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The locus of post-lexical semantic matching effects on semantic priming: biasing a binary response or a binary decision?

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The locus of post-lexical semantic matching effects on semantic priming: Biasing a binary response or a binary decision?

by

Bart Aaron VanVoorhis

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OVERVIEW

Research on the recognition of individual words focuses on those factors that affect the latency or accuracy of recognition. One of these factors is semantic priming. Semantic priming is defined as facilitation in responses to word targets that follow related prime words as compared to responses to word targets that follow unrelated primes (Neely, 1991). The prime word determines the semantic context in which target presentation occurs. Semantic priming research is aimed at investigating how various cognitive processes leading to word recognition are affected by semantic context. Current theories of word recognition, (e.g., Besner, 1990; Seidenberg & McClelland, 1989), and of semantic priming (e.g., Ratcliff & McKoon, 1988; Neely & Keefe, 1989), however, differ in terms of how semantic context is involved. The current research will directly address these different theoretical positions. A better understanding of processes of word recognition is not only of theoretical importance, but of educational importance as well. Word recognition is closely related to reading and comprehension. Understanding the processes of word recognition may have implications in education for the development of reading and comprehension skills.

Two tasks have been used almost exclusively in investigations of semantic priming: lexical decision and
pronunciation. In a lexical-decision task, participants are required to indicate whether a target stimulus is a word or not. In pronunciation, participants pronounce the target. In both tasks, target presentation follows presentation of either a related or an unrelated prime word. In using lexical decision and pronunciation to investigate semantic priming, investigators typically have found differing patterns of priming between these two tasks (e.g., Balota & Lorch, 1986; Seidenberg, Sanders, Waters, & Langer, 1984). That is, under the same conditions, the two tasks do not show equal contextual facilitation of responses to targets. Proponents of each task have suggested that problems exist in using the other task to measure the operation of various theoretical mechanisms that are supposed to produce priming. A resolution to the controversy is important if a more complete understanding of the processes of word recognition is to be developed.

The current research was specifically designed to investigate one of the questions raised in the controversy. At issue is the operation of one theoretical priming mechanism, semantic matching. To help develop the logic of the investigation, semantic priming as a measure will be discussed in depth, followed by a description of the tasks used to investigate semantic priming. Following that will be discussions of theoretical explanations of priming,
dissociative priming effects between tasks, an assessment of each task, and finally, a description of the current research will be offered.
LITERATURE REVIEW

Semantic Priming

The Phenomenon

The paradigm for measuring semantic priming that is of interest in the current research is the single-word priming paradigm. In the single-word priming paradigm, stimuli are presented sequentially. The first stimulus, or prime, determines the semantic context in which the second stimulus, or target, is presented (Neely, 1991). Participants can be asked to respond to the prime, to the target, or to both. The current research focused on responses to the target.

Responses to targets in the single-word priming paradigm are influenced by semantic context in such a way that responses to word targets are faster and/or more accurate when the targets are preceded by associatively related primes than when they are preceded by unrelated primes (see Neely, 1991, for a review). For example, the response to nurse will be faster and/or more accurate if nurse is preceded by doctor than if it is preceded by table.

Latency priming, the effect of a related context on target response latency, is assessed by subtracting response latencies to word targets following related primes from response latencies to word targets following unrelated primes. Accuracy priming, the effect of a related context on target response accuracy, is assessed by subtracting percentage
errors in responses to word targets following related primes from percentage errors in responses to word targets following unrelated primes.

Types of Priming

Although any word-response facilitation is referred to as semantic priming, additional descriptors can be added to indicate the direction and/or the directness of the associative relationship between the prime and the target. The current research relies on distinctions among forward, mediated, and backward semantic priming.

Forward semantic priming refers to target response facilitation when the prime and target are directly related in the forward direction (i.e., from the target to the prime) in such a way that presentation of the prime is likely to make someone think of the target. The relationship between the prime bell and the target hop, for example, is direct and forward. Bell and hop are directly related to each other and bell is associated with hop in the forward direction only.¹

If the relationship between the prime and the target is forward, but the prime and target are only indirectly related,

¹The associative relationship between doctor and nurse is direct and bidirectional. That is, doctor and nurse are directly related to each other and the relationship can either be from doctor to nurse or from nurse to doctor. Although the example given is forward only, in the literature, bidirectional associations are frequently used to measure forward priming. Both forward only and bidirectional relationships were used in the current research.
the resulting target response facilitation is known as **mediated** semantic priming. The prime lion and the target stripes, for example, are not directly related, but both are related to the mediating concept tiger. In this particular example, the association goes from the prime lion, through the mediating concept tiger, to the target stripes.

Facilitation of target responses when the prime and target are directly related, but when the direction of the relationship is only from the target to the prime, is known as **backward** semantic priming. With the target bed and the prime pan, for example, it can be seen that pan is not associated with bed in the forward direction, but bed is associated with pan in the backward direction.

**The Lexical Decision and Pronunciation Tasks**

The single-word priming paradigm has been used extensively as a tool to investigate forward, mediated, and backward priming effects (Neely, 1991). These investigations have used two tasks almost exclusively: lexical decision (e.g., Balota & Lorch, 1986; de Groot, 1983; Meyer & Schvaneveldt, 1971; Seidenberg et al., 1984) and pronunciation (e.g., Meyer, Schvaneveldt, & Ruddy, 1975; de Groot, 1985).

In the pronunciation task, participants are asked to pronounce or name the target aloud. In the lexical-decision task, participants are required to make a word/nonword decision to a string of letters (the target). Responses are
typically indicated by the pressing of one of two keys, one indicating a word response (or "yes" the target is a word), and the other indicating a nonword response (or "no" the target is not a word). Nonwords usually consist of pronounceable letter strings formed by changing one or two letters of a common English word. For example, pliff is created by replacing the "c" in cliff with a "p".

Differences in target response facilitation measured with lexical decision and pronunciation tasks that depend on the directness and direction of the relationship between the prime and the target have been identified (e.g., Balota & Lorch, 1986; de Groot, 1983, 1985; Seidenberg et al., 1984). In other words, type of task (lexical decision or pronunciation) interacts with the type of associative relationship between the prime and the target (forward, mediated, or backward). Following a discussion of theoretical mechanisms proposed to explain forward priming, the ability of each mechanism to explain these task dissociations will be assessed.

Theoretical Explanations of Priming

Accounts of semantic priming effects have relied primarily on three general theoretical mechanisms (Neely, 1991): automatic spreading activation, expectancy, and post-lexical mechanisms. Each mechanism will be discussed separately.
Automatic spreading activation. Many explanations of semantic priming have relied on the concept of automatic spreading activation (e.g., Neely, 1977; McNamara, 1992; Posner & Snyder, 1975). A spreading activation explanation of semantic priming assumes that representations of semantically or associatively related concepts are stored "close together" in memory (Anderson, 1976; Collins & Quillian, 1969; Collins & Loftus, 1975). These representations are referred to as nodes. When a prime word is presented, the node representing that word in the memory system becomes activated. Used in this sense, activation roughly corresponds to an item's node being activated from long-term memory into short-term memory (Shiffrin & Schneider, 1977). Once the level of activation at a node exceeds a recognition threshold, the participant becomes aware of the item's identity. In other words, a node could become activated by a very brief presentation of a word, but the level of activation may not be high enough for the person to consciously recognize the word. Automatic spreading activation is assumed to operate even under these circumstances.

Nodes representing concepts in memory are connected to other nodes via associative "links". Once a node has become activated, the activation begins to spread rapidly and automatically along the associative links to other nodes representing closely related concepts. The spread is
automatic because it reflects the structure of memory; it does not depend on any special type of intentional processing. Once a prime word's node is activated, activation spreads across links to the nodes of semantically related words, which then become activated. If the stimulus onset asynchrony (SOA), or the time between the onset of the prime and the onset of the target, is long enough, nodes of concepts related to the prime may become activated before the target is presented. Therefore, when the target is related to the prime, it is likely that the node representing the target already has been activated from the spread of activation from the related prime. This preactivation occurs before the target is ever presented and it reduces the length of time after target onset that is needed for the activation level of the target node to meet or exceed its recognition threshold. The result is faster response times for targets related to the prime, as compared to response times for targets unrelated to the prime.

In summary, automatic spreading activation (1) does not require intention (2) does not require awareness of the prime, (3) occurs rapidly, and (4) facilitates the processing of targets semantically related to the prime. Note that the direction of spreading activation is forward, or from the prime to the target.
Expectancy. Priming effects have also been attributed to expectancy (e.g., Becker, 1980, 1985; Becker & Killion, 1977; Posner & Snyder, 1975). Expectancy accounts for general semantic priming effects by assuming that participants use the prime word to generate a set of potential targets that are semantically related to the prime. This set of potential targets is called the expectancy set and it can be generated before the target is presented if the prime-target SOA is sufficiently long. When the target is presented, participants also begin to create a set of words that are visually similar to the target, called the visually-defined set. As the visually-defined set is being generated, participants begin to search through the expectancy set for a visual match to the target. If a match is found in the expectancy set, the word is recognized and the appropriate response is executed. If a match is not found in the expectancy set, the visually-defined set is then searched to determine if any of the letters of the words in the visually-defined set completely match the letters of the target word. This spelling-check continues until a match is found or the set is exhausted. A response is made depending on the outcome of the search.

Because an expectancy set contains words semantically related to the prime, related targets are more likely to be included in the expectancy set than unrelated targets. Consequently, it is also likely that related targets can be
recognized and responded to after a search of only the expectancy set. Because unrelated targets are not likely to be contained in the expectancy set, responses to these targets have to await completion of a search through the visually-defined set. Thus, unrelated targets are responded to more slowly than related targets.

Expectancy is a mechanism under the participant's strategic control; it cannot occur without intention or without awareness of the prime. As such, the operation of expectancy is affected by the usefulness of the context in predicting the target. If many prime-target pairs are related, then expectancy will be useful in identifying the target. If few prime-target pairs are related, then expectancy will not be useful.

In summary, unlike automatic spreading activation, expectancy (1) does not operate without intention (2) does not operate without awareness of the prime, (3) occurs slowly, because it takes time to generate an expectancy set, and (4) facilitates the processing of expected targets, which are typically related to the prime.

Both automatic spreading activation and expectancy account for priming by increasing the speed of lexical access for related targets (Neely, 1991). As such, automatic spreading activation and expectancy are often referred to as pre-lexical mechanisms. The third class of mechanism is
called post-lexical. Before detailing the post-lexical mechanisms, it is important to define what is meant by lexical access. Lexical access in the current study refers to stimulus recognition. Processes that lead to word recognition (or lexical access) are pre-lexical, and mechanisms that facilitate these processes are pre-lexical mechanisms. As already stated, automatic spreading activation and expectancy are pre-lexical mechanisms. Processes that operate after word recognition, but before or at the time of response, are post-lexical. Mechanisms that facilitate processing in this way are post-lexical mechanisms.

Post-lexical mechanisms. Rather than producing priming by speeding up access to the target’s lexical node, post-lexical mechanisms produce priming effects after lexical access to the target has occurred (e.g., de Groot, 1983; Dosher & Rosedale, 1989; Neely & Keefe, 1990; Norris, 1986; Ratcliff & McKoon, 1988). For the most part, post-lexical mechanisms operate by influencing binary decisions and/or response processes that occur after the representation of the target has been established (e.g., Balota & Lorch, 1986; de Groot, 1984; Neely, 1991; Neely & Keefe, 1990). Thus, post-lexical mechanisms have been proposed to explain priming effects in lexical decision but not in pronunciation. Neely and Keefe’s (1989) retrospective semantic-matching model, for example, proposes that after lexical access to the
target has occurred, but before a response has been made, participants can utilize information about the prime-target relationship to bias either word or nonword responses. Thus, like expectancy, semantic-matching is a strategic mechanism; it cannot occur without intention and it requires awareness of the prime.

Neely & Keefe's (1989) semantic-matching mechanism operates as follows. If the prime and the target are related, the response necessarily has to be "word". Thus, relatedness can bias a "word" response. If the target is a nonword, then it must be unrelated to the prime. If there is a significant number of nonword targets relative to unrelated word targets (i.e., the nonword ratio is high), then a bias to respond "nonword" to unrelated prime-target pairs also develops. Therefore, if the target is a word but is unrelated to the prime, the nonword bias must be overcome in order to correctly respond "word". Overcoming the bias to respond "nonword" to unrelated word targets slows response latencies. This increases priming measured as the difference between target response latencies to unrelated word targets versus related word targets.

In summary, post-lexical mechanisms (1) do not operate without intention (2) do not operate without awareness of the prime, (3) are slow acting, and (4) facilitate responses to targets after lexical access to the target has occurred.
Adopting a semantic-matching strategy would presumably not provide any useful information about the correct pronunciation of a target (Neely, 1991). Consequently, semantic matching does not operate in the pronunciation task.

**Dissociations in Priming Effects**

Each of the aforementioned priming mechanisms is able to explain with fair success a subset of extant priming effects (see Neely, 1991, for an extensive review of the utility of each mechanism in explaining a vast array of priming phenomena). None of them alone, however, can account for dissociations in priming effects between the lexical-decision and pronunciation tasks in forward, mediated, and backward priming.

**Forward priming.** Recall that forward semantic priming refers to facilitation in responses that occurs from a forward associative relationship between the prime and the target. That is, the prime and target are related in such a way that presentation of the prime is likely to make someone think of the target (e.g., heart-attack). When forward semantic priming effects are measured using the single-word paradigm, lexical decision typically shows a higher magnitude of priming than pronunciation (Balota & Lorch, 1986; de Groot, 1983, 1985; VanVoorhis & Dark, 1995). Automatic spreading activation, expectancy, and post-lexical explanations of priming all fail to adequately explain this dissociation.
The problem for automatic spreading activation and expectancy lies in the fact that both mechanisms are assumed to operate in the same way for both lexical decision and pronunciation. It is difficult, for instance, to explain how activation that spreads automatically would spread further or deeper or more rapidly under one task than the other. Similarly, it is difficult to explain why participants in a pronunciation task would produce more or less complete expectancy sets (or have easier or quicker access to them) in response to the prime than participants in a lexical-decision task, or vice versa.

The only mechanism that is proposed to operate differentially between lexical decision and pronunciation is Neely and Keefe's (1989) semantic-matching mechanism, and then only because it is proposed to operate solely in the lexical-decision task. Semantic matching does not operate in pronunciation because there is no binary word/nonword response to be biased; therefore, it cannot explain the priming found in pronunciation, let alone explain the dissociation in magnitude of priming effects between it and lexical decision. While each of the mechanisms is capable of explaining forward priming effects in either pronunciation or lexical decision, or both, none is able to account for the dissociation in magnitude of forward priming effects seen between lexical decision and pronunciation.
Mediated priming. As discussed earlier, automatic spreading activation has been implicated as a mechanism responsible for producing semantic priming effects (de Groot, 1983; Neely, 1976, 1977; Posner & Snyder, 1975). Some of the research pertaining to the operation of automatic spreading activation in semantic priming has focused on the question of how far (or deeply) activation spreads from the activated prime node (Balota & Lorch, 1986; de Groot, 1983; McNamara, 1992). That is, does activation spread only from the activated prime to closely related concepts and then dissipate, or does activation continue to spread from the closely related concept to other concepts related to these concepts? To answer this question, researchers began to measure mediated priming effects.

In mediated priming using the single-word paradigm, a prime is presented, followed by a target to which participants indicate a response. Recall that the difference between forward and mediated priming lies in the nature of the relationship between the prime and the target. Rather than being directly related from the prime to the target, as they are in forward priming, the prime and target pairs in mediated priming are only indirectly related via a mediating concept (e.g., lion-stripes are related via tiger).

Using the lexical-decision task, de Groot (1983) found reliable priming for directly related (forward) targets, but
she failed to find similar priming for mediated targets. de Groot concluded that activation spreads to directly related concepts but does not spread any further. This conclusion was based on the reasoning that if activation spread more than one step (i.e., beyond only directly related concepts) then mediated priming should have obtained as a result of activation spreading from the prime lion to the mediating concept tiger to the target stripes.

Balota and Lorch (1986), however, questioned this "one-step" interpretation of spreading activation, as opposed to a multiple-step interpretation in which activation does not dissipate at the closest directly related concept but continues to spread to other, more indirectly related concepts via mediating links. Balota and Lorch replicated de Groot and also measured forward and mediated priming effects with the pronunciation task. Results for the lexical-decision task were the same as those found by de Groot: Facilitation was found for responses to directly related targets but not for responses to mediated targets. For pronunciation, however, facilitation was found for responses to directly related and to mediated targets. Other researchers have shown the same dissociation in mediated priming effects with lexical decision and pronunciation (e.g., Seidenberg et al., 1984).

The dissociation poses a theoretical problem. On the one hand, automatic spreading activation was used to explain why
priming was not found with lexical decision (de Groot, 1983),
whereas on the other hand, it was used to explain why priming
was found with pronunciation (Balota & Lorch, 1986). The
problem is that there is no reason to assume that automatic
spreading activation operates differently under different
response conditions. Automatic spreading activation cannot be
used both to explain the absence of mediated priming in
lexical decision and the presence of mediated priming in
pronunciation.

Consider what an expectancy explanation would predict for
mediated priming in lexical decision and pronunciation. Because the target in mediated priming is not directly related
to the prime, it should not be included in an expectancy set
that contains words semantically related to the prime. Based
on this reasoning, an expectancy explanation would incorrectly
predict the absence of mediated priming with pronunciation as
well as with lexical decision. In other words, expectancy is
able to explain why mediated priming does not occur for the
lexical-decision task, but it is unable to explain why
mediated priming does occur for the pronunciation task.

Post-lexical mechanisms of priming would correctly
predict the absence of mediated priming in lexical decision.
Semantic matching operates to bias a "word" response when the
prime and the target are related and to bias a "nonword"
response when the prime and target are unrelated. Semantic
matching would operate to bias a "nonword" response in mediated priming because the prime and the target are not directly related. When the target was a word, biasing an incorrect "nonword" response would actually slow down, or inhibit, the correct "word" response. Post-lexical mechanisms do not operate in pronunciation, so semantic matching cannot account for mediated priming with this task.

**Backward priming.** Koriat (1981, Experiment 3) first showed facilitation in target responding due to a backward association from the target to the prime in the lexical-decision task. This finding was later replicated by Seidenberg et al. (1984, Experiment 3), who also measured backward priming in the pronunciation task. Just as with mediated priming, one task showed evidence of priming while the other did not, only now it was lexical decision that showed a backward priming effect, whereas such an effect was absent in pronunciation.

Recall that in backward priming the prime and the target are related only through a backward association from the target to the prime (e.g., hop-bell); there is no forward association from the prime to the target. Automatic spreading activation could account for a backward priming effect in lexical decision if it is assumed that somehow activation spreads from the prime to the target and then back to the prime again. Even if this were the case, however, it would
lead to the incorrect prediction of a backward priming effect in pronunciation as well as lexical decision (Neely, 1991).

The mere presence of a backward priming effect in lexical decision causes problems for expectancy explanations of priming because participants should not be able to use the prime to generate an expectancy set that includes the target, since the two are only related via a backward association. Expectancy explanations, therefore, would incorrectly predict the absence of backward priming for both lexical decision and pronunciation.

Post-lexical mechanisms, such as semantic matching, can successfully account for the presence of a backward priming effect in the lexical-decision task (see Neely & Sloat, 1994; Seidenberg et al., 1984). The semantic matching mechanism enables the detection of the backward association between the target and the prime after lexical access to the target has occurred. The association can bias the "word" response in backward priming with lexical decision just as it is assumed to do in forward priming. Because semantic matching does not operate in pronunciation, a semantic-matching explanation of priming accurately predicts the absence of backward priming with this task.

**Neely and Keefe's Three-process Account of Dissociations**

Although each of the theoretical mechanisms considered thus far can account, with varying degrees of success, for
semantic priming effects with lexical decision and pronunciation, none of them alone is able to explain the complete set of dissociations in the magnitude of forward, mediated, and backward priming with these two tasks. The problem, of course, is not inherent to the mechanisms themselves, but would limit any single-mechanism theory. Thus, a multi-mechanism account is needed. To date, probably the most successful theory at explaining dissociations in priming effects is Neely and Keefe’s three-process theory (1990; Neely, 1991).

Neely and Keefe (1990; Neely, 1991) proposed that not one, but three mechanisms are responsible for producing semantic priming. The three mechanisms are automatic spreading activation, expectancy, and semantic matching.

The theory says that all three mechanisms operate in parallel to the extent possible as determined by the nature of the task. According to Neely and Keefe, automatic spreading activation and expectancy produce priming in both pronunciation and lexical decision, whereas semantic matching produces priming only in lexical decision.

**Forward priming.** Consider first how Neely and Keefe’s three-process theory can account for dissociations in the magnitude of forward priming. Recall that under the same conditions, lexical decision typically produces larger forward priming effects than does pronunciation. This dissociation is
handled quite simply. Because semantic matching does not operate in pronunciation, only two mechanisms operate to produce priming: automatic spreading activation and expectancy. Three mechanisms, however, operate to produce priming in lexical decision: automatic spreading activation, expectancy, and semantic matching. It is the addition of the third mechanism, semantic matching, that operates in lexical decision but not in pronunciation that produces larger priming effects for lexical decision.

Mediated priming. Consider next how the three-process theory (Neely & Keefe, 1990; Neely, 1991) accounts for the dissociation in mediated priming effects between lexical decision and pronunciation. Recall that pronunciation typically shows a mediated priming effect while lexical decision does not (Balota & Lorch, 1986; de Groot, 1983; Seidenberg et al., 1984). According to Neely and Keefe, mediated priming occurs in pronunciation as the result of activation spreading from the prime node (e.g., lion) to the related mediating concept node (e.g., tiger) to the target node (e.g., stripes). Facilitation is produced by automatic spreading activation in the same manner for the lexical-decision task. The facilitation in this task, however, is offset by the bias, produced by the operation of semantic matching, to respond "nonword". The indirect relationship between the prime lion and the target stripes will not be
detected, and therefore, participants will have a bias for a nonword response. The nonword response bias must be overcome in order to respond with a correct "word" response to indirectly related, mediated prime-target pairs. Thus, the positive effect of automatic spreading activation and the negative effect of the nonword bias effectively cancel each other out in the lexical-decision task.

Expectancy mechanisms will not facilitate target responses in mediated priming for either lexical decision or pronunciation. Because the target is not related to the prime, it is not likely to be in a participant's expectancy set. Therefore, no target responses are facilitated due to expectancy in mediated priming.

**Backward priming.** Neither automatic spreading activation nor expectancy produce backward priming. For automatic spreading activation, this would require the presumption that activation spreads from the target's node to the prime's node and then back to the target's node. Most conceptualizations of automatic spreading activation, however, presume that activation spreads only in the forward direction (Anderson, 1976; Collins & Loftus, 1975; Collins & Quillian, 1969). Further, there is no reason to assume that this process would take place only for the lexical-decision task. Backward priming, therefore, is not the result of automatic spreading activation.
Because the prime and the target in backward priming are not related directly in the forward direction, the expectancy set generated from the prime should not include the target. As a result, backward priming does not result from the operation of an expectancy mechanism.

Backward priming occurs in lexical decision but not in pronunciation because the semantic matching mechanism that operates in lexical decision allows detection of the backward association from the target (e.g., *bed*) to the prime (e.g., *pan*), which in turn biases the correct "word" response. Detection of a backward association between the prime and the target is not possible with the pronunciation task because semantic matching does not operate. Thus, the only mechanism responsible for backward priming is semantic matching.

Assessment of Tasks

Neely and Keefe's (1990; Neely, 1991) three-process theory of semantic priming is able to explain the dissociations in magnitude of priming typically reported with lexical decision and pronunciation. It leaves unanswered concerns about using the lexical-decision and pronunciation tasks to measure semantic priming effects as they are related to word recognition, or lexical access. The unanswered question is which of the two tasks provides better information regarding the processes involved in word recognition.
The lexical-decision task. It has been assumed by most researchers who use the lexical-decision task that factors such as priming have their effects on lexical access, and, thus, that the lexical-decision task could be used to investigate how factors such as priming affected word recognition or lexical-access time. These assumptions, however, are beginning to be questioned (Neumann, 1990).

The lexical-decision task requires participants to discriminate between words and nonwords words and, therefore, ensures recognition of, or lexical access to, word stimuli. Critics of the lexical-decision task, however, claim that responses in this task are also facilitated by mechanisms that facilitate processing that is post-lexical, or that occurs after recognition of the target (e.g., Balota & Chumbly, 1984; Balota & Lorch, 1986; Seidenberg et al., 1984). Priming in the lexical-decision task, therefore, occurs at least in part as a result of facilitation that occurs after the word has been recognized. Because some facilitation in lexical decision occurs after lexical access, it has been argued that pronunciation is a purer measure of lexical-access time.

The pronunciation task. Critics of the pronunciation task argue that the lexical-decision task is a better task to use than pronunciation when investigating effects on word recognition because it is more sensitive to variables that influence lexical access (e.g., Coltheart, Davelaar, Jonasson,
This argument is based on evidence that it is possible for participants to produce a pronunciation response based on grapheme-to-phoneme conversion rules (i.e., spelling to sound correspondence) via a route in processing that bypasses lexical access (Paap et al., 1987). Consequently, any effects on pronunciation latency produced by context or other variables may be, at least some of the time, not reflecting lexical-access time. Based on the logic that making a word/nonword decision in the lexical-decision task requires recognition of the stimulus, critics of pronunciation argue that the lexical-decision task ensures lexical access, whereas pronunciation does not.

It is further argued (Paap et al., 1987; Frederiksen & Kroll, 1976) that voice-keys used in recording latency of pronunciation responses can be activated by a translation of the first segment or consonant of a stimulus before recognition of the stimulus occurs. A participant could, for example, recognize and initiate the initial /k/ sound of COSTUME before a complete pronunciation had been assembled. Once again, response latencies in pronunciation may not be an accurate reflection of lexical access time.

Stages of processing. As typically employed in the literature, the lexical-decision task is a two-choice reaction-time task. Thus, as with any two-choice reaction-
time task, reaction time reflects three stages of processing: encoding, decision, and response selection (Donders, 1886). In the lexical-decision task, participants must first encode the stimulus and then decide whether the stimulus is a word or not. Finally, they must decide which of two possible keys must be pressed to indicate the outcome of the first decision (i.e., response selection). It is, therefore, inappropriate to think of the lexical-decision task as simply recognition and decision.

Some researchers (e.g., Balota & Lorch, 1986) claim that post-lexical effects on priming occur as the result of the binary word/nonword decision that participants must make in the lexical-decision task. They do not consider, however, that the lexical-decision task requires a binary response (e.g., left key/right key) in addition to the binary lexical decision ("word"/",nonword").

Other researchers (e.g., Neely, 1991; Neely & Keefe, 1990) claim that post-lexical effects on priming occur as the result of the binary word/nonword response that participants must make in the lexical-decision task. They do not consider, however, the critical word/nonword decision that must necessarily precede the response. Thus, there has been no consideration in the literature of the processes needed to map the binary lexical decision to the binary response. In each case, the word/nonword decision and the binary response have
been fused into one process that encompasses both. The fact that lexical decision requires three stages of processing has not been explicitly acknowledged in the literature. It is, therefore, important to more closely examine the processing stages required in a lexical-decision task.

The first stage of processing is stimulus encoding and includes early perceptual processing such as feature and letter detection and other processing leading to recognition, or lexical access, of a stimulus. Reaction time measures for the first stage of processing reflect the speed of such processing as well as things like speed of neural conduction. Pronunciation proponents claim that the pronunciation task reflects only the processes that lead to lexical access and thus reflects the speed of lexical access. Lexical-decision proponents, however, claim that pronunciation can occur before or possibly independently of lexical access, and thus, pronunciation latencies are not necessarily a reflection of the outcome of the first stage.

The second stage of processing in a choice reaction-time task is the decision stage. During this stage in the lexical-decision task, the stimulus is classified as a word or a nonword, that is, the binary word/nonword decision is made. The third and final stage in a choice reaction-time task is response selection. During this stage in the lexical-decision task, the word/nonword decision from the previous lexical-
decision stage is mapped onto a binary keypress response. Basically, the response selection stage is deciding which key to press.

These two separate decisions (the word/nonword and response decisions) actually reflect two distinct stages of processing. Previous theorizing as to the locus of post-lexical effects on target processing in the lexical-decision task (e.g., Balota & Chumbly, 1984; Balota & Lorch, 1987; de Groot, 1983, 1985; Neely, 1991; Seidenberg, et al., 19984) has failed to make this distinction clear, although it is an important distinction to make. It is important to know in word recognition research using the semantic priming paradigm whether priming effects found with any given task are due to priming mechanisms that operate on stages of processing that come before or after word recognition has occurred. The current focus is on the locus of semantic-matching effects on semantic priming in the lexical-decision task.

Assumptions About Word Recognition.

The current research directly investigated the locus of semantic-matching effects by using tasks that tease apart processes involved in stimulus encoding, lexical decision, and response selection. Knowing the locus of semantic-matching effects is important to development of theories of word recognition. Only by knowing where semantic matching produces its biasing effects can an informed decision be made regarding
which task, lexical decision or pronunciation, is the most appropriate for investigating word recognition.

If one assumes strict on-line serial processing in which the first substages of stimulus encoding (i.e., feature and letter detection) must be completed before the stimulus is recognized or before access to meaning could occur, then implications of semantic matching effects on the word/nonword decision, on response selection, or on both, would argue against any use of the lexical-decision task to study word recognition. This is because decision and response-selection processing would occur only after processing leading to word recognition, or lexical access, was completed. Therefore, lexical decision would not be a pure measure of lexical-access time.

If one assumes an interactive model of word recognition (e.g., McClelland & Rumelhart, 1981; Balota, 1990) in which it is assumed that information pertaining to the meaning of the word can aid in word recognition in a top-down fashion, then evidence that semantic matching operates only on the binary word/nonword decision and not at the response selection stage would not preclude using the task for word recognition research. This is because the semantic matching mechanism facilitates target responses by using information regarding the prime-target relationship. Thus, it can be reasoned that the semantic-matching mechanism operates by providing
information corresponding to the meaning of the prime and the target (i.e., the meaning of the words must be known in order to know if they are related). If the operation of semantic matching is restricted to the lexical decision only and not to response selection, therefore, semantic matching effects might not all be post-lexical.

If, on the other hand, semantic matching operates only on response selection, then the lexical-decision task should be avoided because the obtained priming will be contaminated by processing not directly related to lexical access. If it is shown that semantic matching operates both at the word/nonword decision and at the binary response, the extent of the effect at the response stage must be determined in order to know how contaminated the obtained priming is likely to be. Only then can a judgement be made as to whether the cost of the contamination outweighs the benefit of ensuring lexical access. This decision will depend on the theory under which one is operating and the question that is being asked.

In summary, even if semantic matching operates at the second stage of processing (i.e., the lexical decision stage), the lexical-decision task might be a useful tool to examine word recognition if one assumes an interactive model of word recognition. If semantic matching operates only at the third stage (i.e., the response selection stage), however, then lexical decision is not a useful tool because obtained priming
will include contamination by post-lexical processes. Finally, if semantic matching operates at both stages, the decision as to whether it is a useful tool or not will depend on a cost/benefit analysis.

Current Research

Tasks

The current research examined forward, mediated, and backward priming in five different tasks designed to require either one, two, or all three of the processing stages previously discussed. Tasks requiring different stages of processing were used in an attempt to more closely define the locus of semantic-matching effects on the various processing stages required by each task.

The first task was standard lexical decision. This task, as described previously, requires stimulus encoding, lexical decision, and response selection. All three mechanisms of priming are assumed to operate in lexical decision: Automatic spreading activation and expectancy facilitate stimulus encoding, while the locus of semantic matching remains unclear. It is not possible using just the standard lexical-decision task to determine whether semantic matching operates on the lexical decision, on response selection, or on both stages.

The second task was standard pronunciation. This task requires that participants pronounce the target stimulus, and
requires only stimulus encoding. It does not require a word/nonword decision or binary response selection. With pronunciation, there is direct access to the appropriate response, with no intervening choice. Only automatic spreading activation and expectancy are assumed to operate in pronunciation.

The other three tasks were versions of standard lexical decision and pronunciation. Modifications in the response requirements of these two tasks were made that were intended to manipulate 1) the stages of processing involved in completing each task, and 2) the operation of priming mechanisms within each task.

The third task was a keypress go/no go task. This task requires participants to press a key if the target is a word and to do nothing (i.e., withhold a response) if the target is a nonword. Presumably, only two stages of processing are involved in this task (Neely, 1991): stimulus encoding and lexical decision. Response selection is presumably not required because there is only one response. If the withholding of a response in go/no go eliminates response selection, than any facilitation that can be attributed to semantic matching must be operating on the lexical decision itself. Automatic spreading activation and expectancy should operate on stimulus encoding.

The fourth task was pronunciation go/no go. This task
requires a pronunciation response to words instead of a keypress response. That is, if the target is a word, participants are required to pronounce it. If the target is a nonword, no response is made. This task was used to equate the pronunciation task and the lexical-decision task in terms of response requirements. Essentially, this is a pronunciation task with a lexical decision requirement added. Other than differences in the mode of response (i.e., manual response in keypress go/no go and vocal response in pronunciation go/no go) this task is identical to the keypress go/no go task. Both tasks require stimulus encoding and lexical decision. Differences in priming between these two tasks would have to be attributed to response mode (manual vs. vocal).

The final task was single-response lexical-decision. Participants in this task are required to press a key immediately upon completion of the lexical decision. Only after the keypress response is made are subjects required to indicate the outcome of the decision by pressing one key for "word" and another key for "nonword". Instructions request a speeded decision, although the "word’/"nonword" response itself is not speeded. Notice that with this task, a response is required to every stimulus (as with standard lexical decision) but the response is not binary, that is, the response is the same to words and to nonwords. As such,
response selection is not required for the speeded response with this task, although a response is made to all stimuli.

The single-response lexical-decision task was used to distinguish between influences on a binary overt response and binary response selection. As mentioned previously, it is assumed that because go/no go tasks do not require overt binary responses (Neely, 1991) that go/no go tasks do not require response selection (see Table 1 for a complete summary of the processing stages required for each task). An argument can be made, however, that withholding a response in go/no go tasks is similar to making a response. In other words, response selection may be required in go/no go tasks between the making and the withholding of a response. As such, the withholding of a response in go/no go tasks may itself be a response that can be biased. If there is response selection in go/no go tasks, then the pattern of expected priming would be different based on where semantic matching operated, as explained in the next section.

**Expected Outcomes**

The expected pattern of priming across the five tasks varied according to (1) whether the task was presumed to require lexical decision, response selection, or both, (2) whether semantic matching was assumed to operate at lexical decision, response selection, or both, and (3) whether response selection was required in go/no go tasks (i.e.,
Table 1. **Processing stages and response mode required for responding in each task.**

<table>
<thead>
<tr>
<th></th>
<th>stimulus encoding</th>
<th>lexical decision</th>
<th>response selection</th>
<th>response mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard pronunciation</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>verbal</td>
</tr>
<tr>
<td>Keypress go/no go</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>manual</td>
</tr>
<tr>
<td>Pronunciation go/no go</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>verbal</td>
</tr>
<tr>
<td>Single-response LD*</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>manual</td>
</tr>
<tr>
<td>Standard LD</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>manual</td>
</tr>
</tbody>
</table>

*LD = lexical decision.

whether withholding a response is itself a response). All possible expected patterns are explained in this section.

Under each of the five tasks, participants responded to a list of prime-target pairs containing forward, mediated, and backward priming trials. Because stimulus encoding was required for all tasks, automatic spreading activation and expectancy were assumed to be operative for all tasks, as these are pre-lexical mechanisms.

Although no differences based on response modality (i.e., manual vs. vocal) were expected, response modality was examined by examining priming collapsed across response mode. Because a response modality effect was not predicted, all expected patterns of priming were the same for the keypress and pronunciation go/no go tasks.
Forward priming. In the literature, standard lexical decision produces more forward priming than pronunciation and this was also predicted for the current study. This difference is attributed to the operation of semantic matching in standard lexical decision but not in pronunciation. Facilitation due to semantic matching produces higher levels of priming with this task.

If semantic matching operated only on the lexical decision, then it was expected that the go/no go and single-response lexical-decision tasks would show magnitudes of priming similar to those found with standard lexical decision because all tasks require a lexical decision and, thus, would all show facilitation due to semantic matching. Only the standard pronunciation task, which does not require a lexical decision, would show a smaller magnitude of priming than all other tasks if semantic matching operated only on the lexical decision.

If semantic matching operated only on response selection, then there are two possible outcomes depending on whether the withholding of a response in the go/no go tasks is itself a response. If it was not, and thus response selection was not required, then standard lexical decision would show more priming than all other tasks because only this task would require response selection. If, on the other hand, the withholding of a response in go/no go is itself a response,
then standard lexical decision and the go/no go tasks would all require response selection and would, consequently, show more priming than pronunciation and single-response lexical decision.

If semantic matching operated at both lexical decision and response selection, then standard lexical decision, which requires both of these processing stages, would show the most priming, followed by the go/no go tasks if they did not require response selection and single-response lexical decision, followed by standard pronunciation, which requires neither lexical decision nor response selection.

If the withholding of a response is a response that can be biased in the same way that an overt response can be biased, then standard lexical decision and the go/no go tasks would show equal magnitudes of priming, followed by single-response lexical decision, followed by standard pronunciation.

**Mediated priming.** Standard pronunciation typically shows a mediated priming effect while standard lexical decision does not. This pattern was expected in the current research. This pattern has been interpreted as reflecting the opposing effects of automatic spreading activation and semantic matching in the lexical-decision task (Neely, 1991). Because the prime and target are not directly related in mediated priming, a nonword decision and/or response will be biased by semantic matching in lexical decision. When the
correct response in the lexical-decision task is "word", overcoming the nonword bias produced by semantic matching offsets facilitation due to automatic spreading activation. Because semantic matching does not operate in pronunciation, responses in this task benefit from automatic spreading activation, and thus a mediated priming effect is seen with this task.

If semantic matching operated only on the lexical decision, the go/no go and single-response lexical-decision tasks would not show mediated priming either, since all of these tasks require a lexical decision and, thus, would all suffer from the conflict between semantic matching and automatic spreading activation. If, on the other hand, semantic matching operated only on response selection, then the pattern of priming across tasks would depend on whether withholding of a response is itself a response that can be biased. If withholding a response is not itself a response, then the go/no go and single-response lexical-decision tasks, along with standard pronunciation, would all show mediated priming because semantic matching would not operate to offset facilitation due to automatic spreading activation. Only standard lexical decision, which requires both a lexical decision and response selection, would not show mediated priming.

If the withholding of a response is itself a response
that can be biased, then neither standard lexical decision nor the go/no go tasks would show mediated priming, but single-response lexical decision and pronunciation would. Finally, if semantic matching operated at the lexical decision and at response selection, then the pattern for mediated priming would look the same as if semantic matching operated only on the lexical decision. That is, only the pronunciation task would show a mediated priming effect because neither a lexical decision nor response selection is required.

**Backward priming.** The typical pattern for backward priming with standard lexical decision and standard pronunciation is the mirror-opposite of the typical pattern for mediated priming with these two tasks. That is, standard lexical decision typically shows backward priming while standard pronunciation does not and this pattern was expected in the current research. This pattern is explained by the operation of semantic matching in standard lexical decision but not in pronunciation. Now, however, semantic matching produces the effect, rather than offsets the effect, as it does with mediated priming.

If semantic matching operated only on the lexical decision, the go/no go and single-response lexical-decision tasks would all show backward priming equal to priming with standard lexical decision because all of these tasks require a lexical decision. If semantic matching operated only on
response selection, then only standard lexical decision would show backward priming if response selection was not required in the go/no go tasks. If response selection was required in the go/no go tasks, however, then standard lexical decision and the go/no go tasks would show equal backward priming. If semantic matching operated at both lexical decision and response selection, then standard lexical decision would show a larger backward priming effect than would the go/no go tasks, if they do not require response selection, and single-response lexical decision. Standard lexical decision and the go/no go tasks would show equal levels of backward priming if the go/no go tasks do require response selection, and all would show a larger backward priming effect than single-response lexical decision, which does not require response selection. Standard pronunciation would still not show backward priming.

A complete summary of all possible expected patterns of priming across tasks can be seen in Table 2. The top-half of Table 2 depicts the expected outcomes in patterns of priming across tasks if the withholding of a response in the go/no go tasks is not itself a response that can be biased. Patterns a-1, then, indicate no response selection in go/no go. Specifically, if the pattern of priming depicted in columns a, d, and g obtains, then semantic matching operated only on the lexical decision. If the pattern depicted in columns b, e,
Table 2. Summary of expected outcomes for forward, backward, and mediated priming as a function of task, the locus of semantic matching, and the nature of withholding a response.

<table>
<thead>
<tr>
<th>Type of Priming</th>
<th>Forward</th>
<th>Mediated</th>
<th>Backward</th>
</tr>
</thead>
<tbody>
<tr>
<td>No response selection with go/no go</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tasks pattern:</strong></td>
<td>a</td>
<td>b</td>
<td>c</td>
</tr>
<tr>
<td>Standard LD</td>
<td>++(^b)</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Standard pronunciation</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Keypress go/no go</td>
<td>++</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Pronunciation go/no go</td>
<td>++</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Single-response LD</td>
<td>++</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Response selection with go/no go</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tasks pattern:</strong></td>
<td>j</td>
<td>k</td>
<td>l</td>
</tr>
<tr>
<td>Standard LD</td>
<td>++</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Standard pronunciation</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Keypress go/no go</td>
<td>++</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Pronunciation go/no go</td>
<td>++</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Single-response LD</td>
<td>++</td>
<td>+</td>
<td>++</td>
</tr>
</tbody>
</table>

\(^a\) LD = lexical decision; R = response; B = both.

\(^b\) N = no priming predicted, +++ = will be greater than ++ or + in same column, ++ = will be greater than + in same column, + = significant priming, but less than ++ or +++ in same column.

and h obtains, then semantic matching operated only on response selection. If the pattern depicted in columns c, f, and i obtains, then semantic matching operated at the lexical decision and at response selection.
The bottom-half of Table 2 depicts the expected outcomes in patterns of priming across tasks if the withholding of a response in go/no go is a response that can be biased. Patterns j-r, then, indicate that response selection is required in go/no go. Specifically, if the pattern of priming depicted in columns j, m, and p obtains, then semantic matching operated only at the lexical decision. If the pattern across tasks depicted in columns k, n, and q obtains, then semantic matching operated only on response selection. Finally, if the pattern depicted in columns l, o, and r obtains, then semantic matching operated at both the lexical decision and at response selection.
Participants

The following research was approved by the Iowa State University Human Subjects Committee and by the University of Wisconsin-LaCrosse Institutional Review Board. A total of two hundred introductory level psychology students at Iowa State University and at the University of Wisconsin-LaCrosse served as participants. Eighty of the participants were enrolled at Iowa State University and participated for 1 point of extra credit towards their course grade. One hundred-twenty of the participants were enrolled at the University of Wisconsin-LaCrosse and participated in fulfillment of a course requirement.

Forty participants each (approximately 30% from Iowa State and 70% from the University of Wisconsin-LaCrosse) were assigned to the between-subjects variable of task type (standard lexical decision, standard pronunciation, keypress go/no go, pronunciation go/no go, and single-response lexical decision). Only participants who spoke English as their native language and who reported normal or corrected-to-normal vision were recruited for participation.

Stimuli

Although, as will be described, participants responded to 320 prime-target pairs, the critical items consisted of three sets of 32 critical pairs each, one set for the forward-
priming trials, one set for the mediated-priming trials, and one set for the backward-priming trials. The set of 32 items for the backward priming trials were taken from Koriat (1981) and from West and Stanovich (1981). These consisted of 32 backward-related pairs. The critical trials for the mediated priming conditions were taken from Balota and Lorch (1986). These consisted of 32 mediated-related triplets. The critical items for the forward priming trials were taken from VanVoorhis and Dark (1995) and consisted of 32 forward-related pairs. The 32 critical items in each set are shown in the Appendix.

Two lists were constructed using the three sets of critical items. In one list, one-half (16) of the primes from each set preceded related targets and one-half (16) of the primes from each set preceded unrelated targets. The unrelated prime-target pairs were created by randomly re-pairing one-half of the primes within a word set with other targets from that word set. The one-half of the primes that preceded related targets in the first list preceded unrelated targets in the second list. The one-half of the primes that preceded unrelated targets in the first list preceded related targets in the second list. The two lists were alternated by participant within each task.

The operation of semantic matching depends on the nonword ratio, which is defined as the probability that a target is a
nonword given that it is unrelated to the prime. Specifically, if this nonword ratio is high, semantic matching will operate (Neely, 1991). Thus, in order to maintain a high nonword ratio, 160 nonword filler trials were also included in each list. Because backward related and unrelated and mediated related and unrelated trials all qualify as forward unrelated trials, 64 forward related filler trials were included to maintain a reasonably high relatedness proportion, the probability that a target is related to the prime, given that it is a word. Thus, there was a total of 320 trials: 80 forward related word-target trials (16 forward related critical trials and 64 forward related filler trials), 80 forward unrelated word-target trials (16 backward related, 16 backward unrelated, 16 mediated related, 16 mediated unrelated, and 16 actual forward unrelated trials) and 160 nonword-target trials. Counting backward related trials and mediated related trials as forward unrelated trials, the lists contained 1 forward-related word target trial for every 1 forward-unrelated word target trial and for every 2 nonword target trials. The nonword ratio was thus .67. The relatedness proportion was .50.

Procedure

Upon arrival at the laboratory, participants were informed of their right to terminate participation at any time in the experiment. Participants were then seated.
approximately 50 cm. in front of a Zenith PC compatible computer monitor. General instructions explaining the task were displayed on the computer monitor and verbally explained by the research assistant. Specific instructions depended on the task the participant was performing.

For standard lexical decision, participants were instructed to press the "/" key if the target was a word and to press the "Z" key if the target was not a word. For keypress go/no go, participants were instructed to press the "/" key if the target was a word and to withhold responses to nonwords. For pronunciation go/no go, participants pronounced word targets and withheld responses to nonwords. Participants in standard pronunciation pronounced all targets, word and nonword. Finally, participants in single-response lexical decision were asked to make a word/nonword decision to the target and to indicate completion of this decision by pressing the spacebar. After completion of this response, participants were asked to manually indicate the outcome of the decision by pressing the "X" key if the target was a word and the "Z" key if the target was not a word. Participants in tasks requiring a speeded manual response were asked to rest their right and left (where appropriate) index finger(s) on the appropriate keys. Participants in all tasks were asked to respond as quickly as possible without making errors.

A trial proceeded as follows. First, a row of plus signs
appeared in the middle of the screen for 500 ms to serve as a ready signal. A 500 ms blank screen followed, followed by the presentation of the prime word, centered and in lower case, in the middle of the screen for 250 ms, followed by a 250 ms blank screen. This was followed by the presentation of the target, centered and in lower case and one line below the location of where the prime had been presented. The target display was terminated upon participant response or at 3000 ms, whichever came first. The next trial began 1500 ms after termination of the target display.

Presentation of the stimuli and recording of response latency was controlled by Micro Experimental Laboratory software (Schneider, 1988, 1990). A voice-key was used to record response latency for the pronunciation tasks, and response accuracy was recorded by the experimenter. The entire procedure, including debriefing, lasted about 45 minutes.
RESULTS

An alpha level of .05 was used in all analyses. Target response accuracy, latency, and response mode data will be presented first, followed by the semantic priming data.²

Target Response Accuracy

Target response accuracy was examined as a function of task in a 5 (type of task: standard lexical decision, single-response lexical decision, pronunciation go/no go, keypress go/no go, and standard pronunciation) x 3 (type of trial: forward, mediated, and backward priming) mixed analysis of variance (ANOVA) with type of task as a between-subjects variable and type of trial as a within-subjects variable. This analysis revealed a reliable main effect of type of task, \( F(4,194) = 4.82, \, MS_e = 0.01 \). The main effect of type of trial and the Type of Task x Type of Trial interaction were not reliable. Mean response accuracy and standard errors as a function of task can be seen in Table 3.

²The data were initially analyzed to examine potential differences as a function of data-collection site. There were no significant differences in total latency (mean of related and unrelated latencies), forward, mediated, or backward priming found between Iowa State University and the University of Wisconsin-LaCrosse. There was, however, a significant difference in overall accuracy between Iowa State and UW-LaCrosse, \( t(197) = 3.1, \, S_a = .007 \). The mean accuracy for participants at Iowa State was .96; at UW-LaCrosse accuracy was .98. This small difference, in light of the fact that no difference in total latency between sites was found, does not indicate the occurrence of a speed-accuracy trade-off. Because no differences in priming or latency were found, the data were collapsed over data-collection site for all further analyses.
Table 3. Mean target response accuracy as a function of task and type of trial.

<table>
<thead>
<tr>
<th>Group</th>
<th>Forward Mean</th>
<th>Forward SE</th>
<th>Type of Trial Mediated Mean</th>
<th>Type of Trial Mediated SE</th>
<th>Backward Mean</th>
<th>Backward SE</th>
<th>Total Mean</th>
<th>Total SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard LDT</td>
<td>.95</td>
<td>.009</td>
<td>.94</td>
<td>.011</td>
<td>.96</td>
<td>.011</td>
<td>.95</td>
<td>.009</td>
</tr>
<tr>
<td>Standard Pronunciation</td>
<td>.98</td>
<td>.006</td>
<td>.97</td>
<td>.008</td>
<td>.98</td>
<td>.006</td>
<td>.98</td>
<td>.006</td>
</tr>
<tr>
<td>Keypress Go/no go</td>
<td>.99</td>
<td>.004</td>
<td>.99</td>
<td>.002</td>
<td>.99</td>
<td>.005</td>
<td>.99</td>
<td>.003</td>
</tr>
<tr>
<td>Pronunciation Go/no go</td>
<td>.97</td>
<td>.011</td>
<td>.97</td>
<td>.013</td>
<td>.97</td>
<td>.010</td>
<td>.97</td>
<td>.011</td>
</tr>
<tr>
<td>Single-response LDT</td>
<td>.98</td>
<td>.005</td>
<td>.98</td>
<td>.004</td>
<td>.98</td>
<td>.006</td>
<td>.98</td>
<td>.004</td>
</tr>
</tbody>
</table>

Because the Type of Task x Type of Trial interaction was not reliable, the simple main effect of accuracy was examined by collapsing across type of trial. A Newman-Keuls comparison of the means showed response accuracy for keypress go/no go to be higher than response accuracy for standard lexical decision (.99 and .95, respectively). Response accuracy for the other three tasks fell in between, and no other differences in response accuracy were found.

Although absolute differences in response accuracy were quite small (see Table 3), standard lexical-decision response accuracy was reliably lower than keypress go/no go response accuracy. Visual examination of accuracy across tasks indicates that accuracy levels for all tasks except standard lexical decision were quite high. Lower response accuracy in
standard lexical decision is not entirely unexpected because it is the only task that requires competition between two speeded overt responses.

**Target Response Latency**

Nonword responses were not required in the pronunciation go/no go and the keypress go/no go tasks, therefore, nonword latencies were excluded from the latency analyses. Latencies for correct responses were examined in a 5 (type of task: standard lexical decision, single-response lexical decision, pronunciation go/no go, keypress go/no go and standard pronunciation) x 3 (type of trial: forward, mediated and backward priming) mixed ANOVA with type of task as the between-subjects variable and type of target as the within-subjects variable. This analysis revealed a reliable main effect of type of task, $F(4,194) = 18.45$, $MS_e = 35,915$, as well as a reliable main effect of type of trial, $F(2,388) = 28.93$, $MS_e = 421$. The Type of Task x Type of Trial interaction was not reliable. The latency means and standard errors are shown in Table 4.

A Newman-Keuls comparison of the mean latencies for forward, mediated and backward priming trials indicated that participants took longer to respond in the forward priming trials ($M = 563$ ms) than in the backward priming trials ($M = 548$ ms). The mean latency for the mediated priming trials ($M = 559$ ms) did not differ from either of these. The effect of
Table 4. Mean target response latencies (in ms) as a function of task and type of trial.

<table>
<thead>
<tr>
<th>Group</th>
<th>Forward Type of Trial</th>
<th>Mediated</th>
<th>Backward</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SE</td>
<td>Mean</td>
<td>SE</td>
</tr>
<tr>
<td>Standard LDT</td>
<td>544</td>
<td>10.6</td>
<td>546</td>
<td>10.9</td>
</tr>
<tr>
<td>Standard Pronunciation</td>
<td>561</td>
<td>13.3</td>
<td>555</td>
<td>11.7</td>
</tr>
<tr>
<td>Keypress Go/no go</td>
<td>530</td>
<td>11.2</td>
<td>528</td>
<td>10.6</td>
</tr>
<tr>
<td>Pronunciation Go/no go</td>
<td>689</td>
<td>19.2</td>
<td>683</td>
<td>19.5</td>
</tr>
<tr>
<td>Single-response LDT</td>
<td>491</td>
<td>28.4</td>
<td>483</td>
<td>27.2</td>
</tr>
</tbody>
</table>

Type of trial most likely reflects a difference in the items used to create the different trials. It is likely that participants responded more quickly to items in the backward-priming trials than to items in the forward-priming trials because many of the backward priming items were created by splitting a compound word into two shorter component words. Bedpan, for example can be broken down into the constituent words bed and pan (where pan serves as the prime and bed serves as the target). Thus, the mean word length for targets in backward priming trials (4.4 letters) was less than the mean word length for targets in forward priming trials (6.2 letters), \( t(78) = 7.64, S_a = 0.17 \).

Because the Type of Task x Type of Trial interaction was not reliable, the simple main effect of type of task was
examined by collapsing across type of trial. A Newman-Keuls comparison of the means indicated that target response latencies in the pronunciation go/no go task (M = 681 ms) were reliably longer than target response latencies with every other task. Also, target response latencies in single-response lexical decision (M = 485 ms) were faster than in all other tasks. No other differences between target response latencies were found.

Response Mode

Possible differences in priming due to response mode differences between tasks were examined by collapsing across response mode in a 2 (response mode: manual, vocal) x 3 (type of trial: forward, mediated, and backward) ANOVA. There was neither a reliable effect of response mode nor a reliable Response Mode x Type of Trial interaction. As expected, there were no differences in priming based on response mode differences between tasks.

Semantic priming

Examining semantic priming is equivalent to looking at the prime-target relatedness effect in an analysis of just word latencies. Differences in the magnitude of priming between tasks would be found in such an analysis in a Type of Task x Relatedness interaction. It is easier to discuss differences, however, by directly analyzing the magnitude of priming, which is computed by subtracting the latency for the
related word targets from the latency for the unrelated word targets. Magnitudes of forward, mediated, and backward priming for each task can be seen in Table 5.

**Forward Priming.**

One-tailed $t$ tests against zero showed reliable forward priming in all conditions: For standard lexical decision, $t(39) = 4.91$, $S_e = 7.06$; for single-response lexical decision, $t(39) = 2.51$, $S_e = 7.83$; for keypress go/no go, $t(39) = 7.97$, $S_e = 6.70$; for pronunciation go/no go, $t(39) = 7.44$, $S_e = 7.02$; and for standard pronunciation, $t(38) = 4.63$, $S_e = 3.93$. To examine the pattern of forward priming across tasks, linear contrasts were performed for each of the expected patterns presented in Table 2. The coefficients for each of the contrasts can be seen in Table 6.

There were five different expected patterns for forward priming in Table 2 (because patterns a and j were identical). Four of the five contrasts performed for the forward priming patterns were reliable. For contrast a/j, $F(1,194) = 8.6$; for contrast c, $F(1,194) = 7.57$; for contrast k, $F(1,194) = 21.1$; and for contrast l, $F(1,194) = 20.1$, all $MS_e = 1768.9$. For two of the contrasts, however, the residual was also reliable, indicating that the contrasts were only explaining part of the variance among the means for forward priming across tasks. For contrast a/j, the residual was reliable, $F(3,194) = 5.8$, as it was for contrast c, $F(3,194) = 6.1$, both
Table 5.  Forward, mediated, and backward priming* (in ms) as a function of target task.

<table>
<thead>
<tr>
<th>Group</th>
<th>Forward Priming</th>
<th>Mediated Priming</th>
<th>Backward Priming</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SE</td>
<td>Mean</td>
</tr>
<tr>
<td>Standard LDT</td>
<td>*35</td>
<td>7.1</td>
<td>*22</td>
</tr>
<tr>
<td>Standard Pronunciation</td>
<td>*18</td>
<td>3.9</td>
<td>7</td>
</tr>
<tr>
<td>Keypress Go/no go</td>
<td>*53</td>
<td>6.7</td>
<td>11</td>
</tr>
<tr>
<td>Pronunciation Go/no go</td>
<td>*52</td>
<td>7.0</td>
<td>*19</td>
</tr>
<tr>
<td>Single-response LDT</td>
<td>*20</td>
<td>7.8</td>
<td>*13</td>
</tr>
</tbody>
</table>

* Priming is computed as the unrelated latency - related latency.
* signifies reliable priming.

MSe = 1768.9.

The expected patterns of priming for patterns k and l are similar except for single-response lexical decision. Note that both contrasts assume that response selection occurs in a go/no go task. The fact that contrasts k and l, the two most strongly supported contrasts, are based on this assumption suggests that response selection is required in go/no go tasks, or, in other words, that the withholding of a response is itself a response that can be biased, much the same as the binary response in standard lexical decision. The contrasts also indicate that on forward priming trials semantic matching is operating at response selection, if not both at response selection and at the lexical decision.
Table 6. Coefficients for linear contrasts performed for forward, backward, and mediated priming patterns across tasks.

No response selection with go/no go

<table>
<thead>
<tr>
<th>Type of Priming</th>
<th>Forward</th>
<th>Mediated</th>
<th>Backward</th>
</tr>
</thead>
<tbody>
<tr>
<td>semantic matching</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>at LD`</td>
<td>R</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>Tasks</td>
<td>contrasts: a b c d e f g h i</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard LD</td>
<td>1 4 2  -1 -4 -1 1 4 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard pronunciation</td>
<td>-4 -1 -5 4 1 4 -4 -1 -5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Keypress go/no go</td>
<td>1 -1 1  -1 1 -1 1 -1 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pronunciation go/no go</td>
<td>1 -1 1 -1 1 -1 1 -1 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single-response LD</td>
<td>1 -1 1  -1 1 -1 1 -1 1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Response selection with go/no go

<table>
<thead>
<tr>
<th>contrasts: j k l m n o p q r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard LD</td>
</tr>
<tr>
<td>Standard pronunciation</td>
</tr>
<tr>
<td>Keypress go/no go</td>
</tr>
<tr>
<td>Pronunciation go/no go</td>
</tr>
<tr>
<td>Single-response LD</td>
</tr>
</tbody>
</table>

` LD = lexical decision; R = response; B = both.

Mediated Priming.

The levels of mediated priming for each task can be seen in Table 5. One-tailed t tests against zero showed reliable mediated priming for standard lexical decision, t(39) = 3.76, S_α = 5.87; for single-response lexical decision, t(39) = 2.46, S_α = 5.42; and for pronunciation go/no go, t(39) = 3.36, S_α = 5.65. Keypress go/no go produced a marginally reliable
mediated priming effect, $t(39) = 1.56$, $S_e = 7.25$. Mediated priming for standard pronunciation was not reliable.

There were two different expected patterns for mediated priming across tasks (patterns d, f, m, n, and o were identical, see Table 2). Linear contrasts were performed for both of these patterns (see Table 6). Neither of the contrasts reached significance, indicating that none of the expected patterns of priming across tasks fit the pattern of mediated priming actually found. A one-way ANOVA for mediated priming showed no reliable effect of type of task, $F(4,194) = 1.00$, $MS_e = 1,382$.

Expected differences in mediated priming across tasks were based on assumptions regarding the operation of semantic matching. These assumptions were not supported. In fact, mediated priming was not found where expected (pronunciation) and was found where not expected (standard lexical decision). This pattern clearly does not fit a semantic-matching explanation of mediated priming.

**Backward Priming.**

Levels of backward priming for each task are presented in Table 5. One-tailed $t$ tests against zero showed reliable backward priming for standard lexical decision, $t(39) = 2.38$, $S_e = 6.77$, and for pronunciation go/no go, $t(39) = 2.46$, $S_e = 5.28$, but not for single-response lexical decision, keypress go/no go, or standard pronunciation.
To examine the pattern of backward priming across tasks, linear contrasts were performed for the three expected patterns (patterns g, p, q, and r were identical). None of the contrasts presented in Table 6 for backward priming reached significance, indicating that none of the expected patterns explained the pattern of backward priming actually found across tasks. A one-way ANOVA showed no reliable effect of type of task, $F(4,194) = 1.74$, $MS_e = 1,554$.

According to a semantic-matching explanation of backward priming, standard lexical decision should show a backward priming effect and pronunciation should not. The current backward priming results support this explanation. As with the pattern of mediated priming obtained across tasks, however, a semantic-matching explanation of backward priming fails to account for the pattern of backward priming obtained across all tasks.
DISCUSSION

Discussion of the results pertaining to target response latencies will be presented first, followed by discussion of the forward, mediated, and backward priming results and their implications for using semantic priming as a tool to investigate processes of word recognition. Implications for theories of priming will also be discussed.

Target Response Latency

Because the focus of the current research was on the locus of post-lexical effects on semantic priming, a priori predictions were not made regarding the pattern of target response latencies across tasks. Assuming that the various processing stages outlined in Table 1 occur in real time, however, it would be expected that tasks that require more or all of these stages would take longer to execute than tasks requiring only one or two of the processing stages.

To this end, it would be expected that standard lexical decision, which requires all three stages (stimulus encoding, lexical decision, and response selection) would produce the longest target response latencies and standard pronunciation, which requires only stimulus encoding, would produce the shortest latencies. As for the other three tasks, single-response lexical decision, which requires stimulus encoding and a lexical decision, should produce shorter latencies than standard lexical decision and longer latencies than
pronunciation. If the go/no go tasks require a binary response (i.e., if withholding a response is itself a response that can be biased), then go/no go latencies would be similar to standard lexical decision since all three tasks would require all three processing stages. If withholding a response is not itself a response (i.e., response selection is not required in go/no go tasks), then target response latencies in the go/no go tasks similar to target response latencies in single-response lexical decision would be expected (recall that go/no go tasks still require a lexical decision).

Contrary to these expectations, single-response lexical decision produced the shortest latencies and pronunciation go/no go produced the longest latencies. Target response latencies for all other tasks fell in between and there were no other differences among them.

That single-response lexical decision produced the shortest target response latencies indicates that progression through the processing stages outlined in Table 1 for this task must not have occurred. It does not mean, however, that single-response lexical decision does not require the processing stages expected. Participants in this task were instructed to make a lexical decision to the target as quickly as possible after presentation of the target stimulus and to press the spacebar immediately after completion of the
decision. The outcome of the decision was then indicated, but
the latency of this response was not recorded.

If participants responded as instructed, they would have
made a lexical decision, which would also have required that
the target had been encoded, and response latencies would have
indicated the time necessary to complete these two processes.
As such, given the short target response latency in single-
response lexical decision, it is probable that participants in
this task were more concerned with responding quickly to the
target than with responding according to the outcome of the
lexical decision, as they were instructed to do. In other
words, it appears that participants in this task may have
responded prior to the lexical decision on at least some of
the trials.

While the single-response lexical-decision task has the
appeal of requiring a lexical decision with no ambiguity as to
whether or not a binary response is required (it is not), it
is not possible to discern whether participants are actually
responding according to the instructions. It is quite
possible that participants often responded (by pressing the
spacebar) as soon as the target appeared and made the lexical
decision after or during the overt response, as opposed to
encoding the target and making the lexical decision before
executing the response. If participants had developed this
type of response strategy, it would explain why responses in
this task were unexpectedly fast. Further evidence for this argument can be seen in the pattern of priming obtained for single-response lexical decision, which looks much like the pattern predicted for standard pronunciation, which does not require a lexical decision. The argument that participants often forego the lexical decision in the single-response lexical-decision task is elaborated in the semantic priming section, which follows.

If go/no go tasks require a binary response, and thus, all three stages of processing (stimulus encoding, lexical decision, and response selection), target response latencies for these tasks would be expected to be similar to standard lexical decision. If, on the other hand, go/no go tasks do not require a binary response (and, therefore, only two of the three stages of processing), target response latencies would be expected to be slower than pronunciation, which only requires one stage, but faster than standard lexical decision, which requires all three stages. Neither of these patterns obtained. Rather, the task that produced the longest target response latency was pronunciation go/no go, which was slower than any other task.

VanVoorhis and Dark (Experiments 2 and 3, 1995) found a similar pattern of target response latencies using standard lexical decision and keypress and pronunciation go/no go to examine forward priming in which pronunciation go/no go showed
longer response latencies than standard lexical decision and keypress go/no go. They suggested that it takes participants longer to assemble and execute the phonological code corresponding to the target word, which is required for the articulatory motor response, than it does to initiate and complete a manual keypress response. This explains why pronunciation go/no go showed longer target response latencies than either of the keypress lexical-decision tasks (standard and go/no go).

Although participants in the standard pronunciation task also have to assemble a phonological code corresponding to the target and execute an articulatory motor response, they do not have to make a lexical decision to the target. Target response latencies with standard pronunciation, consequently, are faster than target response latencies with pronunciation go/no go, which does require a lexical decision.

Semantic Priming

The pattern of priming across tasks will be discussed separately for each type of priming. Forward priming will be discussed first, followed by mediated priming and backward priming.

**Forward Priming.**

Forward priming is measured by subtracting the related target response latency from the unrelated target response latency when the prime and target are related in the forward
direction, from the prime to the target. All tasks in the current study showed reliable forward priming effects. The expected patterns of forward priming across tasks were based on whether withholding a response in go/no go tasks is itself a response and whether semantic matching operated at the lexical decision, at response selection, or at both.

Two of the six contrasts reflecting the expected patterns of forward priming were significant (contrasts k and 1, see Table 6) and the associated residuals were not reliable. Both of these patterns suggested that go/no go tasks do require response selection. That is, it appears that withholding a response in the go/no go tasks is itself a response. They differed in terms of the locus of semantic-matching effects. Contrast k indicates that semantic matching operated at response selection only. Contrast 1, on the other hand, indicates that semantic matching operated at both the lexical decision and at response selection. Both of these contrasts are able to explain the pattern of priming obtained across tasks for forward priming.

Because both contrasts were significant, it is not clear which interpretation to accept based only on the pattern for forward priming. Unfortunately, none of the contrasts for mediated and backward priming were significant, so they cannot provide additional information regarding the operation of semantic matching. In any event, the results showed that
response selection appeared to be facilitated by semantic matching; it is unclear whether semantic matching operated at the lexical decision also.

Recall that response selection occurs after lexical access to the target has occurred, or, in other words, after recognition of the target. When semantic priming is used as a tool to investigate processes leading to lexical access, or word recognition, therefore, it appears that the use of standard lexical decision or go/no go tasks may produce forward priming effects that may be at least partially contaminated by processes occurring after lexical access to the target has been obtained. If the research interest is in examining only pre-lexical processes leading to word recognition and semantic matching operates only at response selection, then neither standard lexical decision nor go/no go tasks should be used because all facilitation from semantic matching would occur after processes leading to word recognition, or lexical access. If semantic matching operates at both the lexical decision and at response selection, then a careful analysis of the most appropriate task, based on a cost-benefit analysis of the contamination of priming effects due to post-lexical semantic matching, should be undertaken.

Although it is not entirely clear which of these two possibilities is most accurate, it might be noted that single-response lexical decision and standard pronunciation produced
almost identical levels of forward priming (20 ms and 18 ms, respectively). The similarity supports the interpretation that semantic matching operates only at response selection and not at the lexical decision. Because single-response lexical decision should have required a lexical decision to the target, semantic matching effects at this stage should have resulted in a larger forward priming effect for single-response lexical decision as compared to standard pronunciation, which does not require a lexical decision. This interpretation should be made with caution, however, in light of the latency data for single-response lexical decision that indicate that participants in this task may have been foregoing the lexical decision on a portion of the trials. If so, then semantic matching would not have operated, or would have operated only part of the time, in the single-response lexical-decision task.

According to the three-process theory of priming (Neely & Keefe, 1990), semantic matching biases a binary response, as was indicated by the pattern across tasks for forward priming. Predictions made for the go/no go task (Neely, 1991), however, indicate that go/no go should not benefit from semantic matching because it does not require an overt binary response. Recent findings (e.g., Neely & Sloat, 1995; VanVoorhis & Dark, 1995), however, have shown similar levels of forward priming for go/no go and standard lexical-decision tasks. These
findings have been interpreted as indicating that semantic matching must operate at the lexical decision, thus producing similar effects in go/no go and standard lexical decision. The current data suggest that these interpretations may have been incorrect. The data, at least for forward priming, are best explained by assuming that go/no go tasks do require a binary response and that this response can be biased by semantic matching. Furthermore, the lexical decision may not be facilitated by semantic matching at all. Further evidence is needed before a clear judgement can be made regarding this point.

**Mediated Priming.**

Mediated priming is measured by subtracting related target response latencies from unrelated target response latencies when the prime and target are related only via a mediating concept. None of the contrasts performed for the expected patterns of mediated priming across tasks were significant. Thus, it is difficult to interpret the obtained pattern in terms of the potential operations of semantic matching or in terms of whether go/no go tasks require response selection. Furthermore, when examined via ANOVA, no differences between tasks were found. Not all of the tasks, however, showed reliable mediated priming.

Pronunciation, the only task expected to show a mediated priming effect under all possible operations of semantic
matching, failed to show reliable mediated priming (7 ms). Standard lexical decision, the only task expected not to show a mediated priming effect under all possible operations of semantic matching, did show reliable mediated priming (22 ms). The only other tasks to show reliable mediated priming were pronunciation go/no go and single-response lexical decision (19 ms and 13 ms, respectively). Keypress go/no go showed a marginally reliable 11 ms effect.

According to the three-process theory (Neely & Keefe, 1990), mediated priming should occur in pronunciation due to automatic spreading activation, but should not occur in standard lexical decision because semantic matching operates to bias a nonword response when the prime and target are not directly related. The nonword response bias counteracts the facilitatory effects of automatic spreading activation in standard lexical decision.

One interpretation of the mediated priming effect in standard lexical decision and pronunciation go/no go, according to the three-process theory (Neely & Keefe, 1989), is that semantic matching was not operating to override the facilitatory effects of automatic spreading activation. The same interpretation, however, cannot account for the fact that backward priming was also found for both of these tasks.

It could be suggested that the mediated priming observed with these tasks resulted from expectancy. The prime and the
target are only indirectly related in a mediated priming trial. Both, however, are directly related to the mediating concept. Because the prime and the mediating concept are directly related in mediated priming trials, it is conceivable that the mediating concept could be part of a participant’s expectancy set of targets related to the prime. Because the mediating concept and the target are directly related, a mediating concept in the participant’s expectancy set could serve as a directly related prime for the to-be-presented target. If this were the case, however, then mediated priming would have obtained for all tasks, since expectancy is assumed to operate the same for all tasks.

Most of the literature on mediated priming (e.g., Balota & Lorch, 1986; de Groot, 1983) is comprised of studies in which mediated priming trials are mixed only with forward priming trials. Hence, the relative proportion of all trials that include related mediated trials is much higher than in the current study, which also contained backward priming trials and forward related filler trials, as well as nonword trials. Balota and Lorch, for example, included 14 mediated-related trials in a total of 112 trials (13%). The current study included 16 mediated related trials in a total of 320 trials (5%). It is possible that when the relative proportion of mediated trials is high, participants recognize the nature of the mediated relationship and thus develop a strategy to
utilize this information. When the relative proportion of mediated priming trials is low, participants may either (1) not recognize that on some of the trials the prime and the target form a mediated relationship, and thus they do not develop a strategy to utilize this information, or (2) recognize the mediated relationship on a small proportion of the trials but choose not to develop a strategy because the proportion of trials in which a mediated relationship exists is too small to make the strategy beneficial. Either of these possibilities could explain why, under the current condition of a low proportion of mediated priming trials, mediated priming was not found for pronunciation when under other circumstances it is (e.g., Balota & Lorch, 1986). It does not explain, however, why mediated priming was found with standard lexical decision and pronunciation go/no go, unless it is assumed that semantic matching was not operating in any conditions, but this would not account for the presence of backward priming in standard lexical decision and pronunciation go/no go.

An additional possibility is that semantic matching does not interfere with automatic spreading activation as hypothesized. The pattern of forward priming results leads to the interpretation that a binary response was required in the go/no go tasks, and, furthermore, that semantic matching operated at response selection, if not both at response
selection and at lexical decision. This interpretation, however, does not fit the pattern obtained for mediated priming. Clearly, other factors were operating in mediated priming that have not yet been considered in the literature. Further research with these tasks under mediated priming conditions is needed to more clearly determine what these factors are and how they are operating.

**Backward Priming.**

Backward priming is measured by subtracting the related target response latency from the unrelated target response latency when the prime and target are related in the backward direction only, from the target to the prime. Linear contrasts performed on the expected patterns of backward priming indicated that none of the expected outcomes adequately explained the pattern of backward priming obtained across tasks. There were also no differences in backward priming between tasks, but not all tasks showed reliable backward priming.

Only two tasks, standard lexical decision and pronunciation go/no go, showed a reliable backward priming effect (16 ms and 13 ms, respectively). A non-reliable backward priming effect for standard pronunciation conforms to all predictions for this task because it requires neither a lexical decision nor response selection. Thus, semantic matching does not operate. Single-response lexical decision
also failed to show backward priming. It has been argued that participants in single-response lexical decision did not actually make the lexical decision before responding on at least a portion of the trials, which would reduce or eliminate the operation of semantic matching. Thus, it is not surprising that backward priming was not found with this task either.

The presence of a backward priming effect in pronunciation go/no go indicates that semantic matching must have been operating for this task. It is unclear, however, whether semantic matching was operating at the lexical decision, at response selection, or at both. As predicted, standard lexical decision produced reliable backward priming, again indicating the operation of semantic matching. The locus of the semantic matching effect, however, is still not clear.

Because pronunciation go/no go showed reliable backward priming, it was surprising that keypress go/no go failed to. The absence of a backward priming effect with this task also fails to replicate the findings of Neely and Sloat (1995) who have obtained backward priming with keypress go/no go. Backward priming was predicted for this task under all possible hypothesized operations of semantic matching with the exception of the case that semantic matching operated only at the binary response and a binary response was not required in
The forward priming data suggest, however, that semantic matching is operating at the binary response. They further suggest that a binary response is required in go/no go tasks. Furthermore, pronunciation go/no go, which differs from keypress go/no go only in terms of response mode, shows backward priming. No differences in priming were found, however, that were based on response mode differences between tasks.

One explanation of the dissociation between the keypress and pronunciation go/no go tasks is that one of the tasks requires response selection and the other does not. It has been argued (e.g., VanVoorhis & Dark, 1995) that participants have a natural tendency to pronounce word stimuli that are visually presented to the extent that having to produce a vocal response other than to pronounce the stimulus leads to response interference. The interference is in the form of competition between the required response (not the target name) and the preferred response (the target name). If their argument is correct, then it is possible that withholding the tendency to respond with the target name when it is visually presented is more difficult than withholding a keypress to a visually presented target. Of course, in the current study, participants were required to withhold responses to nonword stimuli. Interference would occur only to the extent that there is also a tendency to want to pronounce all stimuli.
(words and nonwords) when some of them are being pronounced (words). If so, it would then be possible that actively withholding a preferred response in pronunciation go/no go is the same as actively making a response, whereas withholding a keypress response in keypress go/no go is not the same as making a response.

If pronunciation go/no go required response selection but keypress go/no go did not, then pronunciation go/no go should show backward priming if semantic matching operates at response selection and keypress go/no go should not. This is what the current findings show. Once again, however, the patterns of mediated and forward priming across tasks do not fit this interpretation.

Comparisons to Extant Literature

Each of the mechanisms of Neely and Keefe's (1989) three-process theory (automatic spreading activation, expectancy, and semantic matching) of semantic priming were initially developed to handle forward priming data (e.g., Becker, 1980, 1985; Posner & Snyder, 1975). The mechanisms were combined in an attempt to explain dissociations in forward, mediated, and backward priming between pronunciation and lexical decision. To this end, the three-process theory does well. The current data, however, do not show patterns of priming predicted by the three-process theory. They also do not fit with established patterns for mediated and backward priming found
in the literature. The forward priming data, on the other hand, do conform to patterns established in the literature.

Part of the discrepancy between the patterns of mediated and backward priming patterns shown in the literature and in the current study may be due to differences in design. Prior examinations of priming have not included measurements of mediated and backward priming in the same study. Mediated and backward priming measures have been included with forward priming, but forward, mediated, and backward priming have not been measured together as a within-subjects variable, with the exception of Neely & Sloat (1995). It is, therefore, difficult to predict what effect on priming, if any, presenting mediated and backward related prime-target pairs together may have. It may be that strategies developed to handle one type of relationship between the prime and the target may not be useful in handling a different type of relationship between the prime and the target. Research in which type of priming serves as a between-subjects variable would be useful in answering this question.

Another problem that arises when mediated and backward priming are measured together is that different SOAs are typically used to measure these two types of priming because the mechanisms assumed to produce each type of priming operate under a different time-course. Automatic spreading activation, responsible for producing mediated priming, for
example, operates maximally at shorter SOAs (e.g., 100 - 300 ms; Neely, 1990), whereas expectancy and semantic matching operate only at longer SOAs (e.g., 500 - 1000 ms). The current study employed an SOA of 500 ms in an attempt to allow all priming mechanisms to operate. It may be that the 500 ms SOA was too long for maximal operation of automatic spreading activation, although Balota and Lorch (1986) found equal mediated priming in pronunciation from automatic spreading activation at both 250 and 500 ms SOAs. The current data and the literature (e.g., Neely & Sloat, 1995) also show evidence for the operation of strategic mechanisms at an SOA of 500 ms.

In addition to differences in design and SOA, the current research differs from most of the literature in that it did not include repeated presentations of either primes or targets. In backward priming studies, Seidenberg et al. (1984) repeated both primes and targets and Koriat (1981) repeated targets. In mediated priming, Balota and Lorch (1986) and de Groot (1983) repeated some, but not all, of the primes. Because of the confounding effects of repetition priming (facilitation in responding to repeated presentations of a stimulus) on measurements of semantic priming, it makes comparisons between the current research and research that incorporates designs that repeat either primes, targets, or both, difficult. It is difficult to know what impact repetition of primes and targets has on the various types of
priming. Future research examining context effects in semantic priming should avoid repeating primes and targets.
CONCLUSIONS AND IMPLICATIONS

All expected patterns of priming across tasks were based on possible operations of semantic matching mechanisms proposed by the three-process theory (Neely & Keefe, 1990). Specifically, the expected patterns differed depending on the locus of operation of one of the proposed mechanisms, semantic matching. They also differed according to which stage(s) of processing were assumed to operate for each task. According to the three-process theory, semantic matching operates to bias response selection. Furthermore, response selection should not be required in go/no go tasks.

The pattern of forward priming obtained across tasks indicated that response selection was required in the go/no go tasks. The forward priming results also indicated that semantic matching operates at response selection. Whether semantic matching also operates at the lexical decision was not apparent. Research using semantic priming as a tool to investigate processes leading to lexical access, therefore, should not use the standard lexical-decision task because priming measured with this task is likely to be contaminated by post-lexical semantic matching effects. The pattern of forward priming across tasks indicates that go/no go tasks require response selection as well. As such, the use of go/no go tasks should also be avoided if an uncontaminated measure of semantic priming is needed or desired. Clearly further
examination of go/no go tasks and the processes involved in these tasks needs to be done.

None of the expected outcomes for mediated or backward priming based on the three-process theory (Neely & Keefe, 1990) adequately explained the actual priming found across tasks. As such, no clear conclusions regarding the operation of semantic matching or the nature of the response in go/no go tasks can be made. At best, it appears that semantic matching did operate in pronunciation go no/go under the current conditions, as evidenced by the reliable backward priming effect in pronunciation go/no go. It also appears that semantic matching did not operate in keypress go/no go under the current conditions, as evidenced by the absence of a backward priming effect with this task. It is not clear why semantic matching would operate with pronunciation go/no go but not with keypress go/no go.

The results raise questions regarding the usefulness of the three-process theory of priming (Neely & Keefe, 1990) to account for the varied patterns of priming obtained across tasks under the current conditions. According to this account of priming, mediated priming should obtain for standard pronunciation but not for standard lexical decision. Furthermore, backward priming should obtain for standard lexical decision but not for standard pronunciation. In other words, mediated and backward priming should be inversely
related across these two tasks. Go/no go tasks, according to a three-process account of priming, should show the same inverse relationship with standard lexical decision that pronunciation does because they should not benefit from a semantic matching bias of an overt binary response. Contrary to these predictions, standard pronunciation failed to show mediated or backward priming, whereas standard lexical decision showed both, as did pronunciation go/no go. Theories of priming need to be modified to incorporate the current findings, particularly the large priming effects found under all prime-target relatedness conditions with pronunciation go/no go.

Continued research investigating context effects in word recognition is an important step in the further development of theories of word recognition. A better understanding of these areas is also useful for educators interested in the development of reading and comprehension skills.
REFERENCES


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APPENDIX

CRITICAL PRIME-TARGET PAIRS
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