for a decay of spreading activation (Loftus, 1973; Warren, 1972; Meyer, Schvaneveldt, & Ruddy, Note 1) and the present study's supportive evidence in the form of statistically equivalent inhibition effects in Conditions Shift-Unexpected-Related and Shift-Unexpected-Unrelated at the 700-msec and 2,000-alone SOAs and in the form of a flat facilitation effect as a function of SOA in Condition Nonshift-Expected-Related, it would seem that the problematic finding of statistically less inhibition in Condition Shift-Unexpected-Related than in Condition Shift-Unexpected-Unrelated for the 2,000-msec SOA in the 2,000-mixed groups can be largely discounted, at least for present purposes. Nevertheless, future research should be conducted to help clarify this one minor deviation from the predicted pattern of results.

[2] There was one exception to this general conclusion. In Group 400–2,000, the Category Dominance × Condition interaction just barely met conventional standards for statistical significance, $F(4, 120) = 2.47$, $p = .05$. However, this interaction is of little interest because all of the means for the Expected conditions were facilitation effects and all of the means for the Unexpected conditions were inhibition effects for both HCD and LCD items. Furthermore, this interaction most certainly would not have been statistically significant had a more conservative analysis of variance been conducted with categories and items treated as random factors (cf. Clark, 1973). Categories and items were not treated as random factors in the present analyses because Clark's arguments for such a treatment are less compelling when each category and each item occurs in each condition of theoretical interest, as was the case in the present experiment.

Table 4
Results of t Tests Comparing Facilitation or Inhibition Scores for Each Word-Prime–Word-Target Condition at the 250-msec and 400-msec Stimulus Onset Asynchronies (SOAs) with Facilitation or Inhibition Scores at the 700-msec and 2,000-msec SOAs

Condition	Short SOA	Long SOA 700[a]	Long SOA 2,000[b]
NS-Ex-R	250		
	t	−1.11	−1.13
	n	—	14
	400		
	t	−1.84*	<1
	n	—	15
NS-Ux-U	250		
	t	4.36***	4.32***
	n	—	24**
	400		
	t	1.72*	1.27
	n	—	21
S-Ex-U	250		
	t	1.61**	1.50
	n	—	22*
	400		
	t	1.38	2.78**
	n	—	24**
S-Ux-U	250		
	t	2.63**	3.58**
	n	—	26**
	400		
	t	1.98*	2.46**
	n	—	21
S-Ux-R	250		
	t	3.94***	4.90***
	n	—	25**
	400		
	t	2.92**	3.19**
	n	—	23*

Note. Word-prime–word-target conditions = Nonshift-Expected-Related (NS-Ex-R), Nonshift-Unexpected-Unrelated (NS-Ux-U), Shift-Expected-Unrelated (S-Ex-U), Shift-Unexpected-Unrelated (S-Ux-U), and Shift-Unexpected-Related (S-Ux-R). n = number of subjects, out of 32, showing the effect. The t values are negative if the facilitation or inhibition effect obtained at the longer SOA was smaller than the facilitation or inhibition effect obtained at the shorter SOA.
[a] $df = 360$, between-subjects comparison.
[b] $df = 120$, within-subjects comparison.
* $p < .05$, one-tailed.
** $p < .06$, one-tailed.
* $p < .05$, two-tailed.
** $p < .01$, two-tailed.
*** $p < .001$, two-tailed.

clusion that the magnitude of the facilitation effect for the BIRD–robin trials did not vary with changes in SOA.[3]

In addition to the effects of SOA upon facilitation or inhibition within a condition, certain between-conditions comparisons at the various SOAs are of theoretical importance. The t values associated with these comparisons are presented in Table 5 along with the number of subjects, out of 32, showing the observed effect. As can be seen in Table 5, the t tests and the sign tests support the conclusions made above that (a) there was a difference in the magnitudes of the facilitation effects in Conditions Shift-Expected-Unrelated (BODY–door) and Nonshift-Expected-Related (BIRD–robin) at the two short SOAs but not at the 700-msec SOA; (b) the inhibition effects in Conditions Shift-Unexpected-Unrelated (BODY–sparrow) and Nonshift-Unexpected-Unrelated (BIRD–arm) were equivalent at all three SOAs; and (c) there was less inhibition in Condition Shift-Unexpected-Related (BODY–heart) than in Condition Shift-Unexpected-Unrelated (BODY–sparrow) at the 250- and 400-msec SOAs but not at the 700-msec SOA. In short, the statistical analyses support all five of the theoretically important conclusions drawn above.

RTs for XXX*-Prime–Word-Target Trials*

Although the major theoretical thrust of the data is provided by the facilitation and inhibition scores, a few passing comments need to be made about the RTs to the word targets when they followed the XXX primes. For all four groups, the 2,000-alone group and the three 2,000-mixed groups, the CA × Condition (X-a vs. X-b) interaction was significant: for the 2,000-alone group, $F(2, 21) = 5.27$, $p < .025$, and for the 2,000-

[3] Actually as can be seen in Table 4, there was some evidence that the facilitation effect in Condition Nonshift-Expected-Related was actually greater at the 400-msec SOA than at the 700-msec SOA ($p < .05$, one-tailed). Such an effect can be accounted for by assuming that the facilitation effect produced by automatic spreading activation is slightly greater than the facilitation effect produced by limited-capacity attention (viz., by assuming that + > * in Table 1).

Table 5
Results of t *Tests for Theoretically Critical Comparisons Between Word-Prime–Word-Target Conditions as a Function of Stimulus Onset Asynchrony (SOA)*

Comparison	SOA (in msec) 250	400	700
S-Ex-U vs. NS-Ex-R			
t	1.95*	2.45*	<1
n	23*	24**	15
S-Ux-U vs. NS-Ux-U			
t	1.29	<1	<1
n	13	19	17
S-Ux-R vs. S-Ux-U			
t	2.45*	2.41*	1.14
n	24**	22*	20

Note. Word-prime word-target conditions = Nonshift-Expected-Related (NS-Ex-R), Nonshift-Unexpected-Unrelated (NS-Ux-U), Shift-Expected-Unrelated (S-Ex-U), Shift-Unexpected-Unrelated (S-Ux-U), Shift-Unexpected-Related (S-Ux-R). *n* = number of subjects, out of 32, showing the effect.
* $p < .05$, one-tailed.
* $p < .05$, two-tailed.
** $p < .01$, two-tailed.

mixed groups, all three $Fs(1, 30) > 26.0$. These differences in the xxx-prime RTs as a function of CA group merely demonstrate that exemplars from certain semantic categories were more difficult to classify as words than were the exemplars from other semantic categories. Since such differences are necessarily taken into account in the computation of the facilitation and inhibition scores for the word-prime conditions, they are theoretically uninteresting. Category dominance was the only other variable that had a statistically significant effect on RTs to the word targets following the xxx prime: for the 2,000-alone group, $F(1, 21) = 127.50$, and for the three 2,000-mixed groups, all three $Fs(1, 30) > 130.0$. Averaged across all groups the mean RT for HCD words was 68 msec faster than the mean RT for LCD words. Since the effect of category dominance is most probably a word-frequency effect (e.g., Stanners, Jastrzembski, & Westbrook, 1975), it is not particularly relevant to the theoretical issues under consideration in this article.

Discussion of Word-Target Data

The word-target data confirmed all five of the major predictions derived from Posner and Snyder's (1975a) two-factor theory of attention and therefore offer striking support for that theory. In addition, the word-target data have two other interesting implications.

First, the present data help to clarify whether activation of a prime's logogen automatically spreads to semantically related logogens even when the subject is using that prime to direct his attention to semantically unrelated logogens. This issue was not adequately addressed by Posner and Snyder's (1975b) experiments. That is, although there was evidence in their experiments for automatic activation when the probability was low that a priming cue would appear in the target array, subjects said that they did not use the priming event to direct their attention to a logogen other than the one activated by the priming event. Rather, they tried to ignore the prime. Since facilitation was obtained in this condition, automatic activation apparently occurred without intention on the part of the subject. However, since subjects did not consciously use the prime to direct their attention to a different logogen, there was no evidence that the automatic activation of a logogen did indeed proceed normally even when the subject's attention was focused on a different logogen. In fact, in the animal-name classification experiment in which the subject was focusing his attention on the logogen for the priming word CAT when the target word *dog* was presented, there was no facilitation of the processing of the target word *dog* when it followed the semantically related priming word CAT. Instead, there was an inhibition of the processing of *dog* under such conditions. Since the SOA between the priming event and the target array was long enough (i.e., 500 msec) to allow the subject to focus his attention on the logogen for CAT before the target *dog* appeared, the subject would have needed to shift his attention from the "cat" logogen to the "dog" logogen before he could take advantage of the activation having spread to the "dog" logogen from the "cat" logogen. This required shift in attention could have consumed enough time to override the facilitatory effect of the automatic activation spreading from the "cat" logogen to the "dog" logogen. Consequently, the obtained net inhibition effect could have occurred despite the fact that automatic activation had indeed spread from the "cat" logogen to the "dog" logogen as predicted by the Posner–Snyder (1975a) theory.

The data from Condition Shift-Unexpected-Related (BODY–heart) in the present experiment supports this analysis of why Posner and Snyder (1975b) found an inhibition effect when CAT was the prime for a target array containing *dog* and there was a high probability that the priming word itself would appear in the target array. Since inhibition was obtained for BODY–heart trials at the 700-msec SOA and facilitation was obtained for BODY–heart trials at the 250-msec SOA, if Posner and Snyder (1975b) had used a shorter SOA, presumably they too would have obtained a facilitation effect rather than the inhibition effect they obtained with their 500-msec SOA.

A second implication of the present data concerns the rates at which facilitation and inhibition build up *within* the conscious-attention mechanism. Posner and Snyder (1975a) and other theorists have not addressed this issue explicitly, probably because there are no relevant data, since previous experiments have confounded automatic-activation and conscious-attention facilitation effects. In the present experiment, these two effects were unconfounded, and data from Conditions Shift-Unexpected-Unrelated (BODY–sparrow) and Shift-Expected-Related (BODY–door) indicated that conscious-attention inhibition built up faster than conscious-attention facilitation. This conclusion is based on the observation that at the 400-msec SOA there was a substantial and statistically significant 31-msec inhibition effect for BODY–sparrow trials but only a small and nonsignificant 8-msec facilitation effect for BODY–door trials. Of course, these results may merely reflect a failure to detect a facilitation effect for BODY–door trials at the 400-msec SOA, but if future research should further substantiate this asymmetry in the buildup of conscious-attention facilitation and conscious-attention inhibition, it would be theoretically quite important.

One way in which this asymmetry is important vis à vis the Posner–Snyder (1975a) theory is that it demonstrates that when a prime produces both inhibition and facilitation effects, the inhibition effects do not necessarily build up more slowly than do the facilitation effects. One could therefore conclude with a greater degree of certainty that in the Posner and Snyder (1975b) experiments, facilitation preceded inhibition only because the facilitation was being produced by the fast automatic-activation process, whereas the inhibition was being produced by the slower acting conscious-attention mechanism, and not because facilitation effects in general always precede inhibition effects.

Another theoretical implication of the finding that conscious-attention facilitation builds up more slowly than conscious-attention inhibition is that the conscious-attention facilitation is being produced by activation spreading from the logogen upon which attention is being focused—once attention has been shifted to that logogen. That is, conscious-attention inhibition is being produced *during the time* that attention is being shifted to a logogen that was not automatically activated by the word prime, whereas conscious-attention facilitation is being produced by activation spreading from that logogen—but only *after* attention has been fully shifted to that logogen.

Facilitation and Inhibition for Word-Prime–Nonword-Target Trials

The data for correct responses to the nonword targets for the various conditions and SOAs are given in Tables 6 and 7 in the same format as were the word-target

Table 6
Reaction Times (RTs) (in msec) and Error Percentages to Nonword Targets in Terms of Mean Facilitation (+) or Inhibition (−) Scores for Word-Prime Conditions and of Mean RTs and Error Percentages for XXX-Prime Conditions for the 2,000-msec Stimulus Onset Asynchrony

	Condition			
	Word prime		xxx prime	
Group	Shift	Nonshift	Shift	Nonshift
2,000-alone				
RT	+19**	+21**	852	851
SE_M	6.0	6.6	—	—
n	19*	16	—	—
% errors	−.3	−.7	2.0	2.1
N	1,107	557	1,102	547
250–2,000				
RT	+23**	+18	904	891
SE_M	7.2	11.2	—	—
n[a]	22*	17	—	—
% errors	−.5	−2.4	2.3	1.9
N	723	358	726	358
400–2,000				
RT	+21**	+8	873	868
SE_M	6.1	9.7	—	—
n[a]	22*	22*	—	—
% errors	−.6	.0	1.9	1.4
N	722	366	730	367
700–2,000				
RT	+14*	+6	870	866
SE_M	5.8	12.3	—	—
n[a]	20	17	—	—
% errors	+.4	+1.6	1.8	2.9
N	739	369	738	365

Note. Facilitation (+) and inhibition (−) scores were derived by subtracting word-prime RTs (error percentages) from corresponding xxx-prime RTs (error percentages). n = number of subjects, out of 24, showing the effect. N = total number of correct-response observations remaining after exclusion of errors and shutter-failure trials. Variations in N greater than 30 are due to differences in maximum number of observations possible for different conditions.
[a] Number of subjects, out of 32, showing the facilitation or inhibition effect.
* $p < .05$, one-tailed.
* $p < .05$, two-tailed.
** $p < .01$, two-tailed.

data in Tables 2 and 3. A discussion of the theoretical implications of the facilitation or inhibition scores for the word-prime–nonword-target conditions will be deferred until after these data have been described.

Group 2,000-alone. As can be seen in Table 6, a relatively large and statistically significant facilitation effect of nearly 20 msec was obtained at the 2,000-alone SOA when a nonword target followed a word prime, with the magnitude of the facilitation effects for the Shift and Nonshift conditions differing by less than 3 msec. Since error rates for the nonword targets were even lower than they were for the word targets (i.e., only 2.3% averaged across all conditions, with a 1.9% error rate for HCD nonwords and a 2.7% error rate for LCD nonwords), they are of little interest.

An analysis of variance, with CA as a between-subjects factor and category dominance and condition as within-subjects factors, was conducted on the facilitation scores for the word-prime conditions. The results of this analysis indicated that the size of the facilitation effect was not affected by any of these factors nor by their various combinations.

Groups 2,000-mixed. As was the case for the word-target data for the 2,000-mixed groups, the effects in the word-prime conditions at the 2,000-msec SOA were not different for the nonword targets in Groups 250–2,000, 400–2,000, and 700–2,000 ($F < 1$). As with the 2,000-alone SOA, a facilitation effect was obtained for both word-prime conditions. However, this facilitation effect was statistically significant only for the Shift conditions ($p < .05$), with 64 of the 96 subjects showing the effect.

As can be seen in Table 7, for the shorter SOAs the pattern of data was relatively inconsistent, with both facilitation and inhibition effects being obtained for each of the two word-prime conditions but at different SOAs. Only one of these effects was statistically significant—the facilitation effect in Condition Nonshift at the 400-msec SOA ($p < .05$)—but only 19 of the 32 subjects showed the effect. Error rates were too low to be informative—2.6% overall, 1.9%

for HCD nonwords, and 3.2% for LCD nonwords.

For each of the three 2,000-mixed groups, a separate analysis of variance was performed for the word-prime RT data with CA as a between-subjects factor and category dominance, condition, and SOA as within-subjects factors. The only effect associated with a p value less than .05 was SOA in Group 250–2,000, $F(1, 30) = 5.54$, $MS_e = 5742$. Averaged across the Shift and Nonshift conditions, there was a 2-msec inhibition effect at the 250-msec SOA and a 21-msec facilitation effect at the 2,000-msec SOA. The results of these analyses permit one conclusion pertinent to the theoretical issues under consideration here: Although SOA had no *consistent* effect on the facilitation effects obtained in the word-prime–nonword-target conditions, these facilitation effects were larger at the 2,000-msec SOA than at the 250-msec SOA.

RTs for xxx-*Prime–Nonword-Target Trials*

Although the data of primary concern for the nonword targets are the facilitation and inhibition effects produced by the word primes, one comment needs to be made regarding the RTs to the nonword targets following the xxx prime. For all four groups, the only effect to reach conventional levels of statistical significance was the effect of category dominance: for the 2,000-alone group, $F(1, 21) = 10.31$, and for the three 2,000-mixed groups, all three $F\text{s}(1, 30) > 22.0$. Since the category-dominance effect for the nonword targets following the xxx prime replicates the category-dominance effect for the word targets following the xxx prime, part of the category-dominance effect for the word targets may have been produced by structural differences that were confounded with category dominance. However, since the category-dominance effect was much larger for the word targets (68 msec) than for the nonword targets (18 msec), it may be that frequency per se was operating in conjunction with structural properties to produce the category-dominance effect for the word targets. It should also be noted in this regard that Stanners et al. (1975) have obtained frequency effects for words and nonwords similar to the ones obtained here.

Discussion of Nonword-Target Data

Since the principal finding for the word-prime–nonword-target trials was that the

Table 7
Reaction Times (RTs) (in msec) and Error Percentages to Nonword Targets in Terms of Mean Facilitation (+) or Inhibition (−) Scores for Word-Prime Conditions and of Mean RTs and Error Percentages for xxx-*Prime Conditions for the Short Stimulus Onset Asynchronies (SOAs) in the 2,000-mixed Groups*

	Condition			
	Word prime		xxx prime	
SOA	Shift	Non-shift	Shift	Non-shift
250 msec				
RT	+1	−4	896	891
SE_M	5.7	10.6	—	—
n	20	16	—	—
% errors	−1.2	−1.4	3.4	3.2
N	715	351	722	356
400 msec				
RT	+12	+20*	870	857
SE_M	7.8	10.2	—	—
n	19	19	—	—
% errors	+.4	−1.3	3.8	2.4
N	724	362	722	362
700 msec				
RT	−13	+14	856	857
SE_M	8.8	9.1	—	—
n	20	19	—	—
% errors	+.5	.0	2.4	1.8
N	725	373	735	367

Note. Facilitation (+) and inhibition (−) scores were derived by subtracting word-prime RTs (error percentages) from corresponding xxx-prime RTs (error percentages). n = number of subjects, out of 32, showing the effect. N = total number of correct-response observations remaining after exclusion of errors and shutter-failure trials. Variations in N greater than 30 are due to differences in maximum number of observations possible for different conditions.
* $p < .05$, two-tailed.

word primes facilitated nonword decisions at the 2,000-msec SOA but not at the 250-msec SOA, the crucial theoretical issue is how to accommodate the word primes' facilitatory effect on nonword decisions. In the absence of compelling data forcing the conclusion that the word primes affect the word and nonword RTs by totally independent mechanisms, it would seem more parsimonious to assume that the word primes influence the word and nonword RTs via the operation of similar mechanisms. Within the framework of the Posner–Snyder (1975a) theory, the word prime should affect nonword RTs through the operation of the limited-capacity attentional mechanism but not through the operation of the automatic spreading-activation process. Since the word-target inhibition produced by the word prime is in some sense a "pure" measure of the operation of the limited-capacity attentional mechanism (see Table 1), it would seem that the best strategy for incorporating the nonword facilitation effect into the Posner–Snyder (1975a) theory would be to consider some alternative explanations of how the limited-capacity attentional mechanism might produce inhibition for the word-prime–word-target trials, and then see how these alternative explanations fare with the nonword-target data. When such a strategy is adopted, the nonword-target data become quite important theoretically in that they discriminate among alternative explanations of how the limited-capacity attentional mechanism operates to produce inhibition in the two Unexpected-Unrelated word-prime–word-target conditions BIRD–arm and BODY–sparrow.

As noted in the introduction of this article, one interpretation of the word-prime–word-target inhibition effect is that the word prime depletes the limited resources of attention that must be used to "read out", from the target word's logogen, the information necessary for making the lexical decision. This limited-resources interpretation of the word-prime–word-target inhibition effect corresponds rather closely to the general views of Posner and Snyder (1975a). In the present experiment, when the word prime was a Shift BODY prime, the limited resources of attention would have been depleted by the acts of retrieving the unautomated BODY–"building" association and consciously maintaining the activation in the "building" logogen so that the activation spreading from that logogen would not decay during the 2,000-msec SOA; when the word prime was the Nonshift BIRD prime, the limited resources of attention would have been depleted by the subject's consciously maintaining activation in the "bird" logogen. However, when XXX was the prime, the subject presumably would not have initiated nor maintained activation at a particular logogen, and therefore the XXX prime would not have depleted the limited resources of attention. Thus, according to this view, RTs to word targets were slower following the word primes than following the XXX prime because following the word primes there was less attentional capacity remaining to read out, from the word-target logogen, the information necessary for making the lexical decision.

What does this limited-resources view predict for the nonword targets? It predicts that the word primes should produce an *inhibition* effect for RTs to nonword targets. If the nonword response is made after all word logogens have been searched without finding a lexical entry corresponding to the target letter string (cf. Forster & Bednall, 1976), the search should take longer to complete following the word primes than following the XXX prime because of the word primes' greater depletion of the limited attentional resources needed to conduct the search. The limited-resources view also predicts an inhibition effect for word-prime–nonword-target trials even if the nonword response is based on some process other than an unsuccessful exhaustive search of the word logogens. For example, some researchers (James, 1975; Meyer & Schvaneveldt, 1971; Taft & Forster, 1975) have argued that both words and pronounceable nonwords have logogens or "lexical entries" stored in long-term memory. Since pronounceable nonwords also have lexical entries, when pronounceable nonwords are used as distractors, finding a lexical entry for the target letter string does not provide sufficient information for making a "word" response. Consequently James (1975) has argued that under such circumstances the subject must "look up the meaning" of the letter string in order to make the lexical decision. But even if this meaning-look-up view of the lexical decision process is correct, RTs to nonword targets should still be inhibited by the word primes because they would have depleted some of the limited resources necessary for a meaning look-up. Therefore, regardless of whether a "nonword" response is based on an unsuccessful search or a failure to find a meaning in a meaning-look-up stage of processing, the limited-resources interpretation of the word-prime–word-target inhibition effect predicts that there should also be an inhibition effect on word-prime–nonword-target trials. Obviously, this prediction of the limited-resources view was contravened by the facilitation effect that actually obtained on word-prime–nonword-target trials.

It also should be noted that, according to this limited-resources view, the limited-capacity attentional mechanism produces facilitation on word-target trials through the initiation and/or maintenance of spreading activation (cf. Collins & Loftus, 1975). This view was discussed earlier in this article—in the introduction, and in the discussion of the different rates at which conscious-attention facilitation and conscious-attention inhibition appeared to build up in the present experiment. The fact that the facilitation effect for the nonword targets tends to rule out this particular limited-resources interpretation of the inhibition effect for the Unexpected-Unrelated word-target conditions does not necessarily compel one to abandon the view that the conscious-attention mechanism produces facilitation through the initiation and/or maintenance of spreading activation; one could argue that conscious attention produces facilitation and inhibition through two different mechanisms. However, such an argument is unparsimonious and should not be accepted in the absence of compelling evidence for it. Although the apparent difference in the rates of the buildup of the conscious-attention facilitation and conscious-attention inhibition obtained in the present experiment is suggestive of conscious-attention facilitation and conscious-attention inhibition being produced by different mechanisms, it is not compelling evidence for their being produced by different mechanisms (see earlier discussion). Thus, at present, it is necessary to conclude, for the sake of parsimony, that the conscious-attention facilitation obtained in the present experiment was not produced by the limited-capacity attentional mechanism's initiating and/or maintaining spreading activation in the logogen on which attention was being focused. However, future research should be conducted in order to decide this issue more conclusively. In the same vein, an additional point should be made before examining two other explanations (i.e., the order-of-search and semantic-matching explanations) of the inhibition effect in the Unexpected-Unrelated word-target conditions. The point is that both of these explanations can account for conscious-attention facilitation and conscious-attention inhibition by appealing to only a single underlying mechanism. Thus, they both meet the criterion of parsimony discussed in this paragraph.

According to order-of-search interpretation of the word-prime–word-target inhibition effect, the subject uses the word prime and limited-capacity attention to determine the order in which the three semantic categories employed in the experiment will be searched. When the XXX prime is presented the subject focuses attention on a category that has been randomly selected from among the three categories, and by chance this randomly selected category will be the category containing the word target on one third of the trials. However, when the word-prime is presented and the subject has been given enough time to focus his attention on the category that is cued by that word prime, in the two Unexpected-Unrelated conditions his or her attention will always be focused on a category that does not contain the word target. Consequently, an inhibition effect will be obtained for the word targets in the two Unexpected-Unrelated conditions because the subject will have always searched through the wrong category before searching the category containing the target word, and a conscious-attention facilitation effect will be obtained for the word targets in the two Expected conditions because the subject will always be searching the correct category first.

What does this order-of-search mechanism predict for the nonword targets? If one assumes that a nonword response is based on an unsuccessful exhaustive search of the word logogens, there should be *no difference* in RTs to nonword targets following the word primes and the xxx prime because following both, the subject will have exhaustively searched all three categories, with the only difference between the word-prime and xxx-prime trials being the order in which the categories were searched. Thus, the facilitation effect that obtained in the present experiment for the word-prime–nonword-target trials is problematic for the view that the word prime determined the order in which the categories were searched.

Since both the limited-resources and the order-of-search accounts of the conscious-attention inhibition effect (and the conscious-attention facilitation effect) failed to accommodate the word primes' facilitatory effect upon RTs to the nonword targets, what is required is an alternative conceptualization of the mechanism by which limited-capacity attention produces the word-prime word-target inhibition effect. A clue to what this mechanism might be is provided by the observation that the present word-prime–nonword-target facilitation effect corresponds to the negative-response results obtained by Posner and Snyder (1975b) and Neely (1976). Recall that in these previous experiments, negative-response RTs were faster following the letter prime or the word prime than following the neutral prime. Both Posner and Snyder (1975b) and Neely (1976) attributed this result to the subjects' using limited-capacity attention to match the prime (or an item internally generated to the prime) with the target and then tending to respond "yes" or "word" when there was a match and "no" or "nonword" when there was a mismatch. In an attempt to minimize the likelihood that the subject would adopt such a matching strategy in the present experiment, the word primes were chosen so as to cue the subjects to expect words chosen from very large categories. Presumably, it would be very unlikely that the subject could generate all of the exemplars of these large semantic categories and then respond on the basis of whether the target matched or mismatched with these internally generated exemplars.

Nevertheless, the subjects could have adopted some sort of semantic-matching strategy (cf. Collins & Loftus, 1975; Smith, Shoben, & Rips, 1974). According to this semantic-matching hypothesis, the subject has a tendency to respond on the basis of the similarity between the semantic features of the expectancy generated, via conscious attention, to the word prime and the semantic features activated by the target letter string. If the semantic features of the expectancy generated to the word prime and the semantic features activated by the target letter string are quite similar, the subject would have a tendency to respond "word", thus facilitating, via conscious attention, "word" responses in the Expected condition; if they are dissimilar, the subject would have a tendency to respond "nonword", thus facilitating "nonword" responses to nonword targets and inhibiting "word" responses to word targets in the Unexpected conditions.

Although the subjects in the present experiment were explicitly instructed *not* to adopt such a semantic-matching strategy (see last paragraph of Procedure section), the structure of the experiment was such that it would have been beneficial for them to have violated this proscription. That is, since a word target was a member of an unexpected category on only one third of the word-prime–word-target trials and since a word target followed a word prime on only one half of the word-prime trials, the subjects could have responded on the basis of whether the semantic features of the expectancy generated to the priming word were similar to the semantic features activated by the target letter string; in doing so, they would have been correct and would have benefited on five sixths of the word-prime trials. Thus, given the design of the present experiment, the semantic-match explanation of the inhibition effect for the word-prime–word-target trials in the Unexpected conditions and the facilitation effect for the word-prime–nonword-target trials seems to be a reasonable one. Furthermore, the fact that the facilitation effect for the nonword targets was greatest at the 2,000-msec SOA suggests that the facilitation effect for the nonword targets depended on the commitment of slow-acting conscious attention.

Unfortunately, the issue of whether the inhibition effect obtained for the Unexpected word-target conditions can be *solely* attributed to the operation of a semantic-matching strategy remains open because a substantial inhibition effect of 56 msec was obtained in Condition Shift-Unexpected-Unrelated at the 700-msec SOA, at which there was no evidence that the subject was using a semantic-matching strategy to facilitate his nonword responses in the Shift nonword-target condition. In fact, at the 700-msec SOA for the nonword responses in the Shift nonword-target condition, there was a 13-msec inhibition effect—an effect that, though statistically nonsignificant, certainly did not provide evidence for the operation of a semantic-matching strategy. Thus, at the 700-msec SOA, an inhibition effect occurred in Condition Shift-Unexpected-Unrelated even though in the Shift nonword-target condition there was no evidence for the concurrent involvement of a semantic-matching strategy. Despite this counterevidence at the 700-msec SOA, the overall pattern of data seems to indicate that the facilitation effect for the nonword targets and the inhibition effects for the word targets in the Unexpected conditions can be attributed to a semantic-matching strategy. Of course, there may be alternative explanations that can account for the word-prime–word-target inhibition effect and the word-prime–nonword-target facilitation effect by appealing to the operation of only a single mechanism or of separate mechanisms, but one advantage of the present appeal to the semantic-matching strategy is that this strategy has also been shown to be useful in explaining a broad range of data obtained in other experiments involving speeded retrieval of information from semantic memory (cf. Collins & Loftus, 1975; Smith et al., 1974).

General Discussion

A general, model-free implication of the present experiment is that a priming event can produce two distinctly different types of facilitation effects in the processing of subsequent words. One kind of facilitation effect occurred rather quickly following the prime's presentation. It was not accompanied by an inhibition in the processing of a target word semantically unrelated to the target word whose processing was facilitated, and it depended on the prime and target being semantically related. The second kind of facilitation effect occurred at a later time following the prime's presentation. It was always accompanied by an inhibition in the processing of a target word semantically unrelated to the target word whose processing was facilitated, and it did not depend on the semantic relationship between the prime and the target but rather depended on the probability with which a particular class of words followed a particular priming event within the experimental situation. Thus, these two distinct facilitation effects can be taken as support for Tulving's (1972) distinction between semantic and episodic processes and as support for the general class of theories described in the introduction of this article. However, given the LaBerge (1973a, 1975), Schneider & Shiffrin (1977), and Shiffrin & Schneider (1977) results that an attention-demanding operation can become automated with extended training, if much more training had been given in the present paradigm, the facilitation effect in Condition Shift-Expected-Unrelated presumably would have become automated and would have occurred sooner after the presentation of the prime and without a concomitant inhibition effect in Condition Shift-Unexpected-Unrelated. Nevertheless, the important point is that some brand of two-factor theory is demanded by the present data, which were collected in the early stages of training.

A second general implication of the present research is that a priming stimulus can produce a facilitation in the subsequent processing of more than just itself (e.g., Posner & Snyder, 1975b) or a few highly related primary associates (e.g., Meyer & Schvaneveldt, 1971; Neely, 1976). Although other previous research has demonstrated that there is an overlap in the activation patterns produced by a category name and its exemplars, most of this previous research either has used only a few category exemplars, all having high category dominance (e.g., Warren, 1972), or has involved a task in which the subject was required to decide whether the target stimulus was a member of a particular semantic category (e.g., Rosch, 1975). The present experiment is different from this previous research because it employed several exemplars of low category dominance in a task in which subjects were to decide whether the target letter string was a word or a (pronounceable) nonword, a task that should have required a meaning look-up (cf. James, 1975) but that should not have *necessarily* required that the subject classify the stimulus on the basis of its membership in a particular semantic category. Consequently, the present experiment demonstrates that a category-name prime will facilitate the subsequent processing of its good and poor exemplars to the same degree, even when they are targets in a task in which the subject is not logically required to access information on category membership.

This finding extends the generality of a result obtained by Rosch (1975). She too found that a category-name prime facilitated the processing of its good and poor exemplars to the same degree, but she used a task in which subjects were to decide whether two nonidentical target words were both members of the same semantic category. However, she also found that when the two target words were identical, a category-name prime facilitated the processing of its good exemplars and inhibited the processing of its poor exemplars at SOAs greater than 400 msec, with the inhibition effect occurring when the subjects were making a category-membership decision but not when they were making a physical-identity decision. A general conclusion that can be drawn from Rosch's results is that a category-name prime will produce an equal degree of facilitation in the subsequent processing of its good and poor exemplars whenever the subject is making some sort of semantic decision and cannot respond on the basis of physical identity. The present results are in accord with that general conclusion, but such a conclusion raises the following question: In what sense is the automatic activation *spreading* if both high- and low-category-dominance items are facilitated to an equal degree? Given the available data, it is difficult to answer this question adequately. However, one possibility is that if much shorter SOAs had been used, one would have found that high-category-dominance items are facilitated earlier following the presentation of the category-name prime than are the low-category-dominance items.

Another general implication of the present research relates to how a consciously generated expectancy can be used to modulate performance in a binary classification task. On the basis of the word primes' facilitating nonword responses, it can be argued that subjects were adopting a semantic-matching strategy in which they matched the semantic features included in the expectancies they generated to the word prime with the semantic features activated by the target, even though they were explicitly told to avoid this strategy. The fact that subjects apparently utilized such a strategy in the present lexical-decision paradigm indicates that such a matching strategy is not restricted to situations in which the prime and the target are physically identical (e.g., Posner & Snyder, 1975b) nor to tasks in which the subjects must retrieve relatively specific semantic information about a word (e.g., Collins & Loftus, 1975; Smith et al., 1974). Thus, it seems that conscious expectancies may influence performance via some sort of general matching process, with the features on which the match is based being determined by the particular stimulus materials used.

Finally, the present data have implications for methodologies that have been used to study structure in semantic memory. One such commonly used methodology is the free-classification task, in which subjects sort words into piles according to similarity in their meanings. For example, Miller (1972) has used such a procedure to determine the underlying semantic structure for verbs of motion. On the basis of these free-classification results, Miller concluded that these verbs are categorized according to relatively subtle (at least in this author's view) semantic features such as velocity, direction, and medium of the motion. However, given that the subjects were allowed a virtually unlimited amount of time and were forced to use some sort of categorization schema, it does not necessarily follow that the verbs that were placed in the same category in such an experiment would automatically facilitate one another in a short-SOA priming paradigm similar to the one used in the present experiment. That is, although free-classification and similarity-rating paradigms provide information about semantic components that a subject can utilize when given certain task demands and enough time to make conscious comparisons and inferences, they may not provide information about semantic structures connected by automated associative links. Of course, the present paradigm can be used to provide information about such automated associative links. If two items mutually facilitate the processing of each other without at the same time inhibiting the processing of other items, these two items can be considered to be linked by a well-established automated link in semantic memory. If, on the other hand, two items mutually facilitate the processing of each other only if they inhibit the processing of other items, the facilitation may be considered to be the result of a conscious inference and not the result of those two items' being connected by an automated associative link in semantic memory.

Conclusion

The purpose of the foregoing general discussion has been to delineate the model-free implications of the present research. The main import of the data reported here is that they seem to demand a theory that postulates at least two independent processes. They also have implications for the manner in which conscious expectancies develop and for how people use expectancies to modulate their performance in a binary classification task. And finally, the present results have methodological implications for the study of the organization and structure of semantic memory. But equally as important as these general implications is the fact that the present data provide strong support for a specific theory of attention that has been advanced by Posner and Snyder (1975a). When one allows for a semantic-matching strategy, the data conform almost perfectly to their theory. Thus, for the time being, the concepts of automatic spreading activation and limited-capacity conscious attention seem firmly enough rooted in a broad enough data base that they should serve as a useful point of departure for future research and theory construction.

Reference Note

1. Meyer, D. E., Schvaneveldt, R. W., & Ruddy, M. G. *Activation of lexical memory.* Paper presented at the meeting of the Psychonomic Society, St. Louis, November 1972.

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