University of Alberta

Strategic Control of Semantic Processing in Visual Word Recognition

by

Paul David Siakaluk ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of *Doctor of Philosophy*

Department of Psychology

Edmonton, Alberta

Fall, 2002

0-612-81266-9

University of Alberta

Library Release Form

Name of Author: Paul D. Siakaluk

Title of Thesis: Strategic Control of Semantic Processing in Visual Word Recognition

Degree: Doctor of Philosophy

Year this Degree Granted: 2002

Permission is hereby granted to the University of Alberta to reproduce single copies of this thesis and to lend or sell such copies for private, scholarly or scientific research purposes only.

The author reserves all other publication and other rights in association with the copyright in the thesis, and except as herein before provided, neither the thesis nor any substantial portion thereof may be printed or otherwise reproduced in any material form whatever without the author's prior written permission.

Paul Siakaluk

Paul D. Siakaluk
220 Silver Springs Rise N.W.
Calgary, Alberta
T3B 3Z7
Canada

September 10/2002

University of Alberta

Faculty of Graduate Studies and Research

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled Strategic Control of Semantic Processing in Visual Word Recognition by Paul David Siakaluk in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Lori Buchanan
Co-supervisor

Michael R. W. Dawson
Co-supervisor

Peter Dixon

Kathryn Todd

Ron Borowsky
External Examiner

September 6/2002

Abstract

There has been a considerable amount of research investigating the effects of semantics on the speed and accuracy with which words presented in isolation are recognized. The present thesis contributes to this research by investigating interactions between a novel semantic variable, namely semantic distance (e.g., K. Lund & C. Burgess, 1996), and strategic control of lexical processing. Semantic distance is defined as the mean distance between a word and its ten nearest neighbors in high-dimensional space (L. Buchanan, C. Westbury, & C. Burgess, 2001). Words that have relatively close semantic neighbors are called low semantic distance words, whereas words that have relatively distant semantic neighbors are called high semantic distance words. Interactions were investigated in the lexical decision, semantic categorization, lexical decision/semantic categorization, and word naming tasks. In each task, semantic distance exerted a facilitatory effect (i.e., low semantic distance words were responded to more rapidly than high semantic distance words) when task demands required relatively extensive lexical processing. In task conditions that required relatively less extensive lexical processing, there was no effect of semantic distance. A cross-module activation account of semantic effects in lexical processing is described and the present findings are explained within this framework. It appears that semantic distance exerts at least two types of influence on the lexical processing system. The first type of influence arises from semantic neighbors influencing the settling times of orthographic and phonological codes (codes located outside the semantic module). The second type of influence arises from semantic neighbors influencing the settling times of semantic codes (codes located inside the semantic module).

Acknowledgements

I would like to start by thanking my two supervisors, Lori Buchanan and Mike Dawson. Both of you are great supervisors, and I consider myself lucky to have been your student. Lori, I appreciate all that you have done for me; all the conferences you have taken me to; all the time and energy you have put into my research projects; all the encouragement you gave; and for treating me with respect. Mike, I also appreciate all that you have done for me; helping out to allow me to go to conferences; for 'adopting' me and taking the time to go over my dissertation; for the many chats we had about research and psychology; and for also treating me with respect. There is no doubt that both of you were instrumental in the success I've had thus far in my young research career, and that what you have taught me through your knowledge and example will serve me well in the years to come. I owe you both a huge debt of gratitude.

I would also like to thank Chris Westbury. I consider you my third supervisor. I appreciate all the time and effort you gave me, both in terms of talking about my research and psychology in general, and in the programming assistance you provided for my experiments. You are a large part of my success thus far, thank you.

I would like to thank the members of the BCP lab for welcoming me to their home. Thanks Reiko, Patricia, Leanne, and Darren for your friendship.

I would also like to thank my Master's supervisor, Chris Sears, for continuing to take an interest in me and my research. I also would like to thank Penny Pexman for the time she has taken to talk with me about my research. Thanks go to Simon, Yan, and Geoff for their continuing friendship and support.

I would like to finish by thanking my family. Mum and Dad, thank you for teaching me to love to learn. Thanks also for instilling in me the attitude to do nothing less than my best. These have served me well. Thanks to my children, Kailyn, Chandler, Emily, and Lauren, for your patience to allow dad to do his work. Finally, to my wife Lisa. Thank you for your sacrifice during our years in grad school. Hopefully the rewards we get from this experience will be enough to repay you for all you have done. I love you.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AnimRate	Animalness Ratings
ANOVA	Analysis of Variance
Conc	Concreteness
Cond	Condition
HAL	Hyperspace Analogue to Language Model
Imag	Imageability
LL	Length in Letters
LogF	Log Frequency
Meaning	Meaningfulness
MEL	Micro Experimental Laboratory
ms	Millisecond
N	Neighbor
NoA	Number of Associates
NoM	Number of Meanings
ON	Orthographic Neighborhood Size
PWF	Printed Word Frequency
RCU	Riverside Context Unit
RL	Response Latency
s	Second
SemD	Semantic Distance
SLA	Summed Lexical Activation
SubF	Subjective Frequency
VGA	Video Graphics Array

CHAPTER 1

INTRODUCTION

Research in visual word recognition (i.e., lexical processing) is concerned with the identification of word characteristics and examinations of their effects on the lexical processing system (for reviews, see Balota, 1990, 1994; Forster, 1990). This thesis contributes to this scientific endeavor through a comprehensive examination of the interactions between semantic distance (e.g., Buchanan, Westbury, & Burgess, 2001; Lund & Burgess, 1996) and strategic control of lexical processing across different tasks. This investigation will demonstrate that semantic distance systematically influences lexical processing in each task, and that its effects are largest when task conditions elicit more extensive processing.

The purpose of this chapter is to provide a rationale for the experiments reported in this thesis. This will be done in the following manner. First, I will review the literature examining the effects of semantic variables on lexical processing. This review will unveil and account for the important finding that different semantic variables do not necessarily influence lexical processing in the same way, either within particular tasks or across different tasks. Next, a description of semantic distance and a review of its effects on lexical processing will be presented. This will be followed by a description of the two primary methodological designs used in this thesis, namely ideal strategy manipulations (Gibbs & Van Orden, 1998; Stone & Van Orden, 1993) and procedural strategy manipulations. I will conclude this chapter with a delineation of the different lexical processing tasks used in this thesis and the strategy manipulation that will be employed in each.

Semantic Effects: A Review of the Literature

Early theories of visual word recognition focused on how orthographic (visual) characteristics of words influenced lexical processing (Becker, 1976; Coltheart, 1978; Forster, 1976; McClelland & Rumelhart, 1981; Morton, 1969; Paap, Newsome, McDonald, & Schvaneveldt, 1982; Rumelhart & McClelland, 1982). The prevailing view during this time was that a word had to first be identified—by matching its orthographic stimulus information to an internal representation—before its meaning would become accessible. A well-known example of this view is Forster's (1976) serial-search model.

According to Forster (1976), skilled readers possess several semi-autonomous memory stores (i.e., lexicons) containing all the information known about words in their vocabulary. For the purposes of visual word recognition, orthographic stimulus information is first compared to internal codes in an orthographic access lexicon organized by the visual properties of words. Once a code in the orthographic access lexicon has been sufficiently matched to stimulus information, a pointer for that code accesses a corresponding code in the lexicon proper. This lexicon stores all the orthographic (spelling), phonological (sound), and semantic (meaning) information for every word a skilled reader knows. It is only when a code in the lexicon proper has been accessed that a word's meaning becomes available to the reader. Thus, according to Forster's model, semantics should not influence the speed and the accuracy with which words are recognized.

To test the assumption that semantics does not influence word recognition, Balota, Ferraro, and Connor (1991) reviewed early studies examining the effects of polysemy, concreteness, and imageability. Polysemy refers to the number of meanings a word possesses (e.g., Rubenstein, Garfield, & Millikan, 1970; Jastrzembski, 1981). Polysemous words, such as BARK, possess many meanings, whereas nonpolysemous words, such as CAKE, possess one or few meanings. Concreteness refers to how easily a word's referent can be experienced by the senses, and imageability refers to how easily a word's referent can evoke mental images (e.g., visual, acoustic, or any other sensory image; Toglia & Battig, 1978). The word PEACH, for example, is both a high concrete and a high imagery word because peaches can be experienced by various senses (e.g., sight, touch, smell, taste) and can easily evoke mental images. On the other hand, the word FRAUD is both a low concrete and a low imagery word because frauds cannot be easily experienced by the senses and cannot easily evoke mental images. Because concreteness and imageability are highly correlated (Balota et al.), the remainder of this literature review will consider them jointly.

Early studies by Rubenstein and colleagues (Rubenstein et al., 1970; Rubenstein, Lewis, & Rubenstein, 1971), and Jastrzembski (1981; Jastrzembski & Stanners, 1975) demonstrated that polysemous words yielded faster lexical decision latencies than nonpolysemous words. Facilitatory effects were also reported for concreteness/imageability in lexical decision and word naming, in which high concrete/imagery words were responded to more rapidly than low concrete/imagery words (de Groot, 1989; James, 1975; Kroll & Mervis, 1986; Rubenstein et al., 1970).

The findings of the above studies, however, were challenged on two fronts. First, Clark (1973) reanalyzed the Rubenstein et al. (1970) polysemy data treating both subjects and items as random factors and reported *no* effect of polysemy. Clark thus concluded that the effect might not generalize to new subjects and new items. This conclusion was supported by results from an experiment conducted by Forster and Bednall (1976), who also treated subjects and items as random factors and reported no effect of polysemy.

Second, Gernsbacher (1984) noted that although studies examining polysemy (e.g., Rubenstein et al., 1970; Jastrzembski, 1981) and concreteness/imageability (e.g., James, 1975) equated their experimental items on printed word frequency, they did not equate them on subjective familiarity. Gernsbacher suggested that printed word frequency counts may be subject to sampling error, and thus may not be the best measure to assess how often participants come across words in print. Using a 7-point Likert scale, with one end labeled *very unfamiliar* and the other end labeled *very familiar*, Gernsbacher asked participants to rate how familiar they were with a set of low-frequency words. She then conducted lexical decision experiments in which subjective familiarity was factorially manipulated with either polysemy or concreteness/imageability. In both cases, Gernsbacher reported an effect of subjective familiarity, in that high familiarity words were responded to more rapidly than low familiarity words. However, she reported no effect of either polysemy or of concreteness/imageability. She concluded that previous studies reporting facilitatory effects of polysemy and of concreteness/imageability confounded these variables with subjective familiarity, so that polysemous words and high concrete/imagery words were simply more familiar to participants, thus yielding faster responses.

The item analysis and subjective familiarity challenges have not gone uncontested themselves. Regarding the possible contaminating effects of subjective familiarity, Balota et al. (1991; see also Balota, Pilotti, & Cortese, 2001) stated that it is not clear what types of lexical information participants use when making subjective familiarity judgments. They suggested that participants may use semantic information as part of the familiarity judgment process, and thus partialling out variance accounted for by subjective familiarity could result in inadvertently partialling out variance accounted for by semantic variables. In addition, they reviewed two studies that directly addressed the subjective familiarity and item analysis concerns. Kellas, Ferraro, and Simpson (1988) and Millis and Button (1989) had participants rate their items for subjective familiarity, and were able to closely match their polysemous and nonpolysemous items on this measure. Both studies also analyzed their data with subjects and items as random factors and both reported that lexical decision latencies were faster to polysemous words than to nonpolysemous words. These independent studies thus replicate the results of Rubenstein et al. (1970, 1971) and Jastrzembski (1981; Jastrzembski & Stanners, 1975) using the analyses suggested by Clark (1973) on data collected from stimuli matched on subjective familiarity (Gernsbacher, 1984).

Contrary to early theories of visual word recognition, Balota et al. (1991) claimed that the results from the literature are consistent with the idea that semantic processing is an integral component of the lexical processing system. Thus, the processing of word meaning is not just a product of lexical selection, but is also one of its causes. Since Balota et al.'s review, many studies with carefully constructed stimulus sets have provided additional support for this view regarding polysemy effects (Borowsky & Masson, 1996; Gottlob, Goldinger, Stone, & Van Orden, 1999; Hino & Lupker, 1996; Hino, Lupker, & Pexman, 2002; Hino, Lupker, Sears, & Ogawa, 1998; Lichacz, Herdman, Lefevre, & Baird, 1999; Pexman & Lupker, 1999; Piercey & Joordens, 2000), and concreteness/imageability effects (Cortese, Simpson, & Woolsey, 1997; Strain & Herdman, 1999; Strain, Patterson, & Seidenberg, 1995; Zevin & Balota, 2000).

Semantic variables other than polysemy and concreteness/imageability have also been identified and examined. One such semantic variable is number of features (Pexman, Lupker, & Hino, in press). Pexman et al. used the McRae, de Sa, and Seidenberg (1997) number of feature norms, in which many participants provided features for a large set of words. Pexman et al. reported that words with many features were responded to more rapidly than words with few features in both lexical decision and word naming. Finally, both Hino et al. (2002) and Pecher (2001) examined the effects of synonymy. Both studies reported inhibitory effects of synonymy in lexical decision and word naming, in that words with synonyms were responded to more slowly than words without synonyms. The Hino et al. (2002) study further reported no effect of synonymy in semantic categorization.

An important finding regarding the influence of semantics on lexical processing is that they do not exert uniform effects. This can be demonstrated in two ways. One way is to note how different semantic variables influence processing within a particular task. For example, within the lexical decision task, polysemy (Hino et al., 2002), concreteness/imageability (James, 1975), and number of features (Pexman et al., in press) exert facilitatory effects, whereas synonymy (Hino et al., 2002; Pecher, 2001) exerts inhibitory effects. A second way is to note how a particular semantic variable influences processing across different tasks. Polysemy, for example, exerts facilitatory effects in lexical decision and word naming (Hino & Lupker, 1996), but inhibitory effects in semantic categorization (Hino et al., 2002). These differential effects of semantics on lexical processing have been explained using a cross-module activation account, which is described in the next section.

Semantic Effects in Lexical Processing: The Cross-Module Activation Account

The cross-module activation account provides a framework in which to elucidate the various influences of different semantic variables on the lexical processing system. The 'module' component of the term refers to the assumption that different characteristics of words are processed by different sets of units (e.g., McClelland & Rumelhart, 1981; Plaut, McClelland, Seidenberg, & Patterson, 1996; Seidenberg & McClelland, 1989; Van Orden & Goldinger, 1994). That is, one set of units (or module) is assumed to be dedicated to processing orthographic characteristics of words, a second set of units (or module) is dedicated to the processing of phonological characteristics, and a third set of units (or module) is dedicated to the processing of semantic characteristics. It is important to emphasize here that I am using the term ‘module’ in a non-Fodorian manner (Fodor, 1983), and thus the 'cross' component of the term refers to the assumption that the processing of one module can influence the processing of the other modules.

Hino and colleagues (Hino & Lupker, 1996; Hino et al., 2002; Pexman et al., in press; see also Pecher, 2001) refer to cross-module activation from semantics to orthography or to phonology as 'feedback semantics'. Their version is based on a parallel distributed processing framework. Three important caveats regarding the Hino and colleagues feedback semantics account need to be made at this point. One is that at present it is a general framework rather than a realization of any particularly implemented model of lexical processing. The second is that parallel distributed processing models can take on many different designs, and thus the Hino and colleagues proposal is just one of many possible designs (e.g., see Borowsky & Masson, 1996, and Kawamoto, Farrar, & Kello, 1994, for other parallel distributed processing designs used to model polysemy effects.) The third caveat is that the term 'feed*back*' necessarily implies a specific temporal relationship dictating the flow of activation among modules within the lexical processing system. One problem with this term is that some semantic effects could be argued to be 'feed*forward*' effects. In recognition of the ambiguity of the term 'feedback activation', I have opted to use the more temporally neutral term 'cross-module activation'. Throughout the thesis, the direction of the flow of cross-module activation is explicitly stated through use of the terms 'from' and 'to' (e.g., from semantics to orthography).

Parallel distributed processing models (e.g., Plaut et al., 1996; Seidenberg & McClelland, 1989; see also Van Orden & Goldinger, 1994) usually do not contain lexical units that represent single words. Instead, they assume that presented words produce patterns of activation across an interconnected network of orthographic, phonological, and semantic units. In addition, the processing of one module (or set of units) may influence the processing of other modules. Through learning, the network adjusts its connection weights to reflect the proper relationships between the different units.

According to the cross-module activation account, when a word is presented activation initially accrues among the orthographic units. This activation then spreads to both the phonological units and to the semantic units. An important assumption of this account is that lexical decisions are based primarily on the activation of the orthographic units, naming responses are based primarily on activation of the phonological units, and semantic categorizations are based primarily on the activation of the semantic units (Hino et al., 2002). It is further assumed that responses are made available when processing in a module has 'settled' on a particular pattern of activation. That is, the settling time is influenced by within-module activation and, because the modules are fully-interconnected, cross-module activation. Therefore, the effect of a particular semantic variable in a particular task depends on the interaction between the nature of the variable and the nature of within- and cross-module activation of the lexical processing system. An important consequence of this is that mappings from one module to another may be one-to-one or one-to-many. For example, an orthographic code for a particular word may map onto one phonological code (e.g., nonhomographic words such as TENT) or more than one phonological code (e.g., homographic words such as TEAR; see Plaut et al., 1996; Seidenberg & McClelland, 1989). Likewise, an orthographic code for a particular word may map onto one semantic code (e.g., nonpolysemous words such as CAKE) or more than one semantic code (e.g., polysemous words such as BARK; see Borowsky & Masson, 1996; Joordens & Besner, 1994; Kawamoto et al., 1994).

The cross-module activation account explains facilitatory polysemy effects in the lexical decision and word naming tasks in the following manner. Hino and colleagues (Hino & Lupker, 1996; Hino et al., 2002; Pexman & Lupker, 1999; Pexman et al., in press) suggest that polysemous words generate richer or more extensive semantic activation than nonpolysemous words, because the former would activate, on average, more semantic codes than the latter. Thus, polysemous words generate more cross-module activation from semantics to both orthography and to phonology (as these connections are many-to-one) than nonpolysemous words (which have only one-to-one, or at least fewer-to-one connections). Because polysemous words produce more cross-module activation from semantics to either orthography or to phonology than nonpolysemous words, they settle faster into their particular orthographic or phonological codes and hence yield faster responses. The cross-module activation account provides a similar explanation for facilitatory concreteness/imageability and number of features effects. That is, because high concrete/imagery words and high number of feature words generate more extensive semantic processing, and thus more cross-module activation from semantics to orthography or to phonology, than low concrete/imagery words (e.g., Cortese et al., 1997; Strain & Herdman, 1999; Strain et al., 1995) and low number of feature words (Pexman, et al., in press), they take less time to settle into their particular orthographic or phonological codes.

In contrast, words with synonyms do not benefit from cross-module activation from semantics to orthography or to phonology. This is the case because connections from semantics to both orthography and phonology are relatively inconsistent, in that the connections are one-to-many. These one-to-many connections would diffuse the activation over many different orthographic or phonological codes, thus leading to competition and a corresponding delay in settling times (Hino et al., 2002; Pecher, 2001; Pexman et al., in press).

In semantic categorization, the cross-module activation account assumes that inhibitory polysemy effects arise because of the relatively inconsistent one-to-many connections from orthography to semantics (Hino et al., 2002). More specifically, the cross-module activation of these one-to-many connections from orthography to semantics would diffuse the activation over many different semantic codes, thus leading to competition and a corresponding delay in settling times (Hino et al., 2002). In this account, null effects of synonymy obtain because initial orthographic processing does not appreciably activate the orthographic codes of a word's synonyms, and hence cross-module activation from orthography to semantics is not truly many-to-one for words with synonyms (Hino et al., 2002; Pexman, personal communication, April 22, 2002). Thus, words with synonyms and words without synonyms generate approximately equivalent levels of cross-module activation from orthography to semantics, and therefore no effect of synonymy is expected.

Balota et al. (1991) also proposed an account of semantic effects in lexical decision based on a modification to the interactive activation model (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982). The interactive activation model represents discrete units of information (e.g., individual features, letters, and words) as individual nodes, and each node is connected to many other nodes. There are inter-level reciprocal connections, so that partially activated sublexical nodes and partially activated lexical nodes can mutually excite or inhibit one another, depending on whether connections are excitatory or inhibitory. Excitatory reciprocal connections enable partially activated lexical nodes to eventually exceed an activation threshold. According to the model, when the activation threshold has been exceeded unique word identification takes place. Intra-level inhibition occurs between nodes at each level. That is, lexical nodes that are activated during the presentation of a word compete against one another during the lexical selection process via inhibitory connections.

Balota et al.'s (1991) modification was to expand the interactive activation model to include semantic (or meaning) nodes. Thus, partially activated lexical (i.e., orthographic) nodes and partially activated semantic nodes that share excitatory connections reciprocally excite one another until the activation threshold is exceeded. This expanded interactive activation model accounts for facilitatory polysemy effects in lexical decision in the following manner. When a word is presented to the model, it initially activates the lexical nodes that are consistent with the orthographic stimulus information. Cross-module activation is then sent from the lexical nodes to the semantic nodes, and the semantic nodes associated with the target word's different meanings are activated. These semantic nodes then send cross-module activation back to the lexical nodes, which in turn send cross-module activation back up to the semantic nodes. This reciprocal activation continues until the lexical node corresponding to the presented word has reached its activation threshold, at which point lexical selection is achieved. Polysemous words benefit more from reciprocal cross-module activation than nonpolysemous words, because they activate more semantic nodes and thus more cross-module activation is generated from these nodes to the lexical nodes. The end result would be that activation for polysemous words reaches threshold before activation for nonpolysemous words. A similar account applies for facilitatory effects of concreteness/imagery and number of features if it is assumed that high concrete/imagery words and high number of feature words have either more or stronger connections between the semantic nodes and the lexical nodes than low concrete/imagery words and low number of feature words. The number of or the strength in the connections could be based on the notions that high concrete/imagery and high number of feature words activate more defining semantic features (Jones, 1985), activate more contextual information (Schwanenflugel, Akin, & Luh, 1992), or activate more types of sensory information (Paivio, 1991) than do low concrete/imagery and low number of feature words. Finally, facilitatory effects of these variables in word naming could be similarly explained by including the additional assumption that semantic nodes are mutually connected to a set of phonological nodes.

The expanded interactive activation model (Balota et al., 1991) could also account for inhibitory polysemy and null synonymy effects in semantic categorization. Inhibitory effects of polysemy would occur because polysemous words would activate more semantic nodes than nonpolysemous words. Because of the intra-level inhibition inherent in the model, this would result in greater inhibition being generated among the semantic nodes for polysemous words than for nonpolysemous words, and hence more of a delay and longer latencies for polysemous words. Null effects of synonymy would obtain because, as noted by Hino et al. (2002), initial orthographic processing would not appreciably activate the orthographic nodes of a word's synonyms, and hence cross-module activation from the lexical nodes to the semantic nodes would be similar for words with and without synonyms. This would result in comparable levels of inhibition being generated among the semantic nodes for these two types of words, and thus the null effect of synonymy.

In summary, the cross-module activation account explains semantic effects as arising from relationships between the nature of the semantic variable under consideration and the nature of the lexical processing system. Hino and colleagues (Hino & Lupker, 1996; Hino et al., 2002; Pexman et al., in press; see also Pecher, 2001) based their account on a parallel distributed processing framework, and Balota et al. (1991) based their account on an expanded version of the interactive activation model (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982).

The next section outlines research that has added to the ways of conceptualizing semantics. More specifically, this research has led to the development of a relatively new semantic variable, namely semantic distance. To date there has been little investigation of the effects of semantic distance on lexical processing, but the one study that directly examined its effects will be reviewed.

The Effects of Semantic Distance on Lexical Processing

Burgess and colleagues (Burgess, Livesay, & Lund, 1998; Burgess & Lund, 2000; Lund & Burgess, 1996) developed the hyperspace analogue to language (or HAL) model of semantic memory (see also Landauer & Dumais, 1997, for a similar methodological and theoretical approach). HAL is a high-dimensional, computational model that uses a global co-occurrence learning algorithm to track lexical co-occurrences across a large sample of written text. More specifically, HAL uses a 20-word moving window (10 words in either direction of the word under consideration), to track the local co-occurrences of words. HAL then generates weighted co-occurrence values for words in that 20-word window, with adjacent words on either side receiving a value of 10, and words separated by nine others on either side receiving a value of 1. HAL sums these co-occurrence values and this summing results in a high-dimensional global co-occurrence matrix containing information from the entire learning history of the model. Each word is thus represented by a vector containing many (i.e., 140,000 dimensions with 70,000 words) elements. Each element can be thought of as a coordinate in high-dimensional space: Words with similar vectors occur relatively close together in this high-dimensional space, whereas words with dissimilar vectors are more distant. A distance metric in arbitrary units called Riverside Context Units (RCU: see Lund & Burgess) expresses the distance between any two words in the high-dimensional space.

Burgess et al. (1998) presented many simulations and empirical studies that examined how words are represented in the high-dimensional space. For example, they used multidimensional scaling to demonstrate that the words in the high-dimensional space are clustered together in coherent ways. They demonstrated that HAL vectors are able to categorize words representing different concrete concepts (e.g., foods, clothes, and vehicles), different abstract concepts (e.g., emotional words such as love and romance from legal words such as judge and law), as well as grammatical concepts (verbs from nouns). Other work by Burgess et al. focused on the actual constituents of a given word neighborhood. In the HAL model, a word's neighbors are the words that are closest to it in semantic space. If one is interested in finding, for example, the ten closest neighbors to any word, then the ten words with the lowest RCU values are those ten closest neighbors. An example of this is shown in Table 1-1. The ten closest neighbors of the words AMAZE and ACCEPT are listed from lowest to highest RCU value (i.e., from closest neighbor to farthest neighbor). Burgess et al. demonstrated that RCU values could predict participants' abilities to make discriminations between similar words and to generate words that may be the core concept of a particular neighborhood of words.

The primary focus of Burgess and his colleagues, thus far, has been to develop an account of a word's semantic representation. Integral to this account is that according to HAL, word meaning is a function of the contexts in which words appear (Burgess, 1998; Burgess et al., 1998). In addition, words in similar regions of the high-dimensional space are similar in meaning, and this may result for one of two reasons. First, words may co-occur together in similar contexts and thus have similar values on their vectors. Burgess et al. use the example of the words COP and ARRESTED as not being similar because of item similarity (e.g., they do not share similar features like the words LION and TIGER do) but because they co-occur in similar contexts. Second, similar words may have similar vector values but rarely if ever co-occur. For example, the words ROAD and STREET rarely co-occur but they appear in similar contexts, and thus their locations in the high-dimensional space are similar. In summary, a word's position in HAL's high-dimensional space is a function of summing all the contexts in which it appears, and that words that appear (whether they co-occur or not) in similar contexts are located in similar regions of the high-dimensional space.

Buchanan et al. (2001) extended the empirical study of semantic distance to determine its processing implications for the visual identification of single words. They defined the semantic distance of a word as the mean distance between that word and its ten closest neighbors in semantic space. Note that the two words in Table 1-1 differ in their average semantic distance to their ten closest semantic neighbors. Thus, a word with a high semantic distance, such as AMAZE, is relatively distant from its ten nearest neighbors, and may therefore be said to have a sparse semantic neighborhood. Conversely, a word with a low semantic distance, such as ACCEPT, is relatively close to its ten nearest neighbors, and hence can be said to have a dense semantic neighborhood. Another way of thinking about semantic distance is to imagine that within a specified radius, high semantic distance words will, on average, have fewer semantic neighbors than will low semantic distance words. Thus, high semantic distance words will, on average, have smaller semantic neighborhoods than will low semantic distance words.

Table 1-1
Examples of Semantic Neighbors for the High Semantic Distance Word AMAZE and the Low Semantic Distance Word ACCEPT

Semantic neighbors of high SemD word AMAZE (Mean Distance = 501.46 RCU)		Semantic neighbors of low SemD word ACCEPT (Mean Distance = 239.20 RCU)	
Neighbor	RCU	Neighbor	RCU
avoid	492.90	take	218.08
defend	494.55	give	223.49
learn	497.07	recognize	231.75
convince	501.31	continue	237.39
keep	501.53	follow	241.95
demonstrate	502.41	make	242.14
prove	502.47	keep	247.30
make	507.00	acknowledge	249.21
remind	507.24	speak	249.45
create	508.19	use	251.23

Note. SemD = semantic distance; RCU = Riverside Context Unit.

Table 1-2 provides summary information of correlations between semantic distance and other, more traditional, measures of semantics to provide a bit more information regarding this relatively novel variable. For the 969 words considered in this analysis, the concreteness, imageability, and meaningfulness values were taken from the MRC Psycholinguistic Database (Coltheart, 1981). The number of associates values were taken from the Nelson, McEvoy, and Schreiber (1994) word association norms. The semantic distance values were taken from a list generated by Curt Burgess for possible inclusion in the stimulus sets used in Buchanan et al. (2001). An inspection of Table 1-2 reveals that semantic distance does not capture the same information as object based variables such as concreteness or imageability. However, as Buchanan et al.

Table 1-2
Single-Order Correlations Between Concreteness, Imageability, Meaningfulness, Number of Associates, and Semantic Distance

Combined	Conc	Imag	Meaning	NoA	SemD
Conc	1.00				
Imag	.90*	1.00			
Meaning	.19*	.38*	1.00		
NoA	.00	-.02	.01	1.00	
SemD	.20*	.16*	-.18*	-.15*	1.00

Note. Conc = concreteness; Imag = imageability; Meaning = meaningfulness; NoA = number of associates; SemD = semantic distance.
*$p < .001$.

suggested, semantic distance reflects linguistic relationships rather than featural information and as such may be thought of as more similar to association norms (Nelson, et al.) than to these object centered semantic values.

A primary purpose of the Buchanan et al. (2001) study, therefore, was to examine whether semantic neighborhood size exerts an effect on the speed with which words are recognized. In addition to measuring semantic neighborhood size using semantic distance, Buchanan et al. measured semantic neighborhood size using the Nelson et al. (1994) word association norms. This was done to determine which of these two semantic neighborhood size measures better predicted word recognition performance.

In their first experiment, Buchanan et al. (2001) used regression techniques to address the issue of the effects of semantic neighborhood size on young adult lexical decision and word naming latencies, and on older adult word naming latencies. They obtained the naming latency data for a sample of words taken from the Spieler and Balota (1998) corpus. In a multiple regression analysis that included log frequency, orthographic neighborhood size (Coltheart, Davelaar, Jonasson, & Besner, 1977), letter length, imageability, number of associates, and semantic distance as predictor variables, they reported that semantic distance was the only semantic variable that predicted lexical decision latencies. Moreover, they reported a positive partial correlation, which reflected the fact that as semantic distance decreased so did response latencies. This pattern of results was also obtained for older adult naming latencies, but not for younger adult naming latencies.

Buchanan et al. (2001) also reported factorial lexical decision experiments that further examined the effects of semantic distance. In their Experiment 2, they factorially manipulated semantic distance and number of associates. The crucial finding from this experiment was that semantic distance exerted an influence on response latencies, whereas number of associates did not. In Experiment 3, Buchanan et al. factorially manipulated word frequency and semantic distance, and the most important finding from this experiment was that these two variables interacted, such that semantic distance facilitated performance for only low-frequency words. In summary, the findings across the Buchanan et al. lexical decision experiments demonstrated large and robust effects of semantic distance, particularly for low-frequency words. They also reported a facilitatory semantic distance effect in word naming performance for older, but not younger, adults. They explained facilitatory effects of semantic distance as a reflection of greater cross- and within-module activation generated by low semantic distance words as compared to high semantic distance words.

A Note on Methodology: Strategy Manipulations

The Buchanan et al. (2001) study shows that there is an effect of semantic distance in lexical processing. However, as described above, semantic effects are not necessarily consistent within or across tasks. The purpose of this thesis is to therefore examine the consistency of semantic distance effects under experimental conditions that promote different lexical processing strategies. Consider the following quotation from Gibbs and Van Orden (1998, p. 1163),

> "stimulus effects are always seen through the distorting lens of a laboratory task. Arguably, no laboratory task, or contrast between tasks, has proved to be a transparent lens . . . . an admissible working hypothesis is that component stimulus effects are always interdependent with task demands . . . . if so, it may be impracticable to determine where task demands leave off and stimulus effects begin".

Taking this into consideration, lexical processing tasks, such as lexical decision and word naming, provide opportunities to directly examine different strategies that may be used to process words. Van Orden and colleagues (Gibbs & Van Orden, 1998; Stone & Van Orden, 1993) describe a general experimental design, which they call *ideal strategy manipulations*, that allows researchers to isolate strategic control of lexical processing. Gibbs and Van Orden (p. 1163) continue,

> "ideal strategy manipulations, however, make possible the reverse dissociation: We may yet determine where stimulus effects 'leave off' and interaction effects, due to task demands, begin. Thus, an analysis focused

on patterns of interaction may yet be feasible, even if stimulus effects are inextricably contextually situated".

In an ideal strategy manipulation, the critical items of interest (e.g., words in lexical decision) are identical across experimental conditions, as are the procedural variables (e.g., stimulus duration, stimulus quality), and the required responses from the participants (e.g., lexical decision key presses). The only change across experimental conditions is the context in which the critical items are presented (Stone & Van Orden, 1993). This methodology allows researchers to infer that any observed differences in the pattern of results across experimental conditions are due to top-down, or strategic processing, because all other components of the experimental conditions are identical. Thus, as the second Gibbs and Van Orden (1998) quote above states, a major strength of ideal strategy manipulations is that they can disentangle task demands from stimulus characteristics.

The present series of experiments employ strategy manipulations to examine possible interactions between semantic distance and various processing strategies unique to different lexical processing tasks. It should be emphasized that the term 'processing strategies' does not imply that participants are consciously or deliberately choosing certain strategies over others. Rather, it is more likely that participants settle on a certain strategy without being aware of what the strategy is (Stone & Van Orden, 1993).

The effects of semantic distance and strategic processing will be examined in the lexical decision task (Chapter 2), the semantic categorization task (Chapter 3), the lexical decision/semantic categorization task (Chapter 4), and the word naming task (Chapter 5). The ideal strategy manipulation methodology will be employed in Chapters 2, 4, and 5.

A different strategy manipulation, which I call a *procedural strategy manipulation*, will be described and used in Chapter 3. Chapter 6 will review the present empirical findings and discuss how these findings fit within a cross-module activation account of lexical processing.

CHAPTER 2

LEXICAL DECISION

As noted in Chapter 1, ideal strategy manipulations allow researchers to investigate interactions between variables of interest and strategies used in a particular lexical processing task. The purpose of this chapter is to use an ideal strategy manipulation, which is contingent upon the types of nonwords used, to investigate interactions between semantic distance and processing strategies specific to the lexical decision task.

I will begin by describing the ways by which nonwords can vary in their similarity to real words, because changes in word-nonword discriminations induce changes in processing strategies in the lexical decision task. I will follow this with a review of several examples from the literature that have employed this ideal strategy manipulation to examine semantic effects. I will then introduce one measure of nonword difficulty, the summed lexical activation measure (Grainger & Jacobs, 1996), and describe how it was used to manipulate the difficulty of word-nonword discriminations across the four lexical decision conditions of the experiment presented in this chapter. Finally, I will describe the methodology of the experiment, report the results, and conclude with a discussion of how the cross-module activation account accommodates these results.

Nonwords and the Lexical Decision Task

The lexical decision task requires participants to distinguish real words from nonwords. Pioneering investigators of lexical processing who used this task suggested that access to the mental lexicon is necessary to successfully distinguish real words from nonwords, when those nonwords are orthographically legal and pronounceable (e.g., DAST). For example, Coltheart (1978, p. 171) stated:

> "a task which requires lexical access but little (perhaps nothing) else is judging whether a letter string is a word of English or not—the lexical decision task . . . . if all the non-words used in a lexical decision task are well formed . . . . it is difficult to see how a reader could determine whether a well formed letter string is or is not a word except by consulting his internal lexicon."

Forster (1976, p. 260) agreed:

> "by means of the so-called lexical decision experiment, we can estimate the time required for lexical access to occur . . . since there is no way to perform this task without accessing the internal lexicon".

However, both Coltheart (1978) and Forster (1976) pointed out that if the nonwords used were orthographically illegal and unpronounceable (e.g., DBKH), then a superficial orthographic analysis would allow participants to correctly reject these nonwords without recourse to the mental lexicon. Thus, there appears to be distinct types of processing that could be tapped using the lexical decision task. First, when orthographically illegal nonwords are used participants can base their responses on pre-lexical (i.e., shallow) processing, by focusing on the perceptual characteristics of the stimuli. Second, when orthographically legal nonwords are used participants base their responses on lexical (i.e., deep) processing, by accessing (or not) a mental representation for a presented letter string. Other researchers (e.g., Balota & Chumbley, 1984; Johnson & Pugh, 1994; Grainger & Jacobs, 1996; Seidenberg & McClelland, 1989) have supported this conclusion that the lexical decision task may elicit multiple forms of processing, developing several different but closely aligned accounts of how processing in this task is dependent on the types of nonwords used. But they also noted that not all orthographically legal and pronounceable nonwords are created equally. Important to this conclusion are the theoretical and empirical contributions of Coltheart et al. (1977).

Coltheart et al. (1977) examined the influence of orthographic similarity on lexical decision performance. They defined a letter string's orthographic neighborhood (known as *Coltheart's N*) as the number of different words that can be created by changing one letter of a letter string while maintaining letter positions. For example, the words CAKE, BIKE, and BARE are all orthographic neighbors of the word BAKE, and the words DUST, RUST, and NEST are all orthographic neighbors of the nonword NUST. Pertinent to the present discussion is their finding that responses to nonwords with many orthographic neighbors were slower than responses to nonwords with few orthographic neighbors. This finding has been well replicated (e.g., Andrews, 1989; Carreiras, Perea, & Grainger, 1997; Grainger & Jacobs, 1996; Sears, Hino, & Lupker, 1995; Siakaluk, Sears, & Lupker, 2002) and the conclusion from these studies is that nonwords that are orthographically similar to many words are more 'wordlike' than are nonwords that are orthographically similar to few words. This ‘wordlikeness’ may reflect either familiarity (e.g., Balota & Chumbley, 1984) or generation of early overall lexical activation (e.g., Grainger & Jacobs).

There is one further dimension on which nonwords can vary: Pronounceable nonwords may or may not sound like real words when pronounced. As opposed to nonwords that do not sound like real words when pronounced (e.g., FRANE), nonwords that do sound like real words (e.g., BRANE) are called pseudohomophones. Research has revealed that pseudohomophones are responded to more slowly in lexical decision than are regular nonwords (McCann, Besner, & Davelaar, 1988; Seidenberg, Petersen, MacDonald, & Plaut, 1996; Ziegler, Jacobs, & Kluppel, 2001). The conclusion drawn from these studies is that pseudohomophones may activate phonological and semantic information of their base words, thus requiring more extensive processing to determine if the presented letter string is a real word or not.

Vanhoy and Van Orden (2001) presented data suggesting that not all pseudohomophones are created equally, either. In their study they examined three groups of nonwords. The first group was comprised of pseudohomophones that had extant body rimes. The body has traditionally been defined as the initial vowel(s) and subsequent consonants of monosyllabic words (or nonwords), and the rime is how the body is pronounced (Treiman, Mullennix, Bijeljac-Babic, & Richmond-Welty, 1995). For example, the body rime of the pseudohomophone JALE is extant because its spelling and pronunciation are found in real words, such as MALE. The second group was comprised of pseudohomophones that had novel body rimes. For example, although the pseudohomophone JAEL shares its rime with real words, such as MALE, its body (in this case the letters –AEL) is not found in any real English words. The third group of nonwords was spelling controls created by changing one letter of the base word (e.g., JARL). Thus, the three groups were closely matched on how orthographically similar they were to their base words. With such careful orthographic matching, if pseudohomophones yielded longer response latencies than spelling control nonwords the effect would be due to their sounding like real words.

Vanhoy and Van Orden (2001) reported longer response latencies and higher error rates to the pseudohomophones with extant body rimes than to both the pseudohomophones with novel body rimes and the spelling control nonwords. In contrast, they reported that although there was no statistical difference between response latencies and error rates to the pseudohomophones with novel body rimes and the spelling control nonwords, the former types of nonwords actually produced slightly faster response latencies and slightly lower error rates. Thus, only the pseudohomophones with extant body rimes sufficiently activated phonology to be more wordlike than the spelling control nonwords.

In summary, because nonwords vary in how wordlike they are on both orthographic and phonological dimensions, the lexical decision task is a perfect task with which to conduct ideal strategy manipulations. Through manipulating the nonword context in which words are embedded, different processing strategies may be elicited, and interactions between lexical variables and these different processing strategies can be systematically investigated. The next section reviews several studies that have employed ideal strategy manipulations in lexical decision to examine word frequency and polysemy effects.

Ideal Strategy Manipulations and the Lexical Decision Task

Stone and Van Orden (1993; Experiment 1) examined the word frequency effect—the finding that words of higher printed frequency are responded to more rapidly than words of lower printed frequency—as a function of nonword context (i.e., how wordlike the nonwords were). In one experimental condition the nonwords were all orthographically illegal and essentially unpronounceable; in a second experimental condition the nonwords were all orthographically legal and pronounceable; and in a third experimental condition the nonwords were all pseudohomophones. The same set of high- and low-frequency words was used in the three nonword conditions. They reported several important findings. First, there was a main effect of nonword context on word response latencies. That is, responses to the words were fastest in the illegal nonword context, slower in the legal nonword context, and slowest in the pseudohomophone context. Second, the mean response latencies from their nonwords increased as nonwords became progressively more wordlike (see their Table 2). Third, and most interestingly, the effects of word frequency became larger as the nonwords became more wordlike. Given that the word frequency effect is taken to be a good indicator of the amount of lexical processing involved in lexical decision (i.e., more processing resulting in larger effects of word frequency; see Becker, 1976; Forster, 1976; Grainger & Jacobs, 1996; Whaley, 1978), the Stone and Van Orden results demonstrated that more lexical processing was required as nonwords became more wordlike.

Although the lexical decision task is suitable for conducting ideal strategy manipulations, few studies investigating the effects of semantics in lexical decision have employed the strict criteria necessary for conducting this design (e.g., same words across nonword conditions). Two studies examining the effects of polysemy have, however, and will now be described .

First, Borowsky and Masson (1996) conducted two lexical decision tasks in which the same word stimuli were embedded in either a legal nonword context or an illegal nonword context. (For the legal nonword context, they unfortunately did not provide the mean orthographic neighborhood size, or any other variable, of the nonwords, so it is not possible to determine exactly how wordlike they were.) They reported facilitatory effects of polysemy in the legal nonword context but not in the illegal nonword context. They also conducted analyses comparing the data from the two experiments and reported several interesting findings. First, they reported a main effect of nonword context on word response latencies, in that responses were faster in the illegal nonword context than in the legal nonword context (replicating Stone & Van Orden, 1993). Second, they proposed that an advantage in responding to word stimuli over nonword stimuli (i.e., a lexicality effect) should become larger as word-nonword discriminations become more difficult, because deeper processing should yield disproportionately longer response latencies for nonwords than for words. They reported an interaction between lexicality and nonword context, indicating that the lexicality effect was only present in the legal nonword context. Finally, they reported an interaction between polysemy and nonword context, with effects of polysemy only present in the legal nonword context—the context shown to promote deep lexical processing.

Pexman and Lupker (1999) also employed an ideal strategy manipulation design to examine the effects of polysemy in lexical decision. Their study differed from the Borowsky and Masson (1996) study in that the two nonword conditions contained either legal nonwords or pseudohomophones with extant body rimes (Vanhoy & Van Orden, 2001). They reported facilitatory effects of polysemy in both the legal nonword and the pseudohomophone contexts. But more importantly, they reported an interaction between polysemy and nonword context, in that the effects of polysemy were larger in the pseudohomophone context than in the legal nonword context. The results from these two studies strongly suggest that in the lexical decision task, polysemy exerts its effects under conditions that require relatively deep lexical processing.

The findings described above can be explained using the cross-module activation account of semantic effects in lexical processing. Assuming that lexical decisions are based primarily on the activation of the orthographic units, Pexman and Lupker (1999) stated that under conditions in which word-nonword discriminations are more difficult, more extensive processing is needed to reliably make correct lexical decisions. This more extensive processing allows more opportunity for cross-module activation from semantics to orthography to exert an effect. Although few studies have employed ideal strategy manipulations to examine semantic effects in word recognition, the two studies reviewed above demonstrate the effectiveness of the design.

Summed Lexical Activation as a Measure of Nonword Difficulty

Grainger and Jacobs (1996) provide an account of how the orthographic characteristics of nonwords influence strategic processing in lexical decision. Their multiple read-out model is based on the architecture of the interactive activation model (outlined in Chapter 1), but is different in that it incorporates three decision criteria. The first is the M criterion, which is sensitive to the activation of individual lexical nodes. Lexical selection has occurred when this criterion is exceeded. The second is the Σ criterion, which is sensitive to the degree of overall (or summed) lexical activation that either words or nonwords generate. Words and nonwords with many orthographic neighbors will, on average, generate more summed lexical activation than words and nonwords with few orthographic neighbors. If the Σ criterion is exceeded before the M criterion, then a word response is made prior to lexical selection. The third is the T criterion, which is a temporal deadline for making nonword responses. If either the M criterion or the $\sum$ criterion are exceeded before the T criterion, then a word response will be made; otherwise a nonword response will be made.

Importantly, the summed lexical activation values of words and nonwords can be derived from the implemented multiple read-out model. When a letter string is presented to the model, all the words in its lexicon that are orthographically similar are activated. The overall lexical activation produced by a letter string is its summed lexical activation value. If the summed lexical activation distributions of the words and the nonwords in a stimulus set have little or no overlap, then it is possible for participants to base their responses early in processing on summed lexical activation alone (Grainger & Jacobs, 1996; Siakaluk et al., 2002). This should occur under conditions in which nonwords are either orthographically illegal or have no orthographic neighbors. Conversely, if the summed lexical activation distributions of the words and the nonwords sufficiently overlap, then participant responses would be based on deeper or more extensive processing (Andrews, 1997; Siakaluk et al.). This would occur under conditions in which the words and the nonwords are matched closely on number of orthographic neighbors. Because summed lexical activation values capture the depth of processing needed to perform the lexical decision task, they are an important consideration in the following experiment.

Experiment 1 – Lexical Decision

In the present lexical decision experiment, the nonword context was more extensively manipulated than in the Borowsky and Masson (1996) and Pexman and Lupker (1999) studies. Summed lexical activation values for the word and nonword stimuli were obtained from a version of the multiple read-out model, and this will be described further in the Methods section. The experiment employed an ideal strategy manipulation because the word stimuli, procedural variables, and the response requirements were identical in each of the experimental conditions. The only difference between conditions was the nonword context in which the words were presented. As noted, this design allows inferences to be made regarding interactions between semantic distance and strategic control of processing.

In experimental condition 1A, the nonwords were all illegal consonant strings (e.g., FSCV). It is hypothesized that under these experimental conditions, word-nonword discriminations can be made on the basis of an orthographic analysis of the stimuli. This condition was included to determine if effects of semantic distance could be observed when shallow (i.e., nonsemantic) processing reliably distinguishes words from nonwords.

In experimental condition 1B, the nonwords were orthographically legal and pronounceable but had no orthographic neighbors (e.g., FRUF). These nonwords should be more difficult to discriminate from the words than the illegal nonwords. However, as shown below, the difference between the summed lexical activation distributions for the words and these nonwords was sufficient to support early nonlexical discrimination. Thus, word responses may still be made early in processing.

In experimental condition 1C, the nonwords were orthographically legal and pronounceable, and were matched to the words on number of orthographic neighbors (e.g., FAMP). These nonwords should be more difficult to distinguish from the words than the nonwords with no orthographic neighbors, because as will be shown below, the summed lexical activation distributions for the words and these nonwords have sufficient overlap to preclude the use of summed lexical activation as a reliable predictor of whether a stimulus is a word or a nonword. Thus, in comparison to the two previous nonword contexts, deeper processing of the stimuli will be required for responding.

Finally, in experimental condition 1D the nonwords were pseudohomophones (e.g., FEAL) closely matched to the nonwords of experimental condition 1C on number of orthographic neighbors. Thirty-eight of the 40 pseudohomophones had extant word rimes. The summed lexical activation distributions of the words and these pseudohomophones, as will be shown below, sufficiently overlapped so that summed lexical activation again should not be a reliable predictor of whether a stimulus is a word or a nonword. Further, because the summed lexical distributions of these two nonword types were similar, slower responses in the pseudohomophone context than in the matched nonword context would be attributable to phonological and not orthographic characteristics.

Based on the results of Stone and Van Orden (1993), Borowsky and Masson (1996), and Pexman and Lupker (1999) the following predictions were made. First, there should be a main effect of nonword context for both the word and the nonword stimuli. That is, because word-nonword discriminations should become more difficult in each succeeding experimental condition, response latencies to both words and nonwords should increase across conditions. Second, there should be a main effect of lexicality, defined as the difference in response latencies between word responses and nonword responses (Borowsky & Masson), across the experimental conditions. This should occur, according to Borowsky and Masson, because when word-nonword discriminations become more difficult and hence induce deeper lexical processing, words benefit disproportionately more than nonwords from this increased processing. Finally, there should be an interaction between semantic distance and nonword context, in that larger effects of semantic distance should be observed in the experimental conditions requiring deeper lexical processing.

Method

Participants. One hundred and forty-four first-year undergraduate students from the University of Alberta participated in the experiment: 36 participants in each of the four experimental conditions. All were native English speakers and reported normal or corrected-to-normal vision. None of these individuals participated in more than one experimental condition, or were involved in the collection of norming data. All the participants received course credit.

An additional 24 participants rated the stimuli for number of meanings, another 24 rated the stimuli for concreteness, and a final 24 rated the stimuli for imageability. (The rating procedures are described below.) These participants were drawn from the same population as the individuals who participated in the lexical decision experiment, and also received course credit.

Word stimuli. The complete set of experimental words used in this experiment is presented in Appendix A, and the descriptive statistics for these stimuli are listed in Table 2-1. Forty monosyllabic low-frequency words with high semantic distance values and 40 monosyllabic low-frequency words with low semantic distance values were initially selected. The semantic distance of a word was defined as the mean distance, as measured by RCUs, between that word and its ten closest neighbors in semantic space (for examples see Table 1-1; Buchanan et al., 2001). All of the words were either four letters or five letters in length, and all were of low printed frequency (less than 20 occurrences per million words) according to the printed word frequency norms of the CELEX database (Baayen, Piepenbrock, & Gulikers, 1995).

Stimulus norms. The procedure used for collecting the number of meanings ratings was identical to that employed by Kellas et al. (1988). The 80 words, along with 40 nonwords, were randomly ordered, 20 letter strings per page, and presented in a questionnaire format (page order was randomized across participants). At the right hand of each letter string was a scale from 0 to 2. The participants were asked to rate each letter string as to how many meanings it possessed. Participants were asked to circle '0' when the letter string was judged to have *no meaning*; '1' when the letter string was judged to have *one meaning*; and '2' when the letter string was judged to have *more than one meaning*.

The procedures used to collect the concreteness and imagery ratings were identical to those used by Toglia and Battig (1978), except that different examples of high- and low- concreteness and imageability words were presented. The 80 words were randomly ordered, 20 words per page, and presented in a questionnaire format (page order was randomized across participants). At the right hand of each letter string was a scale from 1 to 7, with 1 indicating low concreteness or imageability and 7 indicating high concreteness or imageability. Twenty-four participants were asked to rate each word for concreteness and another 24 participants were asked to rate each word for imageability.

From these ratings, 20 high semantic distance words and 20 low semantic distance words were chosen, equating as closely as possible the two word conditions for

Table 2-1
Mean Semantic Distance, Printed Word Frequency, Number of Meanings, Concreteness, Imageability, Length in Letters, Orthographic Neighborhood Size, and Summed Lexical Activation for the Word Stimuli Used in Experimental Conditions 1A-1D

SemD Cond	SemD	PWF	NoM	Conc	Imag	LL	ON	SLA
High SemD	416.27	9.85	1.16	4.33	4.68	4.50	6.30	0.41
Low SemD	245.15	9.65	1.18	4.51	4.84	4.50	6.30	0.41

Note. SemD = semantic distance; Cond = condition; PWF = printed word frequency; NoM = number of meanings; Conc = concreteness; Imag = imageability; LL = length in letters; ON = orthographic neighborhood size; SLA = summed lexical activation.

number of meanings, concreteness, and imageability. In addition to the above stimulus constraints the items were matched as closely as possible for printed word frequency, letter length, orthographic neighborhood size, and summed lexical activation (as obtained from the multiple read-out model; Grainger & Jacobs, 1996). The procedure for collecting the summed lexical activation values was identical to that used by Siakaluk et al. (2002). To ensure that their four- and five-letter stimuli generated similar summed lexical activation values, Siakaluk et al. followed Grainger and Jacob's protocol of changing the original interactive activation model's (McClelland & Rumelhart, 1981) letter-to-word excitation parameter from 0.07 to 0.06 for their simulations involving five-letter stimuli. In addition, Siakaluk et al. used the summed lexical activation values after eight processing cycles for their simulations involving four-letter stimuli to further equate the summed lexical activation values generated by the four- and five-letter stimuli (for the five-letter stimuli, summed lexical activation values were obtained after seven processing cycles; see Grainger & Jacobs). As indicated in Table 2-1, the high semantic distance words did not differ from the low semantic distance words on any of these variables ($p > .60$ in all cases).

Nonword stimuli. Four different sets of nonword stimuli were created, and are presented in Appendix B. In experimental condition 1A, the nonwords were illegal consonant strings (hereafter referred to as illegal nonwords). The second and third sets of nonwords were orthographically legal and pronounceable, but varied in orthographic neighborhood size. In experimental condition 1B, the nonwords had no orthographic neighbors (hereafter referred to as no neighbor nonwords). In experimental condition 1C, the nonwords were matched to the words on orthographic neighborhood size (range of 2 to 17, with a mean of 8.2; hereafter referred to as matched nonwords). More specifically, for each word a nonword was created that had the same number of orthographic neighbors + 2 (e.g., the word BIKE has 11 orthographic neighbors and the nonword BOPE has 13 orthographic neighbors). The reason for this matching procedure was to better equate the word and the nonword stimuli on summed lexical activation. In experimental condition 1D, the nonwords were all pseudohomophones. None of the base words of the pseudohomophones were among the experimental words. In addition, the pseudohomophones and the matched nonwords were equated as closely as possible on orthographic neighborhood size (7.42 vs. 8.20, respectively; $t(78) = 1.25, p = .21$).

Summed lexical activation values were collected for the four sets of nonwords to determine if the nonword stimuli used in each succeeding experimental condition would generate more lexical activation and hence be more wordlike. (The procedure was identical to that used for the words.) Table 2-2 presents the mean summed lexical activations, standard deviations, and 95% confidence intervals for the four sets of

Table 2-2
Mean Summed Lexical Activation for the Word and Nonword Stimuli Used in Experimental Conditions 1A-1D

Stimuli	Summed Lexical Activation
All words	.41 (.07, .02)
1A: Illegal nonwords	.07 (.05, .01)
1B: No N nonwords	.15 (.08, .02)
1C: Matched nonwords	.36 (.09, .03)
1D: Pseudohomophones	.36 (.04, .01)

Note. SemD = semantic distance; N = neighbor. Standard deviations and 95% confidence intervals, respectively, in parentheses.

nonwords as well as for the 40 experimental words. Importantly, as can be seen from Table 2-2, the pseudohomophones and the matched nonwords were equated on summed lexical activation.

Apparatus and procedure. Stimuli were presented on a color VGA monitor driven by a Pentium-class microcomputer using Micro Experimental Laboratory (MEL) software (Schneider, 1990). Response latencies were measured to the nearest millisecond.

For every trial, a 50 ms blank screen was followed by a fixation cross that appeared at the center of the computer monitor for 250 ms, and was then replaced by a stimulus item (presented in lowercase letters). Participants responded 'word' by pressing the '0' key and 'nonword' by pressing the '1' key on the computer keyboard. The participant's response terminated the stimulus display, and the next trial was initiated after a timed interval of 1 s. Participants were instructed to make their responses as quickly and as accurately as possible, and were told that each letter string would appear only once during the experiment. The order in which the stimuli were presented was randomized separately for each participant.

Each participant completed 16 practice trials prior to the collection of data. The practice stimuli consisted of eight words (half were four letters in length and half were five letters in length, and all were of the same frequency range as the experimental word stimuli), and eight nonwords that were representative of the nonwords presented in the experimental trials (e.g., the eight nonwords for the practice trials of experimental condition 1A were illegal nonwords; half were four letters in length and half were five letters in length).

Design. A 2 (semantic distance: high, low) x 4 (nonword context: illegal nonwords, no neighbor nonwords, matched nonwords, pseudohomophones) mixed factorial design was used. Semantic distance was a within-subjects manipulation and nonword context was a between-subjects manipulation. For each experimental condition, there were 40 nonwords and 20 items in each of the two word stimulus conditions, for a total of 80 trials.

For the word data, response latencies and error rates from each participant were submitted to a 2 (semantic distance: high, low) x 4 (nonword context: illegal nonwords, no neighbor nonwords, matched nonwords, pseudohomophones) mixed-model ANOVA. Both subject (F_1) and item (F_2) analyses were performed.

For the nonword data, response latencies and error rates from each participant were submitted to a one-way (nonword context: illegal nonwords, no neighbor nonwords, matched nonwords, pseudohomophones) between-subjects ANOVA.

For the effect of lexicality, response latencies (word response latencies minus nonword response latencies) and error rates (word error rates minus nonword error rates) from each participant were submitted to a one-way (nonword context: illegal nonwords, no neighbor nonwords, matched nonwords, pseudohomophones) between-subjects ANOVA.

Results

Response latencies less than 250 ms or more than 2,000 ms were considered outliers and were removed from the data set. For experimental conditions 1A (illegal nonwords) and 1B (no neighbor nonwords), there were no outliers removed by this procedure; for experimental condition 1C (matched nonwords), 0.8% of responses were removed; and for experimental condition 1D (pseudohomophones), 0.6% of responses were removed. The mean response latencies of correct responses, the mean error rates, and the mean semantic distance effects in experimental conditions 1A-1D are listed in Table 2-3. The mean response latencies and error rates for the word and the nonword stimuli, and the mean lexicality effects in experimental conditions 1A-1D are listed in Table 2-4. In this thesis, unless otherwise noted, all effects are significant at $p < .05$. All post hoc tests were one-tailed.

Word response latencies. There was a main effect of semantic distance, $F_1(1, 140) = 124.64$, $MSE = 1{,}037.27$, $F_2(1, 38) = 20.48$, $MSE = 3{,}614.17$, with responses to the low semantic distance words an average of 42 ms faster than responses to the high semantic distance words. There was also a main effect of nonword context, $F_1(3, 140) = 24.52$, $MSE = 15{,}358.16$, $F_2(3, 114) = 155.57$, $MSE = 1{,}344.86$. Post hoc comparisons revealed that word responses were slower in the no neighbor nonword context than in the

Table 2-3
Mean Response Latencies (in Milliseconds) and Standard Errors, Mean Error Rates (Percentages) and Standard Errors, and Mean Semantic Distance Effects and 95% Confidence Intervals in Experimental Conditions 1A-1D

	Response latencies		
Condition	High SemD	Low SemD	SemD Effect
1A: Illegal nonwords	527 (12.0)	524 (9.6)	3
1B: No N nonwords	623 (13.8)	575 (12.3)	48
1C: Matched nonwords	679 (18.0)	620 (14.0)	59
1D: Pseudohomophones	723 (21.0)	664 (16.7)	59
	Error Rates		
Condition	High SemD	Low SemD	SemD Effect
1A: Illegal nonwords	4.6 (0.8)	3.9 (0.7)	0.7
1B: No N nonwords	4.0 (0.8)	1.7 (0.5)	2.3
1C: Matched nonwords	7.2 (1.6)	2.7 (0.7)	4.5
1D: Pseudohomophones	4.9 (1.1)	1.8 (0.5)	3.1

Note. SemD = semantic distance; N = neighbor. Standard errors appear in the parentheses.

illegal nonword context, $t_1(140) = 2.50$, $t_2(114) = 8.90$; were slower in the matched nonword context than in the no neighbor nonword context, $t_1(140) = 1.75$, $t_2(114) = 6.22$; and were slower in the pseudohomophone context than in the matched nonword context, $t_1(140) = 1.50$, $p < .10$, $t_2(114) = 5.36$. Thus, the effect of making word-nonword discriminations more difficult by increasing the wordlikeness of the nonwords was realized in the response latencies to the word stimuli.

There was also a semantic distance by nonword context interaction, $F_1(3,140) = 12.53$, $MSE = 1{,}037.27$, $F_2(3,114) = 5.74$, $MSE = 1{,}344.86$. This interaction was further examined by analyzing the effect of semantic distance within each level of nonword context, and also by examining the effect of nonword context in semantic distance. First, there was no effect of semantic distance in the illegal nonword context, both ts < 1. There was an effect of semantic distance in the no neighbor nonword context, $t_1(140) = 6.41$, $t_2(114) = 5.71$; in the matched nonword context, $t_1(140) = 7.80$, $t_2(114) = 7.79$; and in the pseudohomophone context, $t_1(140) = 7.75$, $t_2(114) = 7.14$.

Second, the effect of semantic distance was larger in the no neighbor nonword context than in the illegal nonword context, $t_1(140) = 8.32$, $t_2(114) = 3.93$; was marginally larger in the matched nonword context than in the no neighbor nonword context in the subject analysis, $t_1(140) = 1.45$, $p < .10$, and was larger in the item analysis, $t_2(114) = 2.07$; but was similar in the pseudohomophone context and in the matched nonword context, both ts < 1.

Word error rates. There was a main effect of semantic distance, $F_1(1, 140) = 20.95$, $MSE = 24.58$, $F_2(1, 38) = 9.93$, $MSE = 29.45$, with more errors made to the high semantic distance words than to the low semantic distance words (5.2 % vs. 2.5%, respectively). There was neither a main effect of nonword context, $F_1(3, 140) = 2.00$, $p = .11$, $MSE = 31.64$, $F_2(3, 114) = 2.04$, $p = .11$, $MSE = 18.84$, nor an interaction between semantic distance and nonword context, $F_1(3, 140) = 1.89$, $p = .13$, $MSE = 24.58$, $F_2(3, 114) = 1.46$, $p = .22$, $MSE = 17.56$.

Nonword response latencies. There was a main effect of nonword context, $F_1(3, 140) = 47.18$, $MSE = 14{,}143.04$, $F_2(3, 156) = 206.20$, $MSE = 3{,}446.92$. Post hoc

Table 2-4
Mean Response Latencies (in Milliseconds) and Standard Errors, Mean Error Rates (Percentages) and Standard Errors, and Mean Lexicality Effects for the Word and Nonword Stimuli in Experimental Conditions 1A-1D

	Response latencies		
Condition	Words	Nonwords	Lexicality Effect
1A: Illegal nonwords	526 (10.5)	545 (8.9)	-19
1B: No N nonwords	599 (12.8)	664 (14.2)	-65
1C: Matched nonwords	650 (15.5)	761 (20.4)	-111
1D: Pseudohomophones	694 (18.4)	864 (29.5)	-170
	Error Rates		
Condition	Words	Nonwords	Lexicality Effect
1A: Illegal nonwords	4.3 (0.6)	3.5 (0.7)	0.8
1B: No N nonwords	2.9 (0.5)	3.0 (0.6)	-0.1
1C: Matched nonwords	5.0 (1.0)	11.0 (1.4)	-6.0
1D: Pseudohomophones	3.3 (0.6)	11.3 (1.5)	-8.0

Note. SemD = semantic distance; N = neighbor. Standard errors appear in the parentheses.

comparisons revealed that responses to the no neighbor nonwords were slower than responses to the illegal nonwords, $t_1(140) = 4.24$, $t_2(156) = 9.44$; were slower to the matched nonwords than to the no neighbor nonwords $t_1(140) = 3.46$, $t_2(156) = 7.23$; and were slower to the pseudohomophones than to the matched nonwords, $t_1(140) = 3.67$, $t_2(156) = 7.08$.

Nonword error rates. There was a main effect of nonword context, $F_1(3, 140) = 15.43$, $MSE = 48.24$, $F_2(3, 156) = 14.14$, $MSE = 56.91$. Post hoc comparisons revealed no differences between errors made to the no neighbor nonwords and to the illegal nonwords, both ts < 1; more errors were made to the matched nonwords than to the no neighbor nonwords, $t_1(140) = 4.88$, $t_2(156) = 4.74$; and no differences between errors made to the pseudohomophones and to the matched nonwords, both ts < 1.

Lexicality effect in response latencies. There was a main effect of lexicality, $F_1(3, 140) = 28.38$, $MSE = 5{,}261.32$, $F_2(3, 156) = 24.17$, $MSE = 6{,}196.22$. Post hoc comparisons revealed that the effect of lexicality was larger in the no neighbor nonword context than in the illegal nonword context, $t_1(140) = 2.69$, $t_2(156) = 2.89$; was larger in the matched nonword context than in the no neighbor nonword context, $t_1(140) = 2.69$, $t_2(156) = 2.44$; and was larger in the pseudohomophone context than in the matched nonword context, $t_1(140) = 3.45$, $t_2(156) = 2.84$.

Lexicality effect in error rates. There was a main effect of lexicality, $F_1(3, 140) = 11.49$, $MSE = 54.06$, $F_2(3, 156) = 10.36$, $MSE = 73.17$. Post hoc comparisons revealed that the effect of lexicality was similar in the no neighbor nonword context and in the illegal nonword context, both ts < 1; was larger in the matched nonword context than in the no neighbor nonword context, $t_1(140) = 3.40$, $t_2(156) = 3.10$; and was similar in the pseudohomophone context and in the matched nonword context, $t_1(140) = 1.15$, $p > .10$, $t_2 < 1$.

Discussion

Summary of experimental conditions 1A-1D. Recall that several predictions were made regarding the effects of semantic distance, nonword context, and their interaction on lexical decision performance in the present experiment. These predictions will now be discussed in more detail.

It was predicted that increases in the difficulty of word-nonword discriminations would correspond to a) increases in word response latencies, b) increases in nonword response latencies, and c) increases in the lexicality effect (see Table 2-4). The data were consistent with these predictions. Considered together, these results strongly support the conclusion that the ideal strategy manipulation in the present experiment had the intended effect of changing the depth of lexical processing across experimental conditions.

This pattern of results (i.e., of more lexical processing occurring under conditions in which word-nonword discriminations were more difficult) is important for the following reason. According to Pexman and Lupker (1999),

> "lexical decisions are made primarily on the basis of activity in the orthographic units. When decisions are more difficult, then processing is more extensive (i.e., more settling is required before a decision can be made) and there is the opportunity for feedback to have more influence. When decisions are easier, processing is more shallow and this feedback should have less influence" (p. 331).

The feedback Pexman and Lupker (1999) refer to is what I called in Chapter 1 cross-module activation—in this case from semantics to orthography. Thus, in the present experiment, the prediction was that because the more difficult experimental conditions required deeper processing, larger effects of semantic distance should be observed in these conditions.

Indeed, for the response latency data, a semantic distance by nonword context interaction was observed. Semantic distance did not influence performance in the illegal nonword context, but it did influence performance in the other, more wordlike, nonword contexts, in that responses to low semantic distance words were faster than responses to high semantic distance words. Moreover, the pattern of this interaction was similar to the patterns observed in the response latencies to the words, to the nonwords, and in the lexicality effect, with one interesting exception. The pattern was similar in that semantic distance increased across the first three nonword contexts, but was dissimilar in that there was no change in the magnitude of the semantic distance effect between the matched nonword and the pseudohomophone contexts.

There is one potential confound, however, that needs to be addressed. The high semantic distance words and the low semantic distance words used in the present experiment were not originally matched on familiarity (i.e., subjective frequency). As indicated below in Table 2-5, for these words semantic distance and subjective frequency were correlated. The negative sign of the correlation indicates that as semantic distance decreases, subjective frequency increases. This finding is consistent with that of Conley, Burgess, and Decker (2001), who reported a correlation between subjective familiarity and semantic distance. This correlation, considered in light of Balota and Chumbley's (1984) discussion regarding potential cross-task differences with respect to familiarity effects, prompted further analyses to ensure that the present effects of semantic distance were not simply due to differences in subjective familiarity.

To determine the subjective familiarity of the experimental items used in the present experiment, the Balota et al. (2001) "subjective frequency" (their term, p. 640) ratings were obtained for the 40 experimental words. Balota et al. collected subjective frequency ratings asking participants how often they encountered words while reading, writing, speaking, listening, and in combination of these different modalities. The ratings are based on a 7-point scale in which each point corresponds to a specific frequency of encounter for any given word. For example, '1' corresponds to never encountering the word, '4' corresponds to encountering the word once a week, and '7' corresponds to encountering the word several times a day. The reading ratings were chosen because they seemed most appropriate for use in examining visual lexical processing. As noted, the experimental items were not matched on subjective frequency (3.32 and 3.75 for the high semantic distance words and the low semantic distance words, respectively, $t(38) = 2.84$). The issue of determining if the effects of semantic distance were due to a confound of subjective frequency will be further investigated in the next section. To anticipate, the effects of semantic distance were not due to subjective frequency. Discussion of this analysis will be complemented with a discussion of how the results of the present experiment are accommodated within the cross-module activation account.

Accounting for interactions between semantic distance and illegal nonword and no neighbor nonword contexts. Recall that the experimental words and each set of nonwords were presented to a version of the multiple read-out model (Grainger & Jacobs, 1996), and their summed lexical activation values were obtained (a description of how this was carried out is provided in the Methods section). To reiterate, summed lexical activation is a measure of the overall lexical activation that a letter string generates in the multiple read-out model. According to Grainger and Jacobs, if the summed lexical activation distributions of words and nonwords do not sufficiently overlap, then it is possible for participants to base their word-nonword discriminations on overall lexical activity generated by stimuli early in processing, and thus make word responses prior to lexical selection. It was hypothesized that this would be the case in the present experiment for the illegal nonword and the no neighbor nonword contexts. If, on the other hand, the summed lexical activation distributions of words and nonwords sufficiently overlap, then early processing of this information would not reliably distinguish words from nonwords, and participants would therefore engage in deeper or more extensive processing before responding. It was hypothesized that this would occur in the matched nonword and pseudohomophone contexts of the present experiment.

Figure 2-1 shows the summed lexical activation distributions for the word and the illegal nonword stimuli. The distributions do not overlap, and therefore participants could use this type of information, early in processing, to reliably distinguish words from illegal nonwords. Figure 2-2 shows the summed lexical activation distributions for the word and the no neighbor nonword stimuli. Although the two distributions are closer together than is the case in Figure 3-1, it is clear that the two distributions do not have much overlap, and so participants could use this information to make decisions early in processing. A comparison of the summed lexical activation distributions for the two types of nonwords shows substantial overlap. The effects of semantic distance are nonetheless quite different between the two experimental conditions.

The results of the illegal nonword condition suggest that the extremely shallow processing induced by these nonwords does not include semantics when making lexical decisions. The decisions can be based purely on the early processing among units in the orthographic module, and thus are made prior to the arrival of any cross-module activation from semantics to orthography. Note that the null effect of semantic distance in the illegal nonword context is consistent with reports of null effects of polysemy (Borowsky & Masson, 1996) and of concreteness (James, 1975) in experimental

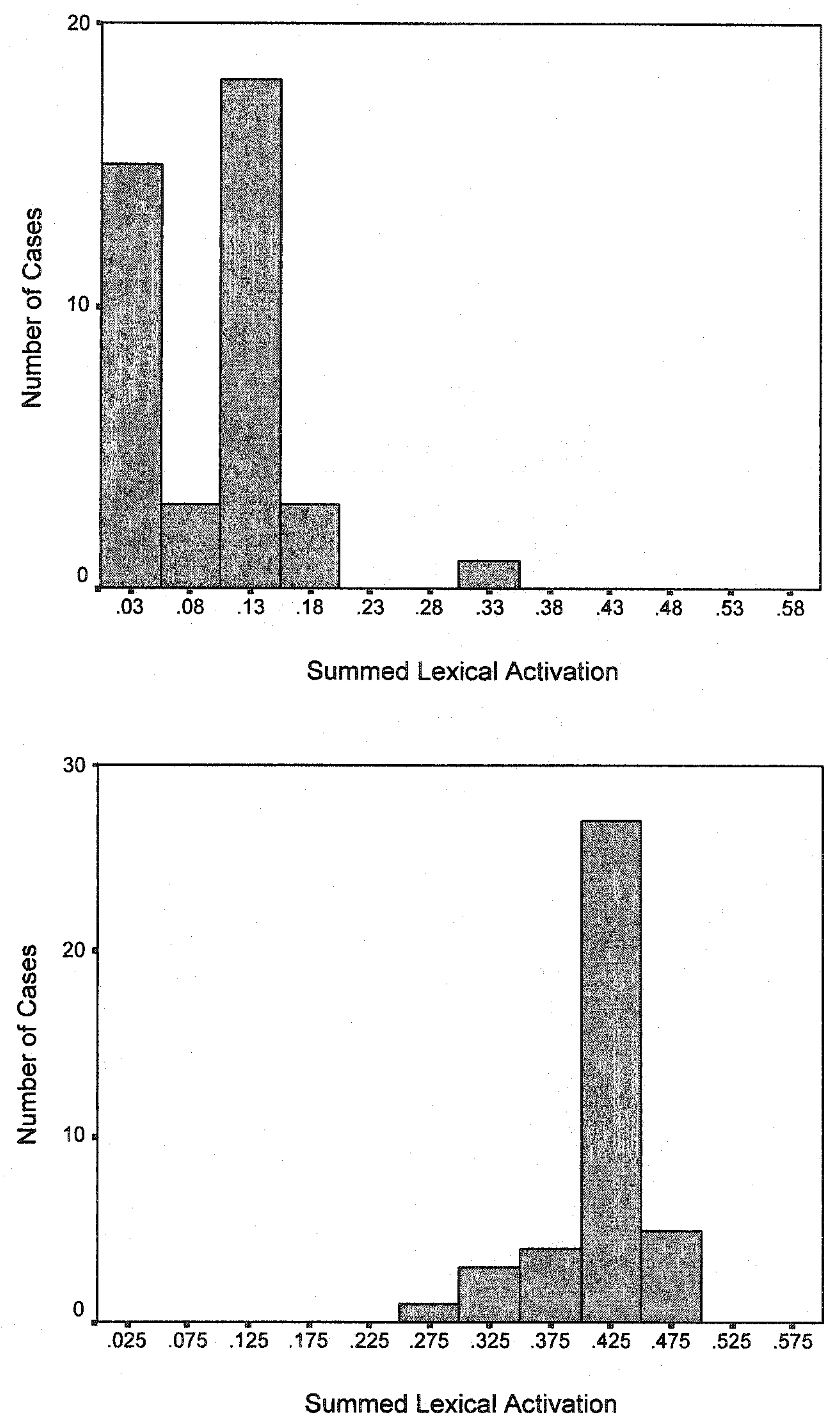

Figure 2-1. The summed lexical activation distributions for the illegal nonwords (top panel) and the experimental words (bottom panel).

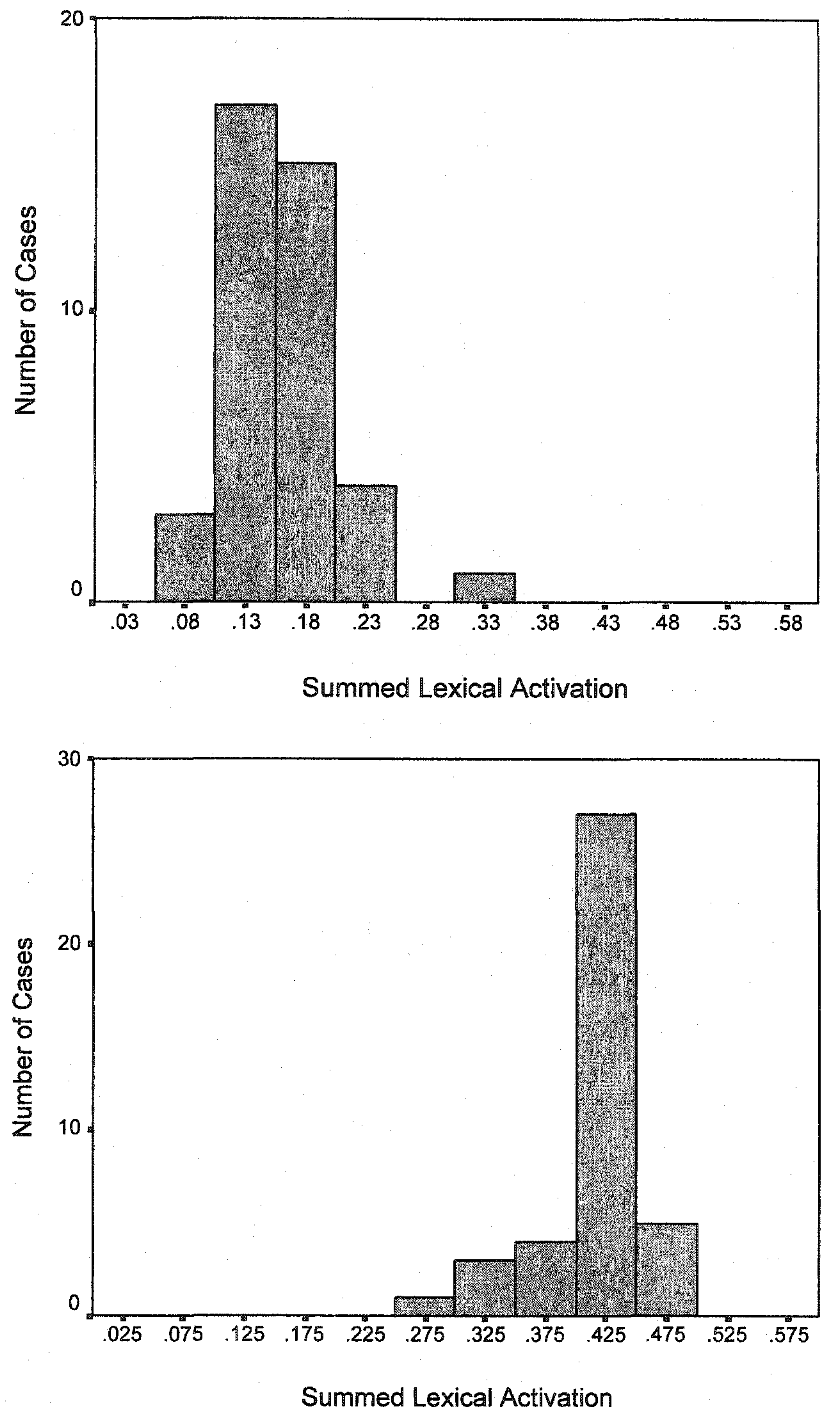

Figure 2-2. The summed lexical activation distributions for the no neighbor nonwords (top panel) and the experimental words (bottom panel).

conditions employing illegal nonwords.

The finding of facilitatory effects of semantic distance in the no neighbor nonword context seems at first glance to be more difficult to accommodate. If participants are able to use summed lexical activation as a reliable cue in making lexical decisions (as suggested by Andrews, 1997, Grainger & Jacobs, 1996, and Siakaluk et al., 2002), then one would expect the effects of semantic distance to be similar to that observed in the illegal nonword context. There are several possible explanations to account for the different effects of semantic distance in these two nonword contexts. First, it could be that participants use some other form of processing the stimuli in the illegal nonword context other than monitoring early levels of summed lexical activation. For example, Borowsky and Masson (1996) suggested that because their illegal nonwords had no vowels, their participants may have been simply looking for the presence or absence of vowels in the letter strings, and deciding that if vowels were present respond 'yes' and if not then respond 'no'. They further suggested that such processing would not be lexical in any sense of the term, because searching for the presence or absence of vowels could be accomplished without accessing any type of lexical information, whether it be an item's familiarity or in the present case, an item's summed lexical activation. Borowsky and Masson rejected the 'searching-for-vowels' account, because even when words were intermixed with illegal nonwords, they reported that subjective familiarity and word frequency—variables typically assumed to reflect lexical processing—predicted response latencies to words.

To determine if the same results would be observed for the word stimuli in the illegal nonword context of the present experiment, relationships were first examined between log frequency, subjective frequency, length in letters, orthographic neighborhood size, summed lexical activation, number of meanings, concreteness, imageability, and semantic distance. These correlations are listed in Table 2-5. Of interest, semantic distance did not correlate with any other semantic variable (i.e., number of meanings, concreteness, or imageability). Relationships between these variables were then examined with mean word item response latency to determine which predictor variables were most strongly correlated with response latency. The guidelines of Borowsky and Masson (1996) were used in selecting predictor variables for the regression analyses. (The same guidelines are used throughout the thesis for the regression analyses performed on the experimental word data.) First, semantic distance was included because it was the variable of interest. Second, subjective frequency (see Table 2-5) was included because it was confounded (i.e., correlated) with semantic distance. Third, any predictor variable that correlated with word response latency and did not correlate with any other predictor variable was included. Finally, if any predictor variables correlated with word response latency and each other, only the predictor variable that most strongly correlated with word response latency was included. To determine whether a predictor variable included in the analysis accounted for variance above that of other predictor variables in the analysis, the variance associated with all predictor variables except the variable of interest was subtracted from the variance associated with all predictor variables (Green, 1978; Pedhazur, 1982). This standard approach is used throughout this thesis.

Table 2-5
Single-Order Correlations Between Log Frequency, Subjective Frequency, Length in Letters, Orthographic Neighborhood Size, Summed Lexical Activation, Number of Meanings, Concreteness, Imageability, and Semantic Distance

	LogF	SubF	LL	ON	SLA	NoM	Conc	Imag	SemD
LogF	1.00								
SubF	-.01	1.00							
LL	.22	-.13	1.00						
ON	-.05	.45*	-.35*	1.00					
SLA	-.15	.48*	-.28	.73*	1.00				
NoM	-.16	.07	.02	.17	.32*	1.00			
Conc	-.27	.10	.22	-.10	.01	.27	1.00		
Imag	-.08	-.13	.13	-.17	-.39*	.14	.48*	1.00	
SemD	-.10	-.49*	-.02	-.01	-.05	-.15	-.13	-.11	1.00

Note. $df = 38$. LogF = log frequency; SubF = subjective frequency; LL = length in letters; ON = orthographic neighborhood size; SLA = summed lexical activation values; NoM = number of meanings; Conc = concreteness; Imag = imageability; SemD = semantic distance.
* $p < .05$.

As indicated in Table 2-6, for experimental condition 1A, the predictor variables length in letters, orthographic neighborhood size, and summed lexical activation were all correlated with word response latency. In addition to semantic distance and subjective frequency, only length in letters and summed lexical activation were included in the regression analyses, because orthographic neighborhood size was correlated with summed lexical activation, which had the stronger correlation with word response latency.

Together, semantic distance, subjective frequency, length in letters, and summed lexical activation accounted for a significant 26.6% of the word response latency variance, $F(4, 35) = 3.16$. Semantic distance and subjective frequency each accounted

Table 2-6

Single-Order Correlations Between Mean Word Item Latency, Log Frequency, Subjective Frequency, Length in Letters, Orthographic Neighborhood Size, Summed Lexical Activation, Number of Meanings, Concreteness, Imageability, and Semantic Distance for Experimental Conditions 1A-1D

Variables	RL – Illegal	RL – No N	RL – Matched	RL – Pseudo
LogF	.14	-.24	-.29	.08
SubF	-.24	-.38*	-.45*	-.49*
LL	.34*	-.12	.00	.25
N	-.36*	-.06	.08	-.10
SLA	-.45*	.01	.08	.07
NoM	.24	-.02	-.10	-.10
Conc	.01	-.13	-.18	-.26
Imag	.24	-.12	-.16	-.34*
SemD	.10	.67*	.67*	.57*

Note. df = 38. RL = response latency; Illegal = illegal nonword context; No N = no neighbor nonword context; Matched = matched nonword context; Pseudo = pseudohomophone context; LogF = log frequency; SubF = subjective frequency; LL = length in letters; N = orthographic neighborhood size; SLA = summed lexical activation values; NoM = number of meanings; Conc = concreteness; Imag = imageability; SemD = semantic distance.
* $p < .05$.

for less than 1% of the variance above that accounted for by the other variables, both *F*s < 1. Length in letters accounted for 5.1% unique variance, which was not significant, $F(1, 35) = 2.48$, $p > .10$. Lastly, summed lexical activation accounted for 11.1% unique variance, which was significant, $F(1, 35) = 5.29$. Thus, in the illegal nonword context of the present experiment, a lexical variable, namely summed lexical activation, predicted word response latency. For the illegal nonword stimuli, summed lexical activation also predicted response latency (see Table 2-7). Just as Borowsky and Masson (1996) concluded, it is highly unlikely that participants exclusively employed a 'searching-for-vowels' strategy in the present illegal nonword experimental condition. Rather, the evidence suggests (as outlined above) that summed lexical activation is a reliable cue as to the lexicality of letter strings under these experimental conditions.

It appears not to be the case that participants use some nonlexical form of analyzing the stimuli in the illegal nonword context (e.g., searching for vowels). A second possible explanation for the differential effects of semantic distance in the illegal and the no neighbor nonword contexts is that the participants in the latter nonword context had not relied on the early levels of summed lexical activation that the participants of the former nonword context had. To more fully investigate the possibility that the participants in the no neighbor nonword context were more deeply processing the stimuli, relationships between word item response latency and the predictor variables, and between nonword item response latency and summed lexical activation, were conducted for the no neighbor nonword context (see Tables 2-6 and 2-7).

The only predictor variables that correlated with word response latency were semantic distance and subjective frequency. The strong correlation between semantic distance and response latency suggests that semantic processing was involved in this experimental condition. The cross-module activation account explains this finding by assuming that low semantic distance words generate deeper or more extensive semantic processing than high semantic distance words, and thus benefit more from cross-module activation from semantics to orthography, even under conditions in which processing is not as extensive as when matched nonwords or pseudohomophones are used.

However, as noted above, semantic distance was confounded (i.e., correlated) with subjective frequency. Regression analyses were conducted to determine if the

Table 2-7
Single-Order Correlations Between Mean Nonword Item Latency and Summed Lexical Activation for Experimental Conditions 1A-1D

Variables	RL – Illegal	RL – No N	RL – Matched	RL – Pseudo
SLA	.47*	.44*	-.25	.00

Note. $df = 38$. RL = response latency; Illegal = illegal nonwords; No N = no neighbor nonwords; Matched = matched nonwords; Pseudo = pseudohomophones; SLA = summed lexical activation values.
* $p < .05$.

effects of semantic distance were due to this confound. Together, semantic distance and subjective frequency accounted for a significant 45.1% of the response latency variance, $F(2, 37) = 15.22$. Semantic distance accounted for a significant 30.7% unique variance, $F(1, 37) = 20.70$. Subjective frequency, on the other hand, accounted for less than 1% unique variance, $F < 1$.

Interestingly, inspections of Tables 2-6 and 2-7 reveal that there were differential effects of summed lexical activation on the word and nonword stimuli. For the word stimuli, the correlation between response latency and summed lexical activation was essentially zero. For the no neighbor nonword stimuli, however, response latency and summed lexical activation were correlated. Thus, it appears that the participants in the no neighbor nonword context used summed lexical activation during nonword but not word trials.

In the no neighbor nonword context of the present experiment, several interesting, and unexpected, findings were unveiled. Summed lexical activation was not correlated with word response latency (but it was correlated with nonword response latency). This finding suggests that participants were more fully processing the word stimuli than the original prediction would have suggested. This conclusion is supported by the finding that semantic distance accounted for almost 31% of the response latency variance, suggesting that participants were using semantic processing in this task. The cross-module activation account assumes that enough time during processing had elapsed to allow cross-module activation from semantics to orthography to influence lexical processing of the stimuli. Finally, even though semantic distance and subjective frequency were correlated with word response latency, it was clearly semantic distance that was driving processing, as subjective frequency accounted for less than one percent of the response latency data.

Accounting for interactions between semantic distance and no neighbor nonword, matched nonword, and pseudohomophone contexts. Figures 2-3 and 2-4 show the summed lexical activation distributions for the word and the matched nonword stimuli and the word and the pseudohomophone stimuli, respectively. As can be seen, the summed lexical activation distributions of these two nonword types have substantial overlap with the summed lexical activation distribution of the word stimuli. The distributions of the two nonword types also overlap a great deal. The conclusion from this qualitative analysis is that summed lexical activation should not be a reliable cue as to the lexicality of the stimuli, and thus it should not correlate with either word or nonword response latency. On the other hand, if the findings from the no neighbor nonword context generalize, then semantic distance should significantly account for word response latency variance above that of subjective frequency.

Table 2-6 lists the relationships between word item response latency and the predictor variables for the matched nonword context. Only semantic distance and subjective frequency were correlated with word response latency in the matched nonword condition. Together, semantic distance and subjective frequency accounted for a significant 47.5% of the word response latency variance, $F(2, 37) = 16.76$. Semantic distance accounted for a significant 26.8% unique variance, $F(1, 37) = 18.88$, whereas subjective frequency accounted for only 2.0% unique variance, which was not significant, $F(1, 37) = 1.41, p > .10$. As was the case in the no neighbor nonword context, semantic distance was not confounded with subjective frequency. Table 2-7 shows that summed lexical activation did not correlate with the matched neighbor nonwords either.

There are two important findings from these analyses. First, as predicted, summed lexical activation did not correlate with either the word or the matched neighbor nonword response latency data, and this supports the assumption that participants were engaged in extensive processing for both types of stimuli in this experimental condition. Second, only semantic distance, and not subjective frequency, predicted response latency. These findings, in conjunction with the ANOVA results, can be accommodated within the cross-module activation account in the following manner. Because more extensive processing was carried out in the matched nonword context than in the no neighbor nonword context, cross-module activation from semantics to orthography was allowed more time to influence lexical processing.

Before considering the pseudohomophone context, the pattern of significant correlations in Table 2-6 indicates that for the word stimuli, processing was more similar in the matched and the no neighbor nonword contexts than in the illegal and the no

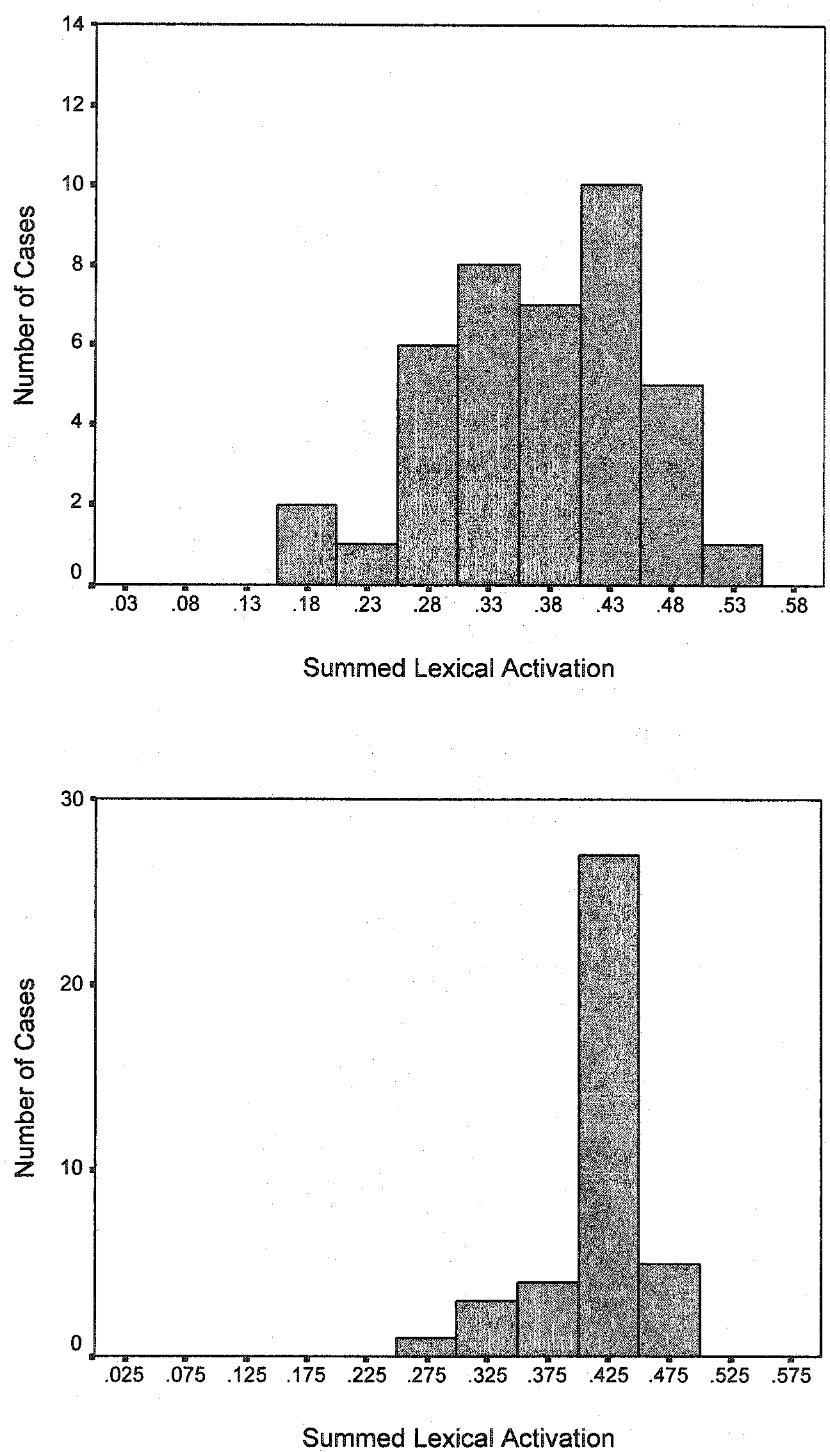

Figure 2-3. The summed lexical activation distributions for the matched nonwords (top panel) and the experimental words (bottom panel).

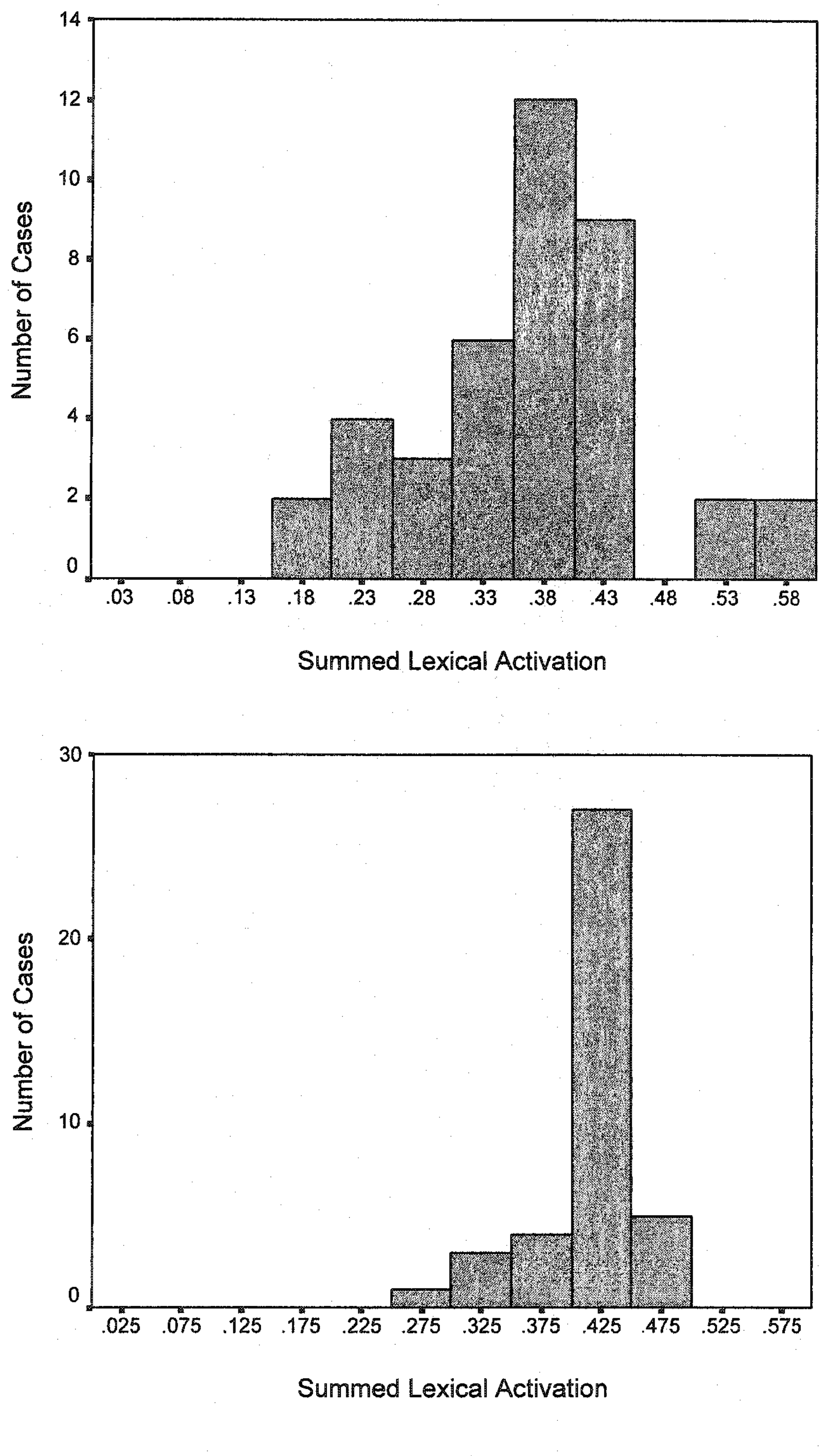

Figure 2-4. The summed lexical activation distributions for the pseudohomophones (top panel) and the experimental words (bottom panel).

neighbor nonword contexts. This pattern is inconsistent with the prediction that summed lexical activation would be correlated with word response latency in the no neighbor nonword context. The pattern of significant correlations in Table 2-7 indicates that for the nonword stimuli, processing was more similar in the no neighbor and the illegal nonword contexts than in the no neighbor and the matched neighbor contexts. This pattern is consistent with the prediction that summed lexical activation would be correlated with nonword response latency in the no neighbor nonword context. It appears then from these data that summed lexical activation is a reliable variable on which to make responses for nonwords that are orthographically legal with no orthographic neighbors, but the same is not true for nonwords that are orthographically legal and matched to the word stimuli on number of orthographic neighbors.

Table 2-6 also lists the relationships between word item response latency and the predictor variables for the pseudohomophone context. Interestingly, not only were semantic distance and subjective frequency correlated with response latency, but so too was imageability. Together, these three variables accounted for 50.2% of the response latency variance, $F(3, 36) = 12.08$. Semantic distance accounted for a significant 9.1% of the variance above that of subjective frequency and imageability, $F(1, 36) = 6.58$. Subjective frequency accounted for a significant 9.8% of the variance above that of semantic distance and imageability, $F(1, 36) = 7.08$. Finally, imageability accounted for a significant 11.9% of the variance above that of semantic distance and subjective frequency, $F(1, 36) = 8.60$. Table 2-7 shows that summed lexical activation did not correlate with the pseudohomophone nonwords either.

The results of the regression analyses for the pseudohomophone context are quite intriguing. Semantic distance continued to predict word response latency, but now so did subjective frequency and imageability. This finding that variables other than semantic distance were involved in lexical processing may partially explain why the effects of semantic distance did not increase from the matched nonword context to the pseudohomophone context, even though overall response latencies were longest in the latter condition. Although semantic distance continued to exert a large effect on lexical decision performance in the presence of pseudohomophones, it seems that participants recruited other forms of semantic information to help in the decision process. The cross-module activation framework could account for this by assuming that multiple forms of semantic information (e.g., number of semantic neighbors, ease of invoking an image, types of sensory memory involved, such as visual or acoustic) can be activated under conditions requiring very extensive processing. In addition, subjective frequency may play a greater role in the pseudohomophone context, because orthography is the only type of information that is truly decisive regarding the lexical status of these letter strings (McCann et al., 1988; Seidenberg et al., 1996; Ziegler et al., 2001). Only the correct spelling, therefore, can determine whether a letter string is a real word or a pseudohomophone. Recall that the Balota et al. (2001) subjective frequency ratings obtained for the experimental words were reading ratings based on how often a word was encountered in print. It is most likely that words with higher subjective frequency reading ratings are words with more familiar spellings (i.e., orthographic codes). Further support for the idea that the Balota et al. subjective reading ratings tap into orthographic knowledge is indicated by a careful inspection of Table 2-6, which reveals that subjective frequency was correlated with orthographic neighborhood size and summed lexical activation, two orthographic variables. Thus, if the assumption is maintained that lexical decisions are made primarily on the basis of the activation among the units in the orthographic module (e.g., Hino & Lupker, 1996; Hino et al., 2002; Pexman & Lupker, 1999), then any variable tapping into how familiar participants are with the spellings of words should contribute to extensive lexical processing, and the Balota et al. (2001) subjective reading ratings may be one such variable.

In summary, semantic distance exerts facilitatory effects on lexical decision performance, but only under conditions in which relatively extensive processing is involved in distinguishing words from nonwords. This finding is consistent with the Buchanan et al. (2001) report of facilitatory effects of semantic distance for low-frequency words in lexical decision. The literature review in Chapter 1 described the increasing body of evidence supporting the view that semantic processing influences visual word recognition. The data from the present chapter adds to this body of evidence and extends it by describing the effects, in lexical decision, of a relatively unstudied semantic variable.

It is important, however, to examine the influence of this semantic variable in lexical processing tasks other than lexical decision. Andrews and Heathcote (2001; see also Andrews, 1997; Balota & Chumbley, 1984, 1985; Carr, Posner, Pollatsek, & Snyder, 1979; Hino & Lupker, 1996; Meyer, Schvaneveldt, & Ruddy, 1975) noted that each lexical processing task engages not only lexical selection processes common across tasks, but also task-specific processes. Thus, to be confident that the lexical variable under investigation is influencing (at least in part) the lexical processes common to word recognition, it is important to determine whether the variable influences processing in multiple tasks. Chapter 3, therefore, investigates the effects of semantic distance in a second task, namely the Forster and Shen (1996) animal/non-animal semantic categorization task.

CHAPTER 3

SEMANTIC CATEGORIZATION

The results of the lexical decision experiment in Chapter 2, along with those of Buchanan et al. (2001), demonstrate that semantic distance facilitates performance in the lexical decision task. This is consistent with the facilitatory effects of polysemy, concreteness/imagery, and number of features in lexical decision (see Chapter 1 for a review of this literature). Recall that the cross-module activation framework explains these facilitatory effects as arising from enhanced cross-module activation from semantics to orthography for words that generate extensive semantic processing (i.e., for low semantic distance words, polysemous words, high concrete/imagery words, and high number of feature words). Thus, it seems that for these variables, at least for lexical decision, "more-means-better" (Balota et al., 1991, p. 214). But what effects do these variables have on tasks in which responses are putatively based on processing in the semantic module? Chapter 3 will address this issue with an examination of the effects of semantic distance in the semantic categorization task.

I will begin by reviewing the assumptions of the cross-module activation account regarding tasks that require access to word meaning. Of specific interest is the view that cross-module activation *from* semantics to either orthography or to phonology is assumed to play little role in semantic processing tasks. I will then review two studies that have investigated either polysemy or synonymy effects in semantic categorization. This will be followed by a description of the methodology and the results of the present yes/no semantic categorization task. A discussion regarding potential task-specific processing in the yes/no semantic categorization task will then lead to a description of a modification of the task designed to address this issue. The results from this go/no-go semantic categorization task will demonstrate that the change in procedure was effective in addressing the task-specific processing issue by eliciting more extensive semantic processing of the experimental words. I will then describe a third semantic categorization experiment that combines methodologies from the previous experiments in a within-subjects design. Finally, it is important to note that the strategy manipulation used in this chapter was not an ideal strategy manipulation but rather a procedural strategy manipulation. The chapter will thus conclude with a discussion of the ramifications of this type of strategy manipulation on the present set of semantic categorization experiments.

The Cross-Module Activation Account and the Semantic Categorization Task

Hino et al. (2002) proposed that responses in tasks requiring meaning resolution are based primarily on the activation of the semantic units. Thus, performance in these tasks should not be influenced by cross-module activation from semantics to either orthography or to phonology. Rather, responses would be sensitive to a) cross-module activation from orthography to semantics, and b) within-module activation of the semantic units. Cross-module activation from orthography to semantics is involved because during visual word recognition the orthographic units are necessarily the first to be activated by the incoming visual stimulus (e.g., Forster, 1976; McClelland & Rumelhart, 1981; Morton, 1969; Plaut et al., 1996; Seidenberg & McClelland, 1989). Semantic activation also plays a role because these tasks require participants to assess the meaning conveyed by the printed item presumably via activation processes that must settle on a specific semantic code. Thus, according to Hino et al. (2002), the speed with which the semantic units settle on a particular semantic code is influenced by the nature of the cross-module activation that semantics receives from orthography.

Hino et al. (2002) chose the living/nonliving semantic categorization task to investigate the effects of polysemy and synonymy during semantic processing. Participants pressed one key if the word was the name of a living object and another if the word was the name of a nonliving object.

Hino et al. (2002) reported inhibitory effects of polysemy in their semantic categorization task. They attributed their findings to less consistent cross-module mappings from orthography to semantics for polysemous than for nonpolysemous words. More specifically, the cross-module mappings from orthography to semantics for polysemous words are one-to-many, resulting in the activation of many different semantic codes. Because many semantic codes were activated, it took more time to settle on a particular one, thus leading to slower responses. The cross-module mappings from orthography to semantics for nonpolysemous words, however, are one-to-one (or at least one-to-fewer than for polysemous words), resulting in the activation of fewer semantic codes and hence less time needed to settle on one.

The same inhibitory effects were not observed for synonymy in semantic categorization. In Hino et al.'s (2002) account of null synonymy effects is the important, but reasonable, assumption that upon the presentation of a target word, the orthographic codes of its synonyms are not initially activated (or are only minimally so) and hence do not send any (or very little) cross-module activation from orthography to semantics (Pexman, personal communication, April 22, 2002). Thus, the cross-module activation from orthography to semantics is similar for words with or without synonyms.

What does the cross-module activation framework predict regarding the effects of semantic distance in the semantic categorization task? Recall from Chapter 1 that low semantic distance words have relatively close semantic neighbors, whereas high semantic distance words have relatively distant neighbors. Thus, within a specified radius, low semantic distance words have, on average, more semantic neighbors than high semantic distance words. Following the logic of the Hino et al. (2002) cross-module activation explanation outlined above, more semantic codes should be activated for low semantic distance words (because mappings would be one-to-many) than for high semantic distance words (because mappings would be one-to-few). Thus, the prediction is that inhibitory effects of semantic distance will be observed in semantic categorization. Experiment 2 tests this prediction.

Experiment 2 – Yes/No Semantic Categorization

Hino et al. (2002) used the category distinction of judging whether a word is the name of a living or a nonliving object. This is not the only category distinction that has been used. Forster and Shen (1996; see also Sears, Lupker, & Hino, 1999) used an animal/non-animal semantic categorization task. Participants pressed one key if the word was an animal name and another if the word was not an animal name. Forster and Shen (1996) argued that a strength of their semantic categorization task (and that of Hino et al., 2002) is that it demands lexical selection, because correct classification requires word meaning retrieval. A further strength of their task is that the use of a single category avoids the requirement that multiple category labels be presented throughout the experiment (as in the Balota & Chumbley, 1984 study; see also Balota & Chumbley, 1990; Monsell, 1990; and Monsell, Doyle, & Haggard, 1989, for further discussion of

Balota & Chumbley's, 1984 original semantic categorization task), and thus reduces the complexity of the task (Bradley & Forster, 1987). In addition, they minimized any possible contaminating effects of semantic priming or category typicality by analyzing only responses to the non-animal items (i.e., the experimental words). The purpose of the present experiment is to determine the effects of semantic distance in the Forster and Shen yes/no semantic categorization task.

Method

Participants. Thirty-six first-year undergraduate students from the University of Alberta participated in the experiment. All were native English speakers and reported normal or corrected-to-normal vision. None of these individuals participated in the collection of any norming data or in the lexical decision experiment. All participants received course credit.

Word stimuli. The word stimuli are identical to those used in Experiment 1, described in Chapter 2.

Animal name stimuli. An additional 40 words were used in the experiment that were animal names matched on length to the experimental words (presented in Appendix C). Therefore, a total of 80 words were presented in the experiment. Following the instructions given by Forster and Shen (1996) and Sears, Lupker, et al. (1999), the participants were explicitly told that the animal names included mammals, fish, reptiles, birds, amphibians, and insects, but excluded humans or other types of living things (e.g., tree). They were further instructed that a) the animal names could appear in the singular (e.g., spider), in the plural (e.g., lions), or in an informal or abbreviated version (e.g., bunny), b) the animal names referred to the whole animal and not to a part of an animal (e.g., hoof), and c) if the meaning of the word was ambiguous (e.g., SLUG, which could refer to either an animal or a verb), these types of words should be considered as referring to the animal (although these types of animal names were avoided as much as possible). The mean CELEX printed word frequency of these animal name stimuli was 10.07.

Animalness norms. Carreiras et al. (1997) used a 10-point animalness scale to obtain animalness ratings for their experimental items and reported small but significant correlations between semantic categorization response data and the ratings. Ratings from the same 10-point animalness scale were used to investigate whether animalness influenced responses to the stimuli in the present study. To obtain these ratings, 60 non-animal words (from which the experimental items were taken) and 60 animal names were randomly ordered, 20 words per page, and presented in a questionnaire format (page order was randomized across participants). At the right hand of each word was a scale from 1 to 10 (1 indicating *not at all animal-like* and 10 indicating *very animal-like*). Twenty participants rated how animal-like each word was. Not surprisingly, the animal names had higher animalness ratings than the experimental items (8.98 vs. 2.54, respectively; $t(78) = 29.51$), but the high and low semantic distance experimental items did not differ (2.43 vs. 2.66, respectively; $t(38) < 1$).

Apparatus and procedure. Stimuli were presented on a color VGA monitor driven by a Pentium-class microcomputer using MEL software. Response latencies were measured to the nearest millisecond.

For every trial, a 50 ms blank screen was followed by a fixation cross that appeared at the center of the computer monitor for 250 ms, and was then replaced by a stimulus item (presented in lowercase letters). Participants responded 'animal' by pressing the '1' key and 'non-animal' by pressing the '0' key on the computer keyboard. The participant's response terminated the stimulus display, and the next trial was initiated after a timed interval of 1 s. Participants were instructed to make their responses as quickly and as accurately as possible, and were told that each word would appear only once during the experiment. The order in which the stimuli were presented was randomized separately for each participant.

Each participant completed 16 practice trials prior to the collection of data. The practice stimuli consisted of eight words (half were four letters in length and half were five letters in length, and all were of the same frequency range as the experimental word stimuli), and eight animal names (half were four letters in length and half were five letters in length).

Design. A single factor (semantic distance: high, low) design was used. There were 40 animal names and 20 items in each of the two semantic distance conditions, for a total of 80 trials. For the experimental word data, response latencies and error rates from each participant were submitted to a single factor (semantic distance: high, low) repeated-measures ANOVA. Both a within-subjects (F_1) analysis and a between-items (F_2) analysis were carried out.

Results and Discussion

Response latencies less than 250 ms or more than 2,000 ms were removed from the data set. A total of 0.1% of the responses were removed by this procedure. The mean response latencies of correct responses and the mean error rates for the experimental word and the animal name stimuli are shown in Table 3-1.

Table 3-1
Mean Response Latencies (in Milliseconds) and Standard Errors, and Mean Error Rates (Percentages) and Standard Errors for the Word and Animal Stimuli in Experiments 2 and 3

	Response latencies		
Experiment	High SemD	Low SemD	SemD effect
2:Yes/no	676 (14.4)	661 (11.7)	15
3: Go/no-go	705 (14.7)	664 (14.4)	41

	Error rates		
Experiment	High SemD	Low SemD	SemD effect
2: Yes/no	2.6 (0.8)	2.9 (0.8)	-0.3
3: Go/no-go	0.1 (0.1)	0.0 (0.0)	0.1

	Animal names	
Experiment	Response latencies	Error rates
2: Yes/no	621 (10.6)	4.1 (0.7)
3: Go/no-go	No RL data collected	5.6 (1.0)

Note. SemD = semantic distance; RL = response latency. Standard errors appear in parentheses.

In the analysis of the response latency data, there was a marginal effect of semantic distance in the subject analysis, $F_1(1, 35) = 3.93, p = .055, MSE = 1{,}087.21$, but no effect in the item analysis, $F_2(1, 38) < 1$. Responses to the low semantic distance words were an average of 15 ms faster than responses to the high semantic distance words. There was no effect of semantic distance in the analysis of the error rate data, both *F*s < 1.

Recall that an inhibitory semantic distance effect was predicted in the present experiment. According to the cross-module activation account outlined above, the orthographic to semantic mappings are less consistent for low semantic distance words (because mappings would be one-to-many) than for high semantic distance words (because mappings would be one-to-few). Because responses in this task are putatively based on semantic processing, this difference in cross-module mapping consistency should result in slower responses to the low semantic distance words than to the high semantic distance words. However, contrary to this prediction, if anything there was a trend toward facilitation. This point will be discussed in more detail in the General Discussion section of this chapter.

Correlation analyses. As was done in the lexical decision experiment in Chapter 2, relationships between mean item response latency and the predictor variables were examined. These analyses differed from the analyses in Chapter 2 in two ways. First, summed lexical activation was not included in the analysis because all of the items were words. Second, the animalness ratings were included in the correlation analysis because Carreiras et al. (1997) reported correlations between their animalness ratings and their experimental word data. The single order correlations between the animalness ratings and the other predictor variables are listed in Table 3-2.

Table 3-3 lists the correlations between response latency and the predictor variables. There are several interesting results from this analysis. First, unlike in lexical decision, semantic distance did not correlate with response latency. Second, no other

Table 3-2
Single-Order Correlations Between Animalness Ratings, Log Frequency, Subjective Frequency, Length in Letters, Orthographic Neighborhood Size, Number of Meanings, Concreteness, Imageability, and Semantic Distance

	LogF	SubF	LL	ON	NoM	Conc	Imag	SemD
Animal ratings	.03	.03	.23	-.21	-.01	.06	.06	-.12

Note. $df = 38$. LogF = log frequency; SubF = subjective frequency; LL = length in letters; ON = orthographic neighborhood size; NoM = number of meanings; Conc = concreteness; Imag = imageability; SemD = semantic distance.

semantic variable correlated with response latency (although number of meanings was marginally significant at $p = .08$). Third, unlike in Carreiras et al. (1997), the animalness ratings did not correlate with response latency. These findings are particularly interesting given that this task is supposed to tap semantic processing.

There is, however, one potential limitation of the animal/non-animal version of the yes/no semantic categorization task. Due to the nature of this particular task (i.e., to classify exemplar and non-exemplar items by a single category), there most likely existed a bias to make 'animal' responses. There are two results that support this idea. First, although animalness ratings did not correlate with the experimental word response latency data (nor with the error rate data, $r = -.08$), they did correlate with the animal name response latency and error rate data ($r = -.54$ and $r = -.38$, respectively). The negative signs of these correlations indicate that the animal names with higher ratings produced faster and more accurate responses. Second, responses to the animal name items were 47 ms faster than responses to the experimental items, $t_1(35) = 9.87$, $t_2(39) = 4.21$, but 1.3% less accurate, $t_1(35) = 1.96$, $t_2(39) = 1.31$, $p > .10$.

Table 3-3
Single-Order Correlations Between Mean Item Latency, Log Frequency, Subjective Frequency, Length in Letters, Orthographic Neighborhood Size, Number of Meanings, Concreteness, Imageability, Animalness Ratings, and Semantic Distance in Experiments 2-4

Variables	SC2-Y/N	SC3-G/NG	SC4-Y/N	SC4- G/NG
LogF	-.06	.01	-.11	-.09
SubF	-.10	-.20	.02	-.24
LL	.22	.06	.06	-.19
ON	.10	.28	.00	.16
NoM	.28	.22	.13	-.07
Conc	-.05	-.27	.22	.01
Imag	.12	-.11	.24	.15
AnimRate	.19	.05	-.02	.17
SemD	.20	.42*	.16	.39*

Note. $df = 38$ for SC2-Y/N and SC3-G/NG. $df = 58$ for SC4-Y/N and SC4-G/NG. SC2-Y/N = Experiment 2; SC3-G/NG = Experiment 3; SC4-Y/N = yes/no condition of Experiment 4; SC4-G/NG = go/no-go condition of Experiment 4; LogF = log frequency; SubF = subjective frequency; LL = length in letters; ON = orthographic neighborhood size; NoM = number of meanings; Conc = concreteness; Imag = imageability; AnimRate = animalness ratings; SemD = semantic distance.
* $p < .05$.

To address this response bias issue, a go/no-go semantic categorization task was conducted, in which participants responded to only the experimental (i.e., non-animal name) items. The expectation was that this procedural change would increase the level of semantic processing for the experimental items by making the responses to these items more like 'yes' responses, because they would now be the only items requiring an overt response.

Experiment 3 – Go/No-go Semantic Categorization

Method

Participants. Thirty-six first-year undergraduate students from the

University of Alberta participated in the experiment for course credit. All were native English speakers and reported normal or corrected-to-normal vision. None of these individuals participated in the previous experiments or in the collection of any of the norming data.

Stimuli. The experimental word and the animal name stimuli, as well as the instructions regarding the criteria to identify a word as an animal name, were identical to those of Experiment 2.

Apparatus, procedure, and design. The apparatus and design were identical to those of Experiment 2. There was one change in procedure. Participants in this experiment were instructed to respond only if the stimulus was not an animal name. They responded to these items (i.e., the experimental words) by pressing the '0' key on the computer keyboard. Participants were instructed not to press a key if the stimulus was an animal name. They were told that the stimulus would remain on the monitor for 2.5 s and then would automatically be replaced by the next stimulus item. Thus, they were instructed that if the stimulus item was an animal name they should simply wait for it to be replaced by the next item. If they did respond by pressing the '0' key, the next item was presented after an interval of 1 s. Where appropriate (i.e., to the experimental items) participants were instructed to make their responses as quickly and as accurately as possible, and were told that each word would appear only once during the experiment. The order in which the stimuli were presented was randomized separately for each participant. Both a within-subjects (F_1) analysis and a between-items (F_2) analysis were carried out.

Results and Discussion

Response latencies less than 250 ms or more than 2,000 ms were considered outliers and removed from the data set. A total of 0.4% of the responses were removed by this procedure. There was only one error made to the experimental words and thus the analysis of error rates was not carried out. There were no mean response latency data to report for the animal name stimuli, because the participants were instructed not to respond if the stimulus item was an animal name. The mean response latencies of correct responses and the mean error rates of the experimental words, and the mean error rates of the animal stimuli (false alarms, in this case) are shown in Table 3-1.

There was a main effect of semantic distance, $F_1(1, 35) = 48.55$, $MSE = 607.72$, $F_2(1, 38) = 5.34$, $MSE = 3{,}051.72$, with responses to the low semantic distance words an average of 41 ms faster than responses to the high semantic distance words.

The effects of semantic distance appear to be larger in the present go/no-go semantic categorization experiment than in the previous yes/no semantic categorization experiment. To further investigate whether this was the case, the response latency data from both experiments were submitted to a 2 (semantic distance: high, low) 2 (task condition: yes/no, go/no-go) mixed-model ANOVA. Semantic distance was a within-subjects manipulation and task condition was a between-subjects manipulation. Both subject (F_1) and item (F_2) analyses were conducted.

There was a main effect of semantic distance in the subject analysis, $F_1(1, 70) = 33.18$, $MSE = 847.47$, and this effect was marginal in the item analysis, $F_2(1, 38) = 3.11$, $p = .08$, $MSE = 4{,}785.80$. Responses to the low semantic distance words were an average of 28 ms faster than responses to the high semantic distance words. There was a main effect of task condition in the item analysis, $F_2(1, 38) = 5.70$, $MSE = 779.59$, but not in the subject analysis, $F_1 < 1$. Responses in the present go/no-go experiment were 16 ms slower than yes/no responses in Experiment 2. Most importantly, there was an interaction between semantic distance and task condition, $F_1(1, 70) = 6.68$, $MSE = 847.47$, $F_2(1, 38) = 4.39$, $MSE = 779.59$: The size of the semantic distance effect almost tripled in the go/no-go task condition as compared to the yes/no task condition (41 ms vs. 15 ms, respectively).

Correlation analyses. Relationships between mean item response latency and the same predictor variables as in the yes/no semantic categorization experiment were examined (see Table 3-3). The animalness ratings were uncorrelated with response latency, as was the case with the yes/no semantic categorization experiment. Unlike the yes/no experiment, however, semantic distance was now correlated with response latency. Moreover, it was the only variable (semantic or otherwise) to correlate with response latency. Both semantic distance and subjective frequency were entered into a regression analysis to determine if semantic distance accounted for any variance above that of subjective frequency. Together, they accounted for 17.3% of the response latency variance, $F(2, 37) = 3.86$. Semantic distance accounted for 13.2% unique variance, $F(1, 37) = 5.90$, whereas subjective frequency accounted for no unique variance.

If semantic distance reflects semantic processing, these results support the idea that the go/no-go task condition was more effective in eliciting semantic processing than the yes/no task condition. Two results indicate that the 'animal' bias is nonetheless maintained in the go/no-go semantic categorization task. First, the animalness ratings were marginally correlated with the animal name error rates, $r = -.30$, $p = .06$. Second, there were many more errors made to the animal name items (5.6%) than to the experimental items (0.07%). Thus, even though the change in task condition was more effective in eliciting semantic processing, a bias was still present towards responding 'animal'. Experiment 4 further investigated the interaction between the effects of semantic distance and task condition, in which these variables were manipulated within-subjects.

Experiment 4 – Within-Subjects Semantic Categorization

Method

Participants. Thirty-six first-year undergraduate students from the University of Alberta participated in the experiment for course credit. All were native English speakers and reported normal or corrected-to-normal vision. None of these individuals participated in the previous experiments or in the collection of any norming data.

Stimuli. Approximately two-thirds of the stimuli used in the present experiment were used in Experiments 2 and 3. The complete set of experimental words used in this experiment is presented in Appendix D, and the descriptive statistics for these stimuli are listed in Table 3-4.

Stimulus norms. In order to include more items in each semantic distance condition, an additional 20 monosyllabic low-frequency words with high semantic distance values and 20 monosyllabic low-frequency words with low semantic distance values were selected. All of these 40 additional words were either four letters or five letters in length, and all were of low printed frequency (< 20 occurrences per million words) according to the printed word frequency norms of the CELEX database (Baayen

Table 3-4
Mean Semantic Distance, Printed Word Frequency, Number of Meanings, Concreteness, Imageability, Length in Letters, Orthographic Neighborhood Size, and Subjective Frequency for the Word Stimuli Used in Experiment 3

SemD Cond	SemD	PWF	NoM	Conc	Imag	LL	ON	SubF
High SemD	402.69	9.00	1.22	456.00	486.06	4.40	6.83	3.69
Low SemD	243.94	9.13	1.31	472.73	493.26	4.40	6.76	3.87

Note. SemD = semantic distance; PWF = printed word frequency; NoM = number of meanings; Conc = concreteness; Imag = imageability; LL = length in letters; ON = orthographic neighborhood size; SubF = subjective frequency.

et al., 1995). Twenty-four participants provided number of meanings ratings for these 40 words, along with 20 nonwords, as was done previously (see the Methods section for Experiment 1).

Concreteness and imageability ratings for the words were taken from the MRC Psycholinguistic Database (Coltheart, 1981). The concreteness and imageability ratings from the MRC psycholinguistic database were multiplied by 100 to give scores from 100 to 700, as the original ratings were taken from questionnaires that had values from 1 to 7. Keeping in line with this data transformation, the concreteness and imageability ratings for the 38 words taken from Experiment 1 (see below) were also multiplied by 100. Thus the different values for these two variables in Table 3-4 as compared to Table 2-1.

As was the case in the previous semantic categorization experiments, the two semantic distance word conditions were equated as closely as possible for printed word frequency, number of meanings, concreteness, imageability, letter length, and orthographic neighborhood size. The two semantic distance word conditions were also equated as closely as possible for subjective frequency, using the Balota et al. (2001)

subjective reading ratings. A total of 30 high semantic distance words and 30 low semantic distance words were selected for use in the present experiment. (Of these 60 items, 19 from each semantic distance condition were used in the previous experiments). The high semantic distance words did not differ from the low semantic distance words on any of these variables ($p > .20$ in all cases).

An additional 60 animal names, matched on length with the experimental items and with a mean CELEX printed word frequency of 7.53, were used in the experiment (presented in Appendix E). Therefore, a total of 120 items were presented in the experiment. Once again, the animal name items had higher animalness ratings than the experimental items (8.75 vs. 2.45, respectively; $t(118) = 33.69$), but the high and low semantic distance experimental items did not differ (2.38 vs. 2.51, respectively; $t(58) < 1$).

Apparatus and procedure. Stimuli were presented on an iMac computer using PsychLab software (Abrams, 1995). Response latencies were measured to the nearest millisecond.

The instructions for the yes/no task condition were identical to those of Experiment 2 and the instructions for the go/no-go task condition were identical to those of Experiment 3. Each participant saw half of the experimental and half of the animal name items in the yes/no task condition, and the other half of the experimental and animal name items in the go/no-go task condition. The experimental and the animal name items were randomly assigned to each task condition for every participant. Task condition was counterbalanced across participants so that half had the yes/no task condition first and the go/no-go task condition second, whereas the other half had the go/no-go task condition first and the yes/no task condition second. To ensure that the participants were well practiced with each task condition, they completed 60 practice trials prior to the collection of data for each task condition. The practice stimuli consisted of 30 words (ten each consisting of four letters, five letters and six letters, all from the same frequency range as the experimental word stimuli), and 30 animal names (ten each consisting of four letters, five letters and six letters). There was a short break between task conditions. Importantly, with the exception of the above procedural changes relating to the within-subjects design, the procedure of the yes/no task condition was identical to that of Experiment 2, and the procedure of the go/no-go task condition was identical to that of Experiment 3.

Design. Semantic distance (high, low) and task condition (yes/no, go/no-go) were varied within-subjects, and order (yes/no first, go/no-go first) was varied between-subjects. Each participant responded to 60 stimuli in each task condition: 30 experimental items (15 high semantic distance words, 15 low semantic distance words) and 30 animal name items. For the word data, response latencies and error rates from each participant were submitted to a 2 (semantic distance: high, low) x 2 (task condition: yes/no, go/no-go) x 2 (order: yes/no first, go/no-go first) mixed-model ANOVA. Both subject (F_1) and item (F_2) analyses were carried out.

Results and Discussion

Response latencies less than 250 ms or more than 2,000 ms were considered outliers and were removed from the data set. A total of 0.3% of the yes/no responses and a total of 0.4% of the go/no-go responses were removed by this procedure. For the experimental word and the animal name stimuli, the mean response latencies of correct responses and the mean error rates are shown in Table 3-5.

Response latencies. There was a main effect of semantic distance, $F_1(1, 34) = 14.59$, $MSE = 2{,}346.41$, $F_2(1, 58) = 6.92$, $MSE = 8{,}8828.66$, with responses to the low semantic distance words an average of 31 ms faster than responses to the high semantic distance words. There was a main effect of task condition, $F_1(1, 34) = 5.16$, $MSE = 7{,}564.52$, $F_2(1, 58) = 10.51$, $MSE = 4{,}948.73$, with responses in the go/no-go task condition an average of 33 ms slower than responses in the yes/no task condition. There was also a main effect of order, $F_1(1, 34) = 4.92$, $MSE = 19{,}433.14$, $F_2(1, 58) = 4.76$, $MSE = 5{,}622.46$. Responses were 52 ms slower when the go/no-go task condition was presented first than when the yes/no task condition was presented first.

There was a semantic distance by task condition interaction, $F_1(1, 34) = 5.69$, $MSE = 2{,}230.84$, $F_2(1, 58) = 4.40$, $MSE = 4{,}948.73$. There was no effect of semantic distance in the yes/no task condition, $t_1(34) = 1.07, p > .10$, $t_2(58) = 1.09, p > .10$, but there was in the go/no-go task condition, $t_1(34) = 4.49$, $t_2(58) = 3.72$. This interaction indicates that semantic distance exerted larger facilitatory effects in the go/no-go task condition (50 ms) as compared to the yes/no task condition (12 ms).

There was no task condition by order interaction in the subject analysis, $F_1(1, 34) = 2.86, p = .10$, $MSE = 7{,}564.57$, but there was in the item analysis, $F_2(1, 58) = 33.13$, $MSE = 4{,}278.34$. Post hoc comparisons of the item means revealed that in the yes/no task condition, responses were an average of 76 ms faster when the yes/no task condition was presented first than when the go/no-go task condition was presented first, $t_2(58) = 6.28$. In the go/no-go task condition, responses were an average of 27 ms faster when the

Table 3-5
Mean Response Latencies (in Milliseconds) and Standard Errors, and Mean Error Rates (Percentages) and Standard Errors for the Word and Animal Stimuli in Experiment 4

	Response latencies		
Condition	High SemD	Low SemD	SemD Effect
Yes/no	690 (14.3)	678 (13.8)	12
Go/no-go	742 (17.3)	692 (15.8)	50

	Error rates		
Condition	High SemD	Low SemD	SemD Effect
Yes/no	2.8 (0.7)	1.3 (0.4)	1.5
Go/no-go	0.7 (0.4)	0.2 (0.2)	0.5

	Animal names	
Condition	Response latencies	Error rates
Yes/no	636 (13.9)	4.4 (0.8)
Go/no-go	No RL data collected	5.9 (1.2)

Note. SemD = semantic distance; RL = response latency. Standard errors appear in parentheses.

yes/no task condition was presented first than when the go/no-go task condition was presented first, $t_2(58) = 2.40$. Importantly, there was no semantic distance by order interaction, nor was there a 3-way interaction, Fs < 1 in all cases.

Error rates. There was a main effect of semantic distance in the subject analysis, $F_1(1, 34) = 6.14$, $MSE = 6.55$, but not in the item analysis, $F_2(1, 58) = 1.08$, $p = .30$, $MSE = 48.62$. There were generally less errors made to the low semantic distance words than to the high semantic distance words (0.8% vs. 1.8%, respectively). There was a main effect of task condition, $F_1(1, 34) = 12.93$, $MSE = 6.55$, $F_2(1, 58) = 8.53$, $MSE = 21.59$. More errors were made in the yes/no task condition than in the go/no-go task condition (2.1% vs. 0.5%). There was no main effect of order, both Fs < 1.

There was no semantic distance by task condition interaction, nor was there a task condition by order interaction, Fs < 1 in all cases. There was a marginal semantic distance by order interaction in the subject analysis, $F_1(1, 34) = 3.40$, $p = .07$, $MSE = 6.55$, but not in the item analysis, $F_2(1, 58) = 2.73$, $p = .10$, $MSE = 21.59$. Finally, there was no three-way interaction between semantic distance, task condition, and order in the subject analysis, $F_1 < 1$, but it was marginal in the item analysis, $F_2(1, 58) = 2.73$, $p = .06$, $MSE = 18.93$.

Correlation analyses. Once again, relationships were examined between mean item response latency and the same predictor variables as in the two previous semantic categorization experiments (see Table 3-3). For the yes/no task condition, none of the predictor variables correlated with response latency (although concreteness and imageability were marginally correlated at $p = .08$ and $p = .06$, respectively). For the go/no-go task condition, only semantic distance was correlated with response latency (although subjective frequency was marginally correlated at $p = .06$). Both semantic distance and subjective frequency were entered into a regression analysis, and both variables accounted for a significant 17.1% of the response latency variance, $F(2, 57) =$

5.87. Semantic distance accounted for 11.2% of the response latency variance above that of subjective frequency, $F(1, 57) = 7.70$. Subjective frequency, however, only accounted for 1.9% of the variance above that of semantic distance, $F(1, 57) = 1.30, p > .25$. The regression findings in the yes/no task condition and the go/no-go task condition are similar to those observed in Experiments 2 and 3, respectively.

This within-subjects experiment also replicated the findings of Experiments 2 and 3 regarding the 'animal' response bias inherent in the animal/non-animal semantic categorization task in two ways. First, none of the dependent variables for the experimental word data correlated with the animalness ratings (response latency and error rates for the yes/no task condition were, $r = -.02$ and $r = .14$, respectively; for the go/no-go task condition they were $r = .17$ and $r = .12$, respectively, $p > .15$ in all cases). The opposite was observed for the animal name response latency and error rate data. For the yes/no task condition data, the correlations between animalness ratings and response latency and error rates were $r = -.33$ and $r = -.44$, respectively. For the go/no-go task condition data, there was a correlation between the animalness ratings and the animal name error rates, $r = -.44$. As was the case in the other semantic categorization experiments, the negative signs of the correlations indicated that as animalness ratings increased, response latencies and error rates to the animal name items decreased. These findings are consistent with an explanation centered on early decisions regarding animalness enabling more rapid and more accurate responses to the animal name items with higher animalness ratings than to the animal name items with lower animalness ratings. These correlations, on the other hand, are not consistent with the idea that the experimental (i.e., non-animal) items with higher animalness ratings should have slower and less accurate responses than the experimental items with lower animalness ratings (Carreiras et al., 1997).

Second, in the yes/no task condition, responses to the animal name items were an average of 48 ms faster, but 2% less accurate, than responses to the experimental items, $F_1(1, 35) = 5.52$, $MSE = 7{,}683.45$, $F_2(1, 118) = 27.61$, $MSE = 2{,}592.39$, and $F_1(1, 35) = 4.73$, $MSE = 16.09$, $F_2(1, 118) = 3.09$, $p = .08$, $MSE = 35.01$, respectively. In addition, in the go/no-go task condition, responses to the animal name items were 5% less accurate than responses to the experimental items, $F_1(1, 35) = 17.07$, $MSE = 27.43$, $F_2(1, 118) = 23.26$, $MSE = 36.24$. Importantly, these findings were limited to task effects and do not compromise the effects of semantic distance that are central to this chapter.

In every respect, then, the results of Experiment 4, in which semantic distance and task condition were manipulated within-subjects, replicated the important findings of Experiments 2 and 3. First, the effect of semantic distance was not obtained in the yes/no task condition, whereas they were obtained in the go/no-go task condition. Second, response latencies to the experimental items were again longer in the go/no-go task condition than in the yes/no task condition. Third, animalness ratings correlated with only the animal name data and not with the experimental word data. There was an additional finding of interest regarding the effects of order. Even though many practice trials (60) were presented before the task conditions to acclimatize the participants to the demands of each task, there seemed to be a 'carry-over' effect from one task condition to the other. More specifically, when the yes/no task condition was presented first, participants were faster than when the go/no task condition was presented first. The influence of procedure order was larger in the yes/no task condition (76 ms) than in the go/no-go task condition (27 ms). Importantly, however, the magnitude of the effect of semantic distance in the response latency data was not influenced by procedure order.

General Discussion

Facilitatory effects of semantic distance have been observed in the lexical decision task (Buchanan et al., 2001; Experiment 1 of this thesis). This finding has been explained in terms of cross-module activation from semantics to orthography influencing the speed with which an orthographic code is activated. The present chapter has focused on determining whether semantic distance influences lexical processing in a task in which responses are based primarily on the processing of the semantic module.

Hino et al. (2002) suggested that semantic processing tasks are not influenced by cross-module activation from semantics to orthography, but rather are influenced by cross-module activation from orthography to semantics. This assumption formed the basis of a prediction that the effects of semantic distance would be inhibitory in semantic categorization, because low semantic distance words would, on average, activate more semantic codes than would high semantic distance words. Experiment 2 employed a yes/no task condition, in which participants were required to respond to both the animal name and the experimental word stimuli, and a marginal effect of semantic distance (in the subject analysis) was observed. Interestingly, the trend in this experiment was towards facilitation, as responses to low semantic distance words were slightly faster than responses to high semantic distance words. This result was contrary to what had been predicted.

In Experiment 3, a go/no-go task was used, in which participants responded only if the stimuli were not animal names. The reason for this procedural change was to increase the level of semantic processing to the experimental items by making them more like 'yes' responses. The expectation was that there would be an increased likelihood of observing effects of semantic distance under these conditions. This expectation was realized. The effects of semantic distance were much stronger in Experiment 3 (go/no-go; 41 ms) as compared to Experiment 2 (yes/no; 15 ms). In addition, none of the predictor variables correlated with response latency in Experiment 2, but semantic distance was correlated with response latency in Experiment 3. Finally, response latencies to the experimental items were longer in Experiment 3 than in Experiment 2. These results were then replicated in Experiment 4, in which semantic distance and task condition were manipulated within-subjects.

The key question to be addressed is, How does semantic distance influence processing in the semantic module? One possibility is that semantic distance effects in semantic processing tasks are similar in nature to orthographic neighborhood effects in orthographic processing tasks. Sears, Hino, et al. (1995; see also Andrews, 1992) suggested that connectionist models (e.g., Plaut et al., 1996; Seidenberg & McClelland, 1989) offer an elegant account of orthographic neighborhood effects. Because orthographically similar words would recruit similar units and connections in the orthographic module, a word's orthographic representation would be strengthened not only when the word itself was presented, but also when its orthographic neighbors were presented. Thus, words with many orthographic neighbors would have their orthographic representations strengthened to a greater degree than would words with few orthographic neighbors. Sears, Hino, and Lupker (1999) conducted a series of statistical analyses of the orthographic, phonological, and cross-entropy error scores of the four and five letter monosyllabic words in the Plaut et al. and Seidenberg and McClelland word corpi. They reported that words with many orthographic neighbors (and words with higher frequency orthographic neighbors) had, on average, lower error scores than words with few orthographic neighbors (and words with no higher frequency neighbors).

A similar account is now offered for the effects of semantic distance. Because semantically similar words would recruit similar units and connections in the semantic module, a word's semantic representation would be strengthened when it and its semantic neighbors are presented. Therefore, because low semantic distance words have more semantic neighbors than high semantic distance words, they would have stronger and richer semantic representations, and would thus benefit more during processing.

As outlined in Chapter 1, cross-module activation has been proposed in frameworks other than parallel distributed processing. Balota et al. (1991) suggested that the interactive activation model (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982) could be expanded to include a semantic level and thus accommodate semantic effects in lexical processing. This level would receive input from and send input to the lexical (i.e., orthographic) level. Thus, according to this model, low semantic distance words would activate more semantic nodes than would high semantic distance words. The model would predict inhibitory effects of semantic distance, because the intra-level connections between activated meaning units are inhibitory. Because low semantic distance words activate more semantic nodes than high semantic distance words, more inhibition at the semantic level should occur for the former words, thus causing a delay in the time taken for a specific semantic node to reach its activation threshold. If responses in the semantic categorization task are based on processing within the semantic level, it is difficult to imagine how this model can account for facilitatory effects of semantic distance.

One important question remains. How did the procedural strategy manipulation alter the influences of semantic processing as measured by the semantic distance effect? If a discrete stage model of semantic categorization performance is assumed, then both the yes/no and the go/no-go task conditions involve two distinct and temporally successive processing stages in responding (see Perea, Rosa, & Gomez, 2002, for an analysis of processing stages in the yes/no and the go/no-go procedures in lexical decision). The first is a lexical processing stage in which the meaning of a word is retrieved. The second is a response processing stage in which a response is chosen.

Due to the nature of the animal/non-animal semantic categorization task, there is most likely an 'animal' bias in the lexical processing stage. The two task conditions differ in that the yes/no task condition ultimately affords participants the opportunity to respond in accordance with the 'animal' bias (i.e., they respond to the animal names), whereas the go/no-go task condition does not (i.e., they do not respond to the animal name items). To ensure that lexical selection will support correct responses in the go/no-go task condition, participants may set a higher processing criterion than in the yes/no task condition. Thus, in the go/no-go task condition deeper semantic processing of the experimental items occurred to rule out the possibility that these items were animal names. This would lead to longer response latencies but lower error rates for the experimental items in the go/no-go experimental condition as compared to the yes/no experimental condition. This was exactly the pattern observed in the within-subjects analyses of Experiment 4.

There is another point that needs to be emphasized regarding this deeper processing hypothesis for the experimental words in the go/no-go task condition. If deeper processing results in slower response latencies (a reasonable assumption), then response latencies to both the high semantic distance words and the low semantic distance words would be slower in the go/no-go task conditions of Experiments 3 and 4 than in the yes/no task conditions of Experiments 2 and 4. An examination of Tables 3-1 and 3-5 reveals that this was the case, but that the effect was more pronounced for the high semantic distance words than for the low semantic distance words. These data are consistent with the explanation offered above concerning how semantic distance influences semantic processing. Specifically, because the low semantic distance words have more semantic neighbors than the high semantic distance words, they should have stronger and richer semantic representations (i.e., their connections have received greater strengthening due to the presentation of more words that are similar in meaning). Thus, the low semantic distance words are the very items that should benefit more from increased semantic processing, and consequently have smaller increases in response latencies going from the yes/no task condition to the go/no-go task condition.

One objection that may be raised at this point is that the differential effects of semantic distance observed in the yes/no and the go/no-go task conditions of Experiment 4 are due primarily to differences in the tails of the response latency distributions. If this is indeed the case, then there should be little or no difference in the effects of semantic distance in the two task conditions if median response latencies are analyzed. These analyses were conducted, and the results mirrored the results of the mean response latency data. In fact, the magnitude of the semantic distance effect in the yes/no and the go/no-go task conditions when median response latencies were the dependent measure (18 ms and 51 ms, respectively) were similar to those when mean response latencies were the dependent measure (12 ms and 50 ms, respectively).

Finally, the two task conditions may have also differed in the processing demands required at the response processing stage. In the yes/no task condition, participants must make two distinct responses, and moreover must remember the correct stimulus-to-response pairing for the two stimuli classes. In the go/no-go task condition, the response selection process is putatively simpler (Gibbs & Van Orden, 1998; Perea et al., 2002). Under these conditions, participants respond to only one class of stimuli and remember only one stimulus-to-response pairing. This analysis predicts that response latencies would be faster in the go/no-go task condition, because of the reduced processing demands at the response selection stage.

Perea et al. (2002) reported faster response latencies (and lower error rates) in their go/no-go lexical decision task than in their yes/no lexical decision task. They noted that this replicates the findings of some researchers (e.g., Chiarello, Nuding, & Pollock, 1988; Gordon & Caramazza, 1982; Measso & Zaidel, 1990; Perea, Fernandez, & Carreiras, 1998), but not of others (e.g., Gibbs & Van Orden, 1998; Hino & Lupker, 1998, 2000). At this point it may be premature to make firm conclusions about whether the reduced response selection demands of go/no-go conditions necessarily lead to faster response latencies than those of yes/no conditions. Indeed, recall that the opposite was true for the present semantic categorization experiments.

There is one important procedural difference between the lexical decision and the animal/non-animal semantic categorization tasks that could account for the disparity between Perea et al.'s (2002) findings of faster response latencies and the present results of slower response latencies in go/no-go conditions. The items responded to in Perea et al.'s lexical decision go/no-go condition were the exemplars of the task (i.e., words are exemplars of the category 'lexical items'). This was not the case in the present semantic categorization experiments. Despite the earlier suggestion that requiring overt responses to the non-animal items would make these responses more like 'yes' responses, they were still non-exemplars of the category 'animal'. An empirical question is whether faster response latencies to the exemplar items (i.e., the animal name items) would be observed if these were the items requiring a response in go/no-go conditions, as Perea et al. reported for lexical decision. To answer this question, another experiment employed the same items and procedures as in Experiment 4. The only change was that in the go/no-go task condition, participants responded to only the animal names. Sixteen participants received the yes/no task condition first and the go/no-go task condition second, whereas 16 participants received the go/no-go task condition first and the yes/no task condition second.

Responses to the animal name items were an average of 32 ms faster and 2.3% more accurate in the go/no-go task condition than in the yes/no task condition, $F_1(1, 31) = 4.61$, $MSE = 3{,}673.99$, $F_2(1, 59) = 12.79$, $MSE = 2{,}233.13$, and $F_1(1, 31) = 11.47$, $MSE = 7.31$, $F_2(1, 59) = 12.44$, $MSE = 12.82$, respectively. These data indicate that responses are faster to the exemplar items of a task in the go/no-go task condition, but are slower to the non-exemplar items. Moreover, the present finding of faster responses to animal names (i.e., the exemplar items) in the go/no-go semantic categorization task is completely consistent with Perea et al.'s (2002) finding of faster responses to words (i.e., the exemplar items) in the go/no-go lexical decision task. A prediction, based on these results, is that if nonwords were the items responded to in a go/no-go lexical decision task, response latencies would increase (as compared to response latencies to the same nonwords in a yes/no lexical decision task), because participants would process them more deeply to ensure that the correct responses were made.

In conclusion, the results from the semantic categorization experiments reported in this chapter demonstrate that, provided the demands of this task require relatively deep semantic processing of the stimuli, semantic distance exerts facilitatory effects. In addition, data from the lexical decision task more directly compare to data from the go/no-go version than the yes/no version of the semantic categorization task. Finally, Balota et al. (1991), in their review of the effects of semantics in lexical processing, did not report any semantic categorization tasks (or other tasks requiring semantic retrieval) that had been used to examine semantic effects in visual word recognition. The results from the present semantic categorization experiments, along with other recent studies (e.g., Gottlob et al., 1999; Hino et al., 2002; Piercey & Joordens, 2000), begin to fill the void in the literature regarding the use of lexical processing tasks, such as semantic categorization, that require the retrieval of meaning to examine the effects of semantics in visual word recognition.

The next chapter introduces a novel lexical processing task that incorporates the lexical decision and the semantic categorization tasks used thus far in this thesis. This task provides an opportunity to investigate the effects of semantic distance on responses that are based on activation in both the orthographic and semantic modules.

CHAPTER 4

LEXICAL DECISION/SEMANTIC CATEGORIZATION

In Chapters 2 and 3, I examined the effect of semantic distance in lexical decision and semantic categorization, respectively. In this chapter, I will examine the effects of semantic distance in a novel methodology that combines the processing requirements of the above tasks. In this novel task, hereafter referred to as the lexical decision/semantic categorization task, participants were presented with experimental items, nonword items, and animal name items. They were required to respond to the experimental items by pressing one key on the computer keyboard, to respond to the nonwords by pressing another key, and to not respond to the animal name items. As in the lexical decision experiment, there were four experimental conditions in which the nonword context was manipulated.

The experiment was conducted for three main reasons. First, this methodology retains the strengths of the semantic categorization task, while overcoming one of its weaknesses. One strength is that participants must access word meaning prior to responding to distinguish the animal from the non-animal words. Another strength is that 'yes' responses were required to the non-exemplar items (i.e., the experimental words), thus avoiding any contaminating effects of semantic priming or category typicality (Forster & Shen, 1996). The weakness that is overcome is that in the yes/no semantic categorization task the experimental items required 'no' responses. Recall that this was the prime motivation for using the go/no-go procedure of the semantic categorization task. It was argued that the procedural change, from yes/no to go/no-go semantic categorization, made the experimental items more like 'yes' responses (as in lexical decision), because these were the only items to which an overt response was required. However, one could argue that at a higher, more abstract level of analysis, the experimental items in the go/no-go semantic categorization task were still 'no' responses. In the lexical decision/semantic categorization task this should not be an issue, because clearly the experimental items require 'yes' responses at both a behavioral level (i.e., these were the items to which participants pressed the 'yes' or 'word' key) and at a higher, more abstract level (i.e., respond 'yes' if the item is a word that is not an animal name).

The second reason for performing this experiment is that the lexical decision/semantic categorization task is amenable to ideal strategy manipulations. The experimental word and animal name stimuli are the same across the four experimental conditions, as are the procedural variables, and the required responses. The only difference between experimental conditions is the nonword context in which the word stimuli are embedded. The procedural strategy manipulation used in Chapter 3 elicited differential processing of the experimental stimuli and hence influenced the effect of semantic distance. One of the objectives of the present experiment was to determine if an ideal strategy manipulation could similarly influence the effect of semantic distance in a task that requires resolution of word meaning.

The third reason for conducting this experiment was to examine the effects of semantic distance in a task in which responses are based on processing from more than one module. In the present experiment, activation in both the orthographic and semantic modules is arguably required. The task involves monitoring the processing of the orthographic module to distinguish words from nonwords. This would be especially relevant in the pseudohomophone context, because McCann et al. (1988), Seidenberg et al. (1996), and Ziegler et al. (2001) argue that in lexical decision, pseudohomophones activate both phonological and semantic codes, thereby making orthographic information the only reliable means upon which to distinguish words from the pseudohomophones. As noted above, the task also requires monitoring the processing of the semantic module, because words will need to be distinguished on the basis of belonging or not belonging to the category of 'animal names'. Lastly, because more extensive processing would be required in this task than in the lexical decision task, perhaps the effects of semantic distance will increase across each nonword context, a result that was not observed between the matched nonword and the pseudohomophone contexts of Experiment 1.

Chapter 2 contained several predictions regarding the effects of increasing the difficulty of the word-nonword discriminations on lexical decision performance. The same predictions hold in the present experiment: Slower response latencies to the word and nonword stimuli, and a corresponding increase in the effects of lexicality and semantic distance.

Experiment 5 – Lexical Decision/Semantic Categorization

Method

Participants. One hundred and forty-four first-year undergraduate students from the University of Alberta participated in the experiment: 36 participants in each of the four experimental conditions. All were native English speakers and reported normal or corrected-to-normal vision. None of these individuals participated in more than one experimental condition, participated in any of the previous experiments, or were involved in the collection of any norming data. All the participants received course credit.

Word and nonword stimuli. The word stimuli and the four sets of nonword stimuli are identical to those used in Experiment 1, described in Chapter 2.

Animal name stimuli. The animal name stimuli are identical to those used in Experiments 2 and 3, described in Chapter 3.

Apparatus and procedure. The stimuli were presented on a color VGA monitor driven by a Pentium-class microcomputer using MEL software. Response latencies were measured to the nearest millisecond.

For every trial, a 50 ms blank screen was followed by a fixation cross that appeared at the center of the computer monitor for 250 ms, and was then replaced by a stimulus item (presented in lowercase letters). Participants were instructed to respond 'word' by pressing the '0' key and 'nonword' by pressing the '1' key on the computer keyboard. They were also instructed not to press a key if the stimulus item was an animal name. They were told that the stimulus would remain on the monitor for 2.5 s and then would automatically be replaced by the next stimulus item. Thus, they were instructed that if the stimulus item was an animal name they should simply wait for it to be replaced by the next item. In trials where a response was made, the response terminated the stimulus display, and the next trial was initiated after a timed interval of 1 s. Where appropriate (i.e., when the item was an experimental word or a nonword) participants were instructed to make their responses as quickly and as accurately as possible, and were told that each letter string would appear only once during the experiment. The order in which the stimuli were presented was randomized separately for each participant.

Each participant completed 24 practice trials prior to the collection of data. The practice stimuli consisted of eight words (half were four letters in length and half were five letters in length, and all were of the same frequency range as the experimental word stimuli), eight nonwords that were representative of the nonwords presented in the experimental trials (e.g., the eight nonwords for the practice trials of experimental condition 5A were random consonant strings; half were four letters in length and half were five letters in length) and eight animal names (half were four letters in length and half were five letters in length).

Design. A 2 (semantic distance: high, low) x 4 (nonword context: illegal nonwords, no neighbor nonwords, matched nonwords, pseudohomophones) mixed factorial design was used. Semantic distance was a within-subjects manipulation and nonword context was a between-subjects manipulation. For each experimental condition, there were 40 nonwords and 40 animal names and 20 items in each of the two word stimulus conditions, for a total of 120 trials. In experimental condition 5A, the illegal nonwords of experimental condition 1A were used. In experimental condition 5B, the no neighbor nonwords of experimental condition 1B were used. In experimental condition 5C, the matched nonwords of experimental condition 1C were used. Finally, in experimental condition 5D, the pseudohomophones of experimental condition 1D were used.

For the word data, response latencies and error rates from each participant were submitted to a 2 (semantic distance: high, low) x 4 (nonword context: illegal nonwords, no neighbor nonwords, matched nonwords, pseudohomophones) mixed-model ANOVA. Both subject (F_1) and item (F_2) analyses were performed.

For the nonword data, response latencies and error rates from each participant were submitted to a one-way (nonword context: illegal nonwords, no neighbor nonwords, matched nonwords, pseudohomophones) between-subjects ANOVA.

For the effect of lexicality, response latencies and error rates from each participant were submitted to a one-way (nonword context: illegal nonwords, no neighbor nonwords, matched nonwords, pseudohomophones) between-subjects ANOVA.

For the animal name data, error rates were submitted to a one-way (nonword context: illegal nonwords, no neighbor nonwords, matched nonwords, pseudohomophones) between-subjects ANOVA.

Results

Response latencies less than 250 ms or more than 2,000 ms were considered outliers and were removed from the data set. For experimental condition 5A (illegal nonwords), 0.1% of the responses were removed by this procedure; for experimental condition 5B (no neighbor nonwords), 1.1% of the responses were removed; for experimental condition 5C (matched nonwords), 0.7% of the responses were removed; and for experimental condition 5D (pseudohomophones), 1.3% of the responses were removed. The mean response latencies of correct responses, the mean error rates, and the mean semantic distance effects in experimental conditions 5A-5D are listed in Table 4-1. The mean response latencies, error rates, and lexicality effects for the word and the nonword stimuli, and the mean error rates for the animal name stimuli in experimental conditions 5A-5D are listed in Table 4-2.

Word response latencies. There was a main effect of semantic distance, $F_1(1, 140) = 124.98$, $MSE = 2{,}005.28$, $F_2(1, 38) = 13.07$, $MSE = 11{,}389.85$, with responses to the low semantic distance words an average of 59 ms faster than responses to the high semantic distance words. There was also a main effect of nonword context, $F_1(3, 140) = 15.91$, $MSE = 19{,}253.23$, $F_2(3, 114) = 91.90$, $MSE = 1{,}910.79$. Post hoc comparisons revealed that word responses were slower in the no neighbor nonword context than in the illegal nonword context, $t_1(140) = 3.01$, $t_2(114) = 10.07$; were similar in the matched nonword context and in the no neighbor nonword context, both ts < 1; and were slower in the pseudohomophone context than in the matched nonword context, $t_1(140) = 1.86$, $t_2(114) = 6.49$. Thus, as in the lexical decision task of Chapter 2, increasing the difficulty of the word-nonword discriminations was generally related to increased response latencies for the experimental words.

There was also a semantic distance by nonword context interaction, $F_1(3,140) = 4.15$, $MSE = 2{,}005.28$, $F_2(3,114) = 3.10$, $MSE = 1{,}910.79$. This interaction was further examined by analyzing the effect of semantic distance within each level of nonword context, and also by examining the effect of nonword context in semantic distance. First, there was an effect of semantic distance in each of the nonword contexts; the illegal nonword context, $t_1(140) = 3.50$, $t_2(114) = 3.68$; the no neighbor nonword context, $t_1(140) = 5.30$, $t_2(114) = 5.62$; the matched nonword context, $t_1(140) = 5.21$, $t_2(114) = 5.93$; and the pseudohomophone context, $t_1(140) = 8.43$, $t_2(114) = 9.71$.

Second, the effect of semantic distance was larger in the no neighbor nonword context than in the illegal nonword context, $t_1(140) = 1.80$, $t_2(114) = 1.94$; was similar in the matched nonword context and in the no neighbor nonword context, both ts < 1; and was larger in the pseudohomophone context than in the matched nonword context $t_1(140) = 3.22$, $t_2(114) = 3.78$.

Table 4-1

Mean Response Latencies (in Milliseconds) and Standard Errors, and Mean Error Rates (Percentages) and Standard Errors, and Mean Semantic Distance Effects in Experimental Conditions 5A-5D

	Response latencies		
Condition	High SemD	Low SemD	SemD effect
5A: Illegal nonwords	815 (14.1)	778 (12.4)	37
5B: No N nonwords	923 (20.2)	867 (17.2)	56
5C: Matched nonwords	920 (19.1)	865 (18.3)	55
5D: Pseudohomophones	998 (17.7)	909 (17.1)	89
	Error rates		
Condition	High SemD	Low SemD	SemD effect
5A: Illegal nonwords	1.5 (0.4)	0.7 (0.3)	0.8
5B: No N nonwords	2.8 (0.6)	1.3 (0.4)	1.5
5C: Matched nonwords	5.7 (0.8)	1.8 (0.7)	3.9
5D: Pseudohomophones	5.4 (0.9)	2.4 (0.6)	3.0

Note. SemD = semantic distance; N = neighbor. Standard errors appear in the parentheses.

Word error rates. There was a main effect of semantic distance, $F_1(1, 140) = 32.00$, $MSE = 12.39$, $F_2(1, 38) = 4.41$, $MSE = 50.23$, with more errors made to the high semantic distance words than to the low semantic distance words (3.9 % vs. 1.6%, respectively). There was also a main effect of nonword context, $F_1(3, 140) = 8.56$, $MSE = 15.48$, $F_2(3, 114) = 5.46$, $MSE = 12.40$. Post hoc comparisons revealed that error rates were similar in the no neighbor nonword context and in the illegal nonword context, $t_1(140) = 1.01$, $p > .10$, $t_2(114) = 1.03$, $p > .10$; were higher in the matched nonword context than in the no neighbor nonword context, $t_1(140) = 1.86$, $t_2(114) = 2.20$; and were similar in the pseudohomophone context and in the matched nonword context, both *t*s < 1.

There was an interaction between semantic distance and nonword context in the subject analysis, $F_1(3, 140) = 2.82$, $MSE = 12.39$, but not in the item analysis, $F_2(3, 114) = 1.59$, $p = .19$, $MSE = 12.40$. Post hoc comparisons of the subject means were conducted to further examine the effect of semantic distance within each level of nonword context, and also by examining the effect of nonword context in semantic distance. First, there was no effect of semantic distance in the illegal nonword context, $t_I(140) = 1.01$, $p > .10$; but there was an effect in the no neighbor nonword context, $t_1(140) = 1.92$; in the matched nonword context, $t_1(140) = 4.75$; and in the pseudohomophone context, $t_1(140) = 3.63$. Second, the effect of semantic distance was similar in the no neighbor nonword context and in the illegal nonword context, $t_1 < 1$; was larger in the matched nonword context than in the no neighbor nonword context, $t_1(140) = 2.82$; and was similar in the pseudohomophone context and in the matched nonword context, $t_1(140) = 1.11$, $p > .10$.

Nonword response latencies. There was a main effect of nonword context, $F_1(3, 140) = 91.97$, $MSE = 15{,}187.61$, $F_2(3, 156) = 289.97$, $MSE = 5{,}203.46$. Post hoc comparisons revealed that responses to the no neighbor nonwords were slower than responses to the illegal nonwords, $t_1(140) = 8.22$, $t_2(156) = 14.75$; were slower to the matched nonwords than to the no neighbor nonwords $t_1(140) = 3.51$, $t_2(156) = 6.20$; and were slower to the pseudohomophones than to the matched nonwords, $t_1(140) = 4.26$,

Table 4-2
Mean Response Latencies (in Milliseconds) and Standard Errors, Mean Error Rates (Percentages) and Standard Errors, and Mean Lexicality Effects for the Word and Nonword Stimuli, and Mean Error Rates (Percentages) and Standard Errors for the Animal Stimuli in Experimental Conditions 5A-5D

	Response latencies		
Condition	Words	Nonwords	Lexicality effect
5A: Illegal nonwords	797 (12.4)	604 (9.2)	192
5B: No N nonwords	895 (18.0)	843 (22.5)	52
5C: Matched nonwords	894 (17.7)	945 (23.7)	-52
5D: Pseudohomophones	954 (16.7)	1069 (23.0)	-115

	Error rates			
Condition	Words	Nonwords	Lexicality effect	Animal names
5A: Illegal nonwords	1.1 (0.3)	0.8 (0.2)	0.3	4.4 (0.8)
5B: No N nonwords	2.1 (0.4)	3.6 (1.1)	-1.5	4.0 (0.6)
5C: Matched nonwords	3.8 (0.5)	8.4 (1.4)	-4.6	6.0 (0.9)
5D: Pseudohomophones	3.9 (0.6)	9.9 (1.4)	-6.0	5.3 (1.0)

Note. SemD = semantic distance; N = neighbor. Standard errors appear in the parentheses.

$t_2(156) = 7.44$.

Nonword error rates. There was a main effect of nonword context, $F_1(3, 140) = 13.90$, $MSE = 45.34$, $F_2(3, 156) = 16.54$, $MSE = 37.60$. Post hoc comparisons revealed that error rates were higher to the no neighbor nonwords than to the illegal nonwords, $t_1(140) = 1.76$, $t_2(156) = 2.05$; were higher to the matched nonwords than to the no neighbor nonwords, $t_1(140) = 2.98$, $t_2(156) = 3.44$; and were similar to the pseudohomophones and to the matched nonwords, $t_1 < 1$, $t_2(156) = 1.02$, $p > .10$.

Lexicality effect in response latencies. There was a main effect of lexicality (word response latencies minus nonword response latencies), $F_1(3, 140) = 64.81$, $MSE = 10,015.25$, $F_2(3, 156) = 56.88$, $MSE = 11,966.88$. Post hoc comparisons revealed that the effect of lexicality differed in the no neighbor nonword context and in the illegal nonword context, $t_1(140) = 5.93$, $t_2(156) = 5.64$; in the matched nonword context and in the no neighbor nonword context, $t_1(140) = 4.41$, $t_2(156) = 4.17$; and in the pseudohomophone context and in the matched nonword context, $t_1(140) = 2.67$ $t_2(156) = 2.29$. Interestingly, as indicated in Table 4-2, word responses were actually slower than nonword responses in the illegal nonword and in the no neighbor nonword contexts, the two types of nonwords that are most unwordlike.

Lexicality effect in error rates. There was a main effect of lexicality (word error rates minus nonword error rates), $F_1(3, 140) = 5.82$, $MSE = 49.90$, $F_2(3, 156) = 4.83$, $MSE = 60.00$. Post hoc comparisons revealed that the effect of lexicality was similar in the no neighbor nonword context and in the illegal nonword context, $t_1(140) = 1.11$, $p > .10$, $t_2(156) = 1.07$, $p > .10$; differed in the matched nonword context and in the no neighbor nonword context, $t_1(140) = 1.79$, $t_2(156) = 1.72$; and was similar in the pseudohomophone context and in the matched nonword context, both ts < 1.

Animal name error rates. There was no main effect of nonword context in the subject analysis, $F_1(3, 140) = 1.68$, $p = .17$, $MSE = 19.56$, but it was marginal in the item analysis, $F_2(3, 117) = 2.33$, $p = .08$, $MSE = 12.20$.

Correlation analyses. Relationships between mean item response latency and the predictor variables were examined. Both summed lexical activation and animalness ratings were included as predictor variables, but as indicated in Table 4-3, neither variable correlated with response latency in any of the experimental conditions.

For experimental condition 5A (illegal nonword context), semantic distance and concreteness were correlated with response latency, and together with subjective frequency accounted for 31.7% of the response latency variance, $F(3, 36) = 5.57$. Semantic distance accounted for 14.9% unique variance, $F(1, 36) = 7.85$, and concreteness accounted for 10.5% unique variance, $F(1, 36) = 5.53$. Subjective frequency, on the other hand, accounted for less than 1% unique variance, $F < 1$.

For experimental conditions 5B (no neighbor nonword context) and 5C (matched nonword context), the only predictor variables that correlated with response latency were semantic distance and subjective frequency. These two predictor variables accounted for 33.5% of the response latency variance in experimental condition 5B, $F(2, 37) = 9.31$, and 32.4% in experimental condition 5C, $F(2, 37) = 8.87$. Semantic distance accounted for 18.2% unique variance in experimental condition 5B, $F(1, 37) = 10.12$, and 16.6% unique variance in experimental condition 5C, $F(1, 37) = 9.08$. Subjective frequency, however, accounted for only 1.8% unique variance in experimental condition 5B, $F(1, 37) = 1.00$, $p > .25$, and only 2.2% in experimental condition 5C, $F(1, 37) = 1.20$, $p > .25$.

For experimental condition 5D (pseudohomophone context), semantic distance, subjective frequency, concreteness, and imageability were all correlated with response latency. Only semantic distance, subjective frequency, and concreteness were included in the regression analyses, however, because concreteness and imageability were

Table 4-3

Single-Order Correlations Between Mean Item Latency, Log Frequency, Subjective Frequency, Length in Letters, Orthographic Neighborhood Size, Summed Lexical Activation, Number of Meanings, Concreteness, Imageability, Animalness Ratings, and Semantic Distance in Experimental Conditions 5A-5D

Variables	RL – Illegal	RL – No N	RL – Matched	RL – Pseudo
LogF	-.14	-.19	-.03	.05
SubF	-.19	-.39*	-.40*	-.49*
LL	-.01	-.03	.02	-.09
ON	.14	.06	.07	.08
SLA	.10	.08	.10	.09
NoM	.02	.10	-.02	-.05
Conc	-.38*	-.26	-.21	-.35*
Imag	-.20	-.06	-.17	-.33*
AnimRate	.22	-.07	-.02	-.08
SemD	.46*	.56*	.55*	.64*

Note. $df = 38$. RL = response latency; Illegal = illegal nonword context; No N = no neighbor nonword context; Matched = matched nonword context; Pseudo = pseudohomophone context; LogF = log frequency; SubF = subjective frequency; LL = length in letters; ON = orthographic neighborhood size; SLA = summed lexical activation values; NoM = number of meanings; Conc = concreteness; Imag = imageability; AnimRate = animalness ratings; SemD = semantic distance.
* $p < .05$.

significantly correlated, and concreteness had the stronger correlation with response latency. Together, the three predictor variables included in the regression equation accounted for 51.4% of the response latency variance, $F(3, 36) = 12.68$. Semantic distance accounted for 18.5% unique variance, $F(1, 36) = 13.70$, and concreteness accounted for 6.8% unique variance, $F(1, 36) = 5.03$. Finally, subjective frequency accounted for only 3.8% unique variance, $F(1, 36) = 2.81, p > .10$.

Discussion

Summary of experimental conditions 5A-5D. As predicted, there was an effect of nonword context on both the experimental word and the nonword response latencies. That is, as word-nonword discriminations became more difficult in each succeeding experimental condition, more time was taken before responses were made. In addition, the effect of lexicality also changed across the experimental conditions. Interestingly, word and nonword latencies were most dissimilar in the illegal nonword and in the pseudohomophone contexts. In addition, the dissimilarities had different signs. That is, in the illegal nonword context responses were *faster* for the nonwords than for the words, whereas in the pseudohomophone context responses were slower for the nonwords than for the words. This 'reverse lexicality' effect observed in the illegal nonword context was also observed in the no neighbor nonword context. Taken together, these findings are consistent with those observed in lexical decision and demonstrate that the inclusion of more wordlike nonwords lead to more extensive processing.

A semantic distance by nonword context interaction was observed in the response latency data. Examination of the effects of semantic distance in each nonword context revealed that semantic distance exerted facilitatory effects on response latencies in all four of the experimental conditions. This is similar to the effects of semantic distance on response latencies observed in the lexical decision experiment, save for the null effect of semantic distance in the illegal nonword context in that experiment. The correlation analyses of the two experiments revealed why the results in the illegal nonword context were different between the experiments. In lexical decision, semantic distance was not correlated with response latency (nor were any other semantic variables), whereas summed lexical activation was. In the present experiment, the opposite was observed, in that semantic distance was correlated with response latency, but summed lexical activation was not. This latter finding suggests that although illegal nonwords are easily distinguished from words, the added semantic categorization component presumably necessitated that participants rely on semantic processing to distinguish between the experimental words and the animal names. Thus, there were no truly 'easy' experimental conditions in the present experiment.

There was also a semantic distance by nonword context interaction in the error rate data. Examination of the effects of semantic distance in each nonword context revealed that semantic distance exerted facilitatory effects on error rates in the no neighbor nonword, in the matched nonword, and in the pseudohomophone contexts, but not in the illegal nonword context.

In addition, the semantic distance by nonword context interactions for the response latency and the error rate data were followed-up by examining whether nonword context influenced the effects of semantic distance. A close inspection of the data reveals an interesting pattern of results. First, in the comparison of the effects of semantic distance between the illegal nonword and the no neighbor nonword contexts, semantic distance exerted larger effects on response latencies but not on error rates. Second, in the comparison between the no neighbor nonword and the matched nonword contexts, semantic distance exerted larger effects on error rates but not on response latencies. Finally, in the comparison between the matched nonword and the pseudohomophone contexts, semantic distance exerted larger effects on response latencies but not on error rates.

This seemingly helter skelter pattern of results may be explained by the following. For the response latency data, in each instance in which there was an increase in response latency to the experimental words, there was a corresponding increase in the effect of semantic distance. The same held for the error rate data, in that when there was an increase in error rates to the experimental words, there was a corresponding increase in the effect of semantic distance. Conversely, for both the response latency and the error rate data, in each instance in which there was a similarity in response latency or error rates to the experimental words, there was no increase in the effect of semantic distance. Thus, increases in the effects of semantic distance across nonword contexts were contingent on the presence of a corresponding increase to response latencies or to error rates.

Although the findings of the present experiment were slightly different than those observed in the lexical decision experiment, the basic patterns were similar: Semantic distance exerted larger effects in the more difficult conditions. Thus, the ideal strategy manipulation methodology, as was the case with the procedural strategy manipulation methodology employed in Chapter 3, elicited differential effects of semantic distance in a task requiring semantic processing.

Interestingly, in the pseudohomophone context of the present experiment, subjective frequency did not account for unique variance, whereas it did in the pseudohomophone context of the lexical decision experiment. This was somewhat unexpected, because it is assumed that participants rely on orthographic information to make word responses when words are intermixed with pseudohomophones. This assumption reflects the observation that orthography would be the only reliable cue as to the lexicality of these stimuli. If, as suggested in Chapter 2, the Balota et al. (2001) subjective reading ratings tap into how familiar participants are with word spellings, then these ratings should have accounted for unique variance in the pseudohomophone context. Further work will need to address this issue through perhaps the development of a more reliable variable that indexes orthographic processing.

Exploratory analyses. How does the addition of a semantic categorization component influence responses in lexical decision? Exploratory analyses were performed to investigate this issue. A caveat must be acknowledged at this point. That is, the intention of conducting the present experiment and the lexical decision experiment in Chapter 2 was to examine interactions between semantic distance and strategic control of processing within each task. As noted, the ideal strategy manipulation methodology is an appropriate design to use to examine within-task comparisons. It is not designed for cross-task comparisons, however, and therefore, it is important to keep in mind that the following analyses are exploratory in nature, and that no major conclusions of this thesis are based on them. Clearly, a within-subjects design would be more appropriate to properly conduct cross-task comparisons of the effects of semantic distance in the lexical decision and lexical decision/semantic categorization tasks. With this caveat in mind, the following analyses were conducted.

To examine whether the magnitude of the effects of semantic distance increased across experiments, the data from each of the nonword contexts from the two experiments were submitted to a 2 (semantic distance: high, low) x 2 (experiment type: lexical decision, lexical decision/semantic categorization) mixed-model ANOVA. Semantic distance was a within-subjects manipulation and experiment type was a between-subjects manipulation. Both subject (F_1) and item (F_2) analyses were performed.

For the illegal nonword condition, there was a main effect of semantic distance, $F_1(1, 70) = 14.17$, $MSE = 991.29$, $F_2(1, 38) = 4.71$, $MSE = 1{,}630.54$, with responses to the low semantic distance words an average of 20 ms faster than responses to the high semantic distance words. There was a main effect of experiment type, $F_1(1, 70) = 275.21$, $MSE = 9{,}599.40$, $F_2(1, 38) = 861.50$, $MSE = 1{,}693.91$, with responses an average of 271 ms faster in lexical decision than in lexical decision/semantic categorization. There was also a semantic distance by experiment type interaction in the subject analysis, $F_1(1, 70) = 10.52$, $MSE = 991.29$, and it was marginal in the item analysis, $F_2(1, 38) = 3.36$, $p = .07$, $MSE = 1{,}693.91$. The effects of semantic distance were larger in lexical decision/semantic categorization (37 ms) than in lexical decision (3 ms).

For the no neighbor nonword condition, there was a main effect of semantic distance, $F_1(1, 70) = 71.71$, $MSE = 1{,}360.82$, $F_2(1, 38) = 13.93$, $MSE = 3{,}766.72$, with responses to the low semantic distance words an average of 52 ms faster than responses to the high semantic distance words. There was a main effect of experiment type, $F_1(1, 70) = 180.44$, $MSE = 17{,}507.15$, $F_2(1, 38) = 1{,}421.51$, $MSE = 1{,}230.67$, with responses an average of 296 ms faster in lexical decision than in lexical decision/semantic categorization. There was no semantic distance by experiment type interaction, both Fs < 1, with the effects of semantic distance similar in both lexical decision/semantic categorization (56 ms) and lexical decision (48 ms).

For the matched nonword condition, there was a main effect of semantic distance, $F_1(1, 70) = 57.62$, $MSE = 2{,}050.65$, $F_2(1, 38) = 13.95$, $MSE = 5{,}269.94$, with responses to the low semantic distance words an average of 57 ms faster than responses to the high semantic distance words. There was a main effect of experiment type, $F_1(1, 70) = 106.39$, $MSE = 19{,}949.82$, $F_2(1, 38) = 870.50$, $MSE = 1{,}351.08$, with responses an average of 243 ms faster in lexical decision than in lexical decision/semantic categorization. There was no interaction between semantic distance and experiment type, both Fs < 1, with the effects of semantic distance similar in both lexical decision/semantic categorization (55 ms) and lexical decision (59 ms).

Finally, in the pseudohomophone context, there was a main effect of semantic distance, $F_1(1, 70) = 116.02$, $MSE = 1{,}682.34$, $F_2(1, 38) = 16.43$, $MSE = 7{,}148.46$, with responses to the low semantic distance words an average of 74 ms faster than responses to the high semantic distance words. There was a main effect of experiment type, $F_1(1, 70) = 109.81$, $MSE = 22{,}166.40$, $F_2(1, 38) = 513.40$, $MSE = 2{,}679.64$, with responses an average of 260 ms faster in lexical decision than in lexical decision/semantic categorization. There was an interaction between semantic distance and experiment type in the subject analysis, $F_1(1, 70) = 4.69$, $MSE = 1{,}682.34$, but not in the item analysis, $F_2(1, 38) = 2.42$, $p = .12$, $MSE = 2{,}679.64$. The effects of semantic distance were larger in lexical decision/semantic categorization (89 ms) than in lexical decision (59 ms).

There are several interesting findings from these exploratory analyses. First, it appears that adding a semantic categorization component to the lexical decision task adds approximately 250 ms to the time taken to respond. This should not be surprising considering that participants in the lexical decision/semantic categorization task make two decisions. Not only do they have to decide if the stimulus is a word or a nonword, but if the stimulus is a word they then have to decide whether it is an animal name.

Second, the addition of the semantic categorization component appears to influence the effect of semantic distance in the illegal nonword and in the pseudohomophone contexts. The most likely reason for the increase in the effects of semantic distance in the illegal nonword context of the lexical decision/semantic categorization task is because this condition now requires semantic processing, unlike in the lexical decision task in which early monitoring of summed lexical activation was sufficient to respond correctly. As for the pseudohomophone context, it appears that the additional semantic processing generated by the inclusion of the pseudohomophones requires more time to make decisions and consequently more time for semantic distance to exert its effect. Future research will need to address these preliminary findings in a more direct way, by designing experiments to explicitly tease apart the effects of adding a semantic categorization component to lexical decision. In so doing, the question of why subjective frequency did not account for unique variance in the lexical decision/semantic categorization task can also be directly examined.

Thus far, facilitatory effects of semantic distance have been observed in lexical decision (Chapter 2), go/no-go semantic categorization (Chapter 3), and lexical decision/semantic categorization (the present Chapter). All of these tasks contain a decisional component. To determine whether the effects of semantic distance would be observed in a task that does not contain a decisional component, the final task in this thesis is the word naming task. Contrasts between decision based and non-decision based tasks are important, because if semantic distance does not influence processing in a task without a decisional component, such as word naming, then perhaps its greatest influence is not on lexical processing per se, but instead on task-specific (i.e., decisional) processing. The focus of Chapter 5, therefore, will be to examine whether effects of semantic distance can be observed in word naming.

CHAPTER 5

WORD NAMING

Thus far, the results of this thesis have demonstrated that semantic distance exerts facilitatory effects in tasks in which responses are based primarily on activation in the orthographic module (lexical decision), the semantic module (semantic categorization), and both the orthographic and semantic modules (lexical decision/semantic categorization). Moreover, these findings demonstrated that the facilitatory effects of semantic distance interacted with strategic control of lexical processing: Larger effects of semantic distance were observed in conditions requiring more extensive processing. The present experiment was therefore conducted to determine whether facilitatory effects of semantic distance would be observed in the word naming task, a task in which responses are based primarily on activation in the phonological module. In addition, the experiment was conducted to examine whether the effects of semantic distance in word naming would be modulated by strategic processing through the use of an ideal strategy manipulation.

I will begin the chapter by discussing the importance of examining the effects of semantic distance in the word naming task. Next, the methodology and results of the present word naming experiment will be described. The chapter will conclude with a cross-module activation account for the results from the present experiment.

The Importance of the Word Naming Task in Examining Semantic Distance Effects

The present investigation of the effects of semantic distance in the word naming task is important. As reviewed at the end of Chapter 2, many researchers (e.g., Andrews, 1997; Andrews & Heathcote, 2001; Balota & Chumbley, 1984, 1985; Carr et al., 1979;

Hino & Lupker, 1996; Meyer et al., 1975) note that there is no one word recognition task free of task-specific processes, and argue that it is crucial to examine a variable of interest in more than one task. Although several different lexical processing tasks have been used in this thesis thus far, all of these tasks contain one or more decisional components. Thus, a claim that semantic distance exerts its influence primarily on decisional processes that are task-specific, and not part of the normal word recognition system, cannot be ruled out. It is therefore important to examine semantic distance effects in a task without a decisional component, such as word naming.

A null effect of semantic distance in word naming performance may be taken as evidence that semantic distance does not influence lexical selection processes common to word naming, lexical decision, and semantic categorization. Instead, semantic distance may be restricted to influencing decisional processes specific to lexical decision and semantic categorization. If, on the other hand, semantic distance exerts an influence on word naming performance, then one can be more confident that at least part of its influence is on lexical selection processes common to the different tasks.

However, recall that Buchanan et al. (2001; Experiment 1) reported a null effect of semantic distance in word naming performance for young adults. This null effect is tempered by the following findings. Buchanan et al. (2001) reported that semantic distance influenced word naming performance for older adults. They suggested that for this population,

> "(semantics) plays an increasing role as other processes decline. This age effect may be a compensatory strategy on the part of the older adults, or it

may reflect an overall slowing of responses that allows secondary processes, such as semantic analysis, to show up in naming RTs" (p. 539).

Relatedly, other investigators have observed that semantic effects in word naming are restricted to items that produce slow response latencies (presumably because they require deeper processing). For example, Hino et al. (2002) used Japanese materials and reported inhibitory synonymy effects in naming for Kanji words, which have relatively inconsistent mappings from character-to-sound, but not for Katakana words, which have more consistent character-to-sound mappings. In addition, Strain et al. (1995) and Cortese et al. (1997) reported facilitatory effects of imagery in naming only for low-frequency irregular words but not for low-frequency regular words.

The above findings argue for the need to increase depth of processing to uncover some semantic effects in word naming. This is consistent with the findings of Chapter 3 demonstrating larger semantic distance effects in the more demanding go/no-go semantic categorization task than in the yes/no semantic categorization task. Consequently, the present experiment was conducted to determine whether facilitatory effects of semantic distance would emerge in word naming as task difficulty increased.

Experiment 6 – Word Naming

The Method section of Experiment 1 describes the stimulus characteristics of the experimental stimuli. In addition to these characteristics, the 40 experimental items are all regular and consistent in their orthographic-to-phonological properties: Regular because they can be correctly pronounced according to spelling-to-sound rules (see Venezky, 1970, and Wijk, 1966, for efforts to list these rules) and consistent because their word body neighbors (e.g., SPENT and TENT are word body neighbors because they possess the same initial vowel(s) and subsequent consonants; see Treiman et al., 1995) are pronounced the same way as the target word (Jared, 1997; Jared, McRae, & Seidenberg, 1990). These phonological properties were controlled in the present experiment, because previous research has demonstrated that regular and/or consistent words are pronounced more rapidly and more accurately than irregular and/or inconsistent words (e.g., Coltheart & Rastle, 1994; Glushko, 1979; Jared, 1997; Jared et al., 1990; Paap & Noel, 1991; Seidenberg, Waters, Barnes, & Tanenhaus, 1984; Taraban & McClelland, 1987; Waters & Seidenberg, 1985).

The experiment has two conditions: A pure condition in which the experimental words were presented alone, and a mixed condition in which the same experimental words were presented with irregular and/or inconsistent words. The experiment thus employed an ideal strategy manipulation because the experimental word stimuli, procedural variables, and the response requirements were identical in both conditions. The only difference between conditions was the context in which the experimental words were presented (i.e., either alone or intermixed with irregular-inconsistent words). This design allows inferences to be made regarding the interaction between semantic distance effects and strategic control of processing. It is assumed that deeper processing will be required in the mixed condition because of the inclusion of the irregular-inconsistent words. Based on this assumption, it is predicted that semantic distance effects will emerge in the mixed condition.

Method

Participants. Seventy-two first-year undergraduate students from the University of Alberta participated in the experiment for course credit; half of the participants were assigned to the pure condition (experimental words alone), and the other half were assigned to the mixed condition (experimental and irregular-inconsistent words). All were native English speakers and reported normal or corrected-to-normal vision. None of these individuals participated in more than one experimental condition, in any of the previous experiments, or in the collection of norming data.

Experimental word stimuli. The experimental word stimuli are identical to those used in Experiment 1, described in Chapter 2.

Irregular-inconsistent word stimuli. In the mixed condition, 80 additional monosyllabic words (40 four-letter and 40 five-letter words) were selected on the basis of their being either irregular (i.e., words that cannot be pronounced according to spelling-to-sound rules, e.g., CHOIR, ACHE), or inconsistent (i.e., words that have phonological neighbors that are pronounced differently, e.g., BROOD-flood, PEAR-dear). The mean CELEX printed word frequency of these irregular-inconsistent word stimuli was 10.11 (presented in Appendix F).

Apparatus and procedure. The stimuli were presented on an iMac computer using PsyScope software (Cohen, MacWhinney, Flatt, & Provost, 1993). In the pure condition, only the 40 experimental items were presented, whereas in the mixed condition these words were intermixed with the 80 irregular-inconsistent items.

The procedure employed was similar to that used by Lichacz, et al. (1999). That is, each participant first named aloud all the words in a speeded naming block, and then named aloud all the words in a delayed naming block. Responses were made into a microphone connected to a voice-activated relay interfaced with the computer. For every trial in the speeded naming block, a 1 s blank screen was followed by a fixation cross that appeared at the center of the computer monitor for 1 s, and was then replaced by a word stimulus (presented in lowercase letters). Participants were instructed to read aloud the stimulus words as quickly and as accurately as possible. The participant's response terminated the stimulus display, and the next trial was initiated after a timed interval of 1 s. Response latencies were measured to the nearest millisecond from the appearance on the monitor of the stimulus word to the onset of the participant's response.

For every trial in the delayed naming block, the stimulus word initially appeared on the monitor for 1.5 s, as black on a white background (the same as in the speeded naming block). After 1.5 s, the stimulus words changed color, from black to red. Participants were instructed to prepare naming responses (but not execute them) while the stimulus words appeared in black, and then to read them aloud as quickly and as accurately as possible when they changed color to red. The stimulus words remained in red on the screen until a response was detected. Response latencies were measured to the nearest millisecond from the time the stimulus words changed color to the onset of the participant's response. The order in which the stimuli were presented in each of the two naming blocks was randomized separately for each participant. The experimenter recorded errors and trials in which the microphone either did not pick up the participant's response or picked up an extraneous noise (e.g., coughing).

This two-phase procedure was used because the two semantic distance word conditions were not matched for initial phoneme. To ensure that this variable did not unduly influence the results, for each participant, and on an item-by-item basis, delayed naming latencies were subtracted from speeded naming latencies. This procedure yielded a difference score for every item for every participant, and these difference scores were used as the dependent measure in the response latency analysis.

Participants completed 20 practice trials prior to the collection of data. In the pure condition, half of the practice stimuli were four letters in length and the other half were five letters in length, and all were regular-consistent and of the same frequency range as the experimental word stimuli. In the mixed condition, half of the practice stimuli were four letters in length and the other half were five letters in length, and all were irregular or inconsistent and of the same frequency range as the experimental word stimuli.

Design. A 2 (semantic distance: high, low) x 2 (word condition: pure, mixed) mixed factorial design was used. For the experimental words, difference score latencies were submitted to a 2 (semantic distance: high vs. low) x 2 (word condition: pure vs. mixed) mixed-model ANOVA. No analyses were carried out on the error rate data because so few errors were made. Semantic distance was manipulated within-subjects and word condition was manipulated between-subjects. Both subject (F_1) and item (F_2) analyses were performed.

Results

In the speeded naming block, 1.0% and 1.5% of the data were removed from the pure and mixed conditions, respectively, because of mechanical error (i.e., the microphone failing to detect a response or detecting an extraneous noise). In the delayed naming block, mechanical error resulted in 0.4% and 1.6% of the data being removed from the pure and mixed conditions, respectively. In addition, 0.9% and 1.0% of the data were removed from the pure and mixed conditions, respectively, because these responses were made prior to the stimuli changing color.

In the speeded naming block, response latencies less than 250 ms or more than 2,000 ms were considered outliers and were removed from the data set. Using this procedure, no data were removed from the pure condition and 0.2% of the responses were removed from the mixed condition. In the delayed naming block, response latencies less than 100 ms or more than 1,000 ms were considered outliers and were removed from the data set. Using this procedure, 0.3% of the responses from the pure condition and 1.2% of the responses from the mixed condition were removed.

If a response to an item was removed from one of the naming blocks, the corresponding response to that item was removed in the other naming block. Thus, in the pure condition, the final data set consisted of 1,375 of the original 1,440 pairs of data points. In the mixed condition, the final data set consisted of 1,348 of the original 1,440 pairs of data points. The mean speeded naming, delayed naming, and difference score latencies for the irregular-inconsistent words were 608 ms, 456 ms, and 152 ms, respectively, and the mean speeded and delayed error rates were 8.3% and 5.3%, respectively. The mean speeded naming, delayed naming, and difference score latencies for correct responses, and the mean speeded naming and delayed naming error rates for each word condition are shown in Table 5-1.

To determine whether the inclusion of irregular-inconsistent words made the naming of the experimental words more difficult (and presumably resulted in deeper processing), the speeded naming and the delayed naming data were submitted to a one-way between-subjects ANOVA. In the speeded naming block, there was a main effect of

Table 5-1
Mean Speeded Naming Latencies (in Milliseconds), Delayed Naming Latencies, Difference Scores, and Standard Errors, and Mean Error Rates (Percentages) and Standard Errors for the Experimental Word Stimuli in the Pure and Mixed Conditions in Experiment 6

	Response latencies			
	Pure condition		Mixed condition	
	High SemD	Low SemD	High SemD	Low SemD
Speeded naming	508 (9.1)	500 (7.5)	585 (12.3)	567 (11.9)
Delayed naming	388 (12.6)	384 (12.1)	453 (16.0)	460 (13.7)
Difference scores	120 (12.7)	116 (11.0)	132 (16.4)	107 (13.6)

	Error Rates			
	Pure Condition		Mixed Condition	
	High SemD	Low SemD	High SemD	Low SemD
Speeded Naming	0.4 (0.2)	0.9 (0.6)	0.5 (0.4)	0.4 (0.4)
Delayed Naming	0.1 (0.0)	0.4 (0.4)	0.0 (0.0)	0.0 (0.0)

Note. SemD = semantic distance. Standard errors appear in parentheses. Error rates for the difference scores include errors made in both the speeded naming and delayed naming conditions.

word condition on the response latencies, $F_1(1, 70) = 25.05$, $MSE = 7{,}436.31$, $F_2(1, 38) = 229.55$, $MSE = 457.81$, but not on the error rates, both Fs < 1. Speeded naming latencies were an average of 72 ms slower in the mixed condition than in the pure condition. In the delayed naming block, there was a main effect of word condition on the response latencies, $F_1(1, 70) = 13.91$, $MSE = 13{,}014.93$, $F_2(1, 38) = 272.32$, MSE = 365.44, but not on the error rates, both Fs < 1. Interestingly, delayed naming latencies were an average of 71 ms slower in the mixed condition than in the pure condition. Thus, even after a 1.5 second delay between the presentation of a word and the signal to initiate a naming response, the inclusion of irregular-inconsistent words made the task of naming the experimental words more difficult. Having demonstrated that more processing was required before naming responses were generated and executed in the mixed condition than in the pure condition, the effects of semantic distance, word condition, and their interaction on the difference score data were examined.

Response latencies. There was a main effect of semantic distance, $F_1(1, 70) = 9.31$, $MSE = 796.13$, $F_2(1, 38) = 8.35$, $MSE = 488.85$, with difference scores to the low semantic distance words an average of 14 ms lower than difference scores to the high semantic distance words. There was no main effect of word condition, both Fs < 1, with difference score latencies in the pure condition and in the mixed condition being identical. There was a semantic distance by word condition interaction, $F_1(1, 70) = 5.44$, $MSE = 796.13$, $F_2(1, 38) = 5.92$, $MSE = 337.40$. In the pure condition, there was no effect of semantic distance, both ts < 1, with difference scores to the low semantic distance words only 4 ms lower than difference scores to the high semantic distance words. Conversely, in the mixed condition there was an effect of semantic distance, $t_1(70) = 3.76$, $t_2(38) = 5.91$, with difference scores to the low semantic distance words 25 ms lower than difference scores to the high semantic distance words.

Correlation analyses. Relationships between mean item response latency and the predictor variables were examined. For the predictor variables, both summed lexical activation and animalness ratings were excluded, as these variables should not influence processing in the word naming task. Nelson et al.'s (1994) number of associates norms were included in the correlation analysis because Buchanan et al. (2001) reported that these values predicted young adult naming latencies. Table 5-2 lists the single order correlations between the number of associates variable and the other predictor variables. As can be seen, number of associates was correlated with both semantic distance and subjective frequency.

Table 5-3 lists the correlations between response latency and the predictor variables. For the pure condition, none of the predictor variables correlated with response latency. For the mixed condition, semantic distance and subjective frequency correlated with response latency. These two variables, along with number of associates, were included in the regression equation and together accounted for 28.7% of the response latency variance, $F(3, 36) = 4.83$. Semantic distance accounted for 13.2% unique variance, $F(1, 36) = 6.66$. Neither subjective frequency (2.2%) nor number of associates (zero percent) accounted for any unique variance.

Discussion

Buchanan et al. (2001) reported that semantic distance did not predict young adult naming latencies. In the present experiment, this null effect of semantic distance on naming performance was replicated when only words with regular and consistent spelling-to-sound characteristics (pure condition) were presented. When these same items were intermixed with irregular-inconsistent words (mixed condition), however, two

Table 5-2
Single-Order Correlations Between Number of Associates, Log Frequency, Subjective Frequency, Length in Letters, Orthographic Neighborhood Size, Number of Meanings, Concreteness, Imageability, and Semantic Distance

	LogF	SubF	LL	ON	NoM	Conc	Imag	SemD
NoA	-.10	.35*	-.23	.28	.15	-.18	-.15	-.37*

Note. $df = 38$. NoA = number of associates; LogF = log frequency; SubF = subjective frequency; LL = length in letters; ON = orthographic neighborhood size; NoM = number of meanings; Conc = concreteness; Imag = imageability; SemD = semantic distance.
* $p < .05$.

important results were uncovered. First, overall speeded naming (and delayed naming) response latencies were slower in the mixed condition than in the pure condition, indicating that more processing was required. Second, there was an effect of semantic distance for the difference score latencies in the mixed condition. This effect of semantic distance was facilitatory in that difference scores were lower to the low semantic distance words than to the high semantic distance words.

The finding of facilitatory effects of semantic distance in conditions in which the experimental items were intermixed with items that evoked slow responses is similar to the findings of Hino et al. (2002), Cortese et al. (1997), and Strain et al. (1995). These researchers reported that synonymy and imageability effects in word naming were restricted to low-frequency irregular or inconsistent items, items for which the generation of a phonological code is more difficult and hence slower. In the present study, the inclusion of these types of words in the mixed condition increased the difficulty of the task, therefore requiring greater processing of the stimuli. In the cross-module activation account, the increased processing in the mixed condition allows more time for cross-

Table 5-3

Single-Order Correlations Between Mean Item Latency, Log Frequency, Subjective Frequency, Length in Letters, Orthographic Neighborhood Size, Number of Meanings, Concreteness, Imageability, Number of Associates, and Semantic Distance for the Pure and Mixed Conditions in Experiment 6

Variables	Pure condition	Mixed condition
LogF	-.18	.03
SubF	-.19	-.38*
LL	.03	.11
ON	.06	-.28
NoM	.11	-.10
Conc	.07	-.05
Imag	.13	-.09
NoA	-.07	-.22
SemD	.18	.51*

Note. $df = 38$. RL = response latency; Illegal = illegal nonword context; No N = no neighbor nonword context; Matched = matched nonword context; Pseudo = pseudohomophone context; LogF = log frequency; SubF = subjective frequency; LL = length in letters; ON = orthographic neighborhood size; SLA = summed lexical activation values; NoM = number of meanings; Conc = concreteness; Imag = imageability; SemD = semantic distance.
* $p < .05$.

module activation from semantics to phonology to influence word naming performance.

The results of the present experiment are important because they demonstrate that semantic distance effects are observed in a task that contains no decisional component. It seems reasonable to conclude that semantic distance not only influences task-specific decisional processes, but that it influences processes common to word naming, lexical decision, and semantic categorization. This issue will be taken up in more detail in Chapter 6.

In conclusion, the word naming results provide further converging evidence, with those of lexical decision, go/no-go semantic categorization, and lexical decision/semantic categorization, that semantic distance influences lexical selection processes. One interesting finding that has emerged from this thesis is that semantic distance effects were observed only under conditions that required relatively extensive processing. In lexical decision, facilitatory semantic distance effects were observed only when word-nonword discriminations were relatively difficult (i.e., when nonwords were either orthographically legal and pronounceable or pseudohomophones), but not when they were easy (i.e., when nonwords were illegal consonant strings). In semantic categorization, facilitatory effects of semantic distance were observed under go/no-go conditions, but not under yes/no conditions. In lexical decision/semantic categorization, all of the experimental conditions required relatively deep processing, and facilitatory effects of semantic distance were observed in each condition. Finally, in word naming, the results of the present experiment demonstrate that semantic distance facilitates performance only when relatively slow items (i.e., irregular or inconsistent words) comprise part of the list to be named.

In Chapter 6, I will review the findings of this thesis and how they can be accommodated within the cross-module activation account. I will then discuss how these findings, along with other findings of semantic effects, reveal the interplay between task demands and the structure and processing of the visual word recognition system.

CHAPTER 6

GENERAL DISCUSSION

This thesis provides a comprehensive examination of the interactions between semantic distance and strategic control of lexical processing in the lexical decision, semantic categorization, lexical decision/semantic categorization, and word naming tasks, through the use of strategy manipulations. I will begin this final chapter with a review of the design and rationale for the strategy manipulations and a summary of the results obtained in these tasks. Next, I will describe how the present results fit within the cross-module activation account of semantic effects. I will then conclude with a discussion of the importance of considering relationships between the nature of different semantic variables and the nature of the processing evoked by different tasks. Finally, I will argue that consideration of this information can shed light on the lexical structures and processes involved in the identification of visually presented single words.

Strategy Manipulations and Semantic Distance Effects

Strategy manipulations help to isolate interactions between stimulus characteristics and strategic processing (Gibbs & Van Orden, 1998; Stone & Van Orden, 1993). Two types of strategy manipulations were used in the present thesis: Ideal strategy manipulations were used in the lexical decision, lexical decision/semantic categorization, and word naming experiments, and a procedural strategy manipulation was used in the semantic categorization experiments.

In an ideal strategy manipulation, the critical items of interest (referred to as the experimental items), procedural variables, and responses are identical across experimental conditions. The only difference across experimental conditions is the context in which the experimental items are presented (Stone & Van Orden, 1993). In a procedural strategy manipulation, the experimental items and the context in which they are presented are identical across experimental conditions. The only difference across experimental conditions is the procedure in which responses are made to the non-critical items.

In Chapter 2, the ideal strategy manipulation involved changing the nonword context in which the experimental items were embedded in the lexical decision stimulus set. The experimental items were intermixed with illegal nonwords, no neighbor nonwords, matched nonwords, or pseudohomophones. These types of nonwords vary in both their orthographic and phonological similarity to real words (see Chapter 2) and hence rest on different points of a hypothetical 'wordlikeness' continuum (see Figure 6-1), whereby wordlikeness is linked to processing depth. This yoked continuum is suggested because as nonwords become more wordlike, they are more difficult to distinguish from real words, and thus should engage increasingly greater amounts of processing to make reliable word-nonword judgments (e.g., Balota & Chumbley, 1984; Coltheart et al., 1977; Johnson & Pugh, 1994; Grainger & Jacobs, 1996). I hypothesized that this nonword context manipulation would result in increasingly longer response latencies to the words and the nonwords, and an associated increase in the effect of lexicality (i.e., there should be a larger discrepancy between responses to words and to nonwords as the task becomes more difficult; Borowsky & Masson, 1996) across the four nonword contexts. This is exactly the pattern of results that was obtained in the experiment.

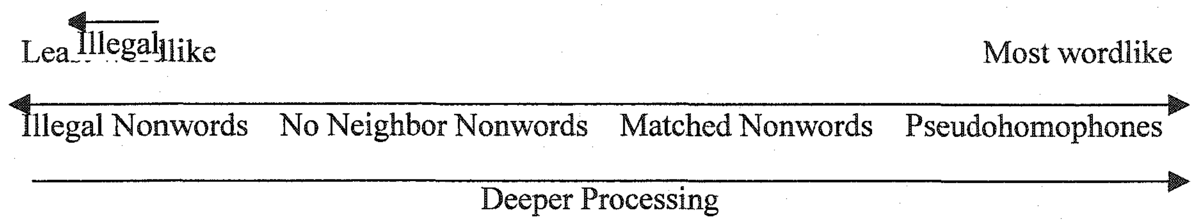

Figure 6-1. Placement of the four types of nonwords used in the lexical decision and lexical decision/semantic categorization experiments on a hypothetical 'wordlikeness' continuum, and the level of processing they would generate in their respective experimental conditions.

I further hypothesized that the illegal nonwords and the no neighbor nonwords would elicit relatively shallow processing because they are the easiest to distinguish from words, and hence the effects of semantic distance would be smallest in these two experimental conditions. Conversely, I hypothesized that the matched nonwords and the pseudohomophones would elicit deeper processing because they are the most difficult to distinguish from the words, and hence the effects of semantic distance would be greatest in these two conditions.

The correlation results indicated that shallow processing was elicited for the experimental items (i.e., the words) in the illegal nonword context but not in the no neighbor nonword, matched nonword, or pseudohomophone contexts. More specifically, summed lexical activation (a variable involved in early processing), but not semantic distance (a variable presumably involved in later processing), was correlated with word response latency in the illegal nonword context. On the other hand, semantic distance, but not summed lexical activation, was correlated with word response latency in the other three nonword contexts. This latter finding was unexpected in the no neighbor nonword context, but as will be discussed below, is consistent with the facilitatory effects of semantic distance observed in this condition.

In the ANOVA results, there was a semantic distance by nonword context interaction in the response latency data: There was no effect of semantic distance in the illegal nonword context, but there was an effect of semantic distance in the no neighbor nonword, matched nonword, and pseudohomophone contexts. This pattern of results is completely consistent with the correlation data. In the one condition in which responses were based early in processing (i.e., in the illegal nonword context responses were based on summed lexical activation generated in the orthographic module) there was no effect of semantic distance. In the other three conditions, responses were based later in processing and there was a strong effect of semantic distance.

The effects of semantic distance were larger in the no neighbor nonword context than in the illegal nonword context; were larger in the matched nonword context than in the no neighbor nonword context; but were similar between the matched nonword and pseudohomophone contexts. The correlation results provide some explanation for why the effects of semantic distance did not increase across the latter two nonword contexts. In the pseudohomophone context, subjective frequency and imageability, in addition to semantic distance, predicted response latency variance. Thus, in the most difficult condition, it appears that participants were recruiting multiple forms of information upon which to base their responses.

In summary, the ideal strategy manipulation used in the lexical decision experiment was successful in isolating when semantic distance influences lexical decision performance. Semantic distance did not influence performance when shallow processing of the stimuli was sufficient to drive responding. When deeper or more extensive processing was required to discriminate words from nonwords, however, semantic distance exerted a strong influence. This deeper processing occurred when words were intermixed with orthographically legal and pronounceable nonwords, and with pseudohomophones.

In Chapter 3, the experimental items were intermixed with animal name items. The procedural strategy manipulation involved changing the required response to the animal name items. In a yes/no condition, participants responded to the animal name and experimental items. In a go/no-go condition, participants responded to only the experimental items. Effects of semantic distance were observed in the go/no-go condition but not in the yes/no condition. A third experiment was conducted in which semantic distance and task condition were within-subject manipulations, and the same pattern of results was obtained.

I proposed that there was likely a bias to respond 'animal' in this particular task. To confirm this hypothesis, animalness ratings were collected for the experimental and animal name items and these ratings correlated with only the animal name stimuli. Moreover, the sign of the correlations was negative, such that responses were faster and more accurate for animal name items that had higher animalness ratings. In addition, responses were faster but less accurate for the animal name items than for the experimental items.

Because of this 'animal' bias, I postulated that deeper processing of the experimental stimuli was undertaken in the go/no-go condition than in the yes/no condition. This was because in the yes/no condition participants responded to the animal name items (and thus responded in accordance with the 'animal' bias), whereas in the go/no-go condition they did not (and thus did not respond in accordance with the bias). I argued that participants set a higher processing criterion in the go/no-go condition than in the yes/no condition to ensure that lexical selection supported correct responses. Thus, deeper processing of the experimental items was carried out in the go/no-go condition to rule out the possibility that these items were animal names, resulting in longer response latencies but lower error rates for the experimental items in this condition than in the yes/no condition.

In summary, the procedural strategy manipulation used in the semantic categorization experiments isolated the influences of semantic distance on semantic categorization performance. Semantic distance did not significantly influence performance when participants were allowed to respond in accordance with the 'animal' bias (i.e., were allowed to respond to the animal name items). When participants were not allowed to respond in accordance with the bias, they engaged in deeper processing of the experimental items to ensure they were not animal names, and semantic distance exerted a strong influence.

In Chapter 4, a novel methodology was introduced in which the lexical decision and semantic categorization tasks were combined into a single task, which I called the lexical decision/semantic categorization task. The same animal name items used in Experiment 2 (yes/no semantic categorization) were used in the lexical decision/semantic categorization experiment. The ideal strategy manipulation involved intermixing the experimental and animal name stimuli with the four different nonword types used in the lexical decision experiment. Participants were asked to respond to the experimental and nonword items, but not to the animal name items. I hypothesized that deeper processing would be necessary to respond as the nonwords became increasingly more wordlike (see

Figure 6-1), and that this would lead to slower response latencies to the word and nonword stimuli, and a corresponding increase in the effects of lexicality and semantic distance.

As predicted, when word-nonword discriminations became more difficult in each succeeding experimental condition, response latencies increased. In addition, the effect of lexicality also changed across the experimental conditions. Interestingly, word responses were slower than nonword responses in the illegal nonword and no neighbor nonword contexts. This reverse lexicality effect was larger in the former condition than in the latter condition. The expected lexicality effect was obtained in the matched nonword and pseudohomophone contexts, with the effect being larger in the latter condition. Taken together, these results demonstrate that the inclusion of more wordlike nonwords lead to deeper processing in this novel task.

The correlation data also revealed that relatively deep processing was carried out in each experimental condition. In all four conditions, summed lexical activation did not correlate with response latency, whereas semantic distance (and subjective frequency and concreteness) did. Thus, although task demands became more difficult across the nonword contexts, there were no truly easy conditions in the lexical decision/semantic categorization task.

A semantic distance by nonword context interaction was observed in the response latency and error rate data. For the response latency data, there was an effect of semantic distance in each nonword context. For the error rate data, there was no effect of semantic distance in the illegal nonword context, but there was an effect of semantic distance in the other three nonword contexts.

There was an interesting pattern of effects when the semantic distance by nonword context interactions for the response latency and the error rate data were followed-up by examining whether nonword context influenced the effects of semantic distance. For the response latency data, in each instance in which there was an increase in response latency to the experimental words, there was a corresponding increase in the effect of semantic distance. This occurred between the illegal nonword and no neighbor nonwords, and between the matched nonwords and pseudohomophones. In the case of the comparison between the no neighbor and matched nonwords, there was no increase in response latency to the experimental words and no corresponding increase in the effect of semantic distance. For the error rate data, in the one instance in which there was an increase in error rates to the experimental words (i.e., between the no neighbor and matched nonwords), there was a corresponding increase in the effect of semantic distance. In the instances in which there was no increase in the error rates, there was no corresponding increase in the effect of semantic distance. This occurred between the illegal nonword and no neighbor nonwords, and between the matched nonwords and pseudohomophones. Thus, increases in the effects of semantic distance across nonword contexts were contingent on the presence of a corresponding increase to response latencies or to error rates. In other words, the semantic distance effect is intimately linked to the effect that depth of processing manipulations have on the overall response characteristics.

In summary, the ideal strategy manipulation used in the lexical decision/semantic categorization experiment isolated when semantic distance influences lexical decision/semantic categorization performance. Relatively deep processing was required in each experimental condition, and semantic distance exerted an effect in every one. The effect, however, became larger across nonword contexts whenever response latency or error rates increased across nonword contexts.

In Chapter 5, the ideal strategy manipulation involved changing the context in which the experimental items were presented in a word naming stimulus set. In one context the experimental items, which were all regular-consistent in their orthographic-to-phonological properties, were presented alone (pure condition). In the other context the experimental items were intermixed with irregular-inconsistent words (mixed condition). Deeper processing of the stimuli was expected in the mixed condition, because many studies have reported that irregular and/or inconsistent words are pronounced more slowly than regular and/or consistent words (e.g., Coltheart & Rastle, 1994; Glushko, 1979; Jared, 1997; Jared et al., 1990; Paap & Noel, 1991; Seidenberg et al., 1984; Taraban & McClelland, 1987; Waters & Seidenberg, 1985).

Deeper processing was indeed elicited in the mixed condition as compared to the pure condition, in both the speeded and delayed naming conditions. Correspondingly, there was a semantic distance by condition interaction, reflecting that semantic distance exerted an effect only in the mixed condition. The ideal strategy manipulation methodology isolated when semantic distance exerted its effects in word naming—only in the condition in which task demands required deep and extensive processing.

The data from the four experimental tasks provide a relatively clear picture that facilitatory semantic distance effects (see Table 6-1) are obtained in lexical processing conditions requiring deep and extensive processing of the experimental stimuli. The next section will review the cross-module activation account and how it explains the present

Table 6-1
Summary of the Effects of Number of Meanings, Concreteness/Imageability, Number of Features, Synonymy, and Semantic Distance in Lexical Decision, Word Naming, Semantic Categorization, and Lexical Decision/Semantic Categorization

Variable	LDT	WNT	SCT	LD/SCT
Number of meanings	+	+	-	?
Concreteness/Imageability	+	+	?	?
Number of features	+	+	?	?
Synonymy	-	-	null	?
Semantic Distance	+	+	+	+

Note. LDT = lexical decision task; WNT = word naming task; SCT = semantic categorization task; LD/SCT = lexical decision/semantic categorization task; + = facilitatory effect; - = inhibitory effect; ? = semantic variable not yet examined; null = null effect.

data.

The Cross-Module Activation Account of Semantic Distance Effects

Hino and colleagues (Hino & Lupker, 1996; Hino et al., 2002; Pexman & Lupker, 1999; Pexman et al., in press) provide an account of various semantic effects on lexical processing. I referred to their account in this thesis as cross-module activation. This account incorporates several key assumptions of Seidenberg and McClelland's (1989, p. 526) general framework of lexical processing. First, it assumes that there are (at least) three separate sets, or modules, of units in the lexical processing system. One module is dedicated to the processing of orthographic information, a second to the processing of phonological information, and a third to the processing of semantic information. Second, these modules are assumed to be fully interconnected, such that the processing of one module may influence the processing of the other modules. Third, words are represented in a distributed fashion, that is, as patterns of activation over many units. For example, a word is represented semantically as a pattern of activation over the semantic units. The cross-module activation account further assumes that responses elicited in a particular task are based on the activation of a particular module. More specifically, lexical decision responses are assumed to be based primarily on the activation of the orthographic module, word naming responses are based primarily on the activation of the phonological module, and semantic categorizations are based primarily on the activation of the semantic module (Hino et al., 2002).

The cross-module activation account explains the effects observed in the lexical decision task in the following manner. When a word is presented, activation first accrues in the orthographic module. Cross-module activation then flows from orthography to semantics, where the semantic codes of the word and its semantic neighbors are then activated. Low semantic distance words generate richer and more extensive semantic processing (i.e., they activate more semantic codes) than high semantic distance words. This is because, within a specified radius in the high-dimensional space, low semantic distance words have, on average, more semantic neighbors than high semantic distance words. Cross-module activation then flows from semantics back to orthography. Because low semantic distance words generated more semantic activation in the semantic module than high semantic distance words, they also generate more extensive cross-module activation from semantics back to orthography. This leads to faster settling of the orthographic codes, and a corresponding decrease in response latency, for low than for high semantic distance words.

According to this account, the null effect of semantic distance in the illegal nonword context is due to responses being based on early levels of activation in the orthographic module, prior to any activation arriving from semantics. In the other three nonword contexts, word-nonword discriminations were difficult enough to allow time for cross-module activation from semantics to orthography to exert an effect. In the most difficult experimental condition, namely the pseudohomophone context, semantic distance was not the only variable to influence performance, and this may have mitigated against an increase in its effects under those conditions.

The cross-module activation account provides the following explanation for the differential effects of semantic distance in the pure and mixed conditions in the word naming task. Activation from the orthographic module flows to the phonological and semantic modules. In the pure condition, the mappings from orthography to phonology are consistent for both the low and the high semantic distance words. If the cross-module activation from orthography to phonology is sufficiently reliable to settle on correct phonological codes before cross-module activation from semantics to phonology can exert an effect, then this would explain why semantic distance does not influence word naming performance in the pure condition. In the mixed condition, however, the orthographic-to-phonological mappings are inconsistent for the majority of the words, and thus more time is needed to determine and settle on correct phonological codes. This allows time for cross-module activation from semantics to phonology to exert an effect. The increased semantic activation generated by low semantic distance words leads to greater cross-module activation from semantics to phonology, and hence a decrease in the time taken to settle on a particular phonological code for these words.

The cross-module activation account provides a different explanation for the semantic categorization results. Because responses in this task are assumed to be based primarily on activation in the semantic module, cross-module activation from semantics to orthography or to phonology is assumed to play little role in this task (Hino et al., 2002). Instead, it is cross-module activation from orthography to semantics that is assumed to play an important role in determining the speed with which responses are made. As described above, cross-module activation from orthography to semantics activates the semantic codes for the target word and its semantic neighbors. Because semantically similar words recruit similar units and connections in the semantic module, the semantic code of a given word would be strengthened whenever it or one of its semantic neighbors is encountered. Low semantic distance words would therefore benefit more than high semantic distance words from the presentation of their semantic neighbors because they have more neighbors. Thus, low semantic distance words would have stronger and richer semantic codes, the consequence being that when these types of words are encountered settling time is reduced, leading to faster responses.

It therefore appears that semantic distance exerts at least two types of influence on the lexical processing system. The first type of influence could be called a *cross-semantic effect*, because the effect arises from semantic neighbors influencing the settling times of orthographic and phonological codes (codes located outside the semantic module). The second type of influence could be called a *within-semantic effect*, because the effect arises from semantic neighbors influencing the settling times of semantic codes (codes located inside the semantic module).

The cross-module activation account assumes that both of these semantic effects influence performance in lexical decision/semantic categorization, because monitoring the activation in the orthographic and semantic modules is arguably required to perform this task (see Chapter 4). If this is the case, then the facilitatory semantic distance effects obtained in this task suggest that cross-semantic and within-semantic effects can co-occur in the same task.

The Cross-Module Activation Account of Interactions Between the Nature of Semantics and the Nature of Task Demands

An inspection of Table 6-1 reveals that the effects of different semantic variables are not necessarily uniform either across or within tasks. To make sense of this pattern of effects, it is necessary to address a) the nature of each semantic variable and the types of mental representations they presumably activate, and b) the types of demands different tasks place on the visual word recognition system.

In the lexical decision and word naming tasks, responses are assumed to be based on activation in the orthographic and phonological modules, respectively. Thus, any influence of semantics will be of the cross-semantic effect variety (see above). In cases where cross-module mappings from orthography to semantics are one-to-many and cross-module mappings from semantics to orthography or to phonology are many-to-one (i.e., for polysemous, high concreteness/imageability, high number of features, and low semantic distance words), semantic activation leads to facilitation in performance. Conversely, in cases where cross-module mappings from orthography to semantics are one-to-one and cross-module mappings from semantics to orthography or to phonology are one-to-many (i.e., for words with synonyms), semantic activation leads to inhibition in performance.

In the semantic categorization task, responses are assumed to be based on activation in the semantic module. Thus, any influence of semantics will be of the within-semantic effect variety. In cases where cross-module mappings from orthography to semantics are one-to-one (i.e., words with or without synonyms), no effect of semantics is obtained. In cases where cross-module mappings from orthography to semantics are one-to-many, the effect will depend on the relationship between the activated semantic codes. In the case of polysemy, the multiple meanings of a polysemous word would not necessarily be similar and would thus recruit different units and connections. This would lead to a delay in responses because time would need to be taken to resolve which activated code should be accepted (Hino et al., 2002). In the case of semantic distance, because the semantic neighbors of a word are similar in meaning, they would recruit similar units and connections, and thus a decrease in response time would result for those words whose many semantic neighbors (i.e., low semantic distance words) have strengthened the connections of the target word. Thus, it is vital to consider the relationship between the nature of the variable and the nature of task demands in understanding the differential effects of semantics within and across tasks.

Future theoretical and empirical work regarding semantic distance will need to further investigate how semantic distance is related to other measures of semantics. To date, the present study, as well as that of Buchanan et al. (2001), have investigated how the average distance of a word's ten closest neighbors influences lexical processing. One possible direction that future research may take is investigating whether synonymy interacts with semantic distance. As shown in Table 6-1, synonymy and semantic distance have different effects in the lexical decision, word naming, and semantic categorization tasks. If it is possible to create stimulus sets that factorially manipulate synonymy and semantic distance, it may be possible to determine whether the presence of synonyms in a word's semantic neighborhood attenuates the facilitatory effects of semantic distance in the above tasks.

Conclusions

Semantic distance exerts facilitatory effects in lexical decision, semantic categorization, lexical decision/semantic categorization, and word naming, in that low semantic distance words are responded to more rapidly than high semantic distance words. The research conducted in this thesis, through employing strategy manipulations, was successful in distinguishing the task conditions in which semantic distance exerted an effect from those in which it did not. In all four of the experimental tasks, semantic distance influenced performance only when relatively deep processing was required. Moreover, the findings suggest that semantic distance influences performance in two distinct ways. First, semantic neighbors facilitate performance by decreasing the time taken to settle into either orthographic or phonological codes (cross-semantic effect). Second, semantic neighbors facilitate performance by decreasing the time taken to settle into semantic codes (within-semantic effect). Future research will need to further clarify the processes responsible for these effects.

REFERENCES

Abrams, R. A. (1995). Psych/Lab Experimental Psychology Software [Computer software]. St. Louis: Psych/Lab Software. (Available from Washington University web site: http://www.artsci.wustl.edu/~rabrams/psychlab/).

Andrews, S. (1989). Frequency and neighborhood effects on lexical access: Activation or search? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* 802-814.

Andrews, S. (1992). Frequency and neighborhood effects on lexical access: Lexical similarity or orthographic redundancy? *Journal of Experimental Psychology: Learning, Memory, & Cognition, 18,* 234-254.

Andrews, S. (1997). The effect of orthographic similarity on lexical retrieval: Resolving neighborhood conflicts. *Psychonomic Bulletin & Review, 4,* 439-461.

Andrews, S., & Heathcote, A. (2001). Distinguishing common and task-specific processes in word identification: A matter of some moment? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27,* 514-544.

Baayen, R. H., Piepenbrock, R., & Gulikers, L. (1995). The CELEX Lexical Database (CD-ROM). Linguistic Data Consortium, University of Pennsylvania, Philadelphia, PA.

Balota, D. A. (1990). The role of meaning in word recognition. In D. A. Balota, G. B. Flores d'Arcaise, & K. Rayner (Eds.), *Comprehension processes in reading* (pp. 9-32), Hillsdale, NJ: Erlbaum.

Balota, D. A. (1994). Visual word recognition: The journey from features to meaning. In M. A. Gernsbacher (Ed.), *Handbook of psycholinguistics* (pp. 303-358). San Diego: Academic Press, Inc.

Balota, D. A., & Chumbley, J. I. (1984). Are lexical decisions a good measure of lexical access? The role of word frequency in the neglected decision stage. *Journal of Experimental Psychology: Human Perception and Performance, 10,* 340-357.

Balota, D. A., & Chumbley, J. I. (1985). The locus of word-frequency effects in the pronunciation task: Lexical access and/or production? *Journal of Memory and Language, 24,* 89-116.

Balota, D. A., & Chumbley, J. I. (1990). Where are the effects of frequency in visual word recognition tasks? Right where we said they were! Comment on Monsell, Doyle, and Haggard (1989). *Journal of Experimental Psychology: General, 119,* 231-237.

Balota, D. A., Ferraro, R. F., & Connor, L. T. (1991). On the early influence of meaning in word recognition: A review of the literature. In P. J. Schwanenflugel (Ed.), *The psychology of word meanings* (pp. 187-221). Hillsdale, NJ: Erlbaum.

Balota, D. A., Pilotti, M. & Cortese, M. J. (2001). Subjective frequency estimates for 2,938 monosyllabic words. *Memory & Cognition, 29,* 639-647.

Becker, C. A. (1976). Allocation of attention during visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 2,* 556-566.

Borowsky, R., & Masson, M. E. J. (1996). Semantic ambiguity effects in word identification. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22,* 63-85.

Bradley, D. A., & Forster, K. I. (1987). A reader's view of listening. *Cognition, 25,* 103-134.

Buchanan, L., Westbury, C., & Burgess, C. (2001). Characterizing the neighborhood: Semantic neighborhood effects in lexical decision and naming. *Psychonomic Bulletin & Review, 8,* 531-544.

Burgess, C. (1998). From simple associations to the building blocks of language: Modeling meaning in memory with the HAL model. *Behavior Research Methods, Instruments, & Computers, 30,* 188-198.

Burgess, C., Livesay, K., & Lund, K. (1998). Explorations in context space: Words, sentences, discourse. *Discourse Processes, 25,* 211-257.

Burgess, C., & Lund, K. (2000). The dynamics of meaning in memory. In E. Dietrich and A.B. Markman (Eds.), *Cognitive Dynamics: Conceptual and Representational Change in Humans and Machines* (pp. 117-156). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Carr, T. H., Posner, M. I., Pollatsek, A., & Snyder, C. R. R. (1979). Orthography and familiarity effects in word processing. *Journal of Experimental Psychology: General, 108,* 389-414.

Carreiras, M., Perea, M., & Grainger, J. (1997). Effects of orthographic neighborhood in visual word recognition: Cross-task comparisons. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23,* 587-871.

Chiarello, C., Nuding, S., & Pollock, A. (1988). Lexical decision and naming asymmetries: Influence of response selection and response bias. *Brain & Language, 34,* 302-314.

Clark, H. H. (1973). The language-as-fixed-effect-fallacy: A critique of language statistics in psychological research. *Journal of Verbal Learning & Verbal Behavior, 12,* 335-359.

Cohen, J. D., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: An interactive graphic system for designing and controlling experiments in the psychology laboratory using Macintosh computers. *Behavior Research Methods, Instruments, & Computers, 25,* 257.271.

Coltheart, M. (1978). Lexical access in simple reading tasks. In G. Underwood (Ed.), *Strategies of information processing* (pp. 151-216). London: Academic Press.

Coltheart, M. (1981). The MRC psycholinguistic database. *Quarterly Journal of Experimental Psychology, 33A,* 497-505.

Coltheart, M., Davelaar, E., Jonasson, J. T., & Besner, D. (1977). Access to the internal lexicon. In S. Dornic (Ed.), *Attention and performance VI* (pp. 535-555).

Coltheart, M., & Rastle, K. (1994). Serial processing in reading aloud: Evidence for dual-route models of reading. *Journal of Experimental Psychology: Human Perception and Performance, 20,* 1197-1211.

Conley, P. Burgess, C., & Decker, C. (2001, November). *An examination of semantic density and familiarity in semantic priming.* Poster presented at the 42nd Annual Meeting of the Psychonomic Society, Orlando.

Cortese, M. J., Simpson, G. B., & Woolsey, S. (1997). Effects of association and imageability on phonological mapping. *Psychonomic Bulletin & Review, 4,* 226-231.

de Groot, A. M. B. (1989). Representational aspects of word imageability and word frequency as assessed through word association. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* 824-845

Fodor, J. (1983). *The modularity of mind.* Cambridge, Mass.: Bradford Books, MIT Press.

Forster, K. I. (1976). Accessing the mental lexicon. In R. J. Wales and E. Walk (Eds.), *New approaches to language mechanisms* (pp. 257-287). Amsterdam: North-Holland.

Forster, K. I. (1990). Lexical processing. In D. N. Osherson and H. Lasnik (Eds.), *Language: An invitation to cognitive science, Vol I* (pp. 95-131). Cambridge, MA: The MIT Press.

Forster, K. I., & Bednall, E. S. (1976). Terminating and exhaustive search in lexical access. *Memory & Cognition, 4,* 53-61.

Forster, K. I., & Shen, D. (1996). No enemies in the neighborhood: Absence of inhibitory effects in lexical decision and semantic categorization. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22,* 696-713.

Gernsbacher, M. A. (1984). Resolving 20 years of inconsistent interactions between lexical familiarity and orthography, concreteness, and polysemy. *Journal of Experimental Psychology: General, 113,* 256-281.

Gibbs, P., & Van Orden, G. C. (1998). Pathway selection's utility for control of word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 24,* 1162-1187.

Glushko, R. J. (1979). The organization and activation of orthographic knowledge in reading aloud. *Journal of Experimental Psychology: Human Perception and Performance, 5,* 674-691.

Gordon, B., & Caramazza, A. (1982). Lexical decision for open- and closed-class words: Failure to replicate differential frequency sensitivity. *Brain & Language, 15,* 143-160.

Gottlob, L. R., Goldinger, S. D., Stone, G. O., & Van Orden, G. C. (1999). Reading homographs: Orthographic, phonologic, and semantic dynamics. *Journal of Experimental Psychology: Human Perception and Performance, 25,* 561-574.

Grainger, J., & Jacobs, A. M. (1996). Orthographic processing in visual word recognition: A multiple read-out model. *Psychological Review, 103,* 518-565.

Green, P. E. (1978). Analyzing multivariate data. Hinsdale, Il: The Dryden Press.

Hino, Y., & Lupker, S. J. (1996). Effects of polysemy in lexical decision and naming: An alternative to lexical access accounts. *Journal of Experimental Psychology: Human Perception and Performance, 22,* 1331-1356.

Hino, Y., & Lupker, S. J. (1998). The effects of word frequency for Japanese Kana and Kanji words in naming and lexical decision: Can the dual-route model save the lexical selection account? *Journal of Experimental Psychology: Human Perception and Performance, 24,* 1431-1453.

Hino, Y., & Lupker, S. J. (2000). The effects of word frequency and spelling-to-sound regularity in naming with and without lexical decision. *Journal of Experimental Psychology: Human Perception and Performance, 26,* 166-183.

Hino, Y., Lupker, S. J., & Pexman, P. M. (2002). Ambiguity and synonymy effects in lexical decision, naming, and semantic categorization tasks: Interactions between orthography, phonology, and semantics. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 28,* 686-713.

Hino, Y., Lupker, S. J., Sears, C. R., & Ogawa, T. (1998). The effects of polysemy for Japanese katakana words. *Reading and Writing: An Interdisciplinary Journal, 10,* 395-424.

James, C. T. (1975). The role of semantic information in lexical decisions. *Journal of Experimental Psychology: Human Perception and Performance, 1,* 130-136.

Jared, D. (1997). Spelling-sound consistency affects the naming of high-frequency words. *Journal of Memory and Language, 36,* 505-529.

Jared, D., McRae, K., & Seidenberg, M. S. (1990). The basis of consistency effects in word naming. *Journal of Memory and Language, 29,* 687-715.

Jastrzembski, J. E. (1981). Multiple meanings, number of related meanings, frequency of occurrence, and the lexicon. *Cognitive Psychology, 13,* 278-305.

Jastrzembski, J. E., & Stanners, R. F. (1975). Multiple word meanings and lexical search speed. *Journal of Verbal Learning & Verbal Behavior, 14,* 534-537.

Johnson, N. F., & Pugh, K. R. (1994). A cohort model of visual word recognition. *Cognitive Psychology, 26,* 240-346.

Jones, G. V. (1985). Deep dyslexia, imageability, and ease of predication. *Brain and Language, 24,* 1-19.

Joordens, S., & Besner, D. (1994). When banking on meaning is not (yet) money in the bank: Explorations in connectionist modeling. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 1051-1062.

Kawamoto, A. H., Farrar, W. T., & Kello, C. (1994). When two meanings are better than one: Modeling the ambiguity advantage using a recurrent distributed network. *Journal of Experimental Psychology: Human Perception and Performance, 20,* 1233-1247.

Kellas, G., Ferraro, F. R., & Simpson, G. B. (1988). Lexical ambiguity and the timecourse of attentional allocation in word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 14,* 601-609.

Kroll, J. F., & Mervis, J. S. (1986). Lexical access for concrete and abstract words. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12,* 92-107.

Landauer, T. K., & Dumais, S. T. (1997). A solution to Plato's problem: The latent semantic analysis theory of acquisition, induction, and representation of knowledge. *Psychological Review, 104,* 211-240.

Lichacz, F. M., Herdman, C. M., Lefevre, J., & Baird, B. (1999). Polysemy effects in word naming. *Canadian Journal of Experimental Psychology, 53,* 189-193.

Lund, K., & Burgess, C. (1996). Producing high-dimensional semantic spaces from lexical co-occurrence. *Behavior Research Methods, Instruments, & Computers, 28,* 203-208.

McCann, R. S., Besner, D. & Davelaar, E. (1988). Word recognition and identification: Do word-frequency effects reflect lexical access? *Journal of Experimental Psychology: Human Perception and Performance, 13,* 693-706.

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: Part 1. An account of basic findings. *Psychological Review, 88,* 375-407.

McRae, K., de Sa, V. R., & Seidenberg, M. S. (1997). On the nature and scope of featural representations of word meaning. *Journal of Experimental Psychology: General, 126,* 99-130.

Measso, G., & Zaidel, E. (1990). Effect of response programming on hemispheric differences in lexical decision. *Neuropsychologia, 28,* 635-646.

Meyer, D. E., Schvaneveldt, R. W., & Ruddy, M. G. (1975). Loci of contextual effects on visual word recognition. In P. M. A. Rabbit & S. Dornic (Eds.), *Attention and performance V* (pp. 98-118). London: Academic Press.

Millis, M. L., & Burton, S. B. (1989). The effect of polysemy on lexical decision time: Now you see it, now you don't. *Memory & Cognition, 17,* 141-147.

Monsell, S. (1990). Frequency effects in lexical tasks: Reply to Balota and Chumbley. *Journal of Experimental Psychology: General, 119,* 335-339.

Monsell, S., Doyle, M. C., & Haggard, P. N. (1989). Effects of frequency on visual word recognition tasks: Where are they? *Journal of Experimental Psychology: General, 118,* 43-71.

Morton, J. (1969). Interaction of information in word recognition. *Psychological Review, 76,* 165-178.

Nelson, D. L., McEvoy, C. L., & Schrieber, T. A. (1994). *The University of South Florida word association, rhyme and word fragment norms.* Unpublished manuscript.

Paap, K. R., Newsome, S. L., McDonald, J. E., & Schvaneveldt, R. W. (1982). An activation-verification model for letter and word recognition: The word-superiority effect. *Psychological Review, 89,* 573-594.

Paap, K. R., & Noel, R. W. (1991). Dual-route models of print to sound: Still a good horse race. *Psychological Research, 53,* 13-24.

Paivio, A. (1991). Dual coding theory: Retrospect and current status. *Canadian Journal of Psychology, 45,* 255-287.

Pecher, D. (2001). Perception is a two-way junction: Feedback semantics in word recognition. *Psychonomic Bulletin & Review, 8,* 545-551.

Pedhazur, E. J. (1982). Multiple regression in behavioral research: Explanation and prediction (2nd ed.). New York: Holt, Rinehart and Winston.

Perea, M., Fernandez, L., & Carreiras, M. (1998, December). *Efectos secuenciales en la tarea de deision lexica* [Sequential effects in the lexical decision task]. Paper presented at the II Conference of the Spanish Experimental Psychology Society, Granada, Spain

Perea, M., Rosa, E., & Gomez, C. (2002). Is the go/no-go lexical decision task an alternative to the yes/no lexical decision task? *Memory & Cognition, 30,* 34-45.

Pexman, P. M., & Lupker, S. J. (1999). Ambiguity and visual word recognition: Can feedback explain both homophone and polysemy effects? *Canadian Journal of Experimental Psychology, 53,* 323-334.

Pexman, P. M., Lupker, S. J., & Hino, Y. (in press). The impact of feedback semantics in visual word recognition: Number of features effects in lexical decision and naming tasks. *Psychonomic Bulletin & Review.*

Piercey, C. D., & Joordens, S. (2000). Turning an advantage into a disadvantage: Ambiguity effects in lexical decision versus reading tasks. *Memory & Cognition, 28,* 657-666.

Plaut, D. C., McClelland, J. L., Seidenberg, M. S., & Patterson, K. (1996). Understanding normal and impaired word reading: Computational principles in quasi-regular domains. *Psychological Review, 103,* 56-115.

Rubenstein, H., Garfield, L., & Millikan, J. A. (1970). Homographic entries in the internal lexicon. *Journal of Verbal Learning & Verbal Behavior, 9,* 487-494.

Rubenstein, H., Lewis, S. S., & Rubenstein, M. (1971). Homographic entries in the internal lexicon: Effects of systematicity and relative frequency of meanings. *Journal of Verbal Learning & Verbal Behavior, 10,* 57-62.

Rumelhart, D. E., & McClelland, J. L. (1982). An interactive activation model of context effects in letter perception: Part 2. The contextual enhancement effect and some tests and extensions of the model. *Psychological Review, 89,* 60-94.

Schneider, W. (1990). *Micro experimental laboratory* [Computer software]. Pittsburgh, PA: Psychology Software Tools.

Schwanenflugel, P. J., Akin, C., & Luh, W. (1992). Context availability and the recall of abstract and concrete words. *Memory & Cognition, 20,* 96-104.

Sears, C. R., Hino, Y., & Lupker, S. J. (1995). Neighborhood size and neighborhood frequency effects in word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 21,* 876-900.

Sears, C. R., Hino, Y., & Lupker, S. J. (1999). Orthographic neighbourhood effects in parallel distributed processing models. *Canadian Journal of Experimental Psychology, 53,* 220-229.

Sears, C. R., Lupker, S. J., & Hino, Y. (1999). Orthographic neighborhood effects in perceptual identification and semantic categorization tasks: A test of the multiple read-out model. *Perception & Psychophysics, 61,* 1537-1554.

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review, 96,* 521-568.

Seidenberg, M. S., Petersen, A., MacDonald, M. C., & Plaut, D. C. (1996). Pseudohomophone effects and models of word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22,* 48-62.

Seidenberg, M. S., Waters, G. S., Barnes, M. A., & Tanenhaus, M. K. (1984). When does irregular spelling or pronunciation influence word recognition? *Journal of Verbal Learning and Verbal Behavior, 23,* 383-404.

Siakaluk, P. D., Sears, C. R., & Lupker, S. J. (2002). Orthographic neighborhood effects in lexical decision: The effects of nonword orthographic neighborhood size. *Journal of Experimental Psychology: Human Perception and Performance, 28,* 661-681.

Spieler, D. H., & Balota, D. A. (1998). *Naming latencies for 2820 words* (On-line). Available at http:www.artsci.wustl.edu/~balota/naming.html.

Stone, G. O., & Van Orden, G. C. (1993). Strategic control of processing in word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 19,* 744-774.

Strain, E., & Herdman, C. M. (1999). Imageability effects in word naming: An individual differences analysis. *Canadian Journal of Experimental Psychology, 53,* 347-359.

Strain, E., Patterson, K., & Seidenberg, M. S. (1995). Semantic effects in single-word naming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 1140-1154.

Taraban, R., & McClelland, J. L. (1987). Conspiracy effects in word pronunciation. *Journal of Memory and Language, 26,* 608-631.

Toglia, M. P., & Battig, W. F. (1978). *Handbook of semantic word norms.* Hillsdale, NJ: Erlbaum.

Treiman, R., Mullennix, J., Bijeljac-Babic, R., & Richmond-Welty, E. D. (1995). The special role of rimes in description, use, and acquisition of English orthography. *Journal of Experimental Psychology: General, 124,* 107-136.

Vanhoy, M., & Van Orden, G. C. (2001). Pseudohomophones and word recognition. *Memory & Cognition, 29,* 522-529.

Van Orden, G. C., & Goldinger, S. D. (1994). The interdependence of form and function in cognitive systems explains perception of printed words. *Journal of Experimental Psychology: Human Perception and Performance, 20,* 1269-1291.

Venezky, R. L. (1970). *The structure of English orthography.* The Hague, The Netherlands: Mouton.

Waters, G. S., & Seidenberg, M. S. (1985). Spelling-sound effects in reading: Time-course and decision criteria. *Memory & Cognition, 13,* 557-572.

Whaley, C. P. (1978). Word-nonword classification time. *Journal of Verbal Learning and Verbal Behavior, 17,* 143-154.

Wijk, A. (1966). *Rules of pronunciation for the English language*. Oxford: Oxford University Press.

Zevin, J. D., & Balota, D. A. (2000). Priming and attentional control of lexical and sublexical pathways during naming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26,* 121-135.

Ziegler, J. C., Jacobs, A. M., & Kluppel, D. (2001). Pseudohomophone effects in lexical decision: Still a challenge for current word recognition models. *Journal of Experimental Psychology: Human Perception and Performance, 27,* 547-559.

Appendix A

Word Stimuli Used in Experiments 1, 2, 3, 5, and 6

High Semantic Distance Words: BULB, DUSK, FRAIL, FUSS, GLOBE, HALT, JUNK, LEDGE, NOON, OATH, PORCH, PURSE, RUNG, SCALP, SHRUB, SLUM, SPINE, STAKE, SWIFT, TACT

Low Semantic Distance Words: BIKE, BLADE, BLAME, BRAKE, BUNCH, CHESS, CLIFF, DRUM, FAKE, FOAM, HANG, HURT, PLUG, SHAKE, SING, SPIN, SPRAY, STUCK, TEACH, TWIN

Appendix B

Nonword Stimuli Used in Experiments 1 and 5

Illegal Nonwords: BFKD, BGKN, BPCNX, BTNCF, CLWBT, DHRH, DTRF, FDWFM, FKZB, FLWX, FSCV, FXTJZ, GCSKR, GNPTV, HBXR, HSLM, HWKG, JFNP, LNGWD, NMMH, PCLB, PDPJS, PLBG, PWXHV, RSNW, SBDD, SCHG, SDBM, SGKMN, SJHPB, SKVFN, SNNKL, SRNSQ, SRZTR, SVBKL, SVCGT, TBHKS, TSKD, TWPL, WJKTR

No Neighbor Nonwords: BIMM, BLICH, BLUGE, BLUGG, BREGG, BRUL, CHEND, CRELB, DWIK, DYSP, FEAGE, FEGG, FRUF, FUPP, GRELP, HOIB, HOIG, HOZZ, JORB, LORBE, NALB, OINZ, PLEEM, PLIF, POOTE, RAUM, SCIG, SHOLP, SHROY, SHULG, SKARN, SKOC, SKONG, SMEV, SNONG, SOMCH, SOOFT, TEVE, TRELP, TWUB

Matched Nonwords: BERGE, BLECK, BLUB, BOIND, BOPE, BRAFT, CHEEB, CRINT, DAIN, DOFE, FAMP, FILT, FRAD, FRING, GLENT, HASK, HECT, HELT, JICK, LORCH, NOOT, PRASS, PREED, PREM, RIBE, SHOPE, SKELL, SKIB, SLIFT, SMARD, SMOT, SNOTE, SOATE, SONE, SPOLT, STAP, STAPE, TESK, THOCK, TILD

Pseudohomophones: BERCH, BOAN, BRANE, CHACE, CHEET, DANSE, DEAM, DEAP, FALCE, FEAL, FEER, FORSE, FRUM, GHOOL, GROOP, HAIT, HEET, HOAM, JALE, LEESH, NALE, PADE, PERGE, PLEE, ROAP, ROZE, SEET, SHURT, SKARF, SLEAP, SMOAK, SMYLE, SNOE, SOOP, SOPE, SPANE, SPEEK, STAIL, TOOM, TRATE

Appendix C

Animal Name Stimuli Used in Experiments 2, 3, and 5

BEAR, BEES, BULL, CAMEL, CHIMP, CLAM, COWS, CROW, DEER, DOVE, DUCK, EAGLE, FROG, GOAT, GOOSE, HORSE, LAMB, LION, LYNX, MOUSE, MULE, OTTER, PIGS, PONY, PUPPY, RAVEN, ROACH, ROBIN, SHARK, SHEEP, SKUNK, SNAIL, SNAKE, STORK, SWAN, TIGER, TUNA, WHALE, WOLF, ZEBRA

Appendix D

Word Stimuli Used in Experiment 4

High Semantic Distance Words: BULB, CAPE, CRUMB, DIME, DUSK, FRAIL, FUSS, GLOBE, HALT, ITCH, JUNK, LEDGE, LIMB, MEEK, NOON, OATH, PORCH, PURSE, RUNG, SCALP, SHRUB, SINK, SLUM, SOCK, SPINE, SPOON, SWIFT, TACT, TENSE, TOIL

Low Semantic Distance Words: BIKE, BLADE, BLAME, BRAKE, BUNCH, BURN, CHESS, CLIFF, CRAFT, DRUM, FAKE, FOAM, GRAPH, HANG, HIDE, HURT, KITE, LOOP, PICK, PLOT, PLUG, PUNCH, SAIL, SING, SPIN, SPRAY, STUCK, TEACH, TIRE, TWIN

Appendix E

Animal Name Stimuli Used in Experiment 4

ANTS, BATS, BEAR, BEES, BULL, CALF, CAMEL, CHIMP, CLAM, COLT, COWS, CROW, DEER, DOVE, DUCK, EAGLE, FAWN, FLEA, FOWL, FROG, GOAT, GOOSE, GULL, HAWK, HORSE, HYENA, KOALA, LAMB, LION, LOON, LYNX, MOLE, MOUSE, MULE, NEWT, OTTER, OWLS, PANDA, PIGS, PONY, PUMA, PUPPY, RAVEN, ROACH, ROBIN, SHARK, SHEEP, SKUNK, SNAIL, SNAKE, STORK, SWAN, TIGER, TROUT, TUNA, WASP, WHALE, WOLF, WORM, ZEBRA

Appendix F

Irregular-inconsistent Word Stimuli Used in the Mixed Condition in Experiment 5

ACHE, AISLE, BEIGE, BLOWN, BOUGH, BOWL, BROOD, BUOYS, CASTE, CHOIR, CLOWN, COMB, CORPS, COUGH, COUP, CUBE, CUTE, CZAR, DEAF, DEBT, DOLL, DOSE, DOUGH, DOVE, DREAD, FLOOD, GAUGE, GEESE, GHOST, GNAW, GROSS, GUISE, HOOF, HYMN, KEYS, LIMB, LOSE, LURE, MOULD, MULE, NICHE, PEAR, PHASE, PINT, PLAID, POUR, PROVE, PSALM, PUKE, PUSH, QUEUE, RUSE, SCARF, SEIZE, SEWN, SHALL, SHOE, SKIS, SOOT, SPOOK, STEAK, SWAB, SWAMP, SWATH, SWEAT, SWORD, THOU, TOQUE, TOUGH, TOUR, VASE, WAND, WASH, WOLF, WOMB, WOOL, WORM, YACHT