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Orthographically Mediated Inhibition Effects: Evidence of Activational Feedback During Visual Word Recognition

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Orthographically Mediated Inhibition Effects: Evidence of Activational Feedback During Visual Word Recognition

A Thesis
Presented to the
Department of Psychology
and the
Faculty of the Graduate College
University of Nebraska
In Partial Fulfillment
of the Requirements for the Degree
Masters of Arts
University of Nebraska at Omaha

by
Jason F. Reimer
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THESIS ACCEPTANCE

Acceptance for the faculty of the Graduate College, University of Nebraska, in partial fulfillment of the requirements for the degree Master of Arts, University of Nebraska at Omaha.

Committee

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Date 7/23/96

Abstract

According to the multistage activation model of visual word recognition (Besner & Smith, 1992a, 1992b; Borowsky & Besner, 1993), during visual word recognition, activation can spread from semantic to orthographic representations via a feedback mechanism. Two experiments were conducted in order to test directly whether or not such feedback occurs, and if so, under what conditions. In order to directly measure feedback, a mediated priming paradigm was utilized. In this paradigm, participants named aloud targets that were preceded either by a semantically related prime (e.g., dog - cat) or by a prime that is related to the target via a mediating word (e.g., dog - (cat) - vat). In this case the mediating word cat is semantically related to the prime, and is both orthographically and phonologically related to the target. Direct evidence of activational feedback was obtained in the form of mediated inhibition effects which were found in the presence of semantic priming effects. These mediated inhibition effects are consistent with activational feedback, thus, they support the multistage activation model of visual word recognition and not the activation-verification model (Paap, Newsome, McDonald, & Schvaneveldt, 1982; Paap, McDonald, Schvaneveldt & Noel, 1987).

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Orthographically Mediated Inhibition Effects: Evidence of Activational Feedback During Visual Word Recognition

Perhaps one of the most wide-spread effects cited throughout memory research is the facilitation effect found in both naming and identification tasks, when a target has been preceded by a semantically related prime. It is well documented that the speed at which a word can be named or classified largely depends on whether it was preceded by a related word (Meyer & Schvaneveldt, 1971; Meyer, Schvaneveldt, & Ruddy, 1975; see also Neely, 1977). For example, the identification of the word nurse is faster when preceded by the word doctor than when it is preceded by the word bread. This facilitation effect has been referred to as the single word priming or context effect (Borowsky & Besner, 1993) and has been found under a number of conditions (e.g., Cheesman & Merikle, 1985; Fischler, 1977; see also Becker, 1985).

Similar to context, another factor that has also been found to affect the naming and identification of words is stimulus quality. It has been well documented that responses to stimuli that have been degraded are often slower and less accurate than responses to stimuli that are intact (Becker & Killion, 1977; Meyer et al., 1975).

In addition to the separate effects of both context and stimulus quality, the combined effect of these two variables has also been of interest, particularly in terms of modeling visual word recognition. The joint effect of context and stimulus quality on reaction time (RT) has most often been examined using additive factors logic (Sternberg, 1969). According to additive factors logic, if two factors affect the same stage of a serial-stage process, an interactive effect will result. However, if the effects of the two factors are not exerted on the same stage, but instead affect separate stages of the process, an additive effect will result. Thus, when two factors statistically interact, one explanation is that the factors exert their influence on a common stage of the visual word recognition process. In contrast, any failure to find a statistical interaction between the two variables might suggest that the two factors do not affect the same stage of the serial process (Borowsky & Besner, 1993; Stolz & Neely, 1995).

When the joint effects of context and stimulus quality are investigated using both naming and lexical decision tasks, overadditive effects on RT are obtained (Becker & Killion, 1977; Besner & Smith, 1992a; Borowsky & Besner, 1993; Meyer et al., 1975; Stolz & Neely, 1995). More specifically, larger context effects have been obtained when targets are degraded than when they are intact. According to additive factors logic, one simple explanation of these data is that the effects of both context and stimulus quality influence the same stage of the visual word recognition process. This, of course, requires the conceptualization of a serial process that consists of separate, independent processing components. However, there exist a number of competing models of visual word recognition that do not consist of separate processing stages. Although each of these models uses its own unique architecture in order to explain the word recognition process, most can successfully account for the overadditive effects found between context and stimulus quality. In light of this, a brief review of a few of the current models of visual word recognition and their relative success in accounting for the Context x Stimulus Quality interaction follows.

Accounts of the Context x Stimulus Quality Interaction

Recently, Stolz and Neely (1995) addressed the question of whether two independent mechanisms, automatic spreading activation and compound cueing, could provide an account of the Context x Stimulus Quality interaction. Stolz and Neely argued that although both were able to successfully account for the separate effects of context and stimulus quality, each failed to provide a complete explanation of the combined effects of the two factors (see Stolz & Neely, 1995 for specific arguments). With respect to compound cue theory (Ratcliff & McKoon, 1988), according to Stolz and Neely, no attempt has been make to demonstrate how it can, in its present form, account for the Context x Stimulus Quality interaction. As for automatic spreading activation, they pointed out that since automatic spreading activation has been found to last only for around 400 ms (Neely, 1977), it would be difficult for automatic spreading activation to account for a Context x Stimulus Quality interaction found at stimulus onset asynchronies (SOAs) longer than 400 ms. Because a number of investigations have found overadditive effects between context and stimulus quality at SOAs greater than 400 ms (e.g., Besner & Smith, 1992a; Borowsky & Besner, 1993; Meyer et al., 1975; Stolz & Neely, 1995), Stolz and Neely argued that it is difficult to rely solely on automatic spreading activation in order to account for the Context x Stimulus Quality interaction.

In addition to these two independent mechanisms, a number of more encompassing models of visual word recognition have also claimed to have successfully accounted for this interaction. Although these models are able to provide an account of the overadditive effects found between context and stimulus quality with some degree of success, there exist considerable differences among them in terms of their architecture. In order to address more easily the various ways in which the Context x Stimulus Quality interaction can be accounted for, Borowsky and Besner (1993) have recently organized a number of these models into three classes based on their architecture. One such class of models that has been somewhat successful in accounting for the Context x Stimulus Quality interaction are what Borowsky and Besner called "activation-verification models". Among this class of models are both the expectancy model (e.g. Becker, 1985) and the activation-verification model (Paap, Newsome, McDonald, & Schvaneveldt, 1982; Paap, McDonald, Schvaneveldt & Noel, 1987). The common characteristic shared by these models is that they all contain both activation of letter and word detectors by visual input and a verification process in which word candidates are individually compared to a visual representation constructed as a result of the visual input.

Activation-verification models can account for the Context x Stimulus Quality interaction in a number of ways. For example, in Paap et al.'s (1982; Paap et al., 1987; Paap & Noel, 1991) activation-verification model (see Figure 1), activation of word nodes alone is not sufficient for identification. Instead, the activation process must be accompanied by a verification process. Recently, Besner and Smith (1992a) provided an extensive review of the activation-verification model. The present account is based on this review. According to Besner and Smith, in order to recognize input with the activation verification model, the visual presentation of a word causes two processes to begin operating simultaneously along two separate paths. Along one path, all the stored representations of orthographically related words are activated. Once a set of orthographically related words has been activated, the words are organized according to frequency in a subset referred to by Paap et al. as the "sensory set". Since verification is necessary for recognition, the visually presented word candidate is verified against each of the words in the sensory set. The verification process operates in serial fashion and terminates when a positive match has been made.

In addition to a set of orthographically related words becoming activated, when a word is visually presented, a visual representation of the word is created concurrently along the other path. Based on the visual representation, a set of semantically related words is activated in the semantic system. This subset is referred to by Paap et al. as the "semantic set". One critical assumption that the model makes is that whenever an active semantic set is available, the word candidate must first be compared to the items in the semantic set. Only in the case of a failure to find a match in the semantic set will the candidate be compared with items in the sensory set.

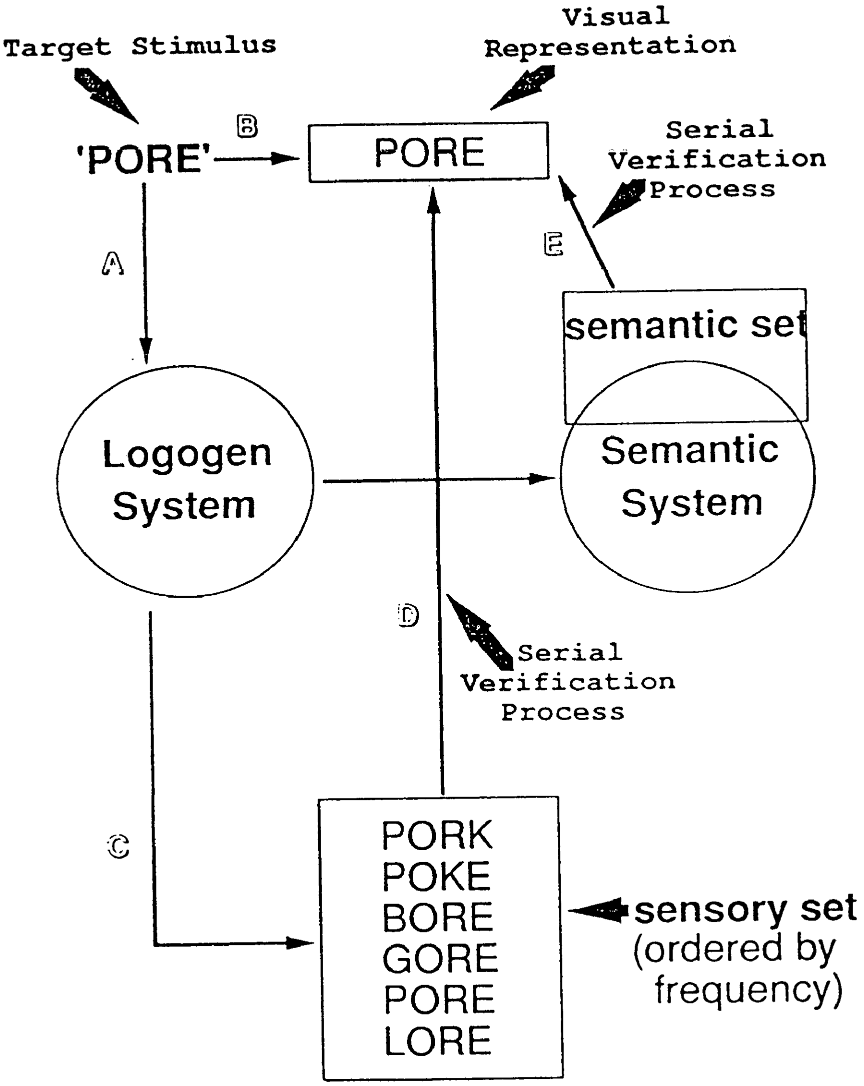

Figure 1. The activation-verification model. From "Models of visual word recognition: When obscuring the stimulus yields a clearer view," by D. Besner and M. C. Smith, 1992, Journal of Experimental Psychology: Learning Memory and Cognition, p. 474. Copyright 1992 by the American Psychological Association. Reprinted with permission of the author.

According to Besner and Smith (1992a), facilitative context effects are handled by the activation-verification model in the following manner. When a target follows a semantically related prime, the search of the active semantic set will result in a successful match since the prime would have preactivated the target's representation. Thus, a search of the sensory set is not required. However, when the target follows an unrelated prime, a match will not be found in the semantic set and a search of the sensory set is required. The additional time required to search the sensory set accounts for the longer RTs that have been obtained when the prime and target are unrelated.

As for stimulus quality effects, the activation-verification model holds that the recognition process as a whole is slowed down by degraded stimuli relative to intact stimuli, regardless of the route taken. However, the model also holds that stimulus degradation affects the construction of the sensory set more than it affects the construction of the visual representation.

In addition to explaining the separate effects of context and stimulus quality, the activation-verification model can also account for their joint effects. According to Besner and Smith (1992a), because of the assumption that degradation affects the construction of the items in the logogen system (or the level containing the word's orthographic representations) along one path to a greater degree than the construction of the visual representation along the other path, the activation-verification model can provide an account of the Context x Stimulus Quality interaction. For unrelated targets, the additional time required to search the logogen system after an unsuccessful search of the semantic system is greater for degraded targets than intact targets. However, due to the asymmetric cost of degradation associated with each of the two pathways, there is not as great of a cost associated with degradation for related targets. Thus, the additional cost associated with degraded unrelated targets, as compared to degraded related targets allows the activation-verification model to account for the interaction between context and stimulus quality.

Although the activation-verification class models are able to provide a somewhat complete account of the Context x Stimulus Quality interaction these accounts are not without their problems. For example, Besner and Smith (1992a) argued that since Paap et al.'s (1982; Paap et al., 1987; Paap & Noel, 1991) activation-verification model relies on the asymmetric cost of degradation on the two pathways, by somehow offsetting this asymmetry the interaction should disappear. According to Besner and Smith, one way of doing so would be to increase the size of the semantic set by presenting a prime that has a large number of associates (e.g., fruit). If the semantic set contains enough items, its required search might take longer than the time required for the construction of items in the logogen system, even if this construction has been slowed by degrading the target. Under these conditions, the greater effect that degradation has on the construction of items in the logogen system (a central assumption in the model's ability to account for the Context x Stimulus Quality interaction) would be offset by the rather lengthy search of the semantic set. Thus, in this way Besner and Smith proposed that the activation-verification models seems to predict that the overadditive effects between context and stimulus quality should decrease as the size of the semantic set increases, a prediction that they claim has yet to be tested (Besner & Smith, 1992a).

In addition, to this problem, Besner and Smith also pointed out that others (e.g., den Heyer, Briand, & Smith, 1985; Smith, Briand, Klein, & den Heyer, 1987) have demonstrated that the activation-verification model has difficulty accounting for the "inhibitionless" facilitation that both Neely (1976; 1977) and Posner and Snyder (1975) have obtained at short SOAs. Both Neely and Posner and Snyder demonstrated that with short SOAs, benefits in the form of the facilitation of RTs were found without any costs.

In contrast, they found that with longer SOAs, those same benefits in one condition were accompanied by the presence of inhibition in another condition. It is the facilitation found in the absence of inhibition that the activation-verification models have been previously shown to have difficulty accounting for.

Other problems have also been found with another model that is classified as an activation-verification model. Stolz and Neely (1995) have recently shown that Becker's (1980, 1985) expectancy model has difficulty accounting for the Context x Stimulus Quality interaction. The expectancy model is very similar to Paap et al.'s (1982; Paap et al., 1987; Paap & Noel, 1991) activation-verification model in its architecture. One exception is that participants can use a mechanism called expectancy in order to actively create an expectancy set during visual word recognition tasks that contains semantically related words. The expectancy set in the expectancy model is analogous to the previously described semantic set in the activation-verification model. By creating an expectancy set that consists of words that are semantically related to the prime, participants can facilitate the identification of target words that are semantically related to a previously presented prime.

Relatedness proportion (RP), or the proportion of prime-target word pairs that are semantically related in a test list, has been argued to affect expectancy by manipulating whether it is beneficial to actively create an expectancy set during word recognition tasks in order to facilitate the identification of related words (see Neely, 1991). When the RP is low, participants will not be as apt to actively create an expectancy set, since doing so might end up costing participants' processing speed more often than it will benefit their processing speed. This is mainly due to the fact that, as with the activation-verification model, in the expectancy model the expectancy set must be searched exhaustively before the visually defined set can be searched. On those trials in which the prime and target are not semantically related a large percentage of the time (i.e., when the RP is low), creating an expectancy set on every trial will end up costing processing more than it will be benefited. However, when the RP is high, creating an expectancy set on every trial will aid in the processing of the targets more times than it will hinder it. Thus, when the RP is high, participants are more apt to continue to use expectancy in their processing of the targets. The manipulation of expectancy by RP has been empirically demonstrated in numerous investigations (e.g., de Groot, 1984; den Heyer, 1985; Keefe & Neely, 1990; Neely & Keefe, 1989; Tweedy, Lapinski, & Schvaneveldt, 1977). In these studies, evidence that expectancy can be manipulated by RP is found in the form of a RP x Context interaction. In the RP x Context interaction, larger context effects are found when the RP is high than when it is low.

Stolz and Neely (1995) further argued that since expectancy is a slow-acting mechanism that can fall under the participant's control (Neely, 1976, 1977, 1991; Posner & Snyder, 1975), it should not be operational with short SOAs (i.e., < 200ms). More importantly, in order for expectancy to be able to solely account for the Context x Stimulus Quality interaction, Stolz and Neely argued that it should only be found under conditions in which expectancy is found to be operating, as indicated by the presence of a RP x Context interaction. However, Stolz and Neely obtained a Context x Stimulus Quality interaction under conditions (200 ms SOA) in which there was no evidence that expectancy was operating (there was no RP x Context interaction). Based on these data, they argued that expectancy alone cannot solely account for the overadditive effects.

There are two remaining types of visual word recognition models that exist within the reading literature. One of these types of models are referred to as parallel distributed processing models, commonly referred to as PDP models. Most PDP models share two main characteristics: (a) information is represented in a distributed fashion as an activational pattern across a number of processing units, and (b) most models of this kind contain three groups of processing units, an input layer, a hidden layer, and an output layer. Although there have been a number of PDP word recognition models proposed, only Seidenberg and McClelland's (1989) distributed model of word recognition and Masson's (1995) distributed memory model will be discussed presently. Seidenberg and McClelland's PDP model will be discussed first.

In terms of its architecture, Seidenberg and McClelland's (1989) PDP model consists of three pools of processing units with each containing a form of lexical information: contextual/semantic information, orthographic information, or phonological information. In addition to the these three processing pools, there is also a level of hidden units to which both the orthographic and the phonological pools are connected. Any processing that occurs between the orthographic and the phonological processing pools is mediated by the hidden units. As discussed above, the information in each of these pools is argued to be represented "as a pattern of activation over a number of primitive representational units" (Seidenberg & McClelland, 1989, p. 526). Thus, representations are not locally represented as in the activation-verification models. It is important to note that although there exists a semantic level within its more general architecture, this level was not yet implemented in the simplified model described in Seidenberg and McClelland (1989).

The main assumption in Seidenberg and McClelland's (1989) PDP model is that orthographic, phonological, and semantic information is involved in the processing of a word. According to Seidenberg and McClelland, codes at one level can influence the processing of codes at all the other levels. When a word enters the system, both orthographic and phonological codes are activated in a parallel fashion. In spite of this interactivity, and although the model is able to simulate a number of naming phenomena, it is difficult to see how Seidenberg and McClelland's model might account for the Context x Stimulus Quality interaction, since the semantic level has not been formally implemented (Besner & Smith, 1992a).

Another PDP word recognition model is Masson's (1995) distributed memory model. This model is similar to Seidenberg and McClelland's model in its general framework since it also consists of three main groups of processing units: orthographic units, phonological units, and meaning units. However, there are two main architectural differences between these models. One difference is that, unlike Seidenberg and McClelland's model, in Masson's distributed memory model there is no hidden layer between the orthographic and phonological units. The other difference is that the semantic level is fully implemented in order to simulate semantic priming. In the distributed memory model, semantic priming is accounted for by assuming that the activational patterns which represent semantically related words are themselves similar. Because RT is directly related to the number of updates that are required in the system, if the target is semantically related to the prime, the patterns of activation in the semantic system will be similar. Thus, the activational pattern for a target will become stable more quickly when it has been preceded by a semantically related prime than when it has been preceded by a semantically unrelated prime.

Although Masson's (1995) distributed memory model does appear to be closer than Seidenberg and McClelland's model in successfully accounting for the Context x Stimulus Quality interaction (as it was specifically designed to account for semantic priming), no attempt has been made to specify how the model would predict how stimulus quality might affect semantic priming. Thus, it becomes difficult to comment on how these models might handle the Context x Stimulus Quality interaction. It should be noted, however, that despite the absence of an explicit attempt to specify how these two PDP models might account for the Context x Stimulus Quality interaction, the high degree of interactivity contained in these models seems to allow for an account to be made quite easily. Because processing at every level of these models is influenced by the other levels, it follows that semantic and orthographic processing should interact with one another.

Besner and Smith's Multistage Activation Model

In light of the various problems associated with the activation-verification models (both the dual-route and expectancy theories) and the PDP models, Besner & Smith (1992a, 1992b; Borowsky & Besner, 1993) have recently proposed a multistage activation model of visual word recognition. The motivation behind the model arose from the nature of the effects found when context, stimulus quality, and word frequency are factorially combined. Using a lexical decision task, Borowsky and Besner (1993) found that context interacted with both word frequency and with stimulus quality. However, word frequency and stimulus quality were found to be additive. According to Borowsky and Besner, this pattern of data is difficult for most current models of visual word recognition to explain in their present forms (see Borowsky & Besner, 1993, for specific arguments); thus they proposed a multistage activation model.

One critical characteristic of the multistage activation model is the distinction it makes between subsystems and pathways. The model consists of five main subsystems: an orthographic input lexicon, a semantic subsystem, a subsystem containing subword spelling-sound correspondences, a phonological output lexicon, and a phonemic buffer (see Figure 2). The various subsystems are connected by pathways which can themselves serve as separate processing units. The distinction between pathways and subsystems is made in order to account for the joint effects of context, stimulus quality, and word frequency. Borowsky and Besner (1993) argued that one explanation for the existence of both additive and overadditive effects associated with the three factors is that there exist

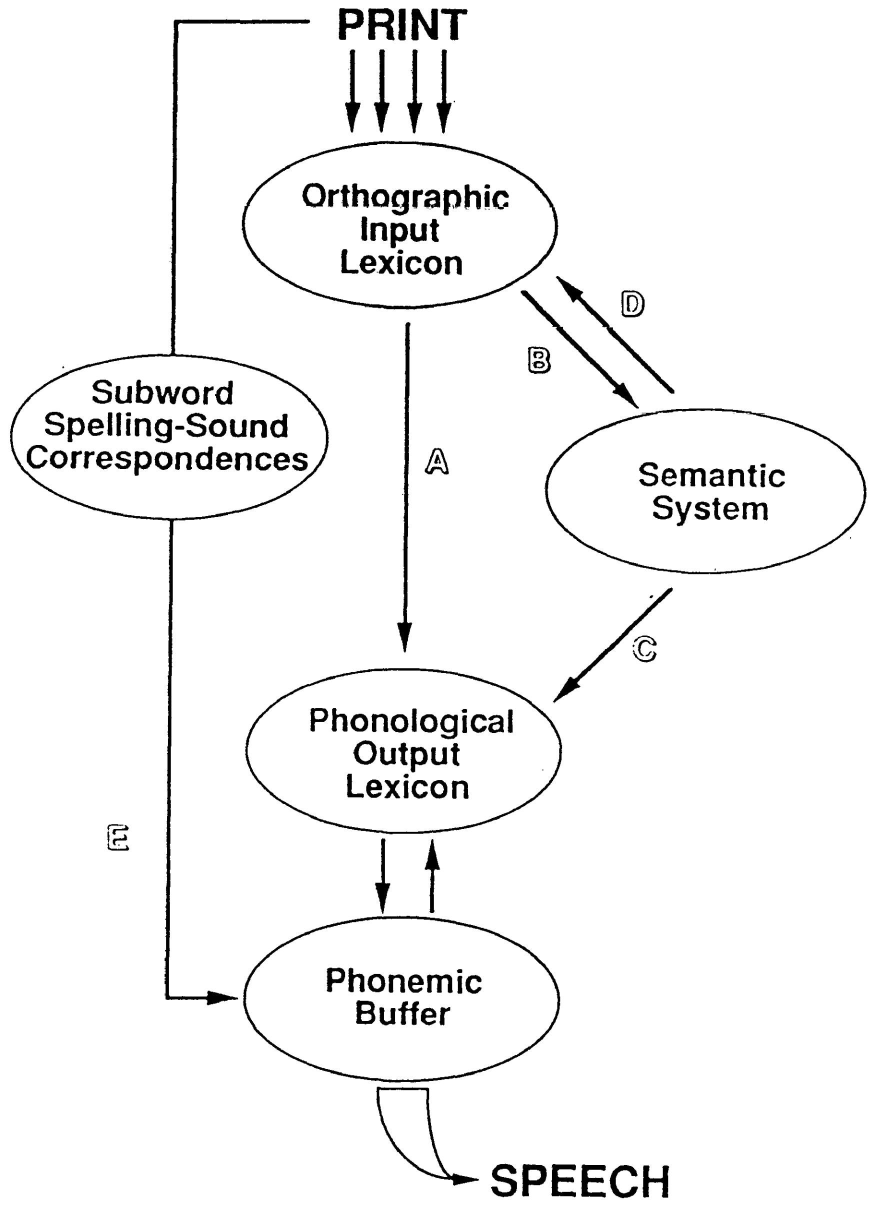

Figure 2. Besner and Smith's (1992a, 1992b) multistage activation model. From "Models of visual word recognition: When obscuring the stimulus yields a clearer view," by D. Besner and M. C. Smith, 1992, Journal of Experimenter Psychology: Learning Memory and Cognition, p. 477. Copyright 1992 by the American Psychological Association. Reprinted with permission of the author.

separate subsystems in the visual word recognition system which serve as separate processing units. With the inclusion of separated processing stages, variables can be argued to influence some subsystems without influencing others, while other variables can influence multiple subsystems at once.

According to Besner and Smith (1992b), there are three ways in which a visually presented word can be processed in the multistage activation model. The simplest way (at least in terms of requiring processing in the fewest number of subsystems) is via an "assembled routine". Utilizing this method of word identification requires the reader only to call up what Besner and Smith (1992b) refer to as "spelling-sound correspondence rules" (p. 14). These rules allow the reader to correctly assemble independent phonological units into the appropriate speech unit. From there, the activation is sent to the phonemic buffer where the phonemes associated with the word can be identified for the eventual speech output. Thus, in a naming task a reader might use this pathway in order to 'sound-out' each of the visually presented words without activating any lexical entries directly.

The second way in which Besner and Smith (1992b) claimed a visually presented word might be processed, is by first utilizing the orthographic input lexicon in which a "meaning free" representation of the word is activated. From there, the activation is fed directly to the phonological output lexicon where a corresponding representation resides containing the phonological information associated with the word. Finally, as with the first path discussed, the phonemic buffer is accessed and final information about the segment's phonemes are acquired for speech output. According to Besner and Smith (1992b), by using this path in a naming task a word can be named by first accessing the lexical entry of the word from the orthographic input lexicon.

Finally, the third way in which Besner and Smith (1992b) claimed a visually presented word can be processed is by first activating a corresponding representation in the orthographic input lexicon. However, rather than the activation moving directly to the phonological output lexicon, the activation is fed to the semantic system where information about the word's meaning is contained. From the semantic system activation presumably spreads to the phonological output lexicon where phonological information can be accessed, and then finally to the phonemic buffer. According to Besner and Smith (1992b), this is the pathway that is utilized in a lexical decision task. They argued that when participants engage in a lexical decision task, the semantic system is accessed and lexical decisions are ultimately made by searching for specific patterns of activation across the semantic system (Besner & Smith, 1992a).

Using such a framework, Borowsky and Besner (1993) were able to provide an account of each of the effects found when context, stimulus quality, and word frequency are combined. They argued that the locus of the stimulus quality effect is at the orthographic input lexicon, suggesting that stimulus quality affects the rate of activation of codes stored at that level. Word frequency, however, was posited to affect only the processing in the pathway connecting orthographic input lexicon and the semantic system. According to Borowsky and Besner, the function of the pathway is to pass along activation from the orthographic input lexicon and to map it onto codes in the semantic system. Words that are of high frequency get passed along from the orthographic system to the semantic system faster than low frequency words, thus accounting for the finding that high frequency words are identified faster than low frequency words. Because stimulus quality and word frequency exert their influence on different processing units, the model can account for the additive effects obtained when the two are combined.

In contrast to word frequency, according to the multistage activation model, context is argued to influence processing in both the orthographic input lexicon and the semantic system. In this way, the model can account for the overadditive effects found between context and both stimulus quality and word frequency. Thus, by using a model of visual word recognition that consists of a number of separate processing units, the multistage activation model can successfully account for the joint effects of context, stimulus quality, and word frequency.

Since the present investigation is concerned with the effects of context and stimulus quality, only the paths involving those subsystems that are argued to be affected by such variables in a lexical decision task will be discussed. According to Besner and Smith (1992a, 1992b; Borowsky & Besner, 1993), when a word is visually presented during a lexical decision task, the word's corresponding features stored in the orthographic input lexicon are activated via a cascaded process. Once a word's representation has been activated in the orthographic input lexicon, the activation is passed along a pathway to the semantic system. In the semantic system, the word's semantic representation is activated and through a spread of activation, the representations of related words also become activated. According to Besner and Smith (1992a, 1992b; Borowsky & Besner, 1993), the critical assumption is that activation from activated representations in the semantic system can be fed along a pathway leading back to the orthographic input lexicon. In this way corresponding representations in the orthographic lexicon can become activated as the result of activation in the semantic system. This assumption is critical to the multistage activation model because it ultimately allows for an accurate account of the Context x Stimulus Quality interaction to be made. Using the multistage activation model, Besner and Smith (1992a, 1992b; Borowsky & Besner, 1993) were able to provide an accurate account of context effects, stimulus quality effects and the Context x Stimulus Quality interaction.

Context Effects

According to Besner and Smith (1992a, 1992b; Borowsky & Besner, 1993), the model can account for context effects found in lexical decision tasks in one of two ways. First, when a prime is presented visually, its representation is activated in the orthographic input lexicon. From there, activation moves along a pathway to the semantic system where semantically related words are activated via spreading activation. If the target follows a semantically related prime, activation of the target's semantic representation in the semantic system is facilitated as a result of preactivation caused by a spread of activation from the prime, thus speeding up the lexical decision process as a whole. In contrast, targets that have been preceded by an unrelated context take more time to identify because they do not benefit from the preactivation at the semantic level as with targets preceded by a related word. Thus, the model can accurately account for context effects in lexical decisions.

More importantly, however, according to the multistage activation model, context effects can also be accounted for in another way; that is, through the use of the semantic feedback mechanism operating between the semantic system and the orthographic input lexicon. As discussed above, when a prime's representation has become activated at the semantic level, other semantically related representations also become activated. However, since activation from these related representations can be fed back to their corresponding representations in the orthographic input lexicon via activational feedback, activation that has spread from the semantic system will lower the activation threshold in each of these codes located in the orthographic input lexicon. The lowering of the code's thresholds will result in less data driven evidence being required for activation of those codes on subsequent encounters with the word they represent. In this way, when the prime and target are related the model predicts that RTs will be faster than trials in which the prime and target are unrelated.

Stimulus Quality Effects

According to the multistage activation model, as stated above, the effect of stimulus quality is only exerted on the orthographic input lexicon. The slower RTs associated with degraded targets as compared with intact targets are argued to be the result of more time being required to activate the code associated with the target word in the orthographic input lexicon, thus slowing down the system by that same amount of time.

Context x Stimulus Quality Interaction

Finally, the multistage activation model makes the prediction that context and stimulus quality will combine in an overadditive fashion since both context and stimulus quality affect a similar stage of processing: the orthographic input lexicon. Because activation can be fed back to the orthographic input lexicon from the semantic system, the model can successfully account for the overadditive effects that have been found with context and stimulus quality. Via activational feedback, only the codes of related words will become preactivated in the orthographic input lexicon by a related prime. The preactivation reduces the amount of data-driven information needed to activate the orthographic representation. Thus, degradation will affect the identification of unrelated targets more than related targets. The amount of time required to activate the orthographic representations will be reduced by the presentation of the prime only for related targets. The activation of unrelated targets at the orthographic level will not benefit from preactivation.

The Present Experiments

The basis for the present experiments is the activational feedback mechanism posited by Besner and Smith (1992a, 1992b; Borowsky & Besner, 1993). Because of this feedback mechanism, the multistage activation model allows for a complete account of the Context x Stimulus Quality interaction to be made, while at the same time, accounting for the additive effects that have been found between stimulus quality and word frequency. As a result of this, the feedback mechanism is a critical characteristic of the model. However, there currently exists no direct evidence of such a mechanism during visual word recognition. The only evidence available that supports the existence of this mechanism is the same evidence for which the mechanism was originally designed to account for. Thus, what is needed is some form of independent evidence that is consistent with activational feedback from the semantic system to the orthographic level.

In the present experiments, the presence of an activational feedback mechanism will be independently tested through the use of a mediated priming paradigm. This paradigm allows for any spread of activation from the semantic system to the orthographic level to be measured directly. The logic in using a mediated priming paradigm is that if activation does spread from the semantic system to the orthographic input lexicon, evidence of this activation should be found in the form of mediated priming effects. According to the multistage activation model (Besner & Smith, 1992a, 1992b; Borowsky & Besner, 1993), activated semantic representations are able to preactivate their corresponding orthographic representations via an activational feedback mechanism. If activation does spread from the semantic system to the orthographic input lexicon, the identification of targets that share a number of features (i.e., letters) with a representation in the orthographic input lexicon that has received activation from the semantic system should be faster than to targets that do not share features with a preactivated orthographic representation. By measuring the speed at which these preactivated orthographic representations can be processed, a more direct form of evidence supporting activational feedback can be obtained.

The critical assumption in the multistage activation model that allows for this prediction to be made is the manner in which the initial feature coding process operates in the orthographic input lexicon. According to Besner and Smith (1992a), "the processing of a printed word begins with activation of that word's representation in the orthographic input lexicon by means of the cascaded processing of features, letters, words, or morphemes" (p. 477). Because of the cascaded nature of the initial coding in the orthographic input lexicon, the multistage activation model predicts that the initial coding process of a word that has entered the word recognition system should be facilitated when that word contains features that have been previously preactivated by feedback from the semantic system. Thus, a facilitation of the coding processing of visual input should be found in the orthographic input lexicon any time that input consists of features that match the features contained in a preactivated representation.

For example, according to the multistage activation model, the semantic representation of the word cat will become activated in the semantic system via a spread of activation as a result of the presentation of the word dog. Furthermore, the model predicts that activation will spread from the "cat" semantic representation and preactivate its corresponding representation located in the orthographic input lexicon via the feedback mechanism. Thus, in the orthographic input lexicon, the orthographic coding of the letters "c", "a", and "t" will be facilitated on the subsequent encounters. However, because of the nature of the initial coding process in the orthographic input lexicon, the multistage activation model predicts that the identification of the word vat, should also be facilitated when preceded by the word dog, relative to when it has been preceded by another unrelated word. In this case, the initial coding operation in the orthographic input lexicon of the letters contained in the word vat that are shared by the word cat ("a" and "t"), should be facilitated because they have been preactivated by the presentation of dog.

Thus, by priming targets with words that are semantically related to words that share features with, or are orthographically related to, those targets, a direct test of the activational feedback mechanism can be conducted.

Because of the savings in processing time with the initial coding process in the orthographic input lexicon, if an activational feedback mechanism is present during visual word recognition, targets should be identified faster when they have been preceded by a prime that has a mediated relationship with that target than when they are preceded by a completely unrelated prime. However, if an activational feedback mechanism is not present, there should be no facilitation in the initial coding process. Thus, RTs for the mediated prime-target pairs should not be faster than their controls. Because this paradigm is able to provide evidence of an activational feedback mechanism in the form of indirect orthographic priming, a direct test of Besner and Smith's (1992a, 1992b; Borowsky & Besner, 1993) claim that feedback exists can be conducted.

Not only can the mediated priming paradigm provide direct evidence of activational feedback during visual word recognition, but, more importantly perhaps, it can provide a way in which the predictions of the activation-verification model (Paap et al., 1982; Paap et al., 1987) and Besner and Smith's (1992a, 1992b) multistage activation model can be compared. By using additive factors methodology alone, it is impossible to test between these models since they both predict that an overadditive effect should be found when context and stimulus quality are factorially combined. However, through the use of a mediated priming paradigm the activation-verification model and multistage activation model can each be unambiguously tested, since they make different predictions concerning mediated priming.

According to the activation-verification model, when the prime and target are semantically related, a semantic priming effect is predicted. Recall that the semantic priming effect occurs in the activation-verification model, because when the related target is compared to all the items in the semantic set a match will be found. However, when the target is not semantically related to the prime, a match will not be found in the semantic set, and the sensory set will be searched. Thus, the semantic priming effect can be accounted for using the activation-verification model because of the extra processing time required to search the semantic set when the prime and target are not semantically related. With respect to word pairs that are related in a mediated fashion, however, in contrast to the multistage activation model, the activation-verification model predicts that the mediated pairs should not be identified any faster than their controls.

For example, according to the activation-verification model, when the word dog is presented as the prime, a semantic set will be constructed that contains all the items in the semantic system that are semantically related to dog (e.g., pet, cat, bark, etc.). Likewise, along another path, a sensory set will be constructed that contains orthographically similar items (e.g., log, jog, fog, etc.). Upon the presentation of the target, vat, nowhere in the system has vat, or any of its features, been activated through the presentation of the word dog. Since the items in the semantic set do not each activate their corresponding related orthographic representations, vat will not be included in the sensory set as a result of the presentation of the word dog. Also, since the words dog and vat are not semantically related, vat will not appear in the semantic set. In this way, according to the activation-verification model, the target vat will be processed as if it was an unrelated target. Therefore, using the activation-verification model in its present form, it would be difficult to account for any mediated priming effects that might be obtained. In contrast to that model, however, the multistage activation model clearly predicts these mediated priming effects. Because of the differences in terms of their predictions concerning mediated priming, the mediated priming paradigm can be used as a way to test between these two models of visual word recognition.

Previous Studies Attempting to Find Evidence of Activational Feedback

As stated above, one of the goals of the present investigation is to provide direct evidence of an activational feedback mechanism by measuring mediated priming. To my knowledge, in the existing literature there exists only two studies (only one by design) that have attempted to measure orthographic priming effects that are the result of a spread of activation from the semantic level to the orthographic level. The results of these studies are of critical interest because they can potentially provide evidence of the activational feedback mechanism posited by Besner and Smith (1992a, 1992b; Borowsky & Besner, 1993). These two studies, McNamara and Healy (1988; see also McNamara & Gray, 1990) and Norris (1984), will be discussed in detail since each is extremely relevant to the present experiments.

Of these two experiments, the set of experiments performed by McNamara and Healy (1988) is most relevant to the current investigation. Although McNamara and Healy were not testing the feedback mechanism present in the multistage activation model, they were interested in testing a similar mechanism found in a model of semantic memory proposed by Collins and Loftus (1975). According to the Collins and Loftus model, semantic memory consists of two separate networks. One network contains graphemic (orthographic) and phonological information contained in words. Words residing in this network are argued to be organized according to this information. The other network contains semantic information, and is organized according to semantic relatedness. Collins and Loftus suggested that codes can be retrieved via a spread of activation at both levels. The component of Collins and Loftus' model that McNamara and Healy were interested in testing is a mechanism that is analogous to the feedback mechanism in the multistage activation model. The assumption made by the Collins and Loftus' semantic memory model is that it is possible for activation to spread from the semantic network to the orthographic network during visual word recognition. Since McNamara and Healy were interested in testing this assumption, the goal of their experiments and the goal of the present experiments are quite similar.

In order to test whether activation spreads from the semantic to the lexical level during word recognition, McNamara and Healy (1988) used a mediated priming paradigm. In their investigation, McNamara and Healy presented semantically related (light - lamp), phonologically related (lamp - damp), and mediated (light - damp) word pairs in both a lexical decision task and a self-paced reading task. Note that in the mediated condition, instead of using a purely semantically mediated relationship such as, lion - (tiger) - stripes (e.g., Balota & Lorch, 1986; de Groot, 1983; McNamara & Altarriba, 1988) in their mediated condition, the meditated relationship was orthographic and phonological. For example, the target (damp) is both orthographically and phonologically related to a word (lamp) that is in turn semantically related to the prime (light). McNamara and Healy argued that if activation does spread from the semantic level to the lexical level during word recognition, then one should find faster RTs for trials in which the prime and target contained a mediated relationship than for trials in which this relationship between the primes and targets was not present.

In their mediated condition, based on Collins and Loftus' (1975) model, McNamara and Healy (1988) predicted that activation from the prime light will spread to the semantically related words at the semantic level (i.e., lamp). If the two networks are linked, the activation should spread back to the lexical level, and lamp's corresponding representations at the orthographic level should become activated. Furthermore, according to Collins and Loftus, since activation also spreads at the orthographic level, the model predicts that those representations that are orthographically related to representations activated at the orthographic level should also become activated (i.e., damp). This activation should then lead to damp being identified more quickly when preceded by the word light than when it has been preceded by some other completely unrelated context.

In addition to the mediated condition, due to the nature of the model on which their experiments were based, McNamara and Healy were forced to also include the two other conditions, semantically related items and phonologically related items. With the addition of these two conditions, if there was a failure to obtain mediated priming (e.g., between light and damp), McNamara and Healy could at the very least demonstrate that activation had spread between the two semantically related words (light and lamp) and the two phonologically and graphemically related words (lamp and damp).

In order to test Collins and Loftus's (1975) prediction that activation can spread from the semantic network to the lexical network, McNamara and Healy (1988) determined whether target words (e.g., damp) took less time to identify when preceded by a prime (e.g., light), than when preceded by a prime that was not related to the target (queen) in any way (neither a mediated nor a semantic relationship). In one task, participants were shown two strings of letters simultaneously and were instructed to make lexical decisions on them. This lexical decision task was done both with and without nonwords included in the test lists. In another task participants were engaged in a reading task, in which they were again presented with two letter strings simultaneously, however, rather than performing a lexical decision on them, they were instructed to simply read each pair of letter stings silently at their own pace. Half of the participants were told that they would subsequently be given a memory test for the words, while the other half of the participants were not told of a memory test. In neither case was a memory test actually given to the participants.

When nonwords were included in the test lists, McNamara and Healy obtained not facilitation but inhibition effects with the mediated word pairs, using both the lexical decision and reading task. In other words, they found that responses to the targets in the mediated condition were, in some cases, both slower and less accurate than responses to those same targets in the control condition. Furthermore, these inhibition effects were found in the presence of facilitatory semantic priming and rhyming effects. When nonwords were not included in the test lists, these inhibition effects disappeared, while the semantic priming and rhyming effects remained.

McNamara and Healy (1988) interpreted these results as evidence against the spread of activation from the semantic level to the lexical level during word recognition. They attributed the inhibitory effects found in the lexical decision task when nonwords were included in the test lists to postlexical decision processing. However, by eliminating postlexical processing through the use of a reading task, when nonwords were included in the test lists, the inhibitory effects remained. McNamara and Healy again accounted for these inhibitory effects by arguing that "subjects [still] made implicit lexical decisions while reading the pairs of words" (p. 406). Furthermore, they claimed that the implicit lexical decisions that the subjects were making in their reading task were the "unavoidable consequence of noticing that some letter strings were not words, or it might have resulted because of the difficulties encountered in reading nonwords" (p. 406). Thus, in all cases, the inhibitory effects found in the mediated condition were argued to be the result of postlexical processing.

In a follow-up study, McNamara and Gray (1990) used the same mediated priming paradigm as was used by McNamara and Healy (1988). However, two changes were made in the procedure in order to eliminate the possibility that the reason McNamara and Healy failed to obtain any facilitative mediated priming effects was due to relatedness-checking strategies. First, the letter strings were presented one at time, as opposed to presenting them simultaneously. And second, semantically related word pairs were not included in the test lists. McNamara and Gray also failed to find any facilitative mediated priming effects, and again interpreted these results as additional evidence against a link between the semantic and orthographic networks.

The second investigation that might provide evidence of an activational feedback mechanism in word recognition was a study conducted by Norris (1984). In that investigation, a lexical decision task similar to McNamara and Healy's was used. The only difference between the two investigations lies in the motivation behind them. In contrast to the McNamara and Healy study, which was designed to examine more directly activational feedback from the semantic to the orthographic systems, Norris was interested in the "mispriming effect" in lexical decisions. The relevant condition in that study was the misprimed condition. The misprimed condition contained trials that consisted of word pairs that were constructed by changing one letter of the target word in semantically related prime-target word pairs (i.e., instead of BREAD - BUTTER, BREAD - BATTER was presented). Although Norris was not directly interested in whether activation could spread from the semantic system to the orthographic input lexicon, the stimuli were constructed in such a way that the results could provide direct evidence of activational feedback. Just as McNamara and Healy used prime-target word pairs that were mediated, Norris' stimuli also consisted of mediated associates. In the misprimed condition, targets were orthographically related to words which were in turn semantically related to the prime.

These prime-target word pairs are quite similar to McNamara and Healy's (1988) critical mediated prime-target word pairs. The only difference is that the targets and the mediating words did not rhyme in Norris' (1984) experiment as they did in McNamara and

Healy's. Because of the similarities between these two studies, it can be argued that Norris' results might also provide evidence of an activational feedback mechanism. However, Norris also failed to find a reliable facilitation effect in either RTs or accuracies for the misprimed pairs. In fact, similar to that which McNamara and Healy found in half their data, Norris also found that the lexical decisions in the misprimed condition were often slower and were always less accurate than the lexical decisions in the control condition. Norris attributed these results to an orthographic check that takes place postlexically during lexical decisions.

Various Problems Associated with Previous Studies

Based on the results of both McNamara and Healy (1988; McNamara & Gray, 1990) and Norris (1984), it might appear that the question of whether a feedback mechanism exists during word recognition has already been addressed. Although both studies did provide some evidence of inhibitory mediated priming, in each case the effects were attributed to postlexical processes, rather than to an activational feedback mechanism. The failure of McNamara and Healy to obtain any mediated effects at all in their "no-nonwords" condition were argued to be the result of an absence of a spread of activation from the semantic network to the lexical network. In other words, they claimed that activational feedback simply does not exist. However, there are at least two issues surrounding these investigations that might lead one to question whether McNamara and Healy (1988) and Norris (1984) have settled the matter definitively with these accounts of their data. The first issue has to do with the type of prime-target word pairs that surrounded the mediated trials in McNamara and Healy's investigation. The second issue has to do with a potential problem associated with using either the lexical decision task or the reading task in order to look for mediated priming effects.

The first issue speaks mainly to McNamara and Healy's failure to find any evidence for activational feedback in their investigations when nonwords were excluded from the test lists. This issue has to do with the possibility that the nature of the superset of trials in which the critical trials resided might have biased the word recognition system in such a way that it was unlikely that activational feedback was even operating. Recently, Stolz and Neely (1995) found that the Context x Stimulus Quality interaction was modulated by the proportion of total trials in a primed lexical decision task in which prime-target pairs were semantically related. More specifically, they found that the Context x Stimulus Quality interaction disappeared when the RP was low (.20). From these data, Stolz and Neely (1995) concluded that, perhaps in the context of a low RP, the word recognition system shuts down the feedback of activation from the semantic system to the orthographic system in order to save a limited amount of activation that is available to the system at any given time. They argued that the only benefit gained in allowing feedback to occur is that the representations of semantically related targets can become activated in the orthographic input lexicon more quickly on subsequent encounters with those words. However, under conditions in which the targets are semantically related to the prime on only 20% of trials, the system would benefit from preactivation in the orthographic input lexicon only 20% of the time. Thus, allowing feedback to occur under these conditions creates a high cost-benefit situation and therefore the feedback is blocked.

In light of Stolz and Neely's (1995) data, the proportion of the total trials that consists of semantically related prime-target word pairs becomes critically relevant. Although in Norris' experiment there was an equal number of semantically related and semantically unrelated prime-target word pairs (creating an RP of .50), the RP never exceeded approximately .16 in McNamara and Healy's investigation. Since no semantically related prime-target word pairs were used in the test list at all in McNamara and Gray (1990), the RP was essentially set at zero. Therefore, one explanation for the failure to find activational feedback with the mediated items in these studies is that the stimulus context was such that the operation of activational feedback was not promoted. If activational feedback does rely on a high RP, it is not at all surprising that McNamara and Healy and McNamara and Gray failed to obtain mediated priming when nonwords were not included in the test lists.

There is a second issue surrounding McNamara and Healy's (1988) study, in particular, that could have also contributed to their failure to obtain meditated priming effects when nonwords were excluded from their test lists. One could argue that the nature of the tasks used by McNamara and Healy led to null effects with half of their data. Recall that McNamara and Healy used both the lexical decision task and a reading task in their investigations. The main problem with the reading task is that there is no way of objectively assessing what the participants are doing during the task. In other words, one problem with the reading task is that it is impossible to know whether subjects are performing the task itself. McNamara and Healy acknowledged this disadvantage, but defended it based on two arguments. First, McNamara and Healy argued that the reading task has been used in the past, citing Aaronson and Scarborough (1976), and added that they were not aware of any problems with its use in that study. Secondly, McNamara and Healy, argued that by adding a condition in which the primes and targets were semantically related (as they did with their inclusion of a semantic-relatedness condition) one can determine whether participants were processing the meaning of the words. In effect they argued that the presence of semantic priming with the reading task can serve as evidence that the participants were reading the words and that the meanings of the word were being accessed.

Their first argument, to me at least, is less than convincing. Just because McNamara and Healy (1988) were not aware of any problems associated with the use of the reading task in previous studies certainly does not justify its use in their study. Their second argument is, however, more convincing, at least up to a point. That is, the inclusion of a semantic-relatedness condition might in fact be used as a diagnostic to indicate whether that the participants were reading the words and were accessing meaning. However, there is still no way of knowing for certain whether subjects were always actually reading the correct words. Granted, if a semantic priming effect is obtained in the semantic-relatedness condition, even if participants were making reading errors, they obviously did not do so at such a high rate that it affected the semantic priming effects. However, the addition of the mediated condition in McNamara and Healy's (1988) study presents a different kind of problem. In McNamara and Healy's mediated condition, two strings of letters were presented in which one of the letter strings was both highly graphemically and phonologically similar to a word that is semantically related to the other letter string. This, coupled with the fact that some of the trials in the test list contained strings of letters that were in fact semantically related might have made it easy for participants to make processing errors. More specifically, the context in which the mediated trials were placed might have biased the participants toward incorrectly processing some of the words in the mediated condition as if they were the semantically related word as opposed to a word that looked very similar to a semantically related word. For example, rather than correctly processing the words, light and damp in the mediated condition, participants may have instead processed light and lamp. Since the participants were not being checked for accuracy, they might not even have been aware that they were processing the wrong word in some of the trials.

This possibility becomes even more convincing if it is assumed that Besner and colleagues (Besner & Smith, 1992a, 1992b; Borowsky & Besner, 1993) are correct in stating that semantically related representations can preactivate their corresponding representations in the orthographic input lexicon. Assuming that this is the case, if the orthographic representation of the word lamp was preactivated by the presentation of the word light, then an unchecked reader might become even more biased towards incorrectly processing the word damp as the word lamp in the mediated condition. It should be noted that this same argument can also be applied to the lexical decision task. Because the participants are not required to actually say each word aloud, some words might be incorrectly processed in the mediated condition without the errors ever being revealed.

In light of the inherent problems in using the reading task to assess mediated priming, McNamara and Healy's (1988) data becomes severely compromised. If their participants were in fact incorrectly reading even a small percentage of the words presented to them, this could have acted to mask any mediated priming effects that were present in their mediated conditions. Given that facilitatory semantic priming effects were found in their semantic-relatedness condition, and that when present, the mediated effects were inhibitory, if McNamara and Healy's participants were incorrectly reading the semantically related word as opposed to correctly reading the mediated word in the mediated condition, this would have served to reduce any existing inhibitory mediated priming effects. Even by incorrectly reading words in only a small percentage of the trials, this relatively small number of errors could have resulted in the elimination of what might already be a very small mediated effect.

More important, however, by using either the lexical decision task or a reading task, there is no way to know for certain if and when participants were making processing errors. This fact would become even more problematic if facilitatory mediated priming effects (as are predicted presently) were obtained in an experiment in which lexical decisions or a reading task was used. By obtaining facilitatory mediated priming using these tasks, a simple alternate explanation of the data would be that the participants were actually at times incorrectly processing the targets as the semantically related word instead of the mediated word. Any facilitatory priming effects found in the mediated condition might simply reflect semantic processing. Unfortunately, by using the reading task or lexical decisions, elimination of this alternate account would not be possible.

Inhibitory Mediated Effects as Evidence of Activational Feedback

Although evidence of activational feedback has been discussed thus far in terms of facilitatory mediated priming effects, given the results of McNamara and Healy (1988; McNamara & Gray, 1990; Norris, 1984) it is perhaps even more likely that mediated inhibition effects will be obtained using the mediated priming paradigm as opposed to mediated facilitation effects. It is important to note that if, in the present investigation, mediated inhibition effects are obtained instead of facilitatory mediated effects, these inhibitory effects would also support the existence of an activational feedback mechanism. The multistage activation model (Besner & Smith, 1992a, 1992b; Borowsky & Besner, 1993) can just as easily account for inhibitory mediated effects as it can facilitatory mediated effects.

One way activational feedback might result in mediated inhibition effects is by producing interference in the orthographic input lexicon. Recall that according to the multistage activation model, corresponding orthographic representations of semantically related words become preactivated in the orthographic input lexicon as a result of the feedback mechanism. These preactivated representations "are less dependent on data-driven stimulus information than are those of unrelated targets" (Besner & Smith, 1992a, p. 478). Since activational feedback lowers the activational thresholds of preactivated representations in the orthographic input lexicon, these representations would not only be less susceptible to degradation, but would also require less data-driven information to exceed to their activational thresholds and fire. When mediated targets (i.e., targets that are orthographically similar to a word that is semantically related to the prime) are presented, these words contain a large number of identical features that are contained in the representations of preactivated semantically related targets residing in the orthographic input lexicon. As a result of this orthographic similarity, and as a result of preactivation, the mediated targets might contain enough orthographic evidence to cause the preactivated semantically related representations to fire. Thus, upon presentation of the mediated targets, two separate representations would become activated simultaneously in the orthographic input lexicon: the actual orthographic representation of the target and the preactivated orthographic representation that is similar of a word semantically similar to the prime. The interference caused by these two representations becoming simultaneously activated would cause an inhibition effect; that is, the interference caused by the inadvertent activation of the preactivated representation might slow down the processing of the actual representation of the target in the orthographic input lexicon. This interference would lead to an increase in RTs and in error rates for mediated targets as compared to their controls.

This account can be presented more clearly through the use of an example. According to the multistage activation model (Besner & Smith, 1992a, 1992b; Borowsky & Besner, 1993), when a prime such as the word mother is presented, activation spreads at the semantic level to the representations of semantically related words (e.g., father). Furthermore, activation from these representations at the semantic level will preactivate their corresponding representations at the orthographic input lexicon via the feedback mechanism. Therefore, the representation of the word father in the orthographic input lexicon will have become preactivated as a result of the presentation of the prime mother. Since the activational threshold of the orthographic representation of the word father has been lowered, upon the presentation of the orthographically mediated target lather, the letters "a-t-h-e-r" might have provided a sufficient amount of data-driven evidence for father's preactivated representation to become activated - despite the fact that father was never actually presented. Since lather was the target that was presented its orthographic representation would also become activated. The simultaneous activation of both representations in the orthographic input lexicon might serve to slow processing of the correct representation in the orthographic input lexicon. In this case, it would slow the processing of the target lather in the orthographic input lexicon, thus, slowing the identification process of the target lather overall. According to this logic, direct evidence of activational feedback during word recognition will be obtained in the present experiments if mediated inhibition effects are found.

Just as with facilitatory mediated effects, the activation-verification model (Paap et al., 1982; Paap et al., 1987) has similar difficulty accounting for mediated inhibition effects that could be found using the mediated priming paradigm. For example, in working through the activation-verification model, upon the presentation of the prime mother a sensory set and a semantic set would become activated. When the target lather is presented, the semantic set would be searched first since one assumption of the activation-verification model is that if a semantic set is available it will be searched before the sensory set. Because the word lather is not semantically related to the word mother the search of the semantic set will fail and a search of the sensory set will be initiated where a match will be found. Thus, the total amount of time required to identify the word lather includes the time it takes to search the semantic set plus the time required to search the sensory set. This amount of time should, however, should be the same in the control condition when the target lather has been preceded by an unrelated prime, such as the word high. In both cases, the semantic set would not include the target since in neither has been preceded by a semantically related prime. Because previously activated representations in the semantic system cannot affect processing in the sensory set in the activation-verification model, the target lather will be processed in the same manner regardless of whether it is preceded by the word mother or high.

Therefore, as with facilitatory mediated priming effects, the activation-verification model cannot account for inhibitory mediated effects. The model clearly predicts that the amount of processing required for both mediated targets and unrelated targets will be identical. Thus, according to the activation-verification model, neither facilitatory nor inhibitory mediated effects should be found using the mediated priming paradigm. Because the multistage activation model can account for either effect the mediated priming paradigm provides a powerful test through which these two models can be tested.

In all, the various problems associated with the previous investigations that have been conducted in order to test for activational feedback during visual word recognition renders the status of an activational feedback mechanism in visual word recognition unknown. The only two investigations that could have shed light on the notion of activational feedback during word recognition have been shown to contain features that may have suppressed or even eliminated the effects of any feedback that might have been present. In light of these methodological issues, two experiments will be conducted in an attempt to provide direct evidence of activational feedback in word recognition by measuring mediated priming effects in the absence of these methodological problems. By using the mediated priming paradigm, two competing models of visual word recognition can be tested, while also addressing other important issues related to activational feedback.

Experiment 1

The first experiment is designed to examine whether activation spreads from the semantic system to the orthographic input lexicon during a naming task. As stated above, the multistage activation model (Besner & Smith, 1992a, 1992b; Borowsky & Besner, 1993) clearly predicts that under certain conditions activation from the semantic system will spread to the orthographic input lexicon. This spread of activation should result in a decrease in the amount of data-driven evidence required in order for orthographic representations to become fully activated. By using the mediated priming paradigm, any decrease in the activation threshold of representations located at the orthographic level can be measured.

Moreover, in Experiment 1, the mediated priming paradigm will be used in order to test between two prominent models of visual word recognition: the activation-verification model (e.g., Paap et al., 1982) and Besner and Smith's (1992a, 1992b) multistage activation model. As shown above, these two models predict different outcomes concerning mediated priming effects. The multistage activation model predicts that if activational feedback is present, either facilitatory or inhibitory mediated effects should be found using the mediated priming paradigm. In contrast, the activation-verification model predicts that the mediated targets should not be faster or slower than their controls, since the amount of processing associated with each should be the same.

In order to test between these two models by testing activational feedback, in Experiment 1, two main types of prime-target relationships will be created. In one type of prime-target relationship, the prime-target word pairs will be semantically related (e.g. dog - cat), in the another, the relationship between the prime and target will be mediated (e.g. dog - (cat) - vat, in which case, cat serves as the mediating word between the prime and target). The mediated condition that will be used is similar to the mediated condition found in McNamara and Healy's (1988). However, there will be two critical features of Experiment 1 that will set it apart from the work that has been previously done in this area. The first important feature of Experiment 1 will be that RP will be manipulated.

The term RP has been used to describe the proportion of total experimental trials in which the prime and target are semantically related (Stolz & Neely, 1995). This definition will also be adopted in the present investigation. Thus, those prime-target word pairs that are related in a mediated fashion will be considered as not related when calculating the proportions. Two RP conditions will be created: (a) a .50 RP condition where 50% of the total word-word trials will be semantically related, and (b) a .20 RP condition where 20% of the total trials will be semantically related.

By manipulating the RP in the test lists, two issues can be addressed. First, RP will be manipulated in order to further examine whether the activational feedback from the semantic system to the orthographic input lexicon is in fact modulated by RP as claimed by Stolz and Neely (1995). Recall that Stolz and Neely (1995) only found overadditive effects between context and stimulus quality when the RP was high (.50). They argued that when RP is too low, feedback of activation from the semantic system to the orthographic level is restricted. If this is the case RP should also be found to modulate mediated priming. Thus, a mediated priming effect should not be found for mediated pairs when RP is low (.20 RP), but should emerge when the RP is high (.50).

The second issue that can be addressed by manipulating RP in Experiment 1 is whether McNamara and Healy (1988; McNamara & Gray, 1990) correctly attributed their null effects to an absence of any spread of activation from the semantic to the lexical levels. By manipulating RP, one other alternative explanation for their failure to find mediated priming can be tested; that being that they failed to find mediated priming because the RP was too low in their experiments. If this is the case, the manipulation of RP should reveal both mediated priming and a failure to find mediated priming, depending on the level of RP. If McNamara and Healy failed to demonstrate mediated priming because of a low RP, when a low RP is used with the mediated priming paradigm, mediated priming should not be found. However, the mediated priming effect should emerge when the RP level is high.

In addition to increasing the RP, the second novel feature of Experiment 1 will be that a naming task will be used instead of a lexical decision or reading task to test for mediated priming. In this naming task, nonwords will not be included in any of the test lists. Three issues can be addressed by using a naming task. First, the possibility that the potential mediated priming effects are the result of postlexical processes can be eliminated. In a naming task participants are not required make any postlexical decisions on the stimuli, but instead are only required to name them as quickly as possible. Thus, by using a naming task, it is possible to eliminate any postlexical processing that might arise as a result of participants being required to make postlexical decisions on letter strings. A naming task rather than the lexical decision task has been used in a number of studies in order to reduce postlexical processing (e.g., de Groot, 1984; de Groot, Thomassen, & Hudson, 1982; Neely & Keefe, 1989; West & Stanovich, 1982). It has been argued that because participants are not required to perform binary decisions on the stimuli, the possibility of any postlexical processing is greatly reduced (Balota & Lorch, 1986). Second, by using the naming task, it can be determined whether participants are processing the correct words on each trial. As stated above, this becomes especially critical in the mediated condition.

Third, if mediated inhibition effects similar to those found by McNamara and Healy (1988) are obtained, by using a naming task without the use of nonwords, their account of these inhibitory mediated effects can be challenged. Recall that McNamara and Healy found inhibitory mediated effects only when nonwords were included in both the lexical decision task and a reading task. Since they obtained inhibitory effects in the mediated condition only when nonwords were included, they attributed their results to the presence of the nonwords. However, it is possible that McNamara and Healy's inhibitory effects were not the result of nonwords being included in the test lists, but instead were real effects caused by activational feedback. By using a naming task where participants are forced to process each word correctly, it is possible that these inhibitory effects will be again found in the present experiments. If so, by using a naming task without nonwords and obtaining inhibitory mediated priming effects, this would serve to eliminate the possibility that postlexical decisions or nonwords were responsible for the effects in McNamara and Healy's experiments.

It should be noted that McNamara and Healy (1988) addressed the possibility of using a naming task in their investigations and argued that it would not be appropriate based on two advantages with using the lexical decision task. They first pointed out that they would be increasing their chances of finding a mediated priming effect in using the lexical decision task since "effect sizes tend to be larger in lexical decisions than in naming" (p.399), citing Balota and Lorch (1986). The other advantage in using lexical decisions cited by McNamara and Healy was that they could independently test the semantic (e.g., light - lamp), phonological (lamp - damp), and mediated links (light - damp) present in their experiments. By using a naming task, McNamara and Healy argued that the phonological link could not be tested since there would be no definitive way of knowing whether priming found in this condition was due to a spread of activation at the lexical level or if it was instead due to the articulatory similarity between the two words. McNamara and Healy correctly pointed out that the testing of all the independent links contained in the mediated word pairs separately would be especially critical to their experiment if a mediated priming effect was not obtained. They argued that if they had not tested each of the independent links separately and had failed to find mediated priming, it would have been impossible for them to know that the null effects were indeed due to a failure of activation to spread between the semantic and lexical networks and not simply the failure of activation to spread at either the semantic level (e.g., from light to lamp) or at the lexical level (from lamp to damp).

As one can see, however, this logic is dependent upon an assumption contained in the Collins and Loftus (1975) semantic memory model, the model on which McNamara and Healy's (1988) study was based. Recall that in the Collins and Loftus model, the representations at the lexical level are organized based on their orthographic (and phonological) relatedness (McNamara & Healy, 1988). Furthermore, the representations at the lexical level are connected, allowing activation to spread at the lexical level. Thus, testing the spread of activation at the lexical level is imperative when testing for mediated priming effects. However, because Besner and Smith's (1992a, 1992b; Borowsky & Besner, 1993) multistage activation model does not make such an assumption, mediated priming can be unambiguously tested for using the mediated priming paradigm, without having to independently test the phonological link. According to Borowsky and Besner (1993) in the multistage activation model, "there are no connections between related words within the orthographic input lexicon (see also Bub, Cancelliere, & Kertesz, 1985, for some supporting data on this point)" (p. 832). Using the multistage activation model then, each mediated prime-target word pair only consists of two links, a link connecting semantically related words, and a link connecting activated semantically related words to their corresponding representations at the orthographic level. Therefore, in the present investigation, as long as semantic priming is found with the semantically related links, any mediated priming effects that are obtained can be assumed to be the result of the preactivated orthographic representations themselves and not the result of a spread of activation in the orthographic input lexicon. By not being in the unfortunate position of having to test a link similar to McNamara and Healy's phonological link, a naming task can be used in the present experiment to test for mediated priming when postlexical processing has been greatly reduced. Furthermore this can be accomplished without compromising any subsequent interpretations of mediated priming effects, regardless if they are in fact obtained.

A somewhat related issue that will be addressed in Experiment 1 is whether the predicted mediated priming effects are the result of the indirect orthographic or the indirect phonological relationship between the prime and target. For example, in using targets that are both orthographically and phonologically related to the mediating word in mediated prime-target word pairs (i.e., cat - (dog) - log) as in McNamara and Healy (1988), it is not possible to know whether the orthographic similarity or the phonological similarity between primes and targets that are related in a mediated fashion contributed to the mediated priming effect. Therefore, in Experiment 1, the type of mediated relationship between the prime and target will be manipulated. In addition to the semantically related word pairs, three types of mediated prime-target word pairs will be included: (a) an orthographically mediated relationship (e.g., sofa - (couch) - touch, (b) a phonologically mediated relationship, (e.g., early- (late) - eight), and (c) a mixed condition, in which there will be both an orthographic and phonological mediated relationship between the target and the mediating word, (cat- (dog) - bog). Although it is difficult in the English language to completely divorce orthography and phonology from one another, these conditions will be included in order to attempt to at least greatly reduce the similarity of the two words based on one of these dimensions, while increasing the similarity of the two words based on the other dimension.

According to the multistage activation model, mediated priming should not be found in the phonologically mediated condition, nor should there be larger priming effects obtained in the phonological/orthographic condition than in the orthographic only condition. For this pattern to emerge, the model would have to include a phonological feedback mechanism in its architecture. Since a phonological feedback mechanism is not present in the multistage activation model, obtaining a larger mediated priming effect in the orthographic/phonological condition than in the orthographic condition, or finding any mediated priming in the phonologically mediated condition, would be difficult for the multistage activation model to accommodate in its present form.

Aside from the methodological problems associated with both McNamara and Healy (1988) and Norris (1984), one final issue that will be examined in Experiment 1, will be to test the expectancy account of the RP x Context interaction. As stated above, expectancy is a slow-acting, strategic mechanism that is thought to be influenced by SOA and RP (Stolz & Neely, 1995). Evidence of this comes in the form of an RP x Context interaction that is only found at long SOAs (i.e., SOAs > 400 ms). This interaction shows larger context effects when RP is high than when it is low (Keefe & Neely, 1990; Neely & Keefe, 1989; Seidenberg et al., 1984; Stolz & Neely, 1995). In most accounts of this interaction, RP is argued to affect context by influencing the decision of whether or not to utilize expectancy based on a cost-benefit ratio. RP is argued to influence expectancy by determining whether or not the overall benefits, in terms of faster processing associated with the utilization of expectancy, are greater than the costs also associated with the mechanism. In this account, the manner in which words are processed is argued to be under strategic control. In other words, subjects strategically adopt a processing style based on the RP. When there are a large number of trials in which the prime and target are semantically related (the RP is high), according to expectancy theory, participants adopt a strategy in order to maximize their processing speed by utilizing expectancy and create an expectancy set. When subjects have adopted a global strategy of this type, processing in each subsequent trial will be the same, and the processing can be said to be under strategic control.

There is however, an alternate explanation of the RP x Context interaction; that is, perhaps the manner in which participants process targets on trial N, solely depends on the nature of the relationship between the prime and the target on trial N - 1. Note that this explanation differs considerably from the expectancy explanation for the RP x Context interaction. In that explanation, the participants are argued to adopt a more global strategy in that they use the expectancy mechanism when the cost-benefit ratio is low. In contrast, with this new explanation each trial is not processed according to a global strategy that has been adopted, but is instead processed in a manner that is simply dictated by trial N - 1. Therefore, according to this data-driven explanation, the RP x Context interaction is seen solely as the result of the word recognition system being driven by context, or the system is under stimulus, not strategic, control.

Whether one argues for expectancy as the cause of the RP x Context interaction or argues that this interaction is the function of the word recognition system operating based on trial N - 1, the nature of the RP x Context interaction would be predicted to be identical. Thus, how might these two explanations be distinguished from one another? In Experiment 1, by using the a naming task and tracking the type of relationship (semantically related vs. semantically unrelated) present on trial N - 1, the two accounts can be distinguished from one another. Since the expectancy account is based on a change in participant's strategy, once a strategy has been adopted, RTs should not change as a direct function of trial N - 1. Instead, because the word recognition system will operate on every trial according to the particular strategy regardless of each individual trial, RT will change as a function of RP. In contrast, if the participants do not adopt a global strategy, but instead operate based on the N - 1 trial the RTs should change directly as a function of the N -1 trial, regardless of RP.

Specifically, Experiment 1 will be conducted in order to directly test for activational feedback from the semantic system to the orthographic input lexicon during visual word recognition. Using a mediated priming paradigm, direct evidence of activational feedback will be obtained if a reliable mediated effect is found for orthographically mediated targets in either the orthographically mediated condition or the orthographically and phonologically mediated condition. That is, direct evidence of activational feedback will be obtained if the RTs or error rates (or both) associated with the identification of mediated targets are reliably different than their controls. While Besner and Smith's (1992a, 1992b; Borowsky & Besner, 1993) multistage activation model predicts that mediated effects should be found using the mediated priming paradigm, the activation-verification model (Paap et al., 1982; Paap et al., 1987; Paap & Noel, 1991) would have difficulty accounting for them. As a result of this, by using the mediated priming paradigm, the predictions of these two models of visual word recognition can be tested. Finding either facilitatory or inhibitory mediated effects using the mediated priming paradigm strongly supports the multistage activation model in its claim that activational feedback exists during visual word recognition. However, because the activation-verification model would have great difficulty accounting for either facilitatory or inhibitory mediated effects, finding either type of a mediated effect using the mediated priming paradigm, would either require the model to be further modified in some way or be abandoned all together.

In addition, by using the mediated priming paradigm, a number of related issues can also be explored in Experiment 1. First, if activational feedback is found using a high (.50) RP, and is not found using a low (.20) RP, this would suggest one reason why both McNamara and Healy (1988) and Norris (1984) failed to obtain mediated priming effects in their studies. Second, if facilitatory mediated priming effects are found, the alternate explanations suggesting that they are either the result of postlexical processes or that they are the result of participants incorrectly processing the targets in the mediated condition can both be eliminated. Similarly, if inhibitory mediated effects are found similar to those which McNamara and Healy obtained in part of their data, by using a naming task without the use of nonwords, again neither of their alternate explanations can be used to account for the effects. Third, the type of mediated relationship will be manipulated in Experiment 1, in order to disentangle the type of relationship that contributes to the mediated priming effect. And finally, the N - 1 trial type will be tracked in order to address the driving force behind the RP x Context interaction.

Method

Participants

Eighty college undergraduates from the University of Nebraska at Omaha served as participants in Experiment 1. By participating, each earned extra credit for an undergraduate class in psychology. Forty participants were randomly assigned to one of the two RP conditions (.50 or .20), and were randomly assigned to one of four test lists. All participants were native English speakers and had normal or corrected-to-normal vision.

Design

A 4 (type of relation: semantically related vs. orthographically mediated vs. phonologically mediated vs. orthographically and phonologically mediated) x 2 (condition: experimental vs. control) x 2 (RP: .50 vs. .20) mixed-design was used. Type of relation and condition varied within-participants, while RP varied between-participants. Both RT and accuracy were measured on each trial.

Materials and Stimuli

Critical items were constructed by first creating 24 mediated word triplets for each of the three mediated type of relations (24 orthographically mediated, e.g., uncle - (aunt) - punt; 24 phonologically mediated, e.g., eating - (food) - rude; and 24 orthographically and phonologically mediated, e.g., cat - (dog) - bog). In all, 72 mediated word triplets were created. These word triplets contained two important characteristics. One characteristic was that the first word (the prime) and second word (the mediating word) of each word triplet were high semantic associates of one another. According to various sets of published norms (e.g., Palmero & Jenkins, 1964; Keppel & Strand, 1970; Marshall & Cofer, 1970), in almost all cases, the mediating word was the primary response provided when the first word of the word triplet was given. The second important characteristic of the word triplets was the relative frequency of occurrence of both the mediating word and the last word of each triplet. Because the mediating words were high associates of the first word, according to Carroll, Davies, and Richman (1971) these words were on average higher in their frequency-per-million count ($\underline{M}$ = 258.81) as compared with the last word in each triplet ($\underline{M}$ = 84.12).

From these word triplets, the critical mediated prime-target word pairs were created for each mediated condition by using the first and last word of the word triplets. The first word of the triplet always served as the prime in each mediated word pair, while the last word of the triplet always served as the target in each mediated word pair (e.g., uncle - punt, eating - rude, cat - bog). Within each of the three mediated word pair types, the word pairs were further separated into two sets, with each set containing 12 word pairs. Since the targets in the mediated conditions were the last word of the word triplets, most of the target words in each of these mediated prime-target word pairs were low-frequency words.

As with the mediated prime-target word pairs, the critical semantically related prime-target word pairs were also created from the 72 mediated word triplets. In creating the semantically related prime-target word pairs, the first word of each meditated word triplet served as the prime while the second or mediating word of each word triplet served as the target (e.g., *uncle* - *aunt*, *eating* - *food*, *cat* - *dog*). Seventy-two semantically related word pairs were constructed in all. These prime-target word pairs were also further divided into two sets. Because the targets in the semantically related word pairs were the mediating words from the word triplets, the targets in each of these word pairs were high-frequency words. The experimental condition in Experiment 1 was composed of all the above prime-target word pairs (72 mediated prime-target word pairs and 72 semantically related prime-target word pairs).

Once the 72 mediated prime-target word pairs (24 of each mediated type of relation) and the 72 semantically related prime-target word pairs were constructed, control prime-target word pairs were created. For each type of relation, control prime-target word pairs were created by reassigning each prime to a different target within each set. Thus, for these control word pairs, there was no relation, neither mediated nor semantic, between the primes and the targets (e.g., *house* - *punt*, *black* - *rude*, *night* - *bog*). The control condition in Experiment 1 was composed of these 144 control items. A complete list of all the critical stimuli used in Experiment 1 can be found in the Appendix.

In addition to the experimental and the control items, 54 filler semantically related prime-target word pairs were also used. The filler items were taken from a larger list of stimuli used by Borowsky and Besner (1993) and can be differentiated from the critical items used in Experiment 1 based on the fact that there were no corresponding control items used for these prime-target word pairs. In addition to the semantically related filler items, 18 mediated filler items (6 orthographically mediated, 6 phonologically mediated, and 6 orthographically and phonologically mediated) were also constructed.

From the complete list of prime-target word pairs, four test lists were constructed using two constraints. First, each target word appeared in both the experimental (mediated or semantic) and the control condition across the four test lists. Second, each prime was only presented once in a given test list. This constraint was imposed on the test list due to the fact that each prime was paired with two different targets in each of the experimental and the control conditions. For example, in the experimental condition, the word in from the word triplet, in - (out) - rut, was used as a prime in the orthographically mediated type of relation and was paired with the target word, rut. Also, in the semantically related type of relation, the word in, from that same word triplet, served as the prime in the prime-target word pair, in - out. Since the control condition consisted of all the primes and targets in the experimental condition, the word in also served as a prime twice in the control condition. In order to avoid presenting the same word twice, either as a prime or as a target to any one participant, four test-lists were constructed for each level of RP (.20 and .50).

The four test lists in both the .20 and the .50 RP conditions consisted of the same number of experimental (semantically related and mediated) and control prime-target word pairs. For the experimental items, each list contained 18 semantically related prime-target word pairs, 6 orthographically mediated word pairs, 6 phonologically mediated word pairs, and 6 orthographically and phonologically mediated word pairs. From these critical items, the semantic and mediated priming effects were measured. For the control items, each of the four lists were composed of 18 control items constructed from the semantically related word pairs, and 18 (6 of each mediated type of relation) controls constructed from the mediated prime-target word pairs. Thus, in both the .20 and the .50 RP condition, each list was comprised of the same number of critical items: 72 total critical prime-target word pairs comprised of 36 experimental items and 36 control items.

Although each of the four test lists in both the .20 and .50 conditions were composed of the same number of critical experimental and control prime-target word pairs, in order to change the RP, they differed in the nature of their filler items. In the .50 RP condition, in addition to the 72 critical items, 54 semantically related filler prime-target word pairs were also included. These were included in order to have 50% of the total trials in each of the four lists in the .50 RP condition contain semantically related prime-target word pairs. In each of the four test lists in the .50 RP condition, of the 144 total prime-target word pairs, 72 were semantically related (18 critical items and 54 filler items), and 72 were either unrelated (control items) or were mediated.

In order to create the four test lists in the .20 RP condition, 11 semantically related filler items were included in the test lists as were 43 control filler items. Thus, unlike the four test lists in the .50 RP condition, in the .20 RP condition test lists, only 29 of the 144 total prime-target word pairs were semantically related (18 critical semantically related items and 11 filler items). With these lists, the primes and targets were semantically related in only 20% of the total trials. Therefore, the only difference between the test lists in the .50 RP condition and the .20 RP condition was the distribution of filler items. The order of presentation of the prime-target word pairs within each list was random.

In addition to the test items used during the experiment, 24 practice items were also constructed. Of these 24 practice items, 12 were semantically related prime-target word pairs, while the other 12 were mediated prime-target word pairs. None of the words in the practice items were also presented in any of the test lists.

Apparatus and Procedure

Participants were run individually in a well lit room containing a microcomputer with a response box and microphone attached, a table, and a chair. Each participant was seated at a distance of approximately 50 cm from the computer monitor and was given a microphone to hold approximately 2 cm from their mouths. The stimuli were presented on the computer monitor through the use of the Micro Experimental Laboratory (MEL) computer software (Schneider, 1990). The MEL software was run on a Gateway 2000 386/SX microcomputer and the stimuli were presented on a 14" color monitor. All participants' RTs and accuracies were collected by the MEL software. All stimuli were presented in the center of the monitor, using white letters on a black background.

Instructions were presented to the participants both orally and on the monitor before they began the experiment. Once the instructions were presented, the participants began the 24 practice trials. Participants were given the opportunity to ask any questions they might have both prior to beginning and after completing the practice trials. After each participant had completed the practice trials, the test trials began. Each trial began with the presentation of a centrally located fixation cross. The fixation cross remained on the monitor until the participant began the trial by pressing the space bar. Once the space bar was pressed, the fixation cross disappeared and was replaced by the prime. Each prime was presented for 500 ms. A 300 ms interstimulus interval (ISI) followed each prime, during which the fixation cross was again presented. After the ISI, the target was presented in the center of the screen in the same location that the prime and fixation cross had been presented. The participants were instructed to read each prime silently and then to name out loud, as quickly but as accurately as possible, the second (target) word into the microphone. Once the participants named the word, the target disappeared and the words "code accuracy" appeared in yellow in the center of the computer screen. These words served to cue the experimenter that the computer had received the participant's response, and that the experimenter could enter the accuracy of the response. At this point the experimenter pressed one key on the response box if the response was correct, and another if, (a) the response was incorrect, (b) the response was not registered by the computer the first time the participant responded, or (c) if an extraneous noise was recorded before the participant was able to give a response. After the accuracy of each response was entered by the experimenter, feedback was given to the participant in the upper left hand corner of the computer monitor. If the response was correct, the words "Correct Response" were presented, while if the response was incorrect, the words, "Incorrect Response" were presented. This feedback remained presented on the screen for 1500 ms before disappearing and was followed by the presentation of a fixation cross which represented the beginning of the next trial. In all, the experiment took approximately 30 min to complete. Once the participants had been presented with 144 such trials, they were debriefed and excused.

Results and Discussion

In the RT analyses, only the data for correct responses were included. In addition, only those RTs that fell between 150 ms and 1500 ms were included in any of the analyses. Only six trials out of a total of 5300 correct trials failed to fall within this range. These trials were excluded from any of the subsequent analyses. Mean RTs and error rates were computed for each condition (see Table 1) and were submitted to a 2 (RP: .50 vs. .20) x 4 (type of relation: semantically related vs. orthographically mediated vs. phonologically mediated vs. orthographically and phonologically mediated) x 2 (condition: experimental vs. control) mixed-design analysis of variance (ANOVA).

Response Times

The three-way interaction between RP, type of relation, and condition was not significant, ($F < 1$). However, the two-way interaction involving type of relation and condition was statistically significant, $F\ (3, 234) = 8.731$, $MSE = 1630.4$, $p < .001$ (see Table 2 for means).

Planned comparisons were used in order to examine this interaction. The comparisons of interest involved determining whether there exist reliable differences in the

Table 1

Mean Correct Response Times (RTs; in ms), Percent Errors (%E) Across both RPs in Experiment 1

	RP = .20				RP = .50			
	Con		Exp		Con		Exp	
Type of Relation	RT	%E	RT	%E	RT	%E	RT	%E
Semantic	527	1.2	508	1.3	554	1.4	522	.7
Orthographic/ Phonological	538	7.3	560	7.3	569	9.2	578	7.3
Orthographic	541	5.5	552	8.4	558	7.3	573	10.5
Phonological	533	5.9	534	7.2	562	7.2	564	6.0

Note: RP = Relatedness Proportion, Con = Control Condition, Exp = Experimental Condition.

Table 2

Mean Correct Response Times (RTs; in ms) and Priming Effects in Experiment 1

	Type of Relation			
Condition	Semantic	Ortho/Phono	Ortho	Phono
Control	541	554	549	548
Experimental	515	569	563	550
Priming Effect	+26	-15	-14	-2

Note: Ortho = Orthographic, Phono = Phonological, Priming Effect = control - experimental difference.

RTs associated with the experimental and the control conditions at each level of type of relation. For the semantically related word pairs, the experimental condition yielded significantly faster RTs ($\underline{M}$ = 515 ms) than did the control condition ($\underline{M}$ = 541 ms), $\underline{F}$ (1, 234) = 16.110, $\underline{MSE}$ = 1630.41, $\underline{p} < .001$. In contrast, for the orthographically and phonologically mediated word pairs, RTs associated with the experimental condition were reliably slower ($\underline{M}$ = 569 ms) than the RTs associated with the control condition ($\underline{M}$ = 554 ms), $\underline{F}$ (1, 234) = 5.847, $\underline{MSE}$ = 1630.41, $\underline{p} < .02$. Likewise, in the orthographically mediated condition, the experimental condition ($\underline{M}$ = 563 ms) also yielded significantly slower RTs than did the control condition ($\underline{M}$ = 549 ms), $\underline{F}$ (1, 234) = 4.307, $\underline{MSE}$ = 1630.41, $\underline{p} < .04$.[1] However, for the phonologically mediated condition, the planned comparison showed that the experimental and control conditions were not significantly different ($\underline{F} < 1$).

In addition to the reliable two-way interaction, a reliable main effect of type of relation was also found, $\underline{F}$ (3, 234) = 20.887, $\underline{MSE}$ = 1652.970, $\underline{p} < .0001$. This main effect was not examined any further due to difficulties in its interpretation based on the fact that different target words were used in the four type of relation conditions. A marginal main effect was also found for RP, $\underline{F}$ (1, 78) = 3.395, $\underline{MSE}$ = 26226.795, $\underline{p}$ = .07, with RTs being faster overall in the .20 RP condition ($\underline{M}$ = 537 ms) than in the .50 RP condition ($\underline{M}$ = 560 ms). No other significant effects were found.

In addition to the above analyses, by using the items as the random variable instead of the participants, a second analysis was conducted on the RT data. This analysis revealed a very similar pattern of results to that which was found in the above set of analyses. The three-way interaction involving RP, type of relation, and condition was not significant ($\underline{F}' < 1$). However, a significant interaction was found between type of relation and condition, $\underline{F}'$ (2, 280) = 7.860, $\underline{MSE}$ = 1258.596, $\underline{p} < .0001$. Planned comparisons were again done at each type of relation to determine whether the RTs in the experimental and control conditions differed significantly. These planned comparisons revealed that for items in the semantically related condition, the experimental condition yielded significantly faster RTs (*M* = 516 ms) than did the control condition (*M* = 542 ms), *F*' (1, 280) = 37.686, *MSE* = 1258.596, *p* < .0001. A planned comparison of the experimental and control conditions in the orthographically mediated condition indicated that the experimental condition (*M* = 564 ms) yielded slower RTs than the control condition (*M* = 550 ms), however, this effect was only marginally significant, *F*' (1, 280) = 3.850, *MSE* = 1258.596, *p* = .051. No other effects in the item analysis were significant.

Error Rates

In contrast to the RT data, neither the three-way interaction involving RP, type of relation, and condition, nor the two-way interaction involving type of relation and condition were significant (see Table 3 for means). As was done with the RT data, planned comparisons were conducted with the error rates in order to determine whether the error rates in the experimental and control conditions significantly differed in each type of relation. The error rates in the experimental and control conditions did not differ with the semantically related word pairs (*F* < 1). Similarly, the two conditions in the orthographically and phonologically mediated type of relation were not significantly different (*F* < 1). However, in the orthographically mediated condition, the experimental condition yielded a significantly higher error rate (*M* = 9.43 %) than the control condition (*M* = 6.4 %), *F* (1, 234) = 3.928, *MSE* = .009, *p* < .04. Finally, in the phonologically mediated condition, the experimental and control conditions did not differ significantly (*F* < 1). With the error rates, the only other significant effect was a significant main effect of type of relation, *F* (3, 234) = 17.120, *MSE* = .010, *p* < .0001.[2]

The results of Experiment 1 provide direct evidence of activational feedback

Table 3

Mean Percent Errors (%E) and Priming Effects in Experiment 1

Condition	Type of Relation			
	Semantic (%E)	Ortho/Phono (%E)	Ortho (%E)	Phono (%E)
Control	1.3	8.2	6.4	6.5
Experimental	1.0	7.3	9.4	6.6
Priming Effect	+.3	+.9	-3.0	-.1

Note: Ortho = Orthographic, Phono = Phonological, Priming Effect = control - experimental difference.

during word recognition. This evidence was found in the form of two reliable mediated inhibition effects. In both the RT and error rate data, a significant inhibition effect was found in the orthographically mediated condition. A reliable inhibition effect was also found in the orthographically and phonologically mediated condition with the RT data. Both of these effects were found in the presence of a significant priming effect in the semantic condition. Because the prime-target word pairs in the semantic condition were comprised of the first two words of the mediated word triplets, the evidence obtained suggests that activation not only spread to the mediating word in these triplets during the naming task, but that activation also spread to the target word in two of the mediated conditions.

Finding these reliable mediated inhibition effects in Experiment 1 is quite consistent with the existence of activational feedback during word recognition. As was argued above, regardless of whether the prime facilitated or inhibited the identification of the targets, the only way either effect could have occurred is via the mediating word. This must be true because the primes and targets in the mediated conditions were not themselves directly related in any way. Furthermore, since a naming task was used, these inhibitory effects further suggest that the inhibitory effects found by McNamara and Healy (1988) were not due to postlexical processing. Although McNamara and Healy failed to obtain their inhibitory effects when nonwords were not included in their test lists, the inhibitory effects obtained presently were found in the absence of nonwords in any of the test lists. Why this discrepancy exists, as well as a more thorough discussion of the mediated inhibition effects will, be discussed in the General Discussion section.

Finally, in Experiment 1, both the mediated priming effects and the semantic priming effects were predicted to be affected by RP. Based on Stolz and Neely (1995), it was argued that the mediated priming effects were most likely to be found in the high

(.50) RP condition as opposed to the low (.20) RP condition. However, the results showed that no overall effect was found for RP nor did RP interact with any of the other variables. Thus, in the mediated conditions, the priming effects did not differ significantly as a function of the two RP conditions. As for semantic priming effects, RP has been shown to affect context effects in a number of previous investigations (e.g., Keefe & Neely, 1990; Neely & Keefe, 1989; Seidenberg, Waters, Sanders, & Langer, 1984; Stolz & Neely, 1995). These studies have found larger context effects when the RP is high as compared to when it is low. In Experiment 1, a reliable semantic priming effect was found in both RTs and error rates, however, RP did not reliably modulate this effect in spite of the fact that the semantic priming effect was numerically larger in the .50 RP condition (+32 ms) than in the .20 RP condition (+19 ms). Because RP did not significantly affect either semantic priming or the mediated inhibition effects, the N - 1 trial type was not tracked. Thus, although it was proposed, the driving force behind the RP x Context interaction was not able to be addressed using these data. This failure of RP to modulate semantic priming will also be discussed further in the General Discussion.

Experiment 2

Because RP did not significantly affect the amount of activational feedback found in any of the mediated conditions, a second experiment was conducted in order to assess the effect of an even higher (.80) RP on these mediated effects. Two interesting possibilities can arise through an increase in RP. First the mediated inhibition effects might grow larger as a function of the increase in RP. This certainly is a possibility since Posner and Snyder (1975) found larger facilitation effects in their 80-20 condition than their 50-50 condition using a matching task. Or, the size of the mediated inhibition effect could remain the same despite the increase in RP. In using the same stimuli as those used in the previous experiment but by increasing the RP to .80, an attempt will be made to replicate the inhibitory effects found in two of the mediated conditions in Experiment 1, and, also, to determine whether a higher RP alters these effects in any way.

Method

Participants

Forty college undergraduates from the University of Nebraska at Omaha served as participants and earned extra credit for an undergraduate class in psychology. Ten participants were randomly assigned to one of four test lists. All four test lists contained an RP of .80. As with Experiment 1, all participants were native English speakers and had normal or corrected-to-normal vision.

Design

The design used was identical to that used in Experiment 1 with the exception of the RP variable. All participants were given a test list that had an RP of .80. Thus, in Experiment 2, a 4 (type of relation: semantically related vs. orthographically mediated vs. phonologically mediated vs. orthographically and phonologically mediated) x 2 (condition: experimental vs. control) within-participants design was used. RT and accuracy were measured on each trial.

Materials and Stimuli

The experimental and control stimuli (critical items) used in Experiment 2 were the same as those used in Experiment 1. This was done in order to prevent the primes and targets from showing up more than once per test list, and in order to keep the targets counterbalanced. However, in order to increase the RP to .80, an additional 144 semantically related prime-target filler word pairs were included. Also, the 18 filler mediated prime-target word pairs that were used in the test list in Experiment 1 were eliminated. Thus, the only difference between the test lists used in Experiment 1 and those used in Experiment 2 was the distribution of additional filler items in order to increase the

RP.

Procedure

The procedure was identical to that used in Experiment 1, with the exception that participants were each presented with 270 trials, thus, Experiment 2 took approximately 40 min to complete. Participants were given the opportunity for a break at the mid-point of the experiment.

Results and Discussion

In the RT analyses, only the data for correct responses were included. As with Experiment 1, only those RTs that fell between 150 ms and 1500 ms were included in any of the analyses. Only two trials out of a total of 2709 correct trials failed to fall within this range. These trials were excluded from any of the subsequent analyses. Mean RTs and error rates were submitted to a 4 (type of relation: semantically related vs. orthographically mediated vs. phonologically mediated vs. orthographically and phonologically mediated) x 2 (condition: experimental vs. control) within-participants analysis of variance (ANOVA).

Reaction Times

With the RT data, the two-way interaction involving type of relation and condition approached significance, $\underline{F}$ (3, 117) = 2.543, $\underline{MSE}$ = 1856.340, $\underline{p}$ = .06. The means associated with this interaction can be found in Table 4. As in Experiment 1, planned comparisons were performed at each level of type of relation in order to determine whether the RTs in the experimental and control conditions differed. With the semantically related items, the experimental condition yielded reliably faster RTs ($\underline{M}$ = 551 ms) than the control condition ($\underline{M}$ = 573 ms), $\underline{F}$ (1, 117) = 5.286, $\underline{MSE}$ = 1856.340, $\underline{p}$ < .025. However, the planned comparisons showed that there were no reliable differences between the experimental and control conditions in any of the three mediated conditions.

Table 4

Mean Correct Response Times (RTs; in ms) and Priming Effects in Experiment 2

	Type of Relation			
Condition	Semantic	Ortho/Phono	Ortho	Phono
Control	573	600	590	588
Experimental	551	585	580	592
Priming Effect	+22	+15	-10	-4

Note: Ortho = Orthographic, Phono = Phonological, Priming Effect = control - experimental difference.

A main effect of type of relation was found, F (3, 117) = 11.536, MSE = 1346.557, $p < .0001$, but as with Experiment 1 it was not investigated any further.

Using items as the random variable, a second analysis performed on the RT data showed that the two-way interaction between type of relation and condition was marginally significant, F' (3, 140) = 2.119, MSE = 1813.474, $p = .101$. Planned comparisons done at each level of type of relation showed that only in the semantically related condition did the experimental and control items differ significantly. With the semantically related word pairs, the experimental condition yielded reliably faster RTs (M = 553 ms) than the control condition (M = 576 ms). None of the other planned comparisons in the item analysis were significant.

Error Rates

With the error rates, the interaction of type of relation and condition was not significant, F (3, 117) = 1.806, $p = .15$. These means can be found in Table 5. Planned comparisons showed that the error rates in the experimental and control conditions in the semantically related condition were not significantly different ($F < 1$). The error rates associated with the experimental and control conditions in the orthographically and phonologically mediated and the phonologically mediated conditions were also not significantly different (both $Fs < 1$). However, a reliable effect was found in the orthographically related condition, F (1, 117) = 7.480, MSE = .010, $p < .01$, with twice as many errors occurring in the experimental condition (M = 11.7 %) than in the control condition (M = 5.5 %). A reliable main effect of type of relation was also found, F (3, 117) = 13.452, MSE = .009, $p < .001$.

The results from Experiment 2 again indicates that activation spread from the semantic system to the orthographic system during visual word recognition. Using an RP of .80, a reliable semantic priming effect was found in the RT data. In addition, with the

Table 5

Mean Percent Errors (%E) and Priming Effects in Experiment 2

	Type of Relation			
Condition	Semantic (%E)	Ortho/Phono (%E)	Ortho (%E)	Phono (%E)
Control	1.0	9.0	5.5	5.9
Experimental	.3	9.5	11.7	7.0
Priming Effect	+.7	-.5	-6.2	-1.1

Note: Ortho = Orthographic, Phono = Phonological, Priming Effect = control - experimental difference.

error rate data, a significant inhibition effect was again found in the orthographically mediated condition with more errors being committed in the experimental condition as compared to the control condition. Thus, although the mediated inhibition effect was not reliable in the RT data when RP was increased to .80, an inhibition effect was found in the error rate data.

General Discussion

The main focus of the present investigation was to determine whether activation can spread from the semantic system to the orthographic input lexicon during visual word recognition as predicted by the multistage activation model (Besner & Smith, 1992a, 1992b; Borowsky & Besner, 1993). Taken together, the results of Experiment 1 and 2 suggest that activation does spread from the semantic system to the orthographic input lexicon during word recognition. First, in both experiments a reliable semantic priming effect was found with the semantically related word pairs. This effect provides evidence that activation did at least first spread at the semantic level. More importantly, however, these data showed that activation not only spread at the semantic level, but that activation spread from the semantic system to the orthographic input lexicon, as well. Evidence of activational feedback was found in the form of mediated inhibition effects. In Experiment 1, a reliable inhibition effect was found in the orthographically mediated condition with both RTs and error rates. This mediated inhibition effect was replicated in the error rates in Experiment 2. A significant inhibition effect was also found in the RT data in the orthographically and phonologically mediated condition in Experiment 1. In each case, these inhibition effects showed that the targets were harder to process (i.e., they were slower and/or more error prone) when they were in the experimental condition than when they appeared as controls.

As a whole, then, the facilitatory semantic priming effects first showed that activation spread at the semantic level, activating semantically related representations. The mediated inhibition effects indicated that the activated semantic representations proceeded to activate their corresponding representations residing at the orthographic level. To my knowledge, this is the first evidence of activation spreading from the semantic system to the orthographic system during visual word recognition.

Mediated Inhibition Effects: Evidence of Activational Feedback

According to the logic presented in the Introduction, if, upon presenting the prime, activation spreads to semantically related representations, which in turn each preactivated their corresponding orthographic representations in the orthographic input lexicon, it was argued that a mediated effect would be obtained. These mediated effects could be mediated in either a facilitatory or inhibitory manner. If the processing of mediated targets in the orthographic input lexicon was aided by the preactivated orthographic representations, it was argued that facilitatory mediated effects would be obtained. However, if the preactivated orthographic representations interfered with the processing of the target word, it was argued that mediated inhibition effects would be obtained.

The present data showed that the targets in the orthographically mediated and in the orthographically and phonologically mediated conditions were more difficult to identify when they were preceded by a mediated prime than when they were preceded by an unrelated prime. That is to say, a mediated inhibition effect was found. Since the primes and targets in these conditions were not directly related, but instead were related via a mediating word, the mediating word must have somehow become activated in order for it to affect the processing of the target word. Since the mediating words were never visually presented, and, since the nature of the relationship between the target and the mediating word was orthographic, the only way the representation of the mediating word could have become activated was through a spread of activation from the semantic system to the orthographic input lexicon.

For example, in the current experiments it was found that through the presentation of the prime crack, responses to the target freak were both significantly slower and less accurate than their controls. Again, because the relationship between the words crack and freak is mediated through the word break, the only way the presentation of the prime crack could have affected responses to the target freak is via the word break. Although break was never actually visually presented, it must have affected the response to the target freak in some way. As stated above, the preactivation of semantically related representations in the orthographic input lexicon might have caused two orthographic representations to become simultaneously activated: the orthographic representation of a semantically related word and the orthographic representation of the target itself. The presence of these two activated representations in the orthographic input lexicon could have caused the mediated targets to become more difficult to process. The mediated inhibition effects that resulted from this interference are indeed quite consistent with the presence of activational feedback during visual word recognition which was predicted in Besner and Smith's (1992a, 1992b; Borowsky & Besner, 1993) multistage activation model of visual word recognition.

As convergent evidence, similar direct inhibition effects have been obtained when two orthographically related words are visually presented in a lexical decision task (e.g., Henderson, Wallis, & Knight, 1984; Meyer, Schvaneveldt, & Ruddy, 1974; Shulman, Hornak, & Sanders, 1978). For example, Meyer et al. (1974) and Henderson et al. (1984) found that responses to two simultaneously presented orthographically similar letter strings (e.g., break - freak) were both significantly slower and less accurate than their controls. When using pseudowords as nonwords as opposed to consonant strings or random letter strings, Shulman et al. (1978) replicated these inhibitory effects. Again, similar to these direct inhibitory effects, in the present study, inhibitory mediated effects were obtained without participants ever being visually presented with the orthographically similar primes. The only way this could have occurred is through activational feedback.

Orthographic or Phonological Inhibition?

In addition to providing evidence of activational feedback during visual word recognition, these data also suggest that the mediated inhibition effects were caused solely by the orthographically mediated relationship between the primes and the targets. Unlike McNamara and Healy (1988; McNamara & Gray, 1990), there was an attempt made in the present investigation to separate the orthographic and phonological components of the target words in order to assess the contributions of each in the mediated conditions. Thus, three mediated conditions were created. In one mediated condition, the primes and targets were both orthographically and phonologically mediated (e.g., cat - bog), while in the other two primes and targets were either orthographically mediated (e.g., crack - freak) or they were phonologically mediated (e.g., early - eight).

By separately manipulating these two dimensions, it was possible not only to determine whether activational feedback was present, but also to assess the locus of the feedback. According to the multistage activation model (Besner & Smith, 1992a, 1992b; Borowsky & Besner, 1993), feedback from the semantic system should only be found at the orthographic input lexicon. There does not exist in this model a pathway that carries activation from semantically related words to corresponding phonological representations located at the phonological output lexicon. Therefore, the model predicts that any evidence of feedback (i.e., mediated inhibition effects) should only be found at the orthographic level. The current investigation support this prediction. Not only was evidence of feedback obtained, but the feedback was found to be localized within the orthographic input lexicon. The mediated inhibition effects in the orthographically and phonologically mediated condition could have been the result of either the mediated orthographic or the mediated phonological relationship present between the primes and targets in this condition. However, the additional findings that the inhibition effects remained in the orthographically mediated condition and disappeared in the phonologically mediated condition clearly suggest that these effects were caused solely by the orthographic mediated relationship between the primes and targets. With respect to the multistage activation model, as predicted, the feedback mechanism only seems to feed activation from the semantic system to the orthographic system during visual word recognition.

One other issue that warrants further discussion is the discrepancy that exists between the present data and McNamara and Healy's data (1988). Recall that using both lexical decisions and a reading task, McNamara and Healy obtained inhibitory mediated effects when nonwords were included in the test list. These inhibition effects disappeared, however, when nonwords were not included in the test lists in both tasks. As stated above, the mediated priming effects that McNamara and Healy obtained were argued to be the result of the nonwords. More specifically, they attributed their mediated inhibition effects to postlexical processing. Since these effects persisted when the task was changed to a reading task with nonwords, McNamara and Healy claimed that participants might still have been engaged in making lexical decisions. Therefore, as with the lexical decision task, the inhibitory mediated effects that were obtained with a reading task were also attributed to some type of postlexical processing.

McNamara and Healy's (1988) explanation of their inhibitory mediated priming effects is severely undermined by the present data in at least two ways. First, in the present investigation, the mediated inhibition effects were obtained in two of the three mediated conditions using a naming task in which postlexical decisions are not required.

Second, nonwords were not included in any of the test lists used in the present investigations. These two features of the present experiments rule out McNamara and Healy's account of the inhibitory mediated effects they obtained in their study. The present data instead suggest that McNamara and Healy's effects were the result of activational feedback and not merely the function of postlexical processing.

However, if this is the case, one might wonder why McNamara and Healy (1988) did not find inhibition effects when nonwords were not included in the test lists. One possibility is that their participants were not processing the correct words on some portion of the trials. Because neither the lexical decision or reading task contains a mechanism for objectively checking for processing errors, it is difficult to rule this explanation out. As discussed above, it would have been extremely easy for participants to process the semantically related word as opposed to the actual target word in the mediated conditions (i.e., incorrectly process the word lamp instead of damp when preceded by light). In doing so, the facilitation that accompanies the processing of the semantically related word, as opposed to the visually similar target, might have served to eliminate the inhibition effects and consequently may have been responsible for their failure to find any mediated effects. When nonwords were included, the presence of these letter stings might have forced participants to pay more attention to the letter strings. When participants began to pay more attention to the letter strings, they would have been more likely to process the targets correctly, thereby causing the inhibition effects to emerge. One way this explanation of McNamara and Healy's data can be tested is by manipulating the relative importance of accuracy in the instructions given to participants. If this account is correct, as accuracy becomes increasingly more important, the inhibition effects should get larger in the RT data. In contrast, as accuracy becomes less important, these inhibition effects should grow smaller, if not disappear altogether. However, they should then be found in the error rates.

To some degree, evidence of the above explanation was found in the present investigation. In Experiment 2 when the RP was set at .80, a mediated inhibition effect was not found in the RT data with the orthographically mediated word pairs. Similar to what was argued above, this might have been due to participants not monitoring their responses for accuracy very closely. The mediated inhibition effects found could be the result of a type of interference at the orthographic input lexicon that can be reduced by participants simply responding with the incorrect word (the semantically related word) in the mediated conditions. In other words, although the interference itself could be caused by feedback that occurs automatically, the degree to which the interference affects participants' processing may vary. Since 80% of the trials contained semantically related prime-target word pairs in Experiment 2, the participants might have been encouraged to respond to the targets quickly without closely monitoring their responses for accuracy. This is supported by the high error rates found in the orthographically mediated condition in Experiment 2. In this condition, the error rate was more than twice as large in the experimental condition (11.7%) than in the control condition (5.5%). However, when the participants are responding to the targets as quickly as they can but keeping the accuracy of their output closely monitored, the interference is allowed to slow down response times and the inhibition effects reemerge. This was the case in Experiment 1 where the mediated inhibition effects were found in the RT data and in the error rates (however, the effect in the error rates was not as large). Note that although this explanation calls for participants being able to control the interference by using different processing strategies during the task, this does not mean that a speed-accuracy tradeoff can account for the data. For example, in Experiment 2 where the mediated inhibition effect was found in the error rates but not in the RTs, the mediated effect in the RTs was in the same direction as the error rates (a -10 ms inhibition effect), however, it was simply not reliable.

Mediated Inhibition Effects and Other Competing Models of Visual Word Recognition

As stated above, by testing for activational feedback using the mediated priming paradigm, a test between the multistage activation model of visual word recognition (Besner & Smith, 1992a, 1992b; Borowsky & Besner, 1993) and the activation-verification model of visual word recognition (Paap, Newsome, McDonald, & Schvaneveldt, 1982; Paap, McDonald, Schvaneveldt & Noel, 1987) can be performed. With respect to the present data, although the multistage activation model can be shown to successfully account for the mediated inhibition effects that were obtained, it is extremely difficult to show how these same effects can be accounted for using the activation-verification model in its present form.

In the present investigation, mediated inhibition effects were found in two of the three mediated conditions. This inhibition effect is difficult for the activation-verification model to explain, given that the model predicts that the targets in both the experimental and control conditions should be processed in an identical manner. For example, recall that according to the activation-verification model, the target word lather should be processed in the exact same manner regardless of whether it had been preceded by the orthographically mediated prime, mother, or by the completely unrelated word high. The primary reason for this is that the prime and target are not semantically related in either case. When the prime and target are semantically unrelated, a search of the semantic set will be unsuccessful and a search of the sensory set will be required where a match will be found. Because in both cases the targets are being processed in an identical fashion, using the activation-verification model, it is difficult to show how the orthographically mediated targets would become harder to process than their controls as was found in the present data.

It is interesting to note that the main reason why the activation-verification model is unable to account for the mediated inhibition effects found in the present investigation largely has to do with the type of representation that becomes activated along each pathway when a word is visually presented. That is, the failure of the activation-verification model to fully account for the mediated effects is primarily the function of exactly what becomes activated in both the semantic set and the sensory set. More specifically, recall that according to the activation-verification model, along one path the prime dog will activate a semantic set which contains the representations of semantically related words dog (e.g., pet, cat, bark, etc.). Concurrently, along another path, a sensory set will be created that contains the representations of words that are orthographically related to the word dog (e.g., log, jog, fog, etc.). The critical point is that the representation of an orthographically mediated target such as the word vat will not become activated in either set. Since vat is not semantically or orthographically related to the word dog, its representation will not become activated in either of the two sets. Without the representation of the target word becoming activated in either of the two sets, it is difficult for the activation-verification model to account for the interference that resulted in the mediated inhibition effects that were obtained. In both cases vat would simply be processed as if it were an unrelated target, regardless of whether it was preceded by an orthographically mediated prime or a completely unrelated prime.

Although the activation-verification model may not account for the mediated inhibition effects, the model can successfully account for the inhibition effects when the "correct" representations have been activated. Indeed, when two orthographically related words are presented simultaneously (e.g., Henderson, Wallis, & Knight, 1984; Meyer, Schvaneveldt, & Ruddy, 1974; Shulman, Hornak, & Sanders, 1978), the activation-verification model can account for the inhibition effects that have been found. In this case, since the both words are orthographically related to one another, the inhibition might easily arise from the interference caused by two similar orthographic representations becoming activated in the sensory set. However, without incorporating some type of mechanism by which the representations located in the semantic set can influence the activation of representations in the sensory set, the activation-verification model will continue to fail in its attempts to account for any mediated effects that are obtained when the prime and target are not directly related.

In addition to the activation-verification model, how might recent PDP models account for the mediated inhibition effects? Two PDP models of visual word recognition were previously discussed, Seidenberg and McClelland's (1989) distributed model of word recognition and Masson's (1995) distributed memory model. Although these two models differ in some regards, one shared characteristic is that representations are distributed across a network of processing units. Patterns of activation across these processing units can represent information, either a word or some characteristic of a word. At least in some respects, the strength of PDP models is the amount of interactivity employed when processing a word. Although most PDP models contain separate pools of processing units, with each containing different types of information, when a word is being processed, processing taking place at one level is influenced by processing at all other levels. It is this general assumption that might allow PDP models to provide an account of the mediated inhibition effects found in the present experiments.

Because of the high degree of interactivity contained in most PDP models, a feedback mechanism similar to that contained in the multistage activation model is in a sense already "built-in" to the system. For example, according to Masson's (1995) distributed memory model, the activational patterns of semantically related words are themselves very similar. Therefore, when the word crack has been processed in the semantic layer, the processing units at that layer will be set in a pattern which is very similar to the activational pattern that represents the word break. Due to the interactivity of the system, this processing at the semantic layer might affect the processing at the orthographic level by setting the processing units at the orthographic level to a similar configuration. With the processing units at the orthographic level set in a configuration very similar to the activational pattern representing the word break, when the target freak is presented, the incorrect orthographic activational pattern representing the word break might become stable more quickly than the correct activational pattern representing freak. The time required for the system to correct itself in these cases would account for the slower RTs obtained in the orthographically mediated and phonologically mediated conditions where the targets were structurally similar to a word that was semantically related to the prime.

There is one problem with the PDP account of the mediated inhibition effects, however. That is, the high degree of interactivity contained in these models predicts that the mediated effects should have also been found in the phonologically mediated condition as well as in the other two mediated conditions. It is unclear why, with total interactivity, the phonological level would not also become influenced by processing at the semantic level.

One last model that can be addressed by the present data is Collins and Loftus' (1975) semantic memory model. Recall that according to this model, activation can spread at the orthographic level as it does at the semantic level. In this way graphemically similar representations residing in the orthographic network can activate one another via spreading activation. The mediated inhibition effects obtained in the present investigation suggest that this is not the case. If activation does spread to orthographically similar representations in the orthographic network, mediated facilitation effects should have been found in the orthographically mediated and the phonologically mediated conditions, as opposed to mediated inhibition effects. For example, when the representation of the word break became activated, activation should have spread to the orthographic representation of the word freak. The preactivated orthographic representation of the word freak would have led to mediated facilitation effects in the orthographically mediated and orthographically and phonologically mediated conditions in the present experiment, as opposed to the mediated inhibition effects that were obtained.

Although clear direct evidence of activational feedback was obtained in the present investigation, this investigation was not able to address all the issues that had been raised. First, as pointed in the results of Experiment 1, an effect of RP was not found, nor did RP interact with any of the other variables in the present investigation. Furthermore, RP did not even affect semantic priming in the present investigation, even though this effect has been demonstrated numerous times in the literature (e.g. de Groot, 1984; den Heyer, 1985; Keefe & Neely, 1990). The failure of RP to affect priming in the semantically related condition suggests that for some reason the RP manipulation was not powerful enough to influence participants' expectancy during the naming task. As a result of this, these data are unable to address Stolz and Neely's (1995) claim that RP influences activational feedback to orthographic representations during visual word recognition. Similarly, the related question of whether feedback is automatic or not could not be addressed (see Borowsky & Besner, 1993, footnote 14). In order to make any unambiguous claims about RP and activational feedback, or the nature of activational feedback, one must first obtain an RP x Context interaction and then determine its effect on mediated inhibition. Also, since RP did not affect semantic priming, the expectancy account of the RP x Context interaction was not able to be tested.

Conclusions

Based on the reliable mediated inhibition effects found in these two experiments, direct evidence of activational feedback from the semantic system to the orthographic input lexicon during visual word recognition was obtained. While this activational feedback facilitated the identification of semantically related targets, the identification of orthographically mediated and orthographically and phonologically mediated targets were slowed and became less accurate. Since targets were not affected by phonologically mediated primes, interference located only in the orthographic input lexicon seemed to cause the slowed processing found in the current investigation. This interference was argued to be the result of two orthographic representations becoming activated simultaneously in the orthographic input lexicon. Further investigations are currently underway in order to determine unambiguously the role RP plays in activational feedback, and also to determine more precisely the timecourse of activational feedback during visual word recognition.

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Appendix

Word Triplets From Which Prime-Target Word Pairs Were Constructed and Their Corresponding Controls

	Control Items	
Word Triplets[1]	Semantic	Mediated
<u>Orthographically and Phonologically Mediated Condition</u>		
cat - dog - bog	night - dog	night - bog
doctor - nurse - curse	pepper - nurse	cat - curse
night - day - hay	doctor - day	doctor - hay
pepper - salt - malt	cat - salt	hammer - malt
sleep - bed - led	hammer - bed	pepper - led
hammer - nail - wail	shallow - nail	sleep - wail
slow - fast - cast	sleep - fast	shallow - cast
shallow - deep - seep	slow - deep	web - seep
web - spider - cider	over - spider	slow - cider
square - round - pound	sweep - round	over - pound
over - under - blunder	web - under	sweep - blunder
sweep - broom - groom	square - broom	square - groom
water - drink - brink	hill - drink	loud - brink
loud - soft - loft	brush - soft	water - loft
long - short - port	water - short	hill - port
hill - mountain - fountain	loud - mountain	long - fountain
girl - boy - joy	speak - boy	judge - joy
judge - jury - bury	lost - jury	girl - bury

lost - found - hound	girl - found	speak - hound
speak - talk - balk	judge - talk	lost - balk
city - town - gown	old - town	swift - gown
swift - fast - past	carpet - fast	city - past
carpet - floor - poor	city - floor	old - poor
old - new - pew	swift - new	carpet - pew

Orthographically Mediated Condition

in - out - rut	mother - out	tulip - rut
mother - father - lather	in - father	high - lather
high - low - now	lemon - low	mother - now
lemon - sour - tour	high - sour	wish - tour
wish - want - pant	tulip - want	lemon - pant
tulip - flower - blower	wish - flower	in - blower
dry - wet - wit	music - wet	uncle - wit
music - sound - wound	dry - sound	dry - wound
house - home - hole	cold - home	music - hole
cold - hot - hut	house - hot	justice - hut
justice - law - low	uncle - law	cold - low
uncle - aunt - punt	justice - aunt	house - punt
bread - butter - batter	scissors - butter	scissors - batter
scissors - cut - cute	always - cut	bread - cute
thief - robber - rubber	bread - robber	always - rubber
always - never - fever	thief - never	thief - fever
hard - soft - sift	brush - soft	brush - sift
brush - comb - tomb	hard - comb	hard - tomb

green - grass - gross	faster - grass	faster - gross
faster - slower - tower	green - slower	green - tower
up - down - dawn	anger - down	anger - dawn
anger - mad - wad	up - mad	up - wad
crack - break - freak	north - break	north - freak
north - south - youth	crack - south	crack - youth

Phonologically Mediated Condition

heavy - light - quite	table - light	train - quite
bitter - sweet - suite	train - sweet	heavy - suite
train - track - plaque	bitter - track	table - plaque
table - chair - rare	heavy - chair	bitter - rare
knife - blade - raid	needle - blade	needle - raid
needle - thread - said	knife - thread	knife - said
sheep - wool - pull	hint - wool	hint - pull
hint - clue - crew	sheep - clue	sheep - crew
foot - shoe - blue	live - shoe	live - blue
live - die - rye	foot - die	foot - rye
book - read - seed	early - read	early - seed
early - late - eight	book - late	book - eight
smooth - rough - cuff	head - rough	head - cuff
head - hair - bear	thirsty - hair	smooth - bear
sell - buy - lie	smooth - buy	thirsty - lie
thirsty - water - daughter	sell - water	sell - daughter
eating - food - rude	black - food	black - rude
black - white - fight	robin - white	eating - fight

color - red - dead	eating - red	lamp - dead
robin - bird - heard	color - bird	color - heard
lamp - shade - laid	hand - shade	hand - laid
hand - foot - put	open - foot	robin - put
stove - hot - bought	lamp - hot	open - bought
open - close - toes	stove - close	stove - toes

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[1] Experimental semantically related prime-target word pairs were constructed using the first two words of each word triplet. Experimental mediated prime-target word pairs for each type of mediated relation consisted of the first and third word of each word triplet.

Footnotes

[1] In addition to these planned comparisons, a sign-test was also performed on the RT data in these two conditions. In each of these two mediated conditions, the number of participants who yielded a larger mean RT in the experimental condition than in the control condition was calculated. In the orthographically mediated condition, the mean RT in the experimental condition was greater than the mean RT in the control condition for 48 of the 80 participants, $z = 1.67$, $p < .05$. However, in the orthographically and phonologically mediated condition, only 45 of the 80 participants yielded a larger mean RT in the experimental condition than in the control condition, $z = 1.01$, $p = .16$.

[2] In order to gain more information on the reliability of these effects, the RT and error rate data in Experiment 1 were split in half by randomly assigning participants to one of two groups. Two separate ANOVAs were then performed on each group. The three-way interaction involving type of relation, RP, and condition was not significant in either data group (both Fs < 1). However, the two-way interaction involving type of relation and condition was significant with both groups [for Group 1, $F(3, 114) = 4.874$, $MSE = 1692.40$, $p < .01$; for Group 2, $F(3, 114) = 4.456$, $MSE = 1574.89$, $p < .01$]. Similar to what was done in the main analyses, planned comparisons were also performed at each type of relation separately for each group. For both groups, a significant semantic priming effect was found [for Group 1, $F(1, 114) = 7.684$, $MSE = 1692.40$, $p < .01$; for Group 2, $F(1, 114) = 8.420$, $MSE = 1574.89$, $p < .01$]. The only other effect found was a marginally significant mediated inhibition effect in the orthographically and phonologically mediated condition in Group 1, $F(1, 114) = 3.882$, $MSE = 1692.40$, $p = .051$. Although the planned comparison in the same condition in Group 2 was not significant, the means in both groups were in the same direction, the effect was simply larger in Group 1. None of the other planned comparisons were significant and all the means associated with the

remaining comparisons were in the same direction. As for the error rates, none of the effects of interest were significant and each set of means associated with the planned comparisons were in the same direction. The orthographically mediated condition was the only condition in which the means were in an inhibitory direction, however, this effect was not reliable for either group.