2013

Aging and Semantic Processing

Gillian Macdonald
University of Windsor

Aging and Semantic Processing

by

Gillian Macdonald

A Dissertation
Submitted to the Faculty of Graduate Studies
through the Department of Psychology
in Partial Fulfillment of the Requirements for
the degree of Doctor of Philosophy at the
University of Windsor

Windsor, Ontario, Canada
2013

Aging and Semantic Processing

by

Gillian Macdonald

APPROVED BY:

M. Fernandes, External Examiner
University of Waterloo

P. Boulos
Department of Philosophy

C. Abeare
Department of Psychology

A. Baird
Department of Psychology

L. Buchanan, Advisor
Department of Psychology

M. Rehse, Chair of Defense
Faculty of Graduate Studies

January 24, 2013

AUTHOR'S DECLARATION OF ORIGINALITY

I hereby certify that I am the sole author of this thesis and that no part of this thesis has been published or submitted for publication.

I certify that, to the best of my knowledge, my thesis does not infringe upon anyone's copyright nor violate any proprietary rights and that any ideas, techniques, quotations, or any other material from the work of other people included in my thesis, published or otherwise, are fully acknowledged in accordance with the standard referencing practices. Furthermore, to the extent that I have included copyrighted material that surpasses the bounds of fair dealing within the meaning of the Canada Copyright Act, I certify that I have obtained a written permission from the copyright owner(s) to include such material(s) in my thesis and have included copies of such copyright clearances to my appendix.

I declare that this is a true copy of my thesis, including any final revisions, as approved by my thesis committee and the Graduate Studies office, and that this thesis has not been submitted for a higher degree to any other University or Institution.

ABSTRACT

Semantic neighbourhoods are those clusters of words that have shared or related meanings. They have traditionally been difficult to operationalize because words can be related in many different ways. The present study used an operationalization of semantic neighbourhoods from a computational model of semantics derived from co-occurrences in large bodies of text (Durda & Buchanan, 2008). With this variable, the present study examined how young adults (ages 18-25) and older adults (ages 60-80) differ in their processing of semantics. Results reveal that words with rich semantic representations are processed faster than words that are less richly represented. However, words with many close neighbours were responded to more slowly than words with more dispersed neighbourhoods. In a priming experiment, close semantic neighbours led to faster processing of words compared to distant semantic neighbours. Young and older adults showed similar results on all experiments in terms neighbourhood size, density, and priming effects. The results suggest that older adults have intact semantic processing with respect to neighbourhood effects and show a similar pattern of performance to young adults.

DEDICATION

I would like to dedicate this work to my family, particularly my extended family in P.E.I. As a child you taught me what it means to grow old with enthusiasm, warmth, humour, and above all, care and love for one another. You truly are wonderful examples of growing old gracefully and you have inspired me to learn more about this amazing journey of aging.

ACKNOWLEDGMENTS

I would like to begin by acknowledging my supervisor, Lori Buchanan. It was during her undergraduate course that I first became interested in neuropsychology. Lori, you have been instrumental in my academic journey right from the beginning, thank you for your guidance and unwavering support over the years.

Thanks are extended to each of my committee members: Chris Abeare, Anne Baird, Pierre Boulos, and Myra Fernandes. Your interest, guidance, and many helpful suggestions and comments throughout this process have been so appreciated. Thank you to my fantastic lab mates and grad school friends, especially Tara, Ann, and Shelley for all the academic and (most importantly) emotional support.

Thank you to my parents for instilling in me the value of learning and education from an early age. Your love and support has made this degree possible.

And finally thank you to my husband for his love, patience, and endless words of encouragement through this long academic journey.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1:

INTRODUCTION

Cognitive models of word recognition are often informed by research examining the effects of various word characteristics such as semantics, phonological, and orthographic features (e.g., Borowsky & Masson, 1996; Coltheart, Davelarr, Johnson, & Besner, 1977; Coltheart, Rastle, Perry, Ziegler, & Langdon, 2001; Forster, 1976; Grainger & Jacobs, 1996; Harm & Seidenberg, 1999; 2004; McClelland & Rumelhart, 1981; Morton, 1969; Seidenberg & McClelland, 1989; Plaut, 1997; Plaut & Booth, 2000; Plaut, McClelland, Seidenberg, & Patterson, 1996). One means of examining the influence of such characteristics is by looking at neighbourhood effects. For example, an orthographic neighbour is a word that differs from a target word by one letter (Sears et al., 1995) whereas a phonological neighbour is a word that differs by one phoneme (Coltheart et al., 1977). To illustrate these concepts, the words *bike and like* are orthographic neighbours because they differ by one letter whereas *bike* and *beak* are phonological neighbors because they differ by one phoneme. Orthographic and phonological neighbourhood effects have been relatively well studied (e.g., Andrews, 1997; Forster & Shen, 1996; Frost, 1998; Lukatela & Turvey, 2000; Luce & Large, 2001; Luce & Pisoni, 1998, Sears et al., 1995; Vitevich & Luce, 1999). However, the structure and influence of semantic neighbourhoods (i.e., words that are closely related to a given target word based on their meaning) are less well understood. Nonetheless, research in the area of semantic influences has increased over the last couple of decades, with results underscoring the important contribution of semantics in visual word recognition (e.g., Balota, Cortese, Sergent-Marshall, Spieler, & Yap, 2004; Balota, Ferraro, & Connor, 1991; Buchanan, Westbury, & Burgess, 2001; Dunabeitia, Aviles, & Carreiras, 2008; Grondin, Lupker, & McRae, 2009; Hino, Lupker, & Pexman, 2002; Locker, Simpson, & Yates, 2003; Pexman, Hargreaves, Edwards, Henry, & Goodyear, 2007; Pexman, Hargreaves, Siakaluk, Bodner, & Pope, 2008; Pexman & Lupker, 1999; Pexman, Lupker, & Hino, 2002; Recchia & Jones, 2012; Schvaneveldt, Durso, & Mukherji, 1982; Siakaluk, Buchanan, & Westbury, 2003; Strain, Patterson, & Seidenburg, 2005; Yap, Pexman, Wellsby, Hargreaves, & Huff, 2012; Yap, Tan, Pexman, & Hargreaves, 2011; Yates, Simpson, & Locker, 2003).

Semantics is an important aspect of language and the store of general knowledge thought to build up over a lifetime (Lund & Burgess, 1996) is commonly referred to as semantic memory (Spaan, Raaijmakers, & Jonker, 2003). Importantly, our knowledge of the world is not static and it has been suggested that lifetime experiences with language dynamically change and shape the structure of our semantic representations (Burke & Shafto, 2008). The age-related changes to the structure and influences of the semantic lexicon are therefore important aspects of our understanding of cognitive aging. Interestingly, although cognitive changes are reported as a part of the normal aging process, research suggests that semantic processing remains relatively stable throughout healthy aging (e.g., Burke, Mackay, & James, 2000; Burke & Shafto, 2008; Kemper, 1992; Thornton & Light, 2006). This relative stability notwithstanding, semantic language deficits, along with other cognitive and neurological symptoms, are widely reported in pathological cognitive aging such as neurodegenerative dementias, including most prominently Alzheimer's disease and semantic dementia, a variant of frontotemporal dementia (e.g., Caine & Hodges, 2001; Chertkow & Bub, 1990; Hodges

& Patterson, 1995; Lambon et al., 2001; Perry & Hodges, 1999; Rabinovici & Miller, 2010). Examining the subtle changes in semantic structure and processes that may occur in healthy aging is therefore an important undertaking as it contextualizes the more pathological changes that occur with dementia.

This review has two main sections. The first section describes the role and the arrangement of the semantic lexicon within relevant models of visual word recognition and outlines the semantic effects that such models must accommodate. The second section of the review describes age effects in semantic language processes including general semantic abilities related to vocabulary and word associations, semantic priming effects and semantic richness in aging. To provide a context for aging and language changes, models of cognitive aging are presented with a focus on how they relate to semantic processing.

The experimental series that follows the review examines semantic neighbourhood effects with young and older adults in order to extend our knowledge of how semantics impacts the word recognition process and how that occurs in the context of aging.

Semantics

Semantics and Models of Visual Word Recognition

The mental lexicon is a mental storehouse of all knowledge acquired about words including orthographic (visual), phonological (auditory), and semantic (meaning) properties. Interest in semantics has grown considerably within the past decade, with findings demonstrating the impact of semantic processing on visual and auditory word recognition (e.g., Buchanan et al., 2001; Locker et al., 2003; Pexman, et al., 2008;

Pexman & Lupker, 1999; Pexman, Lupker, & Hino, 2002; Rodd, Gaskell, & Marslen-Wilson, 2002; Strain, Patterson, & Seidenburg, 1995; Wurm, Vakoch, & Seaman, 2004; Yates et al., 2003). Similar to findings for other word properties (orthography and phonology) words that are closely related to many other words based on their meaning are thought to be processed more quickly than words with few semantic neighbours (Buchanan et al., 2001, Pexman et al., 2007; Plaut & Shallice, 1993). This section reviews models of visual word recognition with an emphasis on semantic processing.

In Morton's (1969) threshold activation model, each unit of meaning is divided into units called "logogens". These logogens are composed of information related to a word including visual, auditory, and semantic properties of the word. Logogens behave like detectors, gathering evidence from input units within the sensory system. Once a certain amount of evidence has been accumulated (through visual or auditory activation), a threshold is reached and a logogen's meaning is activated, thus allowing a response. A logogen's basic resting level of activation may vary according to several factors, such as word frequency and context (Morton, 1969). For example, frequency effects occur as each logogen has a resting activation level that is proportional to its frequency within a language (Coltheart et al., 2001). Thus, low frequency words need greater activation to reach threshold than their high frequency counterparts.

In terms of semantics, when a word occurs without contextual information, its semantic content only becomes activated once activation of the logogen itself has reached threshold. Therefore, in this model, with identification occurring prior to semantic activation, it is not possible for the semantic content of a word to play a role in the visual word identification process.

Unlike the logogen model, Forster's serial search model (1976) is not a threshold model but assumes a matching processing between incoming information about a word and knowledge of words already stored. According to this model, incoming information, in either orthographic or phonological form, is grouped into bins based on similar descriptions. These bins are ordered by frequency, with higher frequency words appearing first in the bin. Words are then compared to a master file, containing all information in the mental lexicon. When a sufficient match is made between the lexical entry and the master file, word recognition occurs. Therefore, the search process is akin to the structure of a library search (Forster, 1976). The serial search model is similar to the logogen model in that it assumes that semantic information becomes activated only after access to the word has occurred (Rodd, 2004).

The Interactive Activation Model (IAC) proposed by McClelland and Rumelhart (1981) consists of three distinct layers of activation related to visual word perception. Activation first occurs at the feature level, then spreads to the letter level, which finally causes activation at the word level. In this view activation spreads automatically to other levels in a cascaded process and this occurs before the lexical representation is fully activated. For example, activation at the feature level will automatically spread activation to the letter level. Another key feature of the IAC model is the interactive component. This component proposes that "bottom-up" activation from sensory information interacts with "top-down" activation from higher order levels of processing to constrain and determine perception (McClelland & Rumelhart, 1981). In other words, activation at the letter level receives activation from "bottom-up" connections (the feature level) at the same time as it receives activation from "top-down" connections (the word level). The activation of words or “nodes” occurs through a combination of excitatory and inhibitory connections.

To accommodate demonstrations of pre-lexical semantic influences on word recognition researchers have proposed modifications to some of the above models (e.g., Balota et al., 1991; Forster & Hector, 2002). Forster and Hector (2002) suggest that selection of a candidate does not involve activation of semantic features, but rather is influenced by a network of semantic associates that occur between a specific lexical entry and previously established semantic connections. In this way, the check is akin to referencing “a thesaurus” that provides some information about category membership but does not activate full semantic features (Forster & Hector, 2002).

Balota et al. (1991) further proposed a modification to the IAC model, in which a meaning-level unit is added to the system. This meaning-level unit is added to the previous model as a fourth level of activation. With this addition to the model, activation is spread first from the feature level to the letter level, the letter level to the word level, and finally word level to the meaning-level. In keeping with the IAC model, the “bottom-up” driving force of activation spreads in a continuous flow through the units. Once activated, semantic-level units can activate word-level units through feedback connections. In the case of a lexical decision task, the semantic meaning level provides feedback to the orthographic level, which then increases the activation at the orthographic level. Because the orthographic level is the level at which word recognition occurs, this increased activation may then allow for faster recognition of the word item. The authors propose that more meaning may provide an extra source of activation through a feedback “top-down” process. Thus, Balota et al. (1991) suggest the possibility of a “more-means-better" approach to semantics: stronger meaning representations provide for greater facilitation for word recognition. According to this modification, more semantic neighbours would therefore increase activation at the semantic level, which feeds down to the orthographic level. Facilitation is achieved through this increase in activation at the orthographic level, which as previously stated, is necessary for making lexical decisions during visual word identification.

The models presented thus far can all be described as localist models because in such architectures word meanings are represented by a single unit. For word recognition to occur, a single unit corresponding to the word needs to be activated. However, more recent distributed models of word recognition propose a different type of representation in visual word recognition (e.g., Borowsky & Masson, 1996; Plaut & McClelland, 1993; Plaut, et al., 1996; Rogers & McClelland, 2004; Seidenberg & McClelland, 1989).

Distributed Models

Although distributed models may vary considerably, the general principles are as follows: Instead of word meaning corresponding to a particular unit, word information is represented as patterns of activation across many neuron-like processing units. More specifically, during the visual word recognition task, these processing units may be orthographic, phonological, and semantic, with interconnections between all three units (e.g., Borowsky & Masson, 1996; Seidenberg & McClelland, 1989). The architecture of distributed models resembles more of a neural-network pattern with processing occurring via propagation of activation over simple processing units. The connections between the simple processing units are "hidden" weighted units and these weights determine the representation that arises internally. These weighted units are learned and shaped by experience (Rogers & McClelland, 2004). Learning is an important assumption of distributed models as a means to model how representations develop. It is emphasized in order to examine how children acquire language (e.g., Harm & Seidenberg, 1999), how skilled cognitive processes develop and also how degradation can occur in the system (e.g., Rogers et al., 2004). For example, Rogers et al. (2004) trained a model of semantics based on visual features and verbal descriptors of objects and then simulated lesions in the model to examine whether error types were similar to those made by people with semantic dementia. The implementation of these distributed models provides a way to examine how cognitive processes are acquired, become skilled, and mature or decline.

Connections between the units can be competitive or cooperative. Each time the units are activated, a reconstruction of internal representations occurs through a "*filling in*" process. Knowledge is reconstructed when propagation occurs over a certain pattern of activation (Rogers & McClelland, 2004). During visual word recognition, incoming information through orthography activates hidden weighted units, which in turn activate semantic units and phonological units (Harm & Seidenberg, 2004). Due to the dynamic nature of the model, interconnected units serve to constrain each other. Activation eventually settles into a distributed pattern over time. The meaning that is computed is the one that satisfies the most constraints between the units in the network (Harm & Seidenberg, 2004).

Findings of facilitation in lexical decision tasks for words with multiple meanings (polysemous words; e.g., *bank*), has led to an interactive distributed feedback model to account for such findings in word recognition (e.g., Hino & Lupker, 1996; Pexman & Lupker, 1999). This model has also been suggested as an explanation for the findings of the impact of semantics on word recognition (Yates et al., 2003). In a distributed model of this type, connections between orthography, phonology, and semantics are interactive and bidirectional.

These bidirectional connections allow for a cascade of activation. Models that rely on cascaded processing assume activation is spread throughout the system automatically, and therefore allow the possibility of semantic influences on word recognition, before the stimulus has been fully recognized (Coltheart et al., 2001; McClelland & Rumelhart, 1981; Plaut, et al., 1996). For example, a person may read the letters “spli” that begin a word, and activate word meanings such as “split” or “splinter” providing semantic feedback to the word recognition process, before the word gains complete lexical access and is recognized.

Lexical decisions are made primarily based on activation in the orthographic units (Pexman & Lupker, 1999) with responses made once settling occurs in the orthographic units. Settling refers to the process where as many as possible constraints are satisfied between the phonological, orthographic, and semantic connections to find the appropriate solution. The amount of time it takes for settling can vary, and semantics may play a role in this model by influencing the settling process (e.g., Pexman & Lupker, 1999; Yates et al., 2003). According to Yates et al. (2003), when words have large semantic neighbourhoods, they are likely to be more richly represented at the semantic level. During visual word recognition, activation spreads to the semantic units. If words have richer semantic representations the pattern of activation in semantics will be stronger and more enhanced. This stronger activation will then feed back to orthography to allow the orthographic units to reach a stabilization point more quickly resulting in a facilitatory effect during lexical decision (Yates et al., 2003).

In sum, the presumed role of semantics within models of visual word recognition varies considerably. In localist models, the original assumption regarding semantics was that activation only happened once full lexical access had occurred and as a result semantics could not affect the word recognition process. In contrast, interactive models have provided a way to accommodate semantic neighbourhood influences on word recognition through spread of activation and feedback (Balota et al., 1991; Hino & Lupker, 1996). Distributed models, propose a similar feedback mechanism as means for semantic influence despite a different underlying mechanism. Semantic neighbourhoods may influence the rate of settling due to richer representations providing stronger feedback to orthographic units which are used when making lexical decisions (Yates et al., 2003).

Semantic Processing

Semantic processing is the way in which semantic information is transmitted and communicated. The following review focuses on semantic activation and its transmission.

Quillian's original theory (1969) of semantic processing described concepts (e.g., words) as being represented as nodes with relational links to other concept nodes. Memory searches resulted in "*tagging*" related conceptual nodes that would, in turn, "*tag*" other related nodes. The architecture of a taxonomic hierarchy provided a way to store and retrieve semantic information. For example, activation of the word *canary* would spread to the superordinate category of *bird,* which would then spread to concepts or attributes related to birds. Although several types of relational links were hypothesized, words that were more related were proposed to have stronger links between them.

Building on semantic processing experiments, Collins and Loftus (1975) expanded Quillian's (1969) theory with their automatic spreading activation hypothesis. This theory posits that a word automatically causes a spreading of activation throughout the semantic system activating a related concept node (Collins & Loftus, 1975). One extension of their original theory is that the spreading of activation occurs as a decreasing gradient, losing strength over time. Another extension is the assumption that concepts are organized by semantic similarity: The more properties words have in common, the more closely they will be linked in the network. For example, *fire engine* will prime *vehicle*, which will, in turn, prime *ambulance* and *bus*.

In the case of semantic priming, when a prime is presented, activation spreads to semantically related words causing them to be above resting level (Collins & Loftus, 1975). This higher resting level means less visual encoding and processing resources are needed in order to recognize the word. The amount of activation necessary for recognition is reduced, and activation is facilitated for a related word.

In sum, although the mechanisms for semantic processing differ based on theoretical orientation, one general commonality is that once semantic activation occurs, there is automatic activation of semantically related concepts. However, the structure and organization of semantic space is less well understood. It is difficult to ascertain which words or concepts are considered as "related" and which are not, as words may be related to each other in many different ways.

Semantic Neighbourhoods

In visual word recognition, context or semantic priming has been used to examine how people respond to context within sentences, paragraphs, and also as single words (e.g., Balota et al., 1991; Balota et al., 2004; Zelinski & Hyde, 1996). There have been a variety of outcome measures to examine this processing, the majority of which examine response times. In the lexical decision task, participants are shown either a real word or a non-word, and are asked to make a decision about whether it is a real English word (Rubenstein, Garfield, & Millikan, 1970). Furthermore, they are asked to make this decision as quickly as possible. In a word naming task, participants are required to read the presented word aloud as quickly as possible. In a semantic categorization task, participants are shown words that either belong to a certain category, or do not, and are asked to decide whether a particular word is part of that category (e.g., is an animal).

Generally, large orthographic neighbourhoods have a facilitative effect on reaction times, possibly due to global activation and feedback from multiple neighbours (Grainger & Jacobs, 1996). Prior research has demonstrated that words with many orthographic neighbours are responded to more quickly in lexical decision and semantic organization tasks (e.g., Andrews, 1997; Forster & Shen, 1996; Sears et al., 1995). However, this is not always the case for phonological neighbourhoods. When examining spoken word production, close phonological neighbours have actually created an inhibitory effect with a slowed reaction time (e.g., Luce & Pisoni, 1998). Therefore, neighbourhood effects have been shown to be both facilitative and inhibitory for different word characteristics.

Less is known regarding semantic lexical arrangement than about its phonological or orthographic counterparts. One reason is that unlike orthography and phonology, words related to each other based on meaning have considerably more variability (Buchanan et al., 2001). Buchanan et al. propose that at one extreme this may mean that semantic organization is completely unique to each individual and therefore cannot be defined beyond the individual level. At the other end, it may mean that semantics has a large and variable structure but it also has many shared characteristics. Buchanan et al.'s (2001) approach is midway between the extremes with the assumption that although individual variability exists in semantics, there are nonetheless organizational influences that define the structure of semantic space.

There have been many ways that the organization of semantic space is said to occur. Early categorization based models (Collins & Quillian, 1969) proposed that semantic organization followed a taxonomic structure based on a hierarchy. Over time, there have been many additions to the dimensions of semantics. Contextual dispersion, which examines the number of times words appear in different content areas, is said to capture semantic information as words that are more widely distributed across content areas are thought to be more richly represented (Pexman et al., 2008). Research has found that words that appear in more samples from a corpus (i.e., have greater contextual dispersion) facilitate reaction times in lexical decision tasks (Adelman, Brown, & Quesada, 2008; Pexman et al., 2008). Furthermore, polysemous words, words with multiple meanings that are unrelated (e.g., *bank*) have shown facilitatory effects in lexical decision tasks (e.g., Hino and Lupker, 1996; Hino et al., 2002). Body-object interaction (BOI), which is based on principles of embodied cognition, relates to the ease that an object has in interacting with the human body (Siakaluk et al, 2008). Words high in body-object interaction have shown facilitation effects in lexical decision and semantic categorization tasks due to greater activation of sensorimotor information for high BOI words enhancing semantic feedback (Siakaluk et al., 2008; Siakaluk, Pexman, Aguilera, Owen, & Sears, 2008).

One commonly used measure for representing semantics involves the number of features of a word. Feature based models propose that nearness in a semantic system reflects the amount of feature overlap between representations, as well as correlations between features and the distinctiveness of features related to a concept (McRae, de Sa, & Seidenberg, 1997). In this view, neighbourhoods are developed by presenting participants with concepts and asking them to give all the features that come to mind when they think of that concept (McRae, Cree, & Seidenberg, 2005; Vinson & Vigliocco, 2008). For example, *TIGER* and *DOG* share many features such as “has four legs”, “has fur” etc. When a word is activated, its semantic features also become activated through automatic spreading of activation. Through the same automatic spreading activation principle, these semantic features will activate another word that also has those features in common. For example, *TIGER* may activate the feature *FUR* which in turns activates the word *DOG* because it has that feature. Therefore, similarity is based on the number of shared features (McRae et al., 2005).

In contrast to feature-based models, association-based models are organized on the basis of associates in language (Dunabeitia et al., 2008). One such model uses word association norms in which participants are provided with a word and are asked to name the first related word they think of (Nelson, Bennett, & Leibert, 1997; Nelson, McEvoy,

& Schreiber, 1994). For example, for the word *CAT*, responses may include *MEOW*, *DOG*, *WHISKERS*, etc. The proportion of participants producing a response to a word is then used as the "strength" of connection between two words; responses given more often (by more people) are closer associates than words that are given less often (Nelson et al., 1997).

An alternative method for generating association values comes from lexical co-occurrence models derived from a large corpus of text. The number of times pairs of words co-occur within large bodies of text is computed and used to determine a measure of semantic relatedness (e.g., Durda & Buchanan, 2008; Lund & Burgess, 1996; Shaoul & Westbury, 2006; 2010). One early example of a co-occurrence model is the hyperspace analogue to language (HAL; Lund & Burgess, 1996). This model sees words or concepts as represented as points or vectors in a multi-dimensional space. Once established, relationships between these points are quantified and can be tested through distance metrics (Lund & Burgess, 1996). In this model, a large number of words (e.g., 300 million) are examined using a moving window over 10 words at a time. HAL generates co-occurrence values for the words that occur together within this window of words. The associative strength is inversely related to the number of words separating them. For example, words that are adjacent receive a value of 10, while words that are separated by nine other words receive a value of one. A matrix for each word is constructed to create a high-dimensional space in which words are represented as vectors. Words that have similar vectors are located closer to each other in high-dimensional space. Thus, close "neighbours" in semantic space as defined by how often they co-occur, are those that are most similar semantically. Words used together in similar lexical contexts that occur close to one another will form clusters of semantic neighbourhoods. HAL has been shown to capture semantic (words that have similar meanings; e.g., *bed-table*), categorical (words that capture categorical information; e.g., *bird-eagle*), and associative information (words that tend to occur together; e.g., *coffee-cup*) as well as behavioural data (Lund & Burgess, 1996; Lund et al., 1995).

There is support for the value of lexical co-occurrence models in word recognition (e.g. Bodner, & Pope, 2008; Buchanan et al., 2001; Lund & Burgess, 1996; Pexman et al., 2003; Siakaluk et al., 2003). However, early models of HAL have been criticized for the influence of frequency on both its vector representations and also the distances between vectors (e.g., Shaoul & Westbury, 2006).

This criticism is of concern, as visual word recognition effects are known to be quite sensitive to frequency (Durda & Buchanan, 2008). The WINDSORS model of lexical co-occurrence (Durda & Buchanan, 2008) is a modification to the HAL model and offers an advantage over HAL by controlling for the effects of word frequency, which can have a strong influence on word co-occurrence values. The WINDSORS model has been shown to capture many aspects of semantic memory, including concept similarity, features, and category information (Durda & Buchanan, 2008). Shaoul and Westbury (2010) proposed an extension to their model that instead of using a fixed number of words to be included as a neighbourhood created a membership threshold which involved using a certain threshold by taking the mean and SD for a word to every other word in the database with the number of neighbours within that threshold defined as NCOUNT (Shaoul & Westbury, 2010). They further defined the mean distance between a word and every other word within the defined threshold as average radius of co-occurrence or

ARC. However, no such measures exist for the WINDSORS model of lexical co-occurrence (Durda & Buchanan, 2008). Experiment 1 of the present study addresses this gap.

Additionally, lexical co-occurrence models examine large bodies of text produced by adults across the lifespan and consequently the values derived from them can be assumed to reflect sampling across a wide age-range. In contrast, word association norms and feature norms are typically developed by asking university students (e.g., Nelson et al., 1994) to name the first meaningful word that comes to mind when reading a target word or to name features associated with a word. This may be especially relevant for research on semantics and aging as word associates produced by university students, composed mainly of young adults, may not be the same as those produced by older adults and may not be representative of their semantic networks. Co-occurrence models eliminate those effects by examining texts produced by adults of various age ranges.

To summarize the above, models of the semantic lexicon have historically been difficult to create because words may be related by meaning in many different ways creating large amounts of variability within models (Buchanan et al., 2001). Many models of semantic space have been proposed based on shared features, number of associations produced, contextual dispersion, words with multiple meanings (polysemous words), words high in body-object interaction, and computation models of lexical co-occurrence. These have allowed for a greater examination of how semantics may influence the visual word recognition process. The following describes the results of those examinations.

Semantic Influences in Visual Word Recognition

Words that have a high number of semantic features have resulted in faster lexical decision and naming times (Pexman et al., 2002). Pexman, Holyk, and Monfils (2003) examined how context information might influence the facilitation effects seen for words with many semantic features. Participants read sentences where a congruent word was presented at the end of the sentences (e.g., After the crash Bob was nervous about getting on an *airplane*), an incongruent word was at the end of the sentences (e.g., When I go home from work I tend to travel by *airplane*), or unrelated word was at the end of the sentences (e.g., After a heavy snowfall, Joel has to wear his *airplane*). When congruent sentences were presented, context appeared to constrain processing such that the facilitation advantage for words with many semantic features did not occur. Furthermore, in a semantic categorization task, when the semantic category provided specific contextual information (bird/non-bird) compared to less specific contextual information (animal/non-animal), Pexman et al. (2003) found less facilitation for words with many features. Therefore, neighbourhood size produces a process-constraining effect that is similar to that produced by context.

Pexman et al. (2007) examined differences in neural activation using fMRI measurement during a semantic categorization task. Participants were asked whether a presented word was a consumable object (e.g., *almonds*) by indicating “yes” or “no” on a keypad. Results revealed that words with greater semantic richness (more semantic neighbours), or more semantic associates, resulted in less overall neural activation, than words with few semantic associates. They suggest that faster settling occurs for words with richer semantic representations (more neighbours), and more effortful and extensive lexical activation is required for words that are less rich semantically. Enhanced N400 amplitudes were also seen during EEG recordings for words with many semantic features when participants' ERPs were recorded while performing a lexical decision task (Rabovsky, Sommer, & Rahman, 2012).

Semantic relatedness has been found to impact memory performance (Fernandes, Craik, Bialystok, & Krueger, 2007). When participants heard words and were simultaneously asked to perform a visual task involving either semantically related (compared to unrelated words) during encoding, they later had poorer recall of words. Thus competition effects may also emerge for words that are more similar in meaning than unrelated words during learning trials.

Although there are many ways of measuring semantic neighbourhood size or semantic richness, it appears that words with larger semantic neighbourhoods result in faster processing than words with smaller semantic neighbourhoods (e.g., Buchanan et al., 2001; Pexman et al., 2008; Siakaluk et al., 2003; Yap et al., 2011; Yap et al., 2012; Yates et al., 2003). The effect of semantic neighbourhood size or semantic richness was found even after other word characteristics were controlled (e.g., Balota et al., 2004; Buchanan et al., 2001).

Buchanan et al. (2001) examined two forms of language-based theories of semantic representation, association norms and lexical co-occurrence models, to see which captured greater variability in response times. Similarity within the semantic lexicon for the association norms was measured by taking the number of associates produced for a given word (Nelson et al., 1994). Recall that association norms are derived by asking participants to read a word, and respond with the first meaningfully related word that comes to mind. For the lexical co-occurrence model, words that are more closely related based on meaning are closer together in high-dimensional space. Semantic distance was measured using the HAL (Lund & Burgess, 1996) model by computing the average distance from a word to its 10 closest neighbours. The lower the semantic distance number, the more semantic neighbours a word has within a specified area. In a hierarchical regression, word characteristics of log frequency, orthographic neighbourhood size, word length, number of associates, and semantic distance were examined. Results reveal that both semantic distance and number of semantic associates impacts lexical decision times, although semantic distance effects were more robust. Additionally, their results revealed that the greater the mean distance from a word to its 10 closest neighbours, the greater the lexical decision time. In sum, close semantic neighbourhoods facilitate word processing (Buchanan et al., 2001).

To further extend these findings, Siakaluk et al. (2003) manipulated semantic distance by creating low and high semantic distance groups formed by examining the mean distance between a word and its 10 closest neighbours. Two forms of semantic categorization tasks were given: a yes/no task, asking participants if the word is an animal name, and a go/no-go task, in which participants only respond to non-animal words. This was done in order to examine the effects of semantic distance on tasks that requires the meaning of a word be activated before making a decision, that is to say, complete lexical selection must take place. Overall, the findings indicated that semantic distance (mean distance from a word to its 10 closest neighbours) impacts word recognition in a categorization task that entails complete lexical processing of a stimulus.

Yates et al. (2003) examined the effect of semantic size using the number of words produced in a word association task (Nelson, Schreiber & McEvoy, 1992) as a measure of semantic neighbourhood size. In a lexical decision task, facilitation was found for words with larger semantic neighbourhoods. They further examined the effect of semantic neighbourhood size by using a pseudohomophone task. A pseudohomophone is a non-word that sounds like a real word but its spelling is not orthographically correct (e.g., *nale*). When participants made lexical decisions about pseudohomophones, words with larger semantic neighbourhoods took longer to reject as real words than those with smaller semantic neighbourhoods (Yates et al., 2003). The authors propose that semantic activation occurs for the word *nail* when *nale* is viewed. If *nail* is part of a large semantic neighbourhood, feedback is increased to the orthographic level, with additional feedback from the phonology level, which makes it appear more “word-like”, and takes longer to reject as a non-word.

The increased interest in semantics has led to many different representations of semantic richness and models of semantic space. In an examination of these multiple measures of semantics, Pexman et al. (2008) compared number of semantic neighbours (through WINDSORS norms), number of semantic features, and context dispersion (how often words appear in a number of different content areas). Results indicate that number of semantic neighbours was significantly related to lexical decision reaction time while number of semantic features and context dispersion were related to both lexical decision time and a semantic categorization task. Thus they report that semantic richness can be defined in many different ways and each of the three measures of semantic richness had unique relationships with different variables. As part of an extension of this work, Yap et al. (2011) included a measure of semantic richness, number of semantic associates (i.e., the number of distinct first associates produced for a word in a free association task), word ambiguity (the number of senses for a given word) and used a different lexical co-occurrence model to estimate number of semantic neighbours (mean semantic similarity 5000; MSS-5000; Shaoul & Westbury, 2010). Three outcome variables were examined: speeded pronunciation, lexical decision, and semantic categorization. In a regression model, their results indicated that the MSS-5000 variable influenced reaction time in a lexical decision task but not speeded pronunciation or semantic categorization. Number of features and context dispersion accounted for unique variance for all three tasks while number of senses was not related to performance on a speeded pronunciation. Interestingly, number of associates was not related to performance on any of the three tasks.

In the most recent extension of this work, Yap et al. (2012) conducted a comprehensive comparison of measures of semantic association or richness. Similar to past research, their results support the influence of semantic richness on various word recognition tasks including lexical decision, speeded pronunciation, semantic categorization, and progressive demasking (Yap et al., 2012). Two richness variables showed the most reliable effects across tasks (imageability and number of features). They further found that several measures showed task-specificity including semantic density. Semantic density was based on average radius of co-occurrence values (ARC) from Shaoul & Westbury (2010) and showed effects in lexical decision tasks but not in other tasks, including semantic categorization. This is similar to semantic density findings by Pexman et al., (2008) and Yap et al., (2011). However, with regards to semantic density, the authors questioned whether their results may have been influenced by competing facilitation and inhibitory effects associated with close and distant neighbours. It was postulated that this may be a reason for the non-effect seen in a semantic categorization task (Yap et al., 2012).

As part of an examination of the effects of close and distant neighbours, Mirman and Magnuson (2008) studied the effect of the spread of semantic neighbourhoods in an investigation of the effectiveness of several models of semantic representation contrasting feature, association-based, and computational models. The authors discovered that in some cases semantic neighbourhood size had an inhibitory effect on speed in a categorization task, while in other cases it was facilitatory. Furthermore, when words had many near neighbours as compared to many distant neighbours, the results were inhibitory. Mirman and Magnuson (2008) argue that near neighbours delay processing, because they act as competitors while distant neighbours create a gradient that increases settling for the correct word. These results indicate that competition and facilitation effects emerge depending on the number of close and distant neighbours. However, research into this area is sparse and a greater understanding of the impact of close and distant neighbours may provide greater insight into the effect of lexical associates across task performance, particularly for lexical decision and semantic categorization tasks.

The preceding studies suggest that semantics has a significant impact on the word recognition process. Thus, the concept of semantic richness, measured in a number of different ways, most prominently in features, associations, and through lexical co-occurrences, has been shown to impact word recognition. Semantics in healthy older adults provides a unique opportunity to examine how meaning within language is impacted by adulthood and aging. The following sections examine the process of cognitive aging and include more specifically language and aging with a review of relevant models of cognitive aging.

Aging and Cognition

Research in the area of aging and cognition suggests that as we age cognitive abilities begin a gradual decline that occurs in some cases beginning in early adulthood; declines are seen behaviourally across a wide variety of cognitive abilities (Craik & Salthouse, 2008; Park, 2002; Park & Gutchess, 2005; Salthouse 1996; Schaie, 1994; 2005). In terms of memory abilities, Rabinowitz, Craik, & Ferguson, (1982) theorized that inadequate processing resources were the mechanisms behind poor memory performance in the form of declining attentional resources. Salthouse (1993; 1996) further suggested a more generalized explanation of poorer cognitive abilities with aging. He proposed that as people age there is general slowing, a reduction in processing speed which constrains other cognitive abilities reliant on this process and, in turn, also limits the amount of information that can be processed at any given time (Salthouse, 1996).

Reductions in working memory capabilities have also been proposed as an underlying mechanism; working memory involves the ability to hold information online, process, and manipulate it. It has been proposed as an important construct in the explanation of age related variance in performance, especially during more effortful tasks (Park et al., 1996). Another function, proposed as part of the general rubric of executive functioning, that is thought to have an impact on older adults is a decline in inhibition (Hasher & Zacks, 1988; Zacks & Hasher, 1997). The authors argue that older adults are less able to inhibit irrelevant information, which interferes with directive attention and cognitive processing.

More recently, with greater technological advances in imaging abilities, there has been growing interest in neuroanatomical changes and cognitive aging. In general, older adults show reduced cerebral volume in the frontal lobes (Raz, 2000). In terms of functional patterns, for certain cognitive processes older adults have broader bilateral activation across the cortices while young adults demonstrate a more lateralized activation (Cabeza et al., 1997). Interestingly, if older adults are given instructions and are asked to deeply process the meaning of a word during a memory task as opposed to simply remember them, they show patterns of neural activity (i.e., greater recruitment of frontal regions) similar to young adults (Logan et al., 2002).

Thus semantic associations appear to reduce age related deficits: During a memory task where young and older adults were provided with contextual information only younger adults effectively used the context rich information for recollection (Skinner & Fernandes, 2009). However, once older adults were instructed to encode stimuli more deeply by creating associations between they were able to effectively use this strategy to improve their recollection on a memory task (Skinner & Fernandes, 2009). Thus, meaning and context appear to shrink the age gap in terms of functional and behavioural abilities.

Despite a decline in many cognitive domains, there are some abilities (e.g., those that are composed of knowledge learned in the past) that show little to no decline. The following section provides a review of vocabulary knowledge with aging as well as a more specific focus on aging and language.

Vocabulary Studies and Word Association Studies

Although age related declines in retrieval have been shown at the orthographic/phonological level of language processing, evidence suggests fewer age related deficits in semantics (Burke & Shafto, 2008). In fact, vocabulary and verbal reasoning scores appear to remain relatively intact over the lifetime for healthy adults and may even show an increase (Lezak, Howieson, Loring, Hannay, & Fischer, 2004). In a longitudinal study examining 5000 adults over the span of as long as 35 years, no decline in verbal abilities was found (Schaie, 1994). In addition, examination of verbal abilities across the lifespan indicates well preserved functioning into the 90s for healthy adults (Schum & Sivan, 1997). Verhaeghen (2003) conducted a meta-analysis examining vocabulary scores between 1986 and 2001, and found an increase in vocabulary test scores with aging. However, some findings indicate an adverse influence for the eldest of older adults. Longitudinal research by Backman and Nilsson (1996), examining changes in semantic memory over a 10-year period, found that even after controlling for intelligence, a decrease in semantic performance began once participants reached their 75th or 80th year. However, prior to 75, no age related deterioration was observed. Findings of intact semantic language functioning also include current-events knowledge, which appears to be positively correlated with age (Beier & Ackerman, 2001).

Federmeier, Mclennan, De Ochoa, and Kutas (2002) recorded event related potentials (ERPs) of older and younger adults while they listened to a sentence in which they heard either the expected word at the end of the sentence, an unexpected word from the same semantic category, or an unrelated, unexpected word. Results revealed both older and younger adults' processing was facilitated by an unexpected word from the same semantic category due to similarities between the two category exemplars. The authors proposed that context effects in the sentence serve to constrain and pre-activate features of likely upcoming words. Thus, younger and older adults showed similar influence of semantics.

In contrast to the above findings, some tasks requiring more complex meaning interpretations from context show decline in older adults. Zelinski and Hyde (1996) examined the effects of context in aging by having older and younger adults produce interpretations after reading short stories. Older adults were more likely than younger adults to generalize, leading to erroneous interpretations.

In word association tasks, participants are asked to give the first word that comes to mind after being presented with a word. Older and younger adults produced similar word associates in these tasks (e.g., Burke & Peters, 1986). Burke and Peters (1986) found that older and younger adults gave the same number and proportion of responses in a word association task, although older adults provided slightly more variability in their responses. When they controlled for verbal abilities, no differences were found in the proportion of unique responses between the younger and older samples. The authors concluded that differences in vocabulary affected variability in responses for word associations and that semantic structure is influenced by verbal abilities and not by age.

In sum, there are many ways to examine semantic organization and semantic processing. Several longitudinal studies have found preservation of semantic skills and vocabulary in older adults, while noting deficits in using context. Taken together, it appears that older adults generally have preserved vocabulary skills as they relate to semantics. One means of measuring changes in fluency with aging in clinical settings is the commonly used verbal fluency task. The following review will examine literature related to fluency and aging.

Aging and Fluency

A commonly used test of verbal abilities in neuropsychology is the verbal fluency test; in this task participants must generate as many words as possible based on phonological criteria, (e.g., words beginning with a certain letter), or a semantic category (e.g., animals) within 60 seconds (Lezak, 1995). A widely used example of this task is the Controlled Oral Word Association Test (COWAT; Benton & Hamsher, 1976) which, in a commonly used version, asks participants to generate as many words as possible in sixty seconds that begin with *C*, *F*, and *L*. Tests of verbal fluency have been widely used as a part of assessments designed to examine cognitive impairment (Henry, Crawford, & Phillips, 2004). They have also been proven effective in determining impairment levels and for diagnostic purposes (Hall, Harvey, Vo & O'Bryant, 2011). Success in these tasks relies heavily on executive processes for self-generation of words and monitoring of responses. However, disproportionate atrophy and deterioration of the frontal lobes is thought to occur with normal aging and may therefore impact executive functioning abilities (e.g., West, 1996). Although both phonemic and semantic fluency tests impose considerable demands on executive functioning, semantic fluency has been shown to be more sensitive to semantic hierarchy and rely more heavily on semantic stores than phonemic tests (Henry & Crawford, 2004). Thus poor performance on tests of semantic fluency may reflect deficits in the semantic memory store, and not executive dysfunction (Henry, Crawford, & Phillips, 2004). Performance on fluency measures has been variable with aging and consequently an examination of results found on fluency tests may provide some insight into language changes with older adults.

Generally, studies have found that older adults perform more poorly than younger adults on fluency tasks (Auriacombe, Farbrigoule, Lafont, Jacqmin-Gadda, & Dartigues, 2001; Kempler, Teng, Dick, Taussig, & Davis, 1998; Lanting, Haugrud, & Crossley, 2009). A meta-analysis of norms for the COWAT found a progressive age related decline in fluency (Loonstra, Tarlow, & Seller, 2001). These findings would suggest that through the lifespan there is a decline in the ability to retrieve words in a certain lexical category. However, one alternate explanation is that the decline is reflective of overall slowed processing speed in older adults rather than impoverished lexical or semantic stores (e.g., Phillips, 1999). Fluency tests are timed and thus processing speed decreases may lead to a reduction in the number of generated words when older adults are compared to younger adults.

However, results in this area have not always been consistent: Some studies report equivalent rates of fluency in older and younger adults (e.g., Bolla, Lindgren, Bonaccorsy, & Bleecker, 1990; Crawford, Bryan, Luszcz, Obansawin, & Steart, 2000; Parkin & Java, 1999; Treitz, Heyder, & Daum, 2007) while others report greater fluency in elderly adults relative to younger adults (e.g., Llewellyn & Matthews, 2009; Salthouse, Fristoe, & Hyun Rhee, 1996). One possible explanation for the discrepant findings may be the influence of other mediating factors, for example verbal IQ. It has been suggested that verbal fluency may be reflective of verbal IQ and may mediate the relationship between fluency and aging (Bolla et al., 1990; Parkin & Java, 1999). Bolla et al., (1990) found that fluency rates were significantly affected by verbal IQ and suggested that their findings of equivalent fluency rates for younger and older adults may have been due to a higher level of verbal intelligence in their population. They suggest that older adults with higher verbal intelligence may use compensatory strategies to mask the normal age related changes in performance with the use of more effective recall and organizational strategies, a broader vocabulary, and greater facility with semantics (Bolla et al, 1990). Studies have also found positive correlations between education level and fluency rates (e.g., Tombaugh, Kozak, & Rees, 1999).

When examining semantic and phonemic fluency rates separately, an interesting finding has emerged in healthy older adults. Semantic fluency abilities appear significantly worse than phonemic fluency in older adults compared to younger adults (e.g., Brickman et al., 2005; Parkin, Hunkin, & Walter, 1995; Troyer, 2000). For pathological aging, semantic and phonemic fluency rates are reduced for older adults with amnestic MCI compared to healthy older controls (Nutter-Upham et al., 2008) and participants with Alzheimer's disease produced significantly fewer animal names than healthy older adults, people vascular dementia, and those with a mild cognitive impairment (Hall, Harvey, Vo & O'Bryant, 2011). Further, poorer semantic fluency compared to phonemic fluency have been shown for those with Alzheimer's disease compared to healthy older adults (Monsch, Bondi, Butters, & Salmon, 1992).

Thus phonemic and semantic fluency rates appear to be reduced in healthy older adults when compared to younger adults, with a greater decline in semantic fluency compared to phonemic for older adults. A similar pattern is also seen when comparing amnestic mild cognitive impairment and Alzheimer's disease. The result may reflect underlying changes in normal aging to the semantic system, however, several alternative possibilities exist as it has also been suggested that education and verbal IQ may influence these findings. To focus more specifically on semantics, a review of semantic priming effects and aging will follow as the vast majority of studies examining the structure of semantic organization and aging have used this paradigm (Ferraro, 1995).

Semantic Priming Effects with Aging

Semantic priming provides a simple way of examining the impact of semantic context on word recognition (e.g., Meyer & Schvaneveldt, 1971; Neely, 1991). In a priming task (see Neely, 1991), two events occur. The first involves presentation of a word (the prime) for a brief period of time, for which no response is needed on the part of the participant. This prime is followed by another word (the target), or by a non-word. Participants are then required to make a word/non-word decision about the target item, referred to as a lexical decision task. In the semantic priming condition, the prime and target are semantically related. For example, the prime *CAT* might be used to prime the target *DOG*. Facilitation is said to occur (i.e., a priming effect occurs) if the response times are faster for the word *DOG* when *CAT* is used as a prime compared to response times to *DOG* when it is primed by an unrelated word such as *PIN*. The semantic priming effect is the difference of the unrelated minus the related condition.

There are several mechanisms that have been proposed to explain semantic priming effects; the two most prominent are automatic spread of activation and expectancy based priming (e.g., Neely, 1991). During semantic priming participants are not required to make an explicit judgment regarding the relatedness between the prime and the target. Therefore, the facilitation induced in a semantic priming task is presumed to be due to automatic processes (Giffard, Desgranges, Kerrouche, Piolino, & Eustache, 2003). Faster automatic recognition of a target after presentation of a semantically related prime is posited to be due to automatic spreading of activation (Collins & Loftus, 1975). When a prime is presented, its activation is spread automatically throughout the semantic system to other memory nodes that are related to the prime. Once these other nodes become activated their resting level is increased. This increased resting levels means that less activation is needed for them to become activated (Collins & Loftus, 1975).

The second mechanism involves expectancy as a means to explain priming. Expectancy is an attentional process such that participants may come to expect that a certain type of word will always follow another word. This expectancy effect, unlike automatic spreading activation, cannot occur without awareness and intention (Neely, 1991). Participants will therefore expect that a particular type of target word will follow the prime word and generate a set of potential targets after viewing the prime (Neely, 1991). Thus, faster recognition occurs by reducing the demands on additional activation requirements. Automatic spreading of activation and expectancy reduces the amount of sensory processing needed for word recognition (Neely, 1991).

The examination of young versus older adults' semantic priming rates has sparked debate in the literature. Although older adults' reaction times in semantic priming are slowed in comparison to younger adults, the difference between the primed and unprimed conditions, termed the semantic priming effect, has generally been equivalent for young and older participants (e.g., Burke, White & Diaz, 1987; Chiarello, Church, & Hoyer, 1985; White & Abrams, 2004); however, some have found larger priming effects for older adults, (e.g., Cerella, 1985; Chiarello et al., 1985; Laver & Burke, 1993; Lima et al., 1991; Madden, Pierce, & Allen, 1993; Myerson et al., 1992). In the case of increased priming effects for older adults, there have been several explanations for the underlying cause of this finding (e.g., Giffard et al., 2003; Laver, 2009; Laver & Burke, 1993; Myerson, Hale, Chen & Lawrence, 1997).

In Laver and Burke's (1993) meta-analysis of semantic priming effects, most individual studies showed a non-significant increase in semantic priming for older adults. However, these effects reached significance in the meta-analysis. The authors conclude that greater semantic priming for older adults is due to greater experience with language and elaboration of connections in the semantic system. Younger adults show smaller semantic priming effects because they do not have the benefit of years of language experience leading to more connections in the semantic system.

However, other studies have supported a general slowing hypothesis as an explanation for larger priming effects in older adults. Myerson et al. (1997) compared young and older adults' reaction times to lexical decision and semantic categorization tasks. Their results reveal that after controlling for lexical slowing, young and older adults had equivalent priming rates. They suggest that the slower responses found for older adults across tasks are consistent with slowed processing speed but otherwise intact semantic organization.

Similarly, results by Giffard et al. (2003) reveal that when using standardized residuals (instead of raw reaction time) in a lexical decision task there were equivalent semantic priming effects obtained for the younger and older groups. The authors concluded that the large difference in semantic priming effects for older adults compared to younger adults is a reduction in processing speed with age, and that once this effect is controlled, and both young and older adults have equivalent amounts of time to allow for the effect of semantics, semantic priming effects are comparable between the two age groups.

Laver (2009) compared semantic and episodic priming (repeated presentation of prime-target pairs) in young, middle aged, and older adults controlling for response time variability. Due to the fact that participants are required to make a response as quickly as possible in a pronunciation task, longer overall response latencies have been found in older adults. This increased time to respond allows for more processing time for older adults compared to younger adults (Laver, 2009). As a result, slowed cognitive processing in aging would lead to an increase in context effects of semantics because the long processing time allows semantics to build up and has a greater chance to take effect (Giffard et al., 2003). In order to control for the extra processing time that older adults may have over younger adults due to their slower responding, several techniques have been used. Laver (2009) incorporated a response signal so that all participants respond within a particular window of time. Results reveal no differences in automatic semantic or episodic priming for young, middle aged, and older adults.

Additionally, further investigation into the neuroanatomical basis for semantic priming has revealed that both younger and older participants show similar neural correlates during this task (Gold, Anderson, Jicha, & Smith, 2009). Activation occurred in the inferior temporal region, for both older and younger adults, in a semantic priming paradigm; the authors concluded that a preserved fMRI response pattern for older adults occurred in lexical decision trials. Gold et al. (2009) propose that the similar neuroanatomical patterns between younger and older participants are due to intact automatic spreading of activation within the semantic system.

Thus, research findings on semantic abilities, particularly in automatic processes, is somewhat mixed. In some cases it appears that older adults have stable priming effects while others show that older adults may be more influenced by semantics when it is extended to a priming paradigm. The following section focuses on semantic neighbourhood and density effects for healthy older adults.

Aging and Semantic Neighbourhoods

Extensive research has examined semantic priming effects in older adults. However, few studies have examined the influence of semantic richness as measured by language based models of semantic arrangement on older adults' word processing. Studies in this area have found interesting results regarding the possible changes in semantic representations with age.

Using word naming data provided by Spieler and Balota (1998), Buchanan et al. (2001) compared different measures of semantic relatedness for young and older adults. Semantic association size, defined as the mean number of responses from participants when they are asked to say the first thing that comes to mind after hearing a word, was provided by Nelson et al. (1994). This was compared with semantic density (defined as the mean distance between a word and its 10 closest neighbours) using a lexical co-occurrence model (HAL; Lund & Burgess, 1996). In a regression analysis controlling for frequency, orthographic neighbourhood size, and word length, results revealed a significant correlation between naming times (the time it takes to name a target word) and the semantic density measure for older adults. These results suggest that older adults may be more influenced by semantics or more sensitive to semantic density.

More recently, Dunabeitia, Marin, and Carreiras (2009) used word association norms to compare words with many semantic associates and words with few semantic associates for a group of individuals with Alzheimer's disease and a control group of healthy older adults. Although healthy older adults responded faster than Alzheimer's patients in a lexical decision task, both groups showed facilitation for words with more semantic associates.

Further investigations into the density of older adults' semantic neighbourhoods have produced some interesting findings. Burgess and Conley (2002) examined bodies of text produced by younger and older adults using a lexical co-occurrence model. When examining their semantic neighbourhoods (10 closest neighbours) they found that older adults had greater semantic similarity between neighbours, which they equated to an increase in density (many close neighbours). It was posited that experience may lead to greater accumulation and elaboration of semantic representations over time, resulting in denser neighbourhoods. However, a similar study was also conducted comparing transcribed text from interviews of older adults and Alzheimer's patients (Conley, Burgess, & Glosser, 2001). Again, using a lexical co-occurrence model they examined the semantic neighbourhoods of those interviews. Comparing the 10 closest neighbours, it was found that Alzheimer's patients had denser (closer semantic neighbours) than healthy older adults.

In sum, the area of aging and semantic neighbourhood size and density has not been well researched and there are mixed results on the influence of semantics for older adults. It is evident that further research is needed to determine how aging may influence semantic lexicon arrangement and, conversely, the influence of semantics in older adults' word processing. The recent expansion of examinations of semantic neighborhood size and density (Mirman & Magnuson, 2008) provides a potential foothold to further our understanding.

Models of Cognitive Aging

Theories of aging and cognition have sought to explain the different patterns of language processing that change with aging (e.g., Cerella, 1985; Hasher & Zacks, 1979; Salthouse, 1996). The following consists of a basic overview of selected models of cognitive aging with an emphasis on how they address language functioning.

General slowing theories have been some of the most extensively researched theories of cognitive aging (Burke & Shafto, 2008). Initially, the assumption was that as people age, there is a slowing of nervous system functioning, which affects all cognitive processes in a similar manner (Birren, Woods, & Williams, 1980), however, it has further been suggested that not all cognitive processes show similar rates of slowing. With aging, speed of information processing decreases, affecting a range of cognitive functions including memory and language (Salthouse, 1996). Salthouse (1996), assumes two main mechanisms through which slowing occurs. The first is the time limit mechanism, which proposes that there is a finite amount of time during which cognitive operations take place. When a large proportion of the time is taken up in the early stages of processing, less is available for later stages. During complex cognitive tasks that involve multiple demands that depend on earlier operations, slowed initial processing may lead to less resource availability. The result may be slowed decision making for later tasks. The second assumption is that information availability decreases over time. Because of slower processing for older adults, initial information that is relevant and may be required in later operations cannot be used due to decay or displacement over time (Salthouse, 1996). The result is processing deficits due to degraded time course of activation. With respect to our current understanding of the impact of semantic neighborhood size and spread on word processing such a view would suggest that older adults will be slowed in terms of their speed of processing semantic and spread variables.

For lexical processing, especially in a semantic priming paradigm, researchers have attempted to find a regression coefficient, known as the Brinley plot, to quantify the amount of slowing for older adults in word recognition (e.g., Cerella, 1985; Lima, Hale, & Myerson, 1991; Myerson, Ferraro, Hale, & Lima, 1992). In a Brinley plot, mean reaction times of older adults are regressed on mean reaction times of younger adults to indicate a consistent slowing factor. This may differ based on the level of difficulty of the task demands (Cerella, 1985).

The inhibition deficit hypothesis by Hasher and Zacks (1988; 1997) proposes that older adults are not as efficient in their ability to inhibit irrelevant materials or distracters as compared to younger adults. Inhibitory responses degrade with aging while excitatory responses do not. This lack of suppression is thought to be due to greater input of non-relevant material during encoding. For example, when older and younger adults were asked to read a passage and ignore distracting text (in a different font) interspersed throughout the passage, older adults had more difficulty ignoring the unrelated stimuli, particularly if it was semantically related (Connelly, Hasher, & Zacks, 1991). Similarly, when reading an ambiguous sentence, older adults maintained possible interpretations of the sentence for a longer period of time than younger adults (Hamm & Hasher, 1992).

These results support the theory that older adults are less efficient in their ability to inhibit semantically related, and possibly irrelevant, information. With respect to semantic neighborhood effects, according to this view, older adults should show a greater disadvantage for words with many near neighbors compared to younger adults.

The transmission deficit theory (Burke et al., 2000; Burke & Shafto, 2004) postulates that language processing depends on how quickly and how much priming can be processed across connections of representational units (nodes), within the language-memory system (Burke & Shafto, 2004). Connections within the representational unit are strengthened with frequent and recent use and weakened with disuse. Aging is thought to weaken connection strength at all levels, leading to processing deficits (Burke & Shafto, 2008). Although transmission deficits may result from weakened connections within the representational units at a general level, architecture and structure of systems such as memory and language provide the framework for examining functional deficits.

More specifically, during reading, bottom-up priming from many orthographic and phonological nodes all converge upon a single node. This then allows for activation of a lexical node, which transmits priming to semantic nodes to activate word meaning (Burke & Shafto, 2004). The phonological system's architecture is such that phonological representations are organized hierarchically from syllables to the lowest level of phonological features. Single connections within the phonological system make the system more vulnerable to transmission deficits and degradation (Burke & Shafto, 2004). Thus because phonological nodes involve one-to-one connections they are vulnerable to transmission deficits that may occur, such as in tip of tongue (TOT) experiences. The TOT experience occurs when people are certain that they have particular information in their memory but are temporarily unable to access or retrieve the information (Brown, 1991). This is one of the most frequent kinds of memory failure in older adults and appears to increase with age (e.g., Juncus-Rabadan, Facal, Rodriguez, & Pereiro, 2010; Rastle & Burke, 1996).

The transmission deficit theory proposes that in contrast to the phonological system, the semantic system remains intact. The semantic system has many redundant and converging connections that are built up over time causing them to be more resistant to degradation (Burke & Shafto, 2004). In other words, older adults have acquired more general knowledge over the course of their lifetime, as compared to younger adults, leading to more elaboration of connections within the semantic system. This enrichment leads to greater interconnections between concepts allowing for convergence or summation priming to occur faster and more easily on semantic nodes (Burke et al., 2000). This has been offered as a possible explanation for the finding of larger semantic priming effects in older adults. In the current context, this view would lead to a prediction that elderly adults show larger effects of semantic neighborhood size than young adults.

The preceding theories of cognitive aging related to language processing and semantics provide a framework for understanding how language representations may change over the course of adulthood. Examining semantic neighbourhood effects in a lexical co-occurrence model provides an interesting way to not only examine how neighbourhood affects word reading but also how it may change with aging.

There were two major goals for these experiments. The first was to further evaluate a model of semantics as defined by lexical co-occurrences (WINDSORS model; Durda & Buchanan, 2008) and to add to the growing literature in the area of semantics and word recognition. The second was to examine semantic effects in aging as research is sparse examining the impact of semantic richness on older adults.

Rationale and Study Outline

In order to address the second goal of the experiment series, both young and older adults participated in all experiments. As was previously mentioned, the WINDSORS model is a model of semantic space, designed to capture semantic information by examining large bodies of text and looking at the number of times words co-occur together. It is similar to other co-occurrence models, such as the Hyperspace Analogue to Language Model (HAL; Lund & Burgess, 1996) but offers an advantage over other models by controlling for the effects of word frequency. In lexical co-occurrence models, such as WINDSORS, words are represented as vectors. The distance between words in semantic space corresponds to their similarity in meaning (Durda & Buchanan, 2008). Words that are very close together in semantic space are, therefore, more similar. Thus, the first experiment used behavioural data to evaluate semantic similarity and define neighbourhood size in the WINDSORS model (Durda & Buchanan, 2008).

The second experiment used the standardized cut-offs derived from experiment one to define semantic neighbourhood size. Words for this experiment had either large or small semantic neighbourhoods. Put differently, some words were related to many other words based on their meaning (large semantic neighbourhood) while other words were related to few words based on their meaning (small semantic neighbourhood). Both young and older adults were tested with these items. This experiment therefore examines the influence of semantic richness and aging on word recognition.

The goal of the third experiment was to examine the effects of semantic density. Previous measures of semantic density used a cut-off of the 10 closest neighbours (Buchanan et al., 2001; Siakaluk et al., 2003). However, one criticism of this approach is that the 10 closest neighbours is an arbitrary measure of distance (Shaoul & Westbury, 2010). This way of measuring does not take into account the potential confounding effect of overall neighbourhood size. It is possible that a word with many semantic neighbours has more close neighbours than a word with few neighbours by sheer virtue of its size and therefore greater probability of both more close and distant neighbours (Shaoul & Westbury, 2010). Further distinction around the distribution of neighbours is therefore needed to disentangle these effects. Recall that for the purposes of the present experiments density refers to the distribution or amount of spread of neighbours through a semantic neighbourhood irrespective of size, while semantic neighbourhood size refers to the sheer number of semantic neighbours within a defined neighbourhood size. The examination of semantic density provides a deeper analysis of the properties of their neighbourhoods and their influence on lexical decision latencies.

The final experiment is designed to examine the effects of semantic distance in a priming paradigm. A primed lexical decision paradigm allows for an examination of how semantic information, which has been shown to impact word reading, is used by older and younger adults. Thus as the final step in the experimental series it provides an indication of how meaning might influence the word reading process through facilitation or inhibition. Although much research has been done regarding semantic priming and aging, typically, the focus has been on examining the priming differences between close semantic associates and controls (e.g., Giffard et al., 2003; Laver, 2000). Consequently, we do not have a great deal of information on how more distant neighbours might impact word recognition for older adults. This experiment will provide a more detailed examination of the priming process by using close, distant, and unrelated prime-target pairs.

CHAPTER 2:

EXPERIMENT SERIES

Experiment One: Defining Semantic Neighbourhood Size in the WINDSORS Model

In order to evaluate the impact of semantic neighbourhood sizes on reaction time, the neighbourhoods first needed to be defined. This experiment was exploratory in nature with the purpose of examining several different thresholds for neighbourhood size to determine which one best captured a target word's semantic information.

Experiment 1: Methods

Participants

Lexical decision reaction times were provided by the Balota, Cortese, and Pilotti (1999) corpus as part of an archival analysis. In this database, thirty young adults (mean age: 21.1 years) and thirty older adults (mean age: 73.6 years) were asked to indicate as quickly as possible whether they thought a word string was a real English word or not. This database contains 2906 monosyllabic words. In order to control for variability associated with certain word characteristics, a subset of words was selected. These words have orthographic frequency counts (how frequently words are used) of less than six per million words and are three to six letters in length, as obtained though Wordmine (Durda & Buchanan, 2006). This resulted in a total of 1343 words. These words were used in the development of semantic neighbourhoods and will be referred to as target words.

Stimuli and Procedure

In order to develop semantic neighbourhoods, the distance between a target word and every other word in the WINDSORS model (Durda & Buchanan, 2008), which contains approximately 50000 words, was calculated. These represent the similarity between words in semantic space. Similarity ratings range from 1 to -1. The scores can be thought of as a continuum with similarity scores close to 1 indicating more semantic similarity and words ranging from 0 to -1 indicating little to no relationship. For example, the words *north* and *south* have a high similarity rating of .73, while *movie* and *usher* have a lower similarity rating of .03. The next step involved calculating the means, standard deviations, and standard scores of these similarities. All words with a standard score above a certain threshold were considered as part of a target word's semantic neighbourhood. Recall that semantic neighbours with larger similarity ratings (i.e. closer to 1) indicate greater semantic closeness. Therefore, words with standard similarity scores *above* a certain cut-off were included in the semantic neighbourhood.

The appropriate cut-offs were the topic of investigation in this study with the resulting values assumed to roughly translate into a marker of the size of their semantic neighbourhoods. Six standard deviation thresholds or cut-offs ranging from .5 SDs to 5.5 SDs above the mean were then examined in separate analyses for young and older adults. Mean semantic neighbourhood sizes and standard deviations are listed in Table 1. The corresponding neighbourhood size values were correlated with the Balota et al. (1999) RTs. These analyses were conducted with the young RT data and the elderly RT data separately to determine whether the age groups differ with respect to their critical cut-off points.

Results

Young Adults

Six hierarchical multiple regressions were run using mean lexical decision reaction times for each word as the dependent variable. The following cut-off points, in standard deviations, were used to determine semantic neighbourhood size: .5 SD, 1.5 SD, 2.5 SD, 3.5 SD, 4.5 SD, and 5.5 SD.. Each distance was tested separately. For each regression step 1 was identical: word characteristics known to influence word recognition were statistically controlled by entering them in step 1. These variables are orthographic frequency and orthographic neighbourhood size, both known to affect lexical decision reaction times. Step 1 was significant for orthographic frequency and orthographic neighbourhood size, $F(2, 1340) = 119.01$, $p < .001$. In the second step of the model, one of six semantic neighbourhood sizes was entered as determined by standard deviation cut-offs. With the addition of semantic neighbourhood size as a predictor in step 2, the model was significant for the 1.5 SD cut-off [$F(1, 5.83) = p < .05$; $R^2 = .151$ in step 1 and .155 in step 2] and 3.5 SD cut-off [$F(1, 1339) = 4.33$, $p < .05$; $R^2 = .151$ in step 1 and .154 in step 2]. The semantic neighbourhood sizes created from remaining four cut-off points (.5 SD, 2.5SD, 4.5 SD, 5.5SD, and 6.5SD) were each run in a hierarchical multiple regression but did not reach significance.

Older Adults

The analyses were identical to those described above except that the dependent or predicted variable was the mean reaction times of thirty older adults. In these analyses, step 1 was significant for orthographic frequency and orthographic neighbourhood size, $F(2, 1340) = 71.1$, $p < .001$. With the addition of semantic neighbourhood size as a predictor in step 2, the model was significant for the 1.5 SD [$F(1, 1339) = 6.96$, $p < .05$; $R^2 = .096$ in step 1 and .101 in step 2) and the 3.5 SD cut-off [$F(1, 1339) = 4.36$, $p < .05$; $R^2 = .096$ in step 1 and .099 in step 2]. The semantic neighbourhood sizes created from remaining four cut-off points (.5 SD, 2.5 SD, 4.5 SD, 5.5 SD, and 6.5 SD) were submitted to hierarchical multiple regression but did not reach significance.

Table 1

Overall Mean semantic neighbourhood sizes and Standard Deviations, as determined by the WINDSORS model of lexical co-occurrences, for a subset of words (1343) provided by the Balota, Cortese, and Pilotti (1999) corpus.

Neighbourhood Cut-off	Mean	SD
.5 SD	13932.08	561.06
1.5 SD	3070.94	344.68
2.5 SD	633.35	100.7
3.5 SD	193.8	90.2
4.5 SD	79.74	62
5.5 SD	37.6	40.78

Discussion

The 1.5 SD and 3.5 SD cut-off criteria for semantic neighbourhood size accounted for a significant proportion of variability in the model for both the young and older adult's RTS when they were added in step 2. This further supports findings that semantics is influential in the single word recognition process. These results also support the

WINDSORS model of lexical co-occurrences and indicate through behavioural data that the model captures semantic information important in word recognition and it provides us with an empirically tested metric that is appropriate for both younger and older adults. Semantics are indeed an influential part of the word processing puzzle. Further experiments directly manipulating WINDSORS semantic neighbourhood size are now possible using the results obtained through this experiment for criteria of a semantic neighbourhood.

The following experiments will use the 3.5 SD cut-off as an indicator of semantic neighbourhood size. Although both the 1.5 SD cut-off and 3.5 SD cut-off were significant predictors of reaction time and could be used to define a semantic neighbourhood, the 1.5 SD produced extremely large neighbourhood sizes with a mean number of semantic neighbours of over 3000 words. There was also a considerable amount of variability with a standard deviation of 330 words. The 3.5 SD neighbourhood size was considerably smaller (M = 193.8) than the 1.5 SD size (M = 3070.94). As a result, the 3.5 SD cut-off was selected because it was expected to minimize the amount of noise and variability in the semantic neighbourhood measure.

Experiment 2: The Effect of Semantic Neighbourhood Size

The previous experiment found that a 3.5 SD cut-off point for semantic neighbourhood size captured the influences of semantic information in word recognition. In order to more closely examine the impact of semantics on reaction times in both young and older adults, a lexical decision experiment was designed using words with many semantic neighbours (large semantic neighbourhoods) and words with few semantic neighbours (small semantic neighbourhoods). Given previous findings (e.g., Buchanan et al., 2001) there should be a facilitation effect for words with larger semantic neighbourhoods.

According to the general slowing hypothesis (Salthouse, 1996) response times for older adults should decrease in all conditions as slowing is generalized to all cognitive functions. However, according to the transmission deficit hypothesis (Burke & Shafto, 2008), older adults have more connections in the semantic system and should therefore show similar or greater facilitation compared to young adults for words with more semantic neighbours compared to few semantic neighbours.

Recruitment Procedures and Pre-test Measures for Experiments 2-4

The following participant recruitment, demographic, and pre-test measures were identical for the remainder of the experiments in the series (2-4). Participants were never involved in more than one study to ensure that all words were not previously experienced as part of an experiment (due to overlap in words used as part of the experimental measures).

Participants

Young adults. Students from the University of Windsor aged 18-25 received course credit in exchange for their participation. Criteria for participation in the research study consisted of individuals whose native language is English. Further demographic variables collected at the time of testing are described in full below.

Older Adults. Healthy men and women aged 60-85 were recruited from the community through posters at local seniors centers and word of mouth. Similar to the young adult group, inclusionary criteria consisted of native English speakers, who were reportedly neurologically intact with no history of neurological incidents. Older adults were also given the Montreal Cognitive Assessment (MoCA; Nassredine et al., 2005) in order to rule out any participants with cognitive impairment. The MoCA is a brief cognitive assessment tool designed to screen for mild cognitive impairment. As a result it is a more conservative estimate of cognitive abilities than more traditional measures (e.g., The Mini Mental State Exam - MMSE; Folstein, Folstein, & McHugh, 1975). It takes approximately five to ten minutes to administer. A cut-off criterion of 26 out of 30 and above was used for inclusion (Nassredine et al., 2005). Older participants were given $10 compensation for their participation.

Demographic Measures. All participants completed a demographics questionnaire (See Appendix A for the young adults full questionnaire and Appendix B for the older adults questionnaire). Participants were asked to provide their age, gender, native language, and number of years of formal education completed. Furthermore, they were asked if they were bilingual, had a personal history of learning disabilities, family history of learning disabilities, diagnosis of ADHD/ADD, speech or language difficulties, speech or language therapy, any neurological conditions (e.g., stroke, epilepsy, tumour etc.), as well as any head injury or loss of consciousness. Handedness information was also collected. This was done in order to ensure consistency in responding. All participants made "*yes*" responses in a lexical decision task with their dominant hand. As a result, left handers received lexical decision instructions to press the "V" key with their left hand if they thought something was a real English word and press the "N" with their right hand if they thought it was a nonword.

Pre-Test Measures. In addition to the demographics questionnaire (and MoCA for older adults) all participants were given a reading proficiency test taken from the Wide

Range Achievement Test – Third Edition (WRAT-3; Wilkinson, 1993) word reading section. Participants were also given a short version of the North American Adult Reading Test (NAART35; Uttl, 2002). These tests provide an estimate of reading levels (WRAT-3) as well as an estimate of IQ (NAART35).

Experiment 2: Methods

English words were generated by the MRC database (www.psy.uwa.edu.au/mrcdatabase/uwa_mrc.htm). All stimuli were monosyllabic words with four to five letters. Low frequency words with frequency counts of less than six per million as obtained through the Wordmine database (Durda & Buchanan, 2006) were used for the experiment. Semantic neighbourhood size was calculated using the cut-off of 3.5 SD that was established in experiment 1. Words with the highest 30% of neighbours and lowest 30% of neighbours were used to make up the word lists. Forty words comprised the many semantic neighbours group and 40 comprised the few semantic neighbours group. Word lists were balanced for orthographic frequency, orthographic neighbourhood size, number of letters, phonemes, and phonological frequency (see Appendix D). Independent t-tests were conducted using the preceding variables to ensure that word lists did not differ on these word characteristics.

Eighty non-word stimuli that look like words, but have no meaning in the English language, were created to match the words used in the experiment on word length, number of syllables, and orthographic neighbourhood size. These nonword stimuli contained pronounceable consonant and vowel blends. Each participant saw all words in random order. Participants viewed a total of 80 real words (40 with large neighbourhoods and 40 with small neighbourhoods) and 80 non-words matched for orthographic neighbourhood size and number of letters.

Procedure

The experimental sessions were conducted individually using a laptop computer with DirectRT software (Empirisoft, 2006). Young adults were tested in laboratory facilities at the University of Windsor. Older adults were tested either in their homes or at the laboratory facilities at the University of Windsor. In all cases (in lab or at home) the testing was completed in a quiet environment free from distraction.

Participants were instructed both verbally and in writing (see Appendix C) to decide whether the presented word was a real English word as quickly as possible.

All experimental stimuli were presented in the center of the computer screen. Participants engaged in five practice trials before beginning the experiment. Feedback was provided during the practice trials. After the final practice trial, they were again presented with the instructions on screen. To begin, a cross symbol (+) was presented on the screen for 500ms to orient participants. The cross was then replaced by a word or non-word that remained on screen until participants made a response. Right-handed participants were to press the “N” key if it was a real word and the “V” key if it was a nonsense word or not a real word. Left-handed participants pressed the “V” key if it was a real word and the “N” key if it was a nonsense word.

Results

A total of 80 participants completed the first experiment; 51 in the young adult condition and 29 in the older adult condition. Data from ten participants in the young adult condition were removed: six people did not meet the inclusionary criteria for age, three participants revealed that English was not their first language and one participants' data was removed due to computer malfunction during administration. Additionally, two participants in the young adult condition had extremely slow mean reaction time latencies (1159 ms and 1595 ms) and their data were removed from the analyses as outliers. Data from five of the older adults were removed: One participant indicated that English was not their first language, three participants had MoCA scores below the cut-off for inclusion in the experiment, and one participant indicated a neurological condition. The remaining 39 participants in the young adult condition and 24 participants in the older adult conditions were included in the analyses.

Demographics

In the young adult condition 8 men and 31 women participated with an average age of 21 years (*SD* = 1.7 years). The average education level was 14 years of schooling (*SD* = 1.4 years). In the older adult condition 3 men and 21 women participated with an average age of 68.25 years (*SD* = 4.6 years). The average education level was 16.6 years for older adults with an average MoCA score of 27.5.

As the complete list of demographic information in Table 2 indicates older adults had significantly higher scores on the NAART35, WRAT-3 Reading, and education level [$t(61) = -7.28$, $p < .01$; $t(61) = -3.35$, $p < .01$; $t(61) = -5.06$, $p < .01$, respectively], they were examined further. However, reading level (WRAT-3), education level, and IQ estimate (from NAART35) did not correlate with reaction time.

Table 2

Experiment 2: Means and Standard Deviations of Participant Characteristics by Age.

Measure	Young Adults (n = 39)	Older Adults (n = 24)
Age in years	21 (1.7)	68.25 (4.6)
Education in years	14 (1.4)	16.6 (2.64)
WRAT-II Reading T-Score	52.48 (5.55)	56.79 (3.72)
NAART-35 score	15.51 (4.67)	24.79 (5.28)
NAART estimated FSIQ	105.39 (4.67)	114.67 (5.28)
MoCA		27.5 (1.22)

Reaction Time Analyses

Reaction times below 350 ms or above 2500 ms were removed from the data set. The outliers comprised less than 1% of the data set. The remaining reaction times for all correct responses for the 47 participants were averaged across participants and stimuli.

Mean lexical decision latencies and percentage error rates are listed in Table 3. Results (in figure 1) were analyzed using a 2 (Semantic neighbourhood size: Large vs. Small) X 2 (Age: Young vs. Older) mixed design analysis of variance (ANOVA). Data were analyzed through participant and item analyses. In a participant analysis (which is the main focus of the experiment), mean reaction times for each participant are used as a depended variable. Alternatively, the data may also be examined through an item analysis. In an item analysis mean reaction times for each item (i.e., each word) are analyzed as dependent variables thus allowing another approach to measuring the effects of the independent variables (age and neighbourhood size). For the participants analysis (F_1), semantic neighbourhood size was the within subjects variable while age was the between subjects variable. In the items analysis (F_2), semantic neighbourhood size was the between item variable while age was the within item variable. There was an advantage for words with many semantic neighbours over words with few neighbours [$F_1(1, 61) = 36.28$, $p < .01$; $F_2(1, 78) = 14.2$, $p < .01$]. Age also had an effect [$F_1(1, 61) = 10.92$ $p < .01$; $F_2(1, 78) = 102.59$, $p < .01$] with younger adults responding faster than older adults. These two factors did not interact [$F_1(1, 61) = 2.59$, $p = .61$; $F_2(1, 78) = 1.07$, $p = .30$).

Table 3

Mean reaction time (RT) in milliseconds (ms), standard deviations (SD), and error rates as a function of semantic neighbourhood size and age in a lexical decision task.

Age and Semantic Neighbourhood Size	RT (ms)	SD	% Error
Young Adults			
Small Semantic Neighb.	688.32	129.89	10.06
Large Semantic Neighb.	644.41	98.51	5.57
Older Adults			
Small Semantic Neighb.	775.69	100.1	1.77
Large Semantic Neighb.	738.61	94.68	1.46

Error Analyses

There was an overall mean accuracy rating of 95% for young and older participants. Analysis of percent errors revealed a main effect of neighbourhood size with fewer errors for words with many semantic neighbours compared to words with few semantic neighbours [$F_1(1, 61) = 18.66$, $p < .01$; $F_2(1, 78) = 4.32$. $p < .05$]. Older adults produced fewer errors than younger adults [$F_1(1, 61) = 28.4$, $p < .01$; $F_2(1, 78) = 61.82$, $p < .01$]. However, these main effects were qualified by an age x semantic neighbourhood size interaction, [$F_1(1, 61) = 14.11$, $p < .01$; $F_2(1, 78) = 5.09$, $p < .05$]. Paired samples t-tests reveal that young adults made more errors for words from smaller neighbourhoods compared to larger neighbourhoods $t_1(38) = -5.83$, $p < .001$; $t_2(78) = 2.19$, $p < .05$. However, older adults showed no difference in error rates for words from large compared to small semantic neighbourhoods $t_1(23) = -.47$, $p = .64$; $t_2(78) = .5$, $p = .62$.

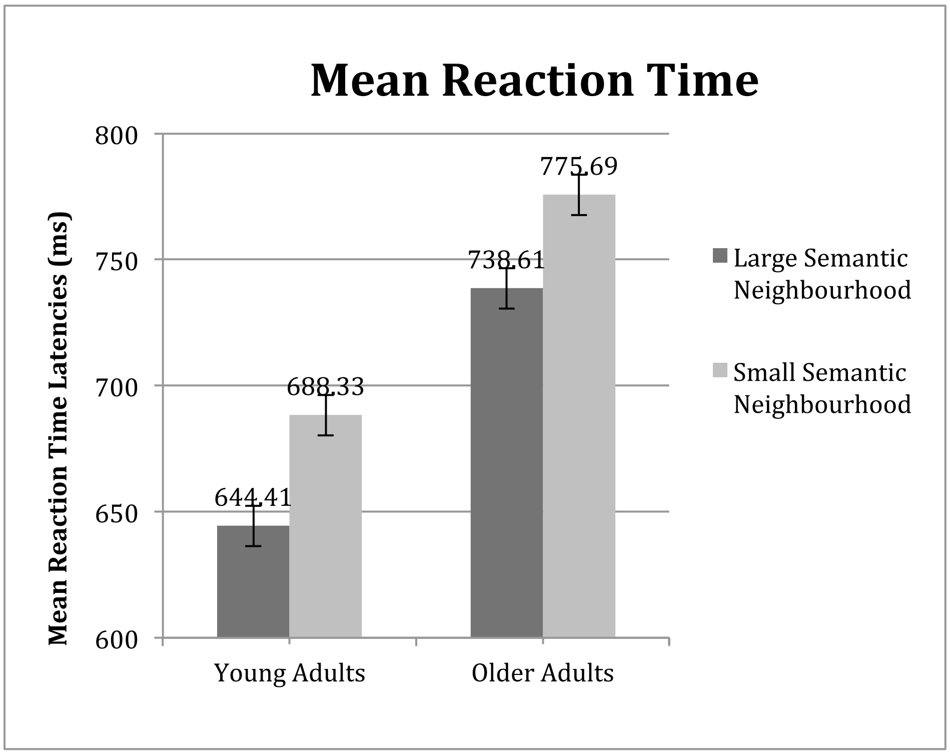

Figure 1. Mean reaction time latencies as a function of neighbourhood size and age.

Discussion

The results reveal an effect of semantic neighbourhood size on word recognition. Words with richer semantic representations are processed more quickly than words with less rich semantic representations as defined by the WINDSORS model (Durda & Buchanan, 2008). This effect holds for both younger and older adults. This finding adds to the growing body of work that reveals and elaborates the role of semantics in word reading and word recognition processes (e.g., Balota et al., 2004; Buchanan et al., 2001; Pexman et al., 2008; Siakaluk et al., 2003; Yap et al., 2011; 2012; Yates et al., 2001). The current findings are consistent with a study by Pexman et al. (2008) who found that number of semantic neighbours (as defined by the WINDSORS model) was related to lexical decision reaction time.

Younger adults had faster overall responses than did older adults but both groups processed words with more semantic neighbours faster than words with few. Similar sensitivity to semantic richness in these two groups suggests that the older adults may have an intact semantic system that operates in much the same way as the younger adults despite an overall slowing. Indeed a reduction in processing speed is a well-known cognitive consequence of successful aging (e.g., Myerson et al., 2000; Salthouse, 1996). The overall finding of slower response times for older adults compared to younger adults may be accounted for by general slowing theories that postulate equally slowed cognitive processes across domains (e.g., Salthouse, 1996). Interestingly, older adults showed overall lower error rates than younger adults and while younger adults made more errors to words from small neighbourhoods compared to large neighbourhoods, older adults showed a consistently low error rate across these two groups. One possible explanation may be a speed accuracy trade-off. Older adults may be more cautious and take more time to ensure a correct response thereby negatively impacting their speed relative to the young adult condition. It is also possible that older adults have greater experience with language and have a more extensive vocabulary leading to fewer errors as they would have encountered fewer unfamiliar words.

The present findings suggest a facilitative role of semantics in a lexical decision task for both young and older adults using metrics from the WINDSORS lexical co-occurrence model. Results from experiment 1 allowed for a direct manipulation of neighbourhood size in the current experiment. These results demonstrated that semantics relationships are well represented by the WINDSORS model and that semantics is an influential part of word recognition. In terms of aging, older adults are intact in their processing of semantics. The next two experiments move beyond semantic neighbourhood size to provide a more in-depth picture of the properties of semantic neighbourhoods and possible age –related effects of those properties on word recognition.

Experiment 3: The Effect of Semantic Density

The previous study revealed that semantic neighbourhood size does indeed impact how quickly people process written words. This finding is an important consideration in the design of study three as this study will control for semantic neighbourhood size when examining density in order to reduce the confounding effect of this variable. Investigation into the properties of semantic neighbourhoods has found a difference in reaction times based on the distribution of neighbours (or density) throughout a neighbourhood (Mirman & Magnuson, 2008). More neighbours clustered around a target produce an inhibitory effect while neighbours spread throughout the neighbourhood create a facilitatory effect. According to Mirman and Magnuson (2008), words with many close neighbours are inhibitory while many neighbours spread out throughout the neighbourhood are facilitatory. As a result, a similar finding may be expected for this experiment. Recall also that Burgess and Conley's (2002) examination of text produced by younger versus older adults showed that older adults produced denser semantic neighbourhoods than younger adults. Therefore, density is an informative variable for semantic neighbourhoods that may be more influential for older adults than their younger counterparts.

According to the inhibition deficit hypothesis (Hasher & Zacks, 1988; 1997) older adults may show greater inhibition with many close neighbours, or denser neighbourhoods, as compared to younger adults because older adults have difficulty inhibiting close distracters. Thus, older adults may have larger differences in mean reaction times comparing dense versus sparse neighbourhoods. In contrast, the transmission deficits hypothesis would predict relatively enhanced facilitation for words with many close semantic neighbours for older adults compared to younger controls. This would be predicted on the basis that facilitation is due to a more extensive semantic network developed through years of experience with language. In contrast, the general slowing hypothesis would predict equivalent rates of slowing across all cognitive processes resulting in longer response latencies for older adults but with generally similar priming patterns for young and older adults.

Experiment 3: Methods

Stimuli

Seventy low frequency words with word counts of less than six per million according to the Wordmine database were used as target words. These words all had large semantic neighbourhoods as defined by the WINDSORS model and had the highest 30% of neighbours for all words in the model. Words with large semantic neighbourhoods were used exclusively in order to control for neighbourhood size. These words were then divided into two groups based on a semantic density measure. Words that had more dense semantic neighbourhoods had clustered groups of neighbours around the target word whereas words from more dispersed neighbourhoods had a greater spread of neighbours with more distance between the target word and each of its neighbours (See figures 2 & 3). Density was calculated as the mean distance between the target word and every other word in its semantic neighbourhood. Words with many close neighbours result in an overall smaller mean and more clustered neighbourhood. Words with more distant neighbours result in a larger mean distance between a target and its neighbours and greater spread of neighbours throughout the neighbourhood.

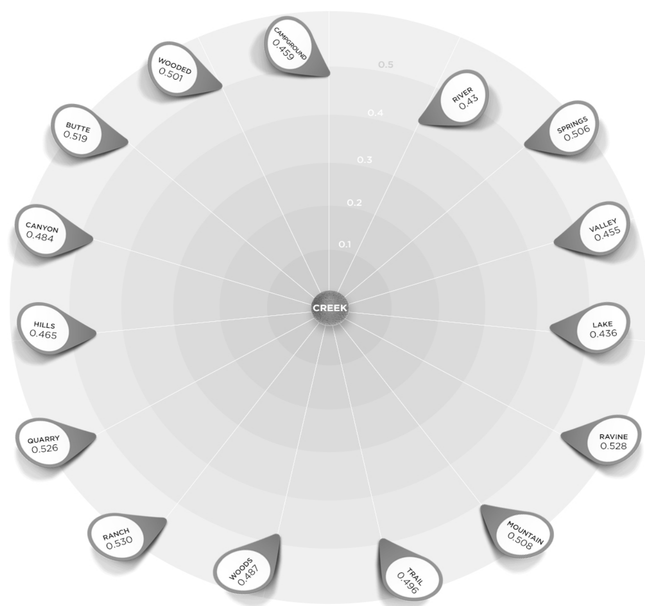

Figure 2. Representation of a sparse semantic neighbourhood using the 15 closest neighbours to the word *creek*.

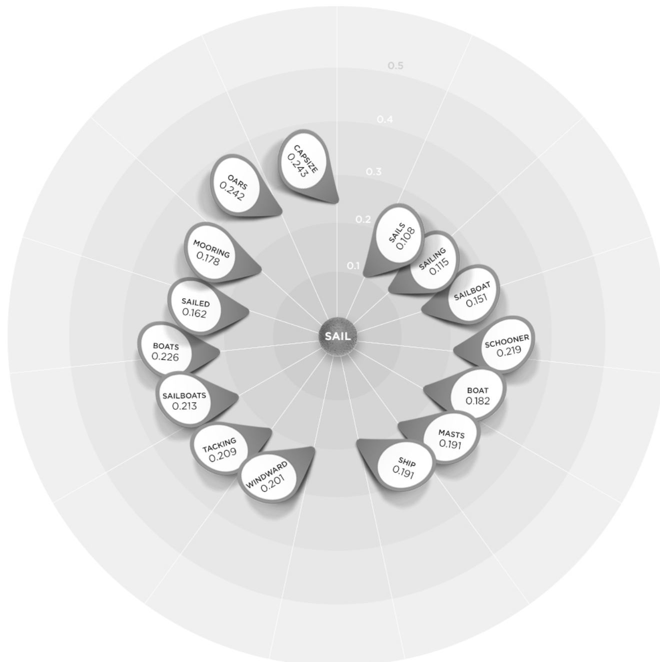

Figure 3. Representation of a dense semantic neighbourhood using the closest 15 neighbours for the word *sail.*

Words with large semantic neighbourhoods were divided into two word lists of 35 words each. These two semantic density lists represent the clustered and dispersed neighbourhoods. The dispersed list had a mean similarity rating between neighbours of .26 while the clustered list had similarity ratings between neighbours of .3. Every participant saw each word. The two word lists were balanced for word length, orthographic neighbourhood size, number of phonemes, and phonological neighbourhood size. Additionally, 70 pronounceable non-words were created and matched for number of letters and orthographic neighbourhood size. Procedures were the same as those listed in experiment 2.

Results

A total of 79 participants completed the experiment; 47 in the young adult condition and 32 in the older adult condition. Data from eight participants in the young adult condition were removed because they revealed during testing that they did not meet the inclusionary criteria for age or English as a first language. Data from seven of the older adults were removed: Three participants chose to discontinue during testing due to arthritis or vision related difficulties and four participants had MoCA scores below the cut-off for inclusion in the experiment. The remaining 39 participants in the young adult condition and 25 participants in the older adult conditions were included in the analyses.

Demographics

In the young adult condition there were 5 men and 34 women and the average age of participants was 21 years (*SD* = 2.2 years). The average education level was 13.5 years of schooling. In the older adult condition there were 6 men and 19 women and the average age of participants was 73.5 years (*SD* = 9.6 years). The average education level was 14.9 years for older adults and the mean score on the MoCA was 27.1.

As the complete listing of demographic information in Table 4 indicates, older adults had higher scores on the NAART35, WRAT-3 Reading, and education level [$t(62) = -5.76$, $p < .01$; $t(62) = -3.01$, $p < .01$; $t(62) = -2.38$, $p < .01$, respectively]. However, as in the previous experiment, these variables were not significantly correlated with reaction time.

Reaction times below 350 ms or above 2500 ms were removed from the data set. The outliers consisted of less than 1% of the data set. Mean lexical decision latencies and percentage error rates are listed in Table 5.

Table 4

Experiment 3: Means and Standard Deviations of Participant Characteristics by Age.

Measure	Young Adults (n = 39)	Older Adults (n = 25)
Age in years	21 (2.2)	73.5 (9.6)
Education in years	13.5 (1.18)	14.9 (2.76)
WRAT-II Reading T-Score	50.92 (6.21)	55.16 (4.08)
NAART-35 score	12.46 (6.18)	22.28 (7.33)
NAART estimated FSIQ	102.34 (6.18)	112.16 (7.33)
MoCA		27.1 (1.11)

Reaction Time Analyses

Results were submitted to a 2 (semantic neighbourhood density: many near neighbours vs. dispersed neighbours) X 2 (age: young vs. older) mixed design analysis of variance (ANOVA) for all correct reaction times to word items. For the participant analysis (F_1), semantic density was the within subjects variable while age was the between subjects variable. In the items analysis (F_2), semantic density was the between items variable while age was the within items variable. There was an advantage for words with dispersed neighbourhoods over words with dense neighbourhoods for participants [$F_1(1, 62) = 9.82$, $p < .01$] but not items [$F_2(1,68) = .56$ $p = .45$](see figure 4). There was a main effect of age [$F_1(1, 62) = 17.49$, $p < .01$; $F_2(1,68) = 148.96$, $p < .01$] with younger adults responding faster than older adults. Age and neighbourhood density did not interact [$F_1(1,62) = .37$, $p = .54$; $F_2(1, 68) = .31$, $p = .58$].

Error Analyses

There was an overall mean accuracy rating of 95% for young and older participants. There was a main effect of age, with older adults producing fewer errors than younger adults [$F_1(1, 62) = 12.34$, $p < .01$; $F_2(1,68) = 26.59$, $p < .01$]. However, there was no main effect of density [$F_1(1, 62) = 2.3$, $p = .13$; $F_2(1,68) = .13$, $p = .72$]. These factors did not interact [$F_1(1, 62) = .37$, $p = .55$; $F_2(1,68) = .03$, $p = .86$].

Table 5

Mean reaction time (RT) in milliseconds (ms), standard deviations (SD), and error rates as a function of semantic density and age in a lexical decision task.

Age and Semantic Density	RT (ms)	SD	% Error
Young Adults			
Dense Semantic Neighb.	656.98	82.09	6.23
Dispersed Semantic Neighb.	638.01	77.57	5.64
Older Adults			
Dense Semantic Neighb.	751.99	122.48	3.08
Dispersed Semantic Neighb.	731.86	89.41	1.71

Discussion

As expected, words with dense (or more clustered) semantic neighbourhoods produce longer reaction time latencies than words with more dispersed semantic neighbourhoods. These findings are consistent with prior research by Mirman and Magnuson (2008) who found an inhibitory effect for words with many close semantic neighbours and facilitation for words with many distant neighbours in a semantic categorization task. These effects of density in semantic neighborhoods mimic those found in manipulations of phonemic density: Spoken words from dense phonological neighbourhoods take longer to be identified than words from sparse phonological neighbourhoods (e.g., Luce & Pisoni, 1998).

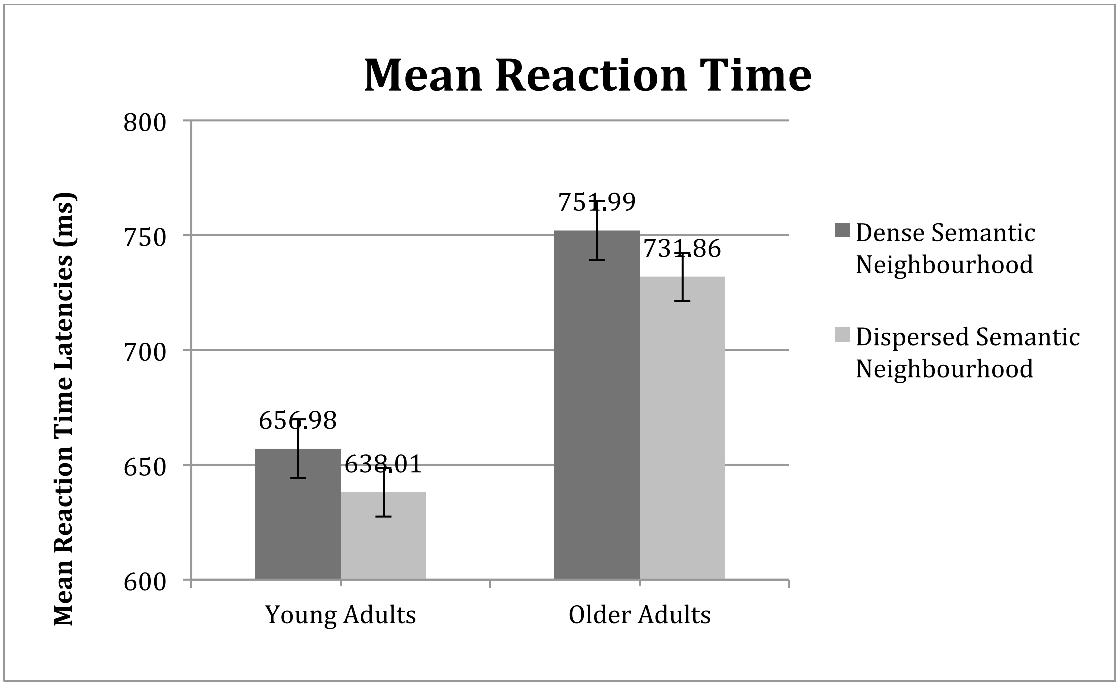

Figure 4. Mean reaction time latencies as a function of neighbourhood density and age.

The second major finding of this experiment is the impact of aging on semantic density. Similar to the findings in experiment one, older adults showed a slower but otherwise similar response pattern to younger adults. Specifically, they produced slower reaction times to words with denser semantic neighbourhoods than words with more dispersed neighbourhoods. The finding that older adults were generally slower in their reaction times than younger adults is in keeping with the general slowing hypothesis (Salthouse, 1996).

Semantic neighbourhood size and density play a role in word recognition and this appears true for both older and younger adults. Experiment 2 results established that semantic neighbourhood size was an important variable in word recognition. This effect was then controlled in the current study in order to gain a greater understanding of how the spread of neighbours throughout a neighourhood may influence reaction times. The results underscore the fact that not only does neighbourhood size matter, but distribution matters as well. This adds to our knowledge of how neighbourhood variables contribute to word recognition. In terms of aging, again older adults appear to have intact semantic processing with similar patterns compared to young adults of inhibition and facilitation in response to density variables. To further explore age-related changes in semantic processing the next experiment uses a semantic priming paradigm where variations in prime-target relatedness will be used to uncover any subtle age-related changes in semantic sensitivity.

Experiment Four: Semantic Priming with Close versus Distant Neighbours

Previous research has found overall slowed response times for older adults but generally equivalent semantic priming effects (e.g., Burke et al., 1986; Chiarello et al., 1985; White & Abrams, 2004), with some findings of increased semantic priming effects for older adults (e.g., Cerella, 1985; Laver & Burke, 1993; Lima et al., 1991; Madden et al., 1993; Myerson et al., 1992). According to the transmission deficit hypothesis (Burke & Shafto, 2008) equivalent or increased semantic priming effects would be expected for older adults compared to younger adults due to their greater experience with language and accumulation of linguistic knowledge over time. A methodological account (Myerson et al., 1997) may also be possible based on slower processing speed in older adults. In this case, a larger priming effect is due to slowed overall response times for older adults. Priming effects are derived by subtracting related from unrelated mean reaction times. In other words, with longer response latencies produced by older adults, reducing the difference by a constant amount leads to larger priming effects. The third possibility is one based on the inhibition deficit model, which would predict less priming for closer semantic neighbours in older compared to younger adults due to poor inhibition of words with very similar meanings leading to greater competition during word recognition.

Experiment 4: Methods

Stimuli

Target words consisted of English words with frequency counts of less than six per million as obtained through the Wordmine database (Durda & Buchanan, 2006) and were from large semantic neighbourhoods (top 30% in terms of neighbourhood size). Prime-target word pairs were selected as stimuli. Three types of prime-target pairs were created based on their level of semantic similarity as obtained through the WINDSORS model database. Using all words in the model, word pairs that had the highest amount of similarity (i.e., those that are closest neighbours in semantic space) were used to create the close neighbour pairs. Forty-eight close neighbour pairs were selected due to their high degree of semantic similarity (average similarity ratings of .3). Forty-eight distant neighbour pairs were selected due to their more distant semantic similarity rating (average similarity ratings of .27). Forty-eight unrelated pairs were created with semantic similarity ratings below zero indicating no semantic relationship. Forty-eight pronounceable non-word targets were created and were matched for word length, number of syllables, and number of orthographic neighbours.

Participants were randomly assigned to one of three conditions. The prime-target pairs were rotated across the three priming conditions such that participants saw targets and primes only once but received all three conditions. Each participant also saw each target word in one of the three priming conditions described above. Therefore, each participant saw 16 close semantic pairs, 16 distant pairs, 16 unrelated pairs, and 48 word-nonword target word pairs. In order to minimize expectancy effects, for each trial, participants had a 50% chance of viewing a non-word target.

Procedure

All stimuli were presented in the center of the computer screen. Participants engaged in five practice trials before beginning the experiment and received feedback on their performance. After the final practice trial they were again presented with the instructions on screen and asked to press any key to begin. Each trial consisted of four consecutive processes. A cross symbol (+) was presented centrally on the screen for 500 ms to orient participants. The cross was then replaced by the prime for 150 ms. The prime was immediately replaced by the target word which remained on the screen until participants made a decision. All primes were presented in lower case and all targets in upper case in order to minimize the amount of orthographic overlap between them. Right-handed participants were to press the "N" key if it was a real word and the "V" key if it was a nonsense word or not a real word. Left-handed participants pressed the "V" key if it was a real word and the "N" key if it was a nonsense word.

Results

A total of 100 participants completed the fourth experiment; 66 in the young adult condition and 34 in the older adult condition. Data from thirteen participants in the young adult condition were removed because they were above the age limit, five revealed during testing that they did not meet the inclusionary criteria for English as a first language, and one participant's data were lost due to computer malfunction. Data from four of the older adults were removed: Three participants had MoCA scores below the cut-off for inclusion in the experiment and one indicated that English was not his first language. The remaining 46 participants in the young adult condition and 30 participants in the older adult conditions were included in the analyses.

Demographics

In the young adult condition there were 7 men and 39 women and the average age of participants was 21 years (*SD* = 2.2 years). The average education level was 14.2 years of schooling for young adults. In the older adult condition there were 10 men and 20 women and the average age of participants was 67.2 years (*SD* = 5.6 years). The average education level was 16.6 years for older adults and the mean score on the MoCA was 27.4.

The demographic variables listed in table 6 reveal that older adults had significantly higher scores on the NAART35, WRAT-3 Reading, and education level [$t(74) = -10.24$, $p < .01$; $t(74) = -6.027$, $p < .01$; $t(74) = -6.02$, $p < .01$, respectively]. However, as with the previous experiments, these variables were not significantly correlated with reaction time.

Table 6

Experiment 4: Means and Standard Deviations of Participant Characteristics by Age.

Measure	Young Adults (n = 46)	Older Adults (n = 30)
Age in years	21 (2.2)	67.2 (5.6)
Education in years	14.2 (1.27)	16.6 (2.20)
WRAT-II Reading T-Score	51.32 (4.67)	57.03 (2.77)
NAART-35 score	14.13 (4.86)	26.3 (5.83)
NAART estimated FSIQ	104.01 (4.86)	116.18 (5.38)
MoCA		27.4 (1.33)

Reaction Time Analyses

Reaction times below 350 ms or above 2500 ms were removed from the data set. The outliers consisted of less than 1% of the data set and the cut-off points were used in order to remove only the minimal amount of valid reaction times. No list effects emerged [$F(2,73) = .52$, $p = .59$]. In other words, there was no significant difference in reaction times across the three experiment lists. As no list effects emerged, it was removed from the remaining analyses.

Priming Effects

Because we were interested in the possible facilitatory effects of semantic distance between prime-target pairs, results were analyzed using priming effects[1]. These scores are derived by taking each participant's mean RT in the semantically close and distant pairs and subtracting it from their mean RT in the control (i.e., no semantic similarity) condition. The result is a difference score and this difference score represents the priming effect. A positive score indicates facilitation. A negative score indicates inhibition.

These priming effects were submitted to a 2 (close vs. distant pairs) x 2 (age: young vs. older) mixed design analysis of variance (ANOVA) for participants (F_1) where priming effects was the within subjects variable and age was between subject. The item analysis (F_2) was a 2 (close vs. distant pairs) x 2 (young vs. older) repeated measures ANOVA (for a summary of mean priming effects see Figure 5 and Table 8).

---

[1] As priming effects was our primary focus in the analysis, results from a secondary analysis of overall mean RTs are not described in detail. Mean reaction times, standard deviations, and error percentages are listed in Table 7.

Table 7

Mean reaction time (RT), standard deviations (SD), and mean error rates as a function of semantic distance in prime target pairs and age in a lexical decision task.

Age and Semantic Distance	RT	SD	% Error
Young Adults			
Close Semantic Pairs	696.73	188.78	1.76
Distant Semantic Pairs	732.92	206.07	3.26
Unrelated Pairs	727.40	201.65	2.58
Older Adults			
Close Semantic Pairs	742.04	131.17	.42
Distant Semantic Pairs	769.35	163.44	1.45
Unrelated Pairs	783.25	157.24	1.04

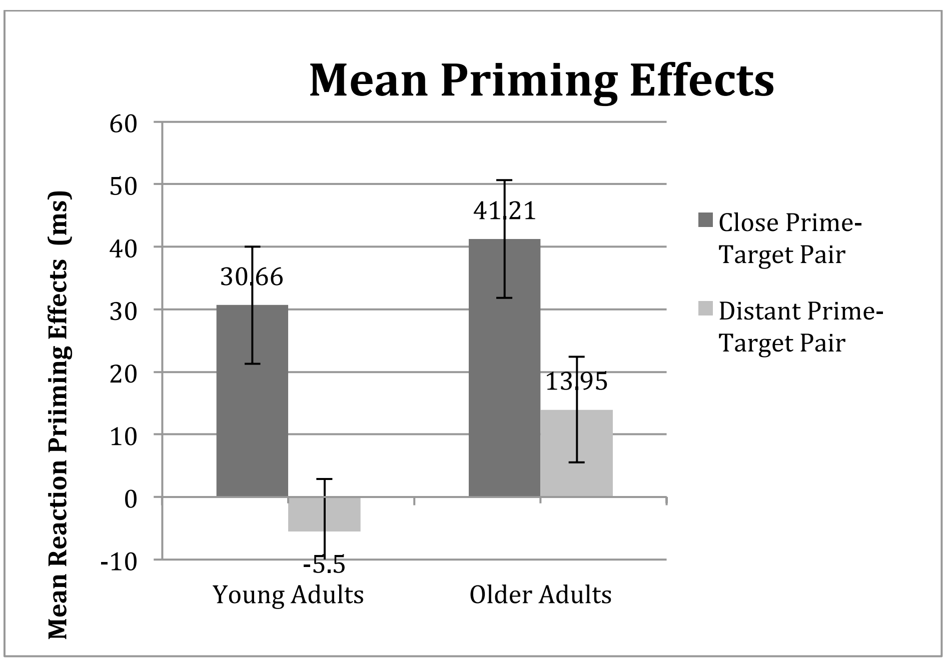

Figure 5. Mean priming effects as a function of semantic similarity in prime-target pairs and age.

The results reveal a main effect of prime type [$F_1(1, 74) = 11.72$, $p < .01$; $F_2(1,47) = 13.19$ $p < .01$] indicating that close semantic pairs show a greater priming effect than distant semantic pairs. No main effects emerged for age [$F_1(1, 74) = .97$, $p = .33$; $F_2(1,47) = .72$ $p = .39$]; thus older adults did not show greater priming effects compared to younger adults.

Older adults therefore show equivalent priming effects compared to young adults. Interestingly, although prior experiments demonstrated significantly slower overall response times for older adults compared to young adults, this difference did not reach significance in the participant analysis [$t_1(74) = -1.11$, $p = .27$]. Nonetheless, in the items analysis it was significant, with older adults responding slower than younger adults [$t_2(47) = -5.75$, $p < .01$].

Table 8

Mean priming effects in milliseconds and standard deviations (SD) as a function of semantic distance of prime target pairs and age in a lexical decision task.

Age and Semantic Distance	Priming Effect	SD
Young Adults		
Close Semantic Pairs	30.66	85.40
Distant Semantic Pairs	-5.5	73.79
Older Adults		
Close Semantic Pairs	41.21	71.01
Distant Semantic Pairs	13.95	68.45

Error Analyses

Older adults had lower error rates than younger adults [$F_1(1, 74) = 8.67$, $p < .01$; $F_2(1, 47) = 15.52$, $p < .01$]. However, there were no differences in errors across prime types [$F_1(2, 148) = 2.31$, $p = .1$; $F_2(2, 94) = 2.17$, $p = .12$]. The prime x age interaction for errors did not reach significance [$F_1(2, 148) = .07$, $p = .93$; $F_2(2, 94) = .34$, $p = .72$].

Discussion

The priming paradigm allows for a potentially more naturalistic experience of language to compliment the findings of semantic impact on single word reading. In this study close semantic neighbours were more effective primes than distant semantic neighbours. This finding provides evidence that even subtle changes in semantic relatedness (from a close to more distant prime) impact word recognition and thus highlights the important contribution of semantics. Similar to past results, older adults were more accurate in their lexical decisions compared to young adults.

The goal of this experiment was to examine subtle differences in the use of semantic information with aging. Although prior research has shown, in some cases, larger semantic priming effects with older adults (e.g., Laver & Burke, 1993 & Myerson et al., 1992; 1997), this was not found in the present experiment. In fact, these results are more in line with prior research demonstrated equivalent priming effects for young and older adults (e.g., Burke, White & Diaz, 1987; Chiarello, Church, & Hoyer, 1985; White & Abrams, 2004). The findings are also consistent with results of Experiments 1-3 demonstrating intact semantic processing for older adults.

CHAPTER 3:

GENERAL DISCUSSION

There were two main objectives in this series of experiments. The first was to examine the influence of semantic neighbourhood characteristics in visual word recognition. Using a lexical co-occurrence model, this was done by first defining what constitutes a semantic neighbourhood. The second and third experiments examined the influence of semantic neighbourhood size and density. Finally, the fourth experiment involved priming with either a close or more distant semantic neighbour. The results of this series of experiments serve to underscore the importance of the role of semantics in word recognition.

The second goal of the experimental series was to examine how aging may affect semantic processing by comparing young and older adults. The results provide an indication of the impact of neighbourhood effects and semantics in healthy aging. The present study is one of few experiments that involves an in depth exploration of semantic neighbourhood characteristics and their impact of word reading alongside an examination of aging and semantics.

In order to understand the impact of semantic neighbourhood size and density, neighbourhoods first needed to be defined within the WINDSORS model. As the model is composed of a very large number of words, at some point semantic relatedness between words becomes quite minimal. Although words that are located close to a target word in semantic space reflect much shared semantic similarity, words that are very distantly related may ultimately reflect loose or weak semantic associations. Defining neighbourhood size provides a means to discriminate between a true semantic neighbour and non-neighbour. By testing various neighbourhood sizes, the results from Experiment 1 provided evidence using behavioural data that neighbourhood size does impact lexical decision times. This finding is consistent with findings from other lexical occurrence models (e.g., HAL; Lund & Burgess, 1996) as they have been found to capture multiple forms of semantic relatedness including associative and categorical information as well as behavioural data. Thus this experiment provides evidence that the WINDSORS model, which has been shown to previously capture many aspects of semantic memory (Durda & Buchanan, 2008), also using behavioural data is able to define semantic neighbourhood size.

The results from experiment 1 formed the basis for further exploration of the effects of neighbourhoods by defining the boundaries of neighbourhood size. The goal of the second experiment was to experimentally manipulate the size of the neighbourhoods in order to examine the effect on lexical decision reaction times. The outcome of experiment 2 revealed that words with many semantic neighbours were responded to more quickly in a lexical decision task than words with few semantic neighbours. This is similar to research findings of a facilitative effect for words with greater semantic richness, denser semantic neighbourhoods, and words with more lexical associates (e.g., Balota et al., 2004; Buchanan et al., 2001; Pexman et al., 2008; Siakaluk et al., 2003; Yap et al., 2011; 2012; Yates et al., 2003). However, the finding of facilitative effects of large semantic neighbourhoods does not take into account the spread or distribution of neighbours throughout the neighbourhood. To address this, the third experiment involved experimentally manipulating semantic density (that is, whether a word had many near neighbours versus a more distributed semantic neighbourhood). Indeed density effects were found as words with dense neighbourhoods resulting in slower lexical decisions than words with dispersed neighbourhoods.

Current findings and models of visual word recognition

The results from experiment 2 can be interpreted within several different models including interactive activation models using top-down/bottom-up processing and PDP models. For example, the modified IAC model proposed by Balota et al. (1991) suggests that semantics is activated pre-lexically and can influence reaction time through feedback connections. For the current results, increased semantic activation is fed back to the orthographic level, which allows for faster reaction times, as the orthographic level is that which is responsible for making lexical decisions. Words with more neighbours create stronger activation at the semantic level that causes greater activation and quicker response in a lexical decision task. In other words, stronger meaning representations provide for greater facilitation for word recognition.

Alternatively, the present results could be accounted for using an interactive distributed feedback model (Hino & Lupker, 1996, Pexman & Lupker, 1999; Yates et al., 2003). In a fully distributed model of this type, there are bidirectional links between orthographic, phonological, and semantic units. Lexical decisions are assumed to be made based on settling within the orthographic units. Once there is sufficient settling and stability, the system is able to make a “yes” response to a real word. The amount of settling that is required to indicate that a letter string is a word will vary based on a number of factors (Yates et al., 2003). In the case of semantics, neighbourhood effects occur due to enhanced feedback from the semantic to orthographic level. Larger semantic neighbourhoods are thought to have richer representations at the semantic level and, as a result, enhance feedback. Strong feedback will lead to rapid settling within orthographic units (Pexman & Lupker, 1999). Therefore, the larger semantic neigbourhoods lead to faster settling and quicker response times in experiment 2 due to being more richly represented.

However, results from experiment 3 indicate that neighbourhood effects are not always purely facilitative. In fact, through a manipulation of the spread of neighbours, it was discovered that density slows reaction time. This is not entirely unexpected, however, if one considers results from neighbourhood effects in orthography and phonology that have been shown to be facilitative and competitive, respectively.

Overall, there is well-established consensus on what determines a phonological or orthographic neighbourhood. In visual word recognition, low frequency words with many orthographic neighbours generally result in faster lexical decision times than words with few neighbours (e.g., see Andrews, 1997). In contrast, for phonology, Luce and Pisoni (1989) found that words with many phonological neighbours (they termed this density) led to an inhibitory effect for spoken word recognition.

Less is known, however, regarding semantic neighbourhood effects. With a multitude of ways to define semantic associations (i.e., features, associations, lexical co-occurrence etc.) there continue to be quite disparate views of how to define semantic relationships and, in turn, semantic neighbourhoods. Additionally, it is important to note that in many cases density and neighbourhood size are used interchangeably in research of orthographic and phonological effects. However, in the present experiments they represent separate constructs: density is defined as the closeness of semantic neighbours to a target word while neighbouhood size is defined as the total number of semantic neighbours. This has allowed for a more detailed examination of neighbourhood effects by looking at these areas separately. As the definitions of orthographic and phonological neighbourhoods' generally does not allow for these separate distinctions, less is known regarding the size x density effects. In the case of orthography, perhaps closest to the present experiments in density is the effect of letter transposition confusability. These experiments allow for a manipulation of lexical similarity as word pairs differ only in the order of two adjacent letters (e.g., *silt/slit* & *trail/trial*; Andrews, 1996). These may represent "closer" neighbours in that the letter is not completely replaced (as in the case of *spit* and *slit*) but is simply transposed thus preserving more of the overall orthography than a letter replacement but still differing slightly. In lexical decision and naming tasks, Andrews (1996) found that words that differed from another word by the order of two adjacent letters (transposition confusable words) were responded to more slowly than control words. Thus, transposition confusable words have an inhibitory effect on word recognition. This was further supported in a priming experiment where neighbour primes (e.g., *sant - SAND*) facilitated priming while the transposed letter prime (e.g., *snad - SAND*) led to inhibition. This is in contrast to facilitatory effects that are generally found with large orthographic neighbourhoods (Andrews, 1997). It was proposed that general similarity may help word identification, such as sharing all but one letter; however, increased similarity hinders identification (Andrews, 1996). Similar to the findings in orthography, in the area of spoken word recognition, when words have a high amount of phonotactic similarity (defined as shared phonetic segments such as morphemes, syllables, and words) this appears to facilitate processing; however, words with large phonological neighbourhoods (words that sound similar to many other words) show an inhibitory effect (Luce & Large, 2001; Vitevich & Luce, 1999). Therefore, in the area of phonology this may represent a similar neighbourhood effect of having many near neighbours creating a competition effect while having much phonotactic similarity is akin to more distant neighbours.

Within an interactive activation model (IAC; McClelland and Rumelhart, 1981) these results may be explained through lateral inhibition and competition. In the lexical inhibition hypothesis, there are inhibitory connections between letter and word strings that compete for identification in a "best matching" strategy leading to word identification. As a result, semantically related words would automatically be activated upon viewing of a semantic associate. Thus words with many close neighbours may cause a delay in word identification as very similar associates are inhibited prior to the identification of the word and "yes" response.

The results may also be explained in terms of connectionist modeling. For example, Mirman and Magnuson (2008) tested an attractor based model of semantics using semantic features. Results from the model were similar to behavioural data in that the model's settling rate was faster for words with few near neighbours and words with more distant neighbours. Thus distant neighbours created settling to the correct attractor and near neighbours behaved as competitor attractors, which resulted in increased processing time. They proposed that these are the effects of "familiarity facilitation" and "competitor inhibition" (Mirman & Magnuson, 2008). This may also account for similar results obtained in the present experiments. Large neighbourhoods produce facilitation because in this overall continuum of settling, more familiar words enhance settling rates while in the case of denser semantic neighbourhoods, many near neighbours may delay the identification as their high degree of shared semantic similarity may create competition and inhibition amongst neighbours. Thus, interestingly, within the same level and task demands, different results are obtained due to varying neighbourhood characteristics.

The final experiment provided an extension using a priming experiment. This allowed for an indication of how semantic information might be used when presented within a context. It also provides information on the relationship between neighbouring words. The findings, as expected, indicate that a close semantic associate facilitates reaction time to a target word compared to both a more distant word. The effects of semantics appear to be most effective for close associates, which show a strong facilitation effect. The priming experiment further validates the lexical co-occurrence model by going beyond the single word and examining how contextual information, which might be more closely associated to procedures used during typical word reading, is impacted.

Aging and Semantics

The second major goal of the experiment series was to further elaborate on the role of aging in neighbourhood effects. As described in the introduction, despite age-related documented declines in many areas of cognitive functioning, verbal abilities appear to be one of the few areas that remain intact during healthy aging (Schum & Sivan, 1997; Verhaeghen, 2003). The current research compared young and older adults' in each experiment. The findings indicate that older and younger adults had identical neighbourhood effects including cut-offs for semantic neighbourhood inclusion in experiment 1, facilitation of large semantic neighbourhoods in experiment 2, and competition for words with dense semantic neighbourhoods in experiment 3.

Not surprisingly, experiments 2 & 3 found that older adults generally have longer reaction times than younger adults. These slowed reaction times for older adults are consistent with declines in processing speed with aging. Indeed, speed of information processing has been shown to steadily decline during adulthood with an onset occurring as early as early adulthood (Salthouse, 2010).

Experiment 4 extended these findings through a priming experiment and examined subtle influences in how older adults use semantics when there is a context. Previous research has shown that older adults show larger priming effects (e.g., Cerella, 1985; Laver & Burke, 1993; Lima et al., 1991; Madden et al., 1993; Myerson et al., 1992). Alternatively, researchers have also found generally equivalent priming rates between older and younger adults (e.g., Burke et al., 1987; Chiarello et al., 1985; White & Abrams, 2004) and others have shown that when cognitive slowing and attention are controlled (e.g., Giffard et al., 2003; Laver, 2009) age related differences in priming disappear. The current findings are consistent with this research and show no significant differences in priming effects with age. This therefore suggests that young and older adults are similarly impacted by semantic information in a priming context.

Several theoretical models were proposed to account for age differences in performance on semantic tasks. For example, the transmission deficit hypothesis (e.g., Burke et al, 2000), proposes that healthy older adults not only have intact semantic systems but have more elaborated interconnected semantic networks. Proponents of this model would predict that older adults are more sensitive to semantic manipulations than their younger participants. According to this theory, a more richly represented semantic system may have created facilitation by distant semantic associates in older but not younger adults. However, the current results are not consistent with this theory. Greater priming effects for older adults were not seen compared to young adults.

According to the inhibition deficit hypothesis (Hasher & Zacks, 1988; 1997), older adults have a more difficult time inhibiting irrelevant stimuli such as semantic information. For example, Hamm and Hasher (1992) found that older adults maintained possible interpretations of stories longer than younger adults. Thus it is possible that older adults are more sensitive to semantic information due to their inability to inhibit its activation during priming. This may result in greater facilitation for more distant neighbours as semantic information is kept "on-line" for a longer duration of time creating an advantage for semantic processing. Though this offers an advantage in an experimental manipulation, it may not translate into an everyday advantage for older adults. With decreases in processing speed that accompany aging, coupled with difficulty inhibiting irrelevant or unnecessary information, older adults may struggle with increasing demands on working memory which, in turn, impacts their ability to process information. However, the prediction of enhanced priming for a distant semantic associate leading to similar priming effects for close and distant neighbours due to a lack of inhibition was not seen in the context of experiment 4. Furthermore, older adults displayed an identical pattern to young adults in experiment 3 of inhibition for words with dense neighbourhoods and facilitation for more distributed neighbourhoods. A lack of inhibition in this experiment would suggest greater competition for older (compared with younger) adults with close and distant neighbours, but this finding was not supported.

According to Salthouse's (1996) general slowing hypothesis, speed of information processing decreases with age affecting a variety of cognitive functions. Although not all abilities are affected equally, the theory posits that within a particular domain, cognitive processes are equally slowed. Despite the fact that older adults had slower reaction times than younger adults in experiments 2 & 3, experiment 4 showed no age related differences in reaction times. The reason for this finding is unclear but it may be possible that this equivalence in reaction times may be the root of equivalent priming effects. Prior research has shown that once cognitive slowing has been controlled age related differences in priming effects disappear, as longer reaction time latencies appear to provide additional time for the build-up of semantic activation within the lexical system (Giffard et al., 2003; Laver, 2009). Thus, in experiment 4, the lack of age related differences in RT may have served to control for general slowness with the result of equivalent priming rates for young and older adults. Equivalent priming effects in experiment 4 support the notion that automatic spreading of activation across the semantic system (with the eventual accumulation on a target node) does not slow with the aging process despite other slowed cognitive abilities such as processing speed.

Additionally, older adults were superior in their accuracy ratings compared to younger adults showing overall lower error rates throughout the experiment series. This may be indicative of a speed-accuracy trade-off in which older adults take longer to respond to ensure their accuracy. However, in experiment 4 there were no age differences in RT and there continued to nonetheless be superior accuracy rates for older adults. One possible explanation for overall greater accuracy in older adults may due to enhanced knowledge of lexical status through experience with language. Older adults consistently showed higher estimated IQ, education levels, and reading levels. Although these variables were not correlated with response times they may have had an impact on error rates as this group of more highly educated older adults likely has more familiarity and experience with language.

Taken together, these results indicate that older adults demonstrate intact neighbourhood effects. At a general level, these findings appear to support the proposition that semantic processing is preserved with aging and adds to growing literature suggesting, at a more global level, intact semantic memory with aging. Information on semantic abilities and aging provides an important opportunity for comparing healthy versus pathological aging, especially given that semantic degradation is a prominent feature of several forms of dementias.

Reading level, Education, and IQ

When examining scores of reading level through the WRAT-3 reading subtest, NAART35 estimated IQ, and education level, older adults scored significantly higher on the reading and IQ scores and had a higher level of education. Though prior research has demonstrated that reader skill is an important variable for examining during word recognition tasks (e.g. Chateau & Jared, 2000; Jared, Levy, & Rayner, 1999; Lewellen, Goldinger, Pisoni, & Greene, 1993; Sears et al., 2008; Stanovich & West, 1989; Unsworth & Pexman, 2003), the present experiments did not demonstrate this effect. More specifically, reading level, estimated IQ (based on the NAART – 35), and education did not relate to reaction time latencies. Interestingly, upon examination of scores on the NAART35 for younger adults the results reveal that mean score for all the young adults participating in these experiments is 14 while normative data collected by Uttl (2002) reports a higher mean score of 20.6 for 20 year-old adults. Nonetheless, NAART scores were not correlated with response time latencies.

Conclusions and Future Experiments

This series of experiments has added to knowledge regarding semantic neighbourhood effects in visual word recognition. It has also added to our understanding of how these effects are impacted by aging. One area for extension of this work may be to examine these effects in different tasks. For example, in a semantic categorization task participants may be asked whether an item is a living or non-living item. By using a task like this performance is clearly dependent on a participant processing semantics and completing semantic coding (Hino, Pexman, & Lupker, 2006). Therefore, examining tasks in which explicit semantic processing is necessary may further add to our understanding of neighbourhood effects.

Another interesting extension of this work on neighbourhood characteristics is to further break down the structure of semantic neighbourhoods. It is likely the case, especially with large neighbourhoods, that there are separate clusters of related words within a neighbourhood. These clusters may be part of a word’s neighbourhood, but the words in the cluster would also be highly related to one another. How the influence of semantic interrelatedness of clusters would impact word reading is unknown. The distribution of neighbours throughout a neighbourhood may be an important variable in semantics as clusters may exert inhibitory or facilitatory influences. Examining the effects of these clusters on processing a target word would add another dimension to the study of density and size.

Altogether, the role of semantics is an integral part of word reading. How semantics influences reading and how we come to represent similarity between words is an exciting area of research that adds tremendously to our knowledge of how we perform the amazingly complex task of translating print into meaning. This research serves to also deepen our understanding of neighbourhood effects by comparing reaction times from young and older adults. The addition of a healthy older adult group therefore provides a small glimpse into semantics in healthy older adults. Though the overall result is positive in that older adults' responses were similar to young adults it also adds to our understanding of aging effects in semantics and provides a comparison group for those suffering from pathological forms of aging such as dementia. Though extraordinarily complex, the search for meaning in language can provide us with invaluable knowledge regarding cognitive abilities throughout the lifespan.

REFERENCES

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

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

Adelman, J. S., Brown, G. A., & Quesada, J. F. (2006). Contextual diversity, not word frequency, determines word-naming and lexical decision times. *Psychological Science, 17*, 814-823.

Auriacombe, S., Fabrigoule, C., Lafont, S., Jacqmin-Gadda, H., & Dartigues, J. (2010). Letter and category fluency in normal elderly participants: a population-based study. *Aging, Neuropsychology, and Cognition, 8*, 98-108.

Backman, L., & Nilsson, L. G. (1996). Semantic memory functioning across the adult life span. *European Psychologist, 1,* 27-33.

Balota, D. A., Cortese, M. J., & Pilotti, M. (1999). Item-level analysis of lexical decision: Results from a mega-study. In Abstracts of the 40th annual meeting of the Psychonomic Society (p. 44). Los Angeles: Psychonomic Society.

Balota, D. A., Cortese, M. J., Sergent-Marshall, S. D., Spieler, D. H., & Yap, M. J. (2004). Visual word recognition for single syllable words. *Journal of Experimental Psychology: General, 133,* 283–316.

Balota, D. A., Ferraro, R. R., & 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. 187-222). Hillsdale, NJ: Erlbaum.

Beier, M. E., & Ackerman, P. L. (2001). Current-events knowledge in adults: An investigation of age, intelligence, and nonability determinants. *Psychology & Aging, 16*, 615-628.

Benton, A. L., Hamsher, K., & and Sivan, A. B. (1976). *Multilingual aphasia examination.* Iowa City, Iowa: AJA.

Birren, J. E., Woods, A. M., & Williams, V. M. (1980). Behavioral slowing with age: Causes, organization, and consequences. In Poon, L. (Ed.) *Aging in the 1980s: Psychological Issues* (pp. 293-308). Washington, DC: American Psychological Association.

Bolla, K. I., Lindgren, K. N., Bonaccorsy, C., & Bleecker, M. L. (1990). Predictors of verbal fluency (FAS) in the healthy elderly. *Journal of Clinical Psychology, 46,* 623–628.

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

Brickman, A.M., Paul, R.H., Cohen, R.A., Williams, L.M., MacGregor, K.L., Jefferson, A.L., Tate, D.F., Gunstad, J., & Gordon, E. (2005). Category and letter verbal fluency across the adult lifespan: Relationship to EEG theta power. *Archives of Clinical Neuropsychology, 20,* 561–573.

Brown, A. S. (1991). A review of the tip of the tongue experience. *Psychological Bulletin, 109*, 204-223.

Buchanan, L., Brown, N. R., Cabeza, R., & Maitson, C. (1999). False memories and semantic lexicon arrangement. *Brain & Language*, *68*, 172-177.

Buchanan, L., Westbury, C., & Burgess, C. (2001). Characterizing semantic space: Neighborhood effects in word recognition. *Psychonomic Bulletin & Review, 8(3),* 531-544.

Burke, D. M. & Shafto, M. A. (2004). Aging and language production. *Current Directions in Psychological Science, 13*, 21-24.

Burke, D. M. & Shafto, M. A. (2008). Language and aging. In Craik, F. & Salthouse T. A. (Eds), *The Handbook of Aging and Cognition* (3rd ed., pp. 373-443). New York, NY: Psychology Press.

Burke, D. M., MaCkay, D. G., & James, L. E. (2000). Theoretical approaches to language. In Perfect, T. J., & Maylor, E. A., (Eds.) *Models of Cognitive Aging* (pp. 204-237). New York, NY: Oxford University Press.

Burke, D. M., & Peters, L. (1986). Word associations in old age: Evidence for consistency in semantic encoding during adulthood. *Psychology and Aging, 9,* 283-292.

Burke, D. M., White, H., & Diaz, D. L. (1987). Semantic priming in young and older adults:

Evidence for age constancy in automatic and attentional processes. *Journal of Experimental Psychology: Human Perception and Performance, 13*, 79-88.

Cabeza, R. et al. (1997). Age-related differences in neural activity during memory encoding and retrieval: A positron emission tomography study. *The Journal of Neuroscience, 17*, 391-400.

Caine, D., & Hodges, J. R. (2001). Heterogeneity of semantic and visuospatial deficits in early Alzheimer's disease. *Neuropsychology, 15*(2), 155–164.

Cerella, J. (1985). Information processing rates in the elderly. *Psychological Bulletin, 98*, 67-83.

Collins, A. M., & Loftus, E. F. (1975). A spreading-activation theory of semantic processing. *Psychological Review, 82,* 407-428.

Coltheart, M., Davelaar, E., Jonasson, J. T., & Besner, D. (1977). Access to the internal lexicon. In S. Dornic (Ed.), *Attention and Performance VI.* San Diego, CA: Academic Press.

Coltheart, M., Rastle., K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: A dual route cascaded model of visual word recognition and reading aloud. *Psychological Review, 108* (1), 204-256.

Connelly, S. L., Hasher, L., & Zacks, R. T. (1991). Age and reading: The impact of distraction. *Psychology and Aging, 6*, 533-541.

Chateau, D. & Jared, D. (2000). Exposure to print and word recognition processes. *Memory and Cognition, 28*, 143-153.

Chertkow, H. and Bub, D. (1990). Semantic memory loss in dementia of Alzheimer's type. *Brain, 113*, 397-417.

Chertkow, H., Bub, D., & Seidenberg, M. (1989). Priming and semantic memory loss in Alzheimer's disease. *Brain and Language, 36,* 420–446.

Chiarello, C., Church, K. L., & Hoyer, W. J. (1985). Automatic and controlled semantic priming: Accuracy, response bias, and aging. *Journal of Gerontology, 40*, 593-600.

Conley, P. & Burgess, C. (2000). Age effects in a computational model of memory. *Brain & Cognition, 43*, 104-108.

Conley, P., Burgess, C., & Glosser, G. (2001). Age vs Alzheimer's: A computational model of changes in representation. *Brain and Cognition, 46*, 86-89.

Crawford, J. R., Bryan, J., Luszcz, M. A., Obonsawin, M. C., & Stewart, L. (2000). The executive decline hypothesis of cognitive aging: do executive deficits qualify as differential deficits and do they mediate age-related memory decline? *Aging, Neuropsychology and Cognition, 7,* 9–31.

Dunabeitia, J. A., Marin, A., & Carreiras, M. (2009). Associative and orthographic neighbourhood density effects in normal aging and alzheimer's disease. *Neuropsychology, 23*, 759-764.

Dunabeitia, J. A., Aviles, A., & Carreiras, M. (2008). NoA's ark: Influence of the number of associates in visual word recognition. *Psychonomic Bulletin & Review, 15*, 1072-1077.

Durda, K. & Buchanan, L. (2008). WINDSORS: Windsor improved norms of distance and similarity of representations of semantics. *Behavior Research Methods, 40 (3),* 705-712.

Durda, K., & Buchanan, L. (2006). WordMine2 [Online] Available: www.wordmine2.org

Empirisoft Corporation. (2006). *Direct RT Version 2006*. New York.

Federmeier, K. D., McLennan, D. B., De Ochoa, E., & Kutas, M. (2002). The impact of semantic memory organization and sentence context information on spoken language processing by younger and older adults: An ERP study. *Psychophysiology, 39,* 133–146.

Fernandes, M. A., Craik, F., Bialystok, E., & Kreuger, S. (2007). Effects of bilingualism, aging, and semantic relatedness under divided attention. *Canadian Journal of Experimental Psychology, 61*, 128-141.

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). Mini-Mental State: A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research, 12,* 189–198.

Forster, K. I. (1976). Accessing the mental lexicon. In R. J. Wales & E. Walker (Eds.), *New Approaches to Language Mechanisms*. Amsterdam: North-Holland.

Forster, K. I., & Hector, J. (2002). Cascaded versus noncascaded models of lexical and semantic processing: The turple effect. *Memory & Cognition*, *30*, 1106-1117.

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, &Cognition*, *22*, 696-713.

Frost, R., Ahissar, M., Gotesman, R., & Tayeb, S. (2003). Are phonological effects fragile? The effect of luminance and exposure duration on form priming and phonological priming. *Journal of Memory and Language, 48*(2), 346-378.

Giffard, B., Desgranges, B., Kerrouche, N., Piolino, P., & Eustache, F. (2003). The hyperpriming phenomenon in normal aging: A consequence of cognitive slowing? *Neuropsychology, 17*, 594-601.

Giffard, B., Desgranges, B., Nore, F., Laleve´e, C., Beaunieux, H., de la Sayette, V., et al. (2002). The dynamic time-course of semantic memory impairment in Alzheimer's disease: Clues from hyperpriming and hypopriming effects. *Brain, 125,* 2044–2057.

Gold, B. T., Anderson, A. H., Jicha, G. A., & Smith, C. D. (2009). Aging influences the neural correlates of lexical decision but not automatic semantic priming. *Cerebral Cortex, 19,* 2671-2679.

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

Grondin, R., Lupker, S. J., & McRae, K. (2009). Shared features dominate semantic richness effects for concrete concepts. *Journal of Memory and Language, 60,* 1-19.

Hall, J.R., Harvey, M., Vo, H.T., & O'Brien, S.E. (2011). Performance on a measure of category fluency in cognitively impaired elderly. *Aging, Neuropsychology, & Cognition, 18*, 353-361.

Hamm, V. P., & Hasher, L. (1992). Age and the availability of inferences. *Psychology and Aging, 7,* 56-64.

Harm, M. W., & Seidenberg, M. S. (1999). Phonology, reading acquisition, and dyslexia: Insights from connectionist models. *Psychological Review, 106 (3),* 491-528.

Harm, M. W., & Seidenberg, M. S. (2004). Computing the meanings of words in reading: Division of labor between visual and phonological processes. *Psychological Review, 111*, 662–720.

Hasher, L., & Zacks, R. T. (1979). Automatic and effortful processes in memory. *Journal of Experimental Psychology: General, 108*, 356-388.

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. *Psychology of Learning and Motivation, 22*, 193-225.

Henry, J. D., & Crawford, J. R. (2004). A meta-analytic review of verbal fluency performance following focal cortical lesions. *Neuropsychology, 18,* 284–295.

Henry, J. D., Crawford, J. R., & Phillips, L. H. (2004). Verbal fluency performance in dementia of the Alzheimer's type: A meta-analysis. *Neuropsychologia, 42,* 1212–1222.

Hodges, J. R., & Patterson, K. (1995). Is semantic memory consistently impaired early in the course of Alzheimer's disease? Neuroanatomical and diagnostic implications. *Neuropsychologia, 33*(4), 441–459.

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, 24, 1431-1453.

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. *Experimental Psychology: Learning, Memory, & Cognition, 28*, 686-713.

Jared, D., Levy, B. A., & Rayner, K. (1999). The role of phonology in the activation of word meaning: Evidence from proofreading and eye movements. *Journal of Experimental Psychology: General, 128*, 219-264.

Juncos-Rabadan, O., Facal, D., Rodriguez, M.S., & Pereiro, A.X. (2010). Lexical knowledge and lexical retrieval in ageing: Insights from a tip-of-the-tongue (TOT) study. *Language and Cognitive Processes, 25*, 1301-1334.

Kemper, S. (1992). Language and aging. In F. I. M. Craik & T. A. Salthouse (Eds.) *The Handbook of Aging and Cognition* (pp. 213-270). Hillsdale, NJ: Lawrence Erlbaum Associates.

Kemper, S. & Sumner, A. (2001). The structure of verbal abilities in young and older adults. *Psychology and Aging, 16*, 312-322.

Kempler, D., Teng, E. L., Dick, M., Taussig, I. M., & Davis, D. S. (1998). The effects of age, education, and ethnicity on verbal fluency. *Journal of the International Neuropsychological Society, 4,* 531–538.

Lambon Ralph, M. A., McClelland, J. L., Patterson, K., Galton, C. J., & Hodges, J. R. (2001). No right to speak? The relationship between object naming and semantic impairment: Neuropsychological evidence and a computational model. *Journal of Cognitive Neuroscience, 13*(3), 341–356.

Lanting, S., Haugrud, N., & Crossley, M. (2009). The effect of age and sex on clustering and switching during speeded verbal fluency tasks. *Journal of the International Neuropsychological Society, 15*, 196-204.

Laver, G. D. (2009). Adult aging effects on semantic and episodic priming in word recognition. *Psychology & Aging, 24*, 28-39.

Laver, G. D., & Burke, D. M. (1993). Why do semantic priming effects increase in old age? A meta-analysis. *Psychology and Aging, 8,* 34-43.

Lewellen, M. J., Goldinger, S. D., Pisoni, D. B., & Greene, B. G. (1993). Lexical familiarity and processing efficiency: Individual differences in naming, lexical decision, and semantic categorization. *Journal of Experimental Psychology: General, 128*, 219-264.

Lezak, M. D. (1995). *Neuropsychological assessment (3rd ed.).* New York: Oxford University Press.

Lezak, M. D., Howieson, D. B., Loring, D. W., Hannay, J. H., & Fischer, J. S.

(2004). *Neuropsychological assessment (4th ed.).* New York: Oxford University Press.

Lima, S., Hale, S., & Myerson, J. (1991). How general is general slowing? Evidence from the lexical domain. *Psychology and Aging, 6,* 416-425.

Linnville, S. E. (1995). Are there age-related processing differences in semantic priming? *Perceptual and Motor Skill, 80*, 585-586.

Locker, L., Simpson, G., & Yates, M. (2003). Semantic neighborhood effects on the recognition of ambiguous words. *Memory & Cognition, 31,* 505–515.

Logan, J. M. et al. (2002). Under-recruitment and non-selective recruitment: dissociable neural mechanisms associated with aging. *Neuron, 33,* 827-840.

Luce, P. A. & Large, N. R. (2001). Phonotactics, density and entropy in spoken word recognition. *Language and Cognitive Processes, 16*, 565=581.

Luce, P. A. & Pisoni, D. B. (1998). Recognizing spoken words: The neighbourhood activation model. *Ear and Hearing, 19,* 1-36.

Lukatela, G., & Turvey, M. T. (2000). An evaluation of the two-cycles model of phonology assembly. *Journal of Memory and Language, 42*(2), 183-207.

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

Madden, D. J., Pierce, T. W., & Allen, P. A. (1993). Age-related slowing and the time course of semantic priming in visual word identification. *Psychology and Aging, 8*, 490-507.

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., Cree, G. S., Seidenberg, M. S., & McNorgan, C. (2005). Semantic feature production norms for a large set of living and nonliving things. *Behavior Research Methods*, *37*, 547-559.

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.

Meyer, D. E., Schvaneveltd, R. W. (1971). Facilitation in recognizing pairs of words: Evidence of a dependence between retrieval operations. *Journal of Experimental Psychology, 90*, 277-234

Meyer, D. E., Schvaneveltd, R. W., & Ruddy, M. G. (1974). Functions of graphemic and phonemic codes in visual word-recognition. *Memory & Cognition, 2*(2), 309-321.

Mirman, D. & Magnuson, J. S. (2008). Attractor dynamics and semantic neighbourhood density: Processing is slowed by near neighbors and speeded by distant neighbors. *Journal of Experimental Psychology, Leaning, Memory, and Cognition, 34*, 65-79.

Monsch, A. U., Bondi, M. W., Butters, N., Salmon, D. P., Katzman, R., & Thal, L. J. (1992). Comparisons of verbal fluency tasks in the detection of dementia of the Alzheimer type. *Archives of Neurology, 49,* 1253–1258.

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

MRC Psycholinguistic Database: Machine Usable Dictionary. Version 2.00 [On-line].

Available http://www.psy.uwa.edu.au/MRCData-Base/mrc2.html.

Myerson, J., Ferraro, F. R., Hale, S., & Lima, S. D. (1992). General slowing in semantic priming and word recognition. *Psychology and Aging, 7,* 257–270.

Myerson, J., Hale, S., Chen, J., & Lawrence, B. (1997). General lexical slowing and the semantic priming effect: The roles of age and ability. *Acta Psychologica, 96,* 83–101.

Nasreddine Z. S., Phillips N. A., Bedirian V., Charbonneau S., Whitehead V., Collin I., Cummings J. L., Chertkow H. (2005). The Montreal Cognitive Assessment, MoCA: a brief screening tool for mild cognitive impairment. *Journal of American Geriatric Society,* 53, 695-699

Neely, J. H. (1991). Semantic priming effects in visual word recognition: A selective review of current findings and theories. In D. Laberge & S. J. Samuels (Eds.), *Basic processes in reading: Perception and comprehension* (pp. 264-336). Hillsdale, NJ: Erlbaum.

Nelson, D. L., Bennett, D. J., & Leibert, T. W. (1997). One step is not enough: Making better use of association norms to predict cued recall. *Memory & Cognition*, *25*, 785-796.

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

Nelson, D. L., Schreiber, T. A., & McEvoy, C. L. (1992). Processing implicit and explicit representations. *Psychological Review*, *99*, 322-348.

Nutter-Upham, K. E., Saykin, A. J., Rabin, L. A., Roth, R. M., Wishart, H. A., Pare, N., et al. (2008). Verbal fluency performance in amnestic MCI and older adults with cognitive complaints. *Archives of Clinical Neuropsychology, 23,* 229–241.

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh Inventory. *Neuropsychologia, 9,* 97-113.

Park, D. C. (2002). Judging meaning improves function in the aging brain. *Trends in Cognitive Sciences, 6*, 227-229.

Park, D. C., Smith, A. D., Lautenschlager, G. Earles, J. L., Frieske, D., Zwahr, M., & Gaines, C. (1996). Mediators of long-term memory performance across the life span. *Psychology and Aging, 11*, 621-637.

Park, D. C., & Gutchess, A. H. (2005). Long-term memory and aging: A cognitive neuroscience perspective. In R. Cabeza, L. Nyberg, & D. Park (Eds.), *Cognitive neuroscience of aging: Linking cognitive and cerebral aging.* (pp. 218-245). New York, NY: Oxford University Press.

Parkin, A. J., Hunkin, N. M., & Walter, B. M. (1995). Relationships between normal aging, frontal lobe function, and memory for temporal and spatial information. *Neuropsychology, 9,* 304–312.

Parkin, A. J., & Java, R. I. (1999). Deterioration of frontal lobe function in normal aging: Influences of fluid intelligence versus perceptual speed. *Neuropsychology, 13,* 539–545.

Perry, R. J., & Hodges, J. R. (1999). Attention and executive deficits in Alzheimer's disease. A critical review. *Brain, 122*(3), 383–404.

Pexman, P. M., Hargreaves, I. S., Edwards, J. D., Henry, L., & Goodyear, B. G. (2007).

The neural consequences of semantic richness: When more comes to mind, less activation is observed. *Psychological Science, 18*, 401-406.

Pexman, P. M., Hargreaves, I. S., Siakaluk, P. D., Bodner, G. E., & Pope, J. (2008). There are many ways to be rich: Effects of three measures of semantic richness on visual word recognition. *Psychonomic Bulletin & Review, 15* (1), 161-167.

Pexman, P. M., Holyk, G. G., & Monfils, M. (2003). Number-of-features effects and semantic processing. *Memory and Cognition, 31*, 842-855.

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. (2002). The impact of feedback semantics in visual word recognition: Number-of-features effects in lexical decision and naming tasks. *Psychonomic Bulletin & Review, 9*, 542-549.

Phillips, L. H. (1999). Age and individual differences in letter fluency. *Developmental Neuropsychology, 15,* 249–267.

Plaut, D. C., & Booth, J. R. (2000). Individual and developmental differences in semantic priming: Empirical and computational support for a single-mechanism account of lexical processing. *Psychological Review, 107*, 786-823.

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

Plaut, D., & Shallice, T. (1993). Deep dyslexia: a case study of connectionist Neuropsychology. *Cognitive Neuropsychology, 10,* 377-500.

Quillian, M. R. (1969). In Minsky, M. (Ed.) Semantic Information Processing (pp.227-270). Cambridge, MA: MIT Press.

Rabovsky, M., Sommer, W., & Rahman, R. (2012). Implicit word learning benefits from semantic richness: Electrophysiological and behavioral evidence. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 38*, 1076-1083.

Rabinovici, G. D., & Miller, B. L. (2010). Frontotemporal lobe degeneration: Epidemiology, pathophysiology, diagnosis and management. *CNS Drugs, 24*, 375-398.

Rabinowitz, J. C., Craik, F. I., Ackerman, B. P. (1982). A processing resource account of age differences in recall. *Canadian Journal of Psychology, 36*, 325-344.

Rasinski, T. V. (2004). *Assessing reading fluency*. Retrieved December 3, 2009, from the Pacific Resources for Education and Learning Web site: www.prel.org/products/re_assessing-fluency.htm

Rastle, K. J., & Burke, D. (1996). Priming the tip of the tongue: Effects of prior processing on word retrieval in young and older adults. *Journal of Memory and Language, 35*, 586-605.

Raz, N. (2000). Aging of the brain and its impact on cognitive performance: Integration of structural and functional findings. In F. Craik, I. M. Fergus, & T. Salthouse (Eds), *The handbook of aging and cognition* (2nd ed.), (pp. 1-90). Mahwah, NJ: Lawrence Erlbaum Associates Publishers.

Recchia, G., & Jones, M. N. (2012). The semantic richness of abstract concepts. *Frontiers in Human Neuroscience, 6:*315, doi: 10.3389/fnhum.2012.00315.

Rodd, J. M. (2004). When do leotards get their spots? Semantic activation of lexical neighbors in visual word recognition. *Psychonomic Bulletin & Review, 11,* 434–439.

Rodd, J., Gaskell, G., & Marslen-Wilson, W. (2002). Making sense of semantic ambiguity: Semantic competition in lexical access. *Journal of Memory and Language, 46*, 245-266.

Rogers, T. T., Lambon Ralph, M. A., Garrard, P., Bozeat, S., McClelland, J. L., & Hodges, J. R., et al. (2004). The structure and deterioration of semantic memory: A neuropsychological and computational investigation. *Psychological Review, 111*(1), 205–235.

Rogers, T. T., & McClelland, J. L. (2004). *Semantic Cognition, A Parallel Distributed Processing Approach*. Cambridge, MA: MIT Press.

Rubenstein, H., Garfield, L., & Millikan, J. A. (1970). Homographic entries in the internal

lexicon. *Journal of Verbal Learning and Verbal Behavior, 9,* 487-494.

Ruchinskas, R. A., & Curyto, K. J. (2003). Cognitive screening in geriatric rehabilitation. *Rehabilitation Psychology, 48*, 14-22.

Salthouse, T. A. (1993). Speed mediation of adult age differences in cognition. *Developmental Psychology, 29*, 722-738.

Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review, 103*, 403-428.

Salthouse, T. A. (2010). Selective review of cognitive aging. *Journal of the International Neuropsychological Society, 16*, 754-760.

Schaie, K. W. (1994). The course of adult intellectual development. *American*

Psychologist, 49, 304-313.

Schaie, K. W. (2005). What can we learn from longitudinal studies of adult development? *Research in Human Development, 2*, 133-158.

Schum, R. L., & Sivan, A. (1997). Verbal abilities in healthy elderly adults. *Applied Neuropsychology, 4*, 130-134.

Schvaneveldt, R. W., Durso, F. T., & Mukherji, B. R. (1982). Semantic distance effects in categorization tasks. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 8*, 1-15.

Sears, C. R., Siakaluk, P. D., Chow, V. C., & Buchanan, L. (2008). Is there an effect of print exposure on the word frequency effect and the neighborhood size effect? *Journal of Psycholinguistic Research, 37*, 269-291.

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*, 876-890.

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review*, *96*, 523-568.

Shaoul, C., & Westbury, C. (2006). Word frequency effect in highdimensional co-occurrence models: A new approach. *Behavior Research Methods*, *38*, 190-195.

Shaoul, C., & Westbury, C. (2010). Exploring lexical co-occurrence space using HIDEX. *Behavior Research Methods, 42*, 393-413.

Siakaluk, P., Buchanan, L., & Westbury, C. (2003). The effect of semantic distance in yes/no and go/no-go semantic categorization tasks. *Memory & Cognition, 31*, 100-113.

Siakaluk, P. D., Pexman, P. M., Aguilera, L., Owen, W. J., & Sears, C. R. (2008). Evidence for the activation of sensorimotor information during visual word recognition: The body-object interaction effect. *Cognition, 106*, 433-443.

Skinner, E. I. & Fernandes, M. A. (2009). Age-related changes in the use of study context to increase recollection. *Aging, Neuropsychology, and Cognition, 16*, 377-400.

Spaan, P., Raajimakers, J., & Jonker, C. (2003). Alzheimer's disease versus normal ageing: A review of efficiency of clinical and experimental memory measures. *Journal of Clinical and Experimental Neuropsychology, 25*, 216-233.

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

Stanovich, K.E., & West, R. F. (1989). Exposure to print and orthographic processing. *Reading Research Quarterly, 24*, 402-433.

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

Tombaugh, T. N., Kozak, J., & Rees, L. (1999). Normative data stratified by age and education for two measures of verbal fluency: FAS and animal naming. *Archives of Clinical Neuropsychology, 14,* 167–177.

Thornton, R., & Light, L. L. (2006). Language comprehension and production in normal aging. In J. E. Birren and K. W. Schaie (Eds.), *Handbook of the Psychology of Aging* (pp. 262-287). Burlington, MA: Elsevier.

Treitz, F. H., Heyder, K., & Daum, I. (2007). Differential course of executive control changes during normal aging. *Aging, Neuropsychology, and Cognition, 14*, 370-393.

Troyer, A. K. (2000). Normative data for clustering and switching on verbal fluency tasks. *Journal of Clinical and Experimental Neuropsychology, 22,* 370–378.

Unsworth, S. J., & Pexman, P. M. (2003). The impact of reader skill on phonological processing in visual word recognition. *Quarterly Journal of Experimental Psychology, 56A*, 63-81.

Uttl, B. (2002). North American reading test: Age norms, reliability, and validity. *Journal of Clinical and Experimental Neuropsychology, 24*, 1123-1137.

Verhaeghen, P. (2003). Aging and vocabulary score: A meta-analysis. *Psychology and Aging, 18*, 332-339.

Vinson, D. P., & Vigliocco, G. (2008). Semantic feature production norms for a large set of objects and events. *Behavior Research Methods, 40*, 183-190.

Vitevitch, M. S. & Luce, P. A. (1999) Probabilistic phonotactic and neighbourhood activation in spoken word recognition. *Journal of Memory and Language, 40*, 374-408.

West, R. L. (1996). An application of prefrontal cortex function theory to cognitive aging. *Psychological Bulletin, 120,* 272–292.

White, K. K. & Abrams, L. (2004). Phonologically mediated priming of preexisting and new

associations in young and older adults. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30*, 645-655.

Wilkinson, G. S. (1993). *Wide Range Achievement Test 3*. Wilmington, DE: Wide

Range, Inc.

Wurm, L. H., Vakoch, D. A., & Seaman, S. R. (2004). Recognition of spoken words: Semantic effects in lexical access. *Language and Speech, 47*, 175-204.

Yap, M. J., Pexman, P. M., Hargreaves, I. S., & Huff, M. J. (2012). An abundance of riches: Cross-task comparisons of semantic richness in visual word recognition. *Frontiers in Human Neuroscience, 6*:72. doi: 10.3389/fnhum.2012.00072

Yap, M. J., Tran, S. E., Pexman, P. M., & Hargreaves, I. S. (2011). Is more always better? Effects of semantic richness of lexical decision, speeded pronunciation, and semantic classification. *Psychonomic Bulletin and Review, 18*, 742-750.

Yates, M., Locker, L., & Simpson, G. (2003). Semantic and phonological influences on the processing of words and pseudohomophones. *Memory & Cognition, 31*, 856-866.

Zacks, R. & Hasher, L. (1997). Cognitive gerontology and attentional inhibition: A reply to Burke and McDowd. *The Journals of Gerontology: Series B: Psychological Sciences and Social Sciences, 52*, 274-283.

Zelinski, E. M., & Hyde, J. C. (1996). Old words, new meaning: Aging and sense creation. *Journal of Memory and Language, 35*, 689-707.

APPENDIX A

Participant ID:________________ Years of Schooling Completed:__________

Gender: M F Age:________ Date of Birth:________________________

Please Answer the Following Questions:

What is your native language?___________________________________

Do you speak any language, other than English, fluently? Y N

Have you ever been diagnosed with a learning disorder or speech disorder? Y N

Have you ever received speech, language, or reading therapy? Y N

If yes, did this therapy focus on a single speech sound such as a lisp

Or difficulty pronouncing “r”? Y N

Do you have a learning disability? Y N If yes, what area does this disability effect:

Reading Y N Writing Y N Math Y N

Do you have dyslexia? Y N

Does anyone in your family have any of the above learning difficulties? Y N

Do you have ADHD/ADD? Y N

Do you have normal (or corrected to normal) vision? Y N

Are you colour blind? Y N

Which hand do you use to hold a pencil when you write? Left Right Both

Which hand do you use to hold scissors? Left Right Both

Which hand do you use to throw a baseball? Left Right Both

Which hand do you use to brush your teeth? Left Right Both

Do you have anyone in your immediate family who is left-handed? Y N

Have you ever had a head trauma resulting in a loss of consciousness? Y N

Have you ever had or do you have any neurological conditions such as Multiple Sclerosis, Parkinson’s or tumour? Y N

APPENDIX B

Participant ID:________________ Years of Schooling Completed:__________

Gender: M F Age:_________ Date of Birth:________________________

Please Answer the Following Questions:

What is your native language?___________________________________

Do you speak any language, other than English, fluently? Y N

Have you ever been diagnosed with a learning disorder or speech disorder? Y N

Have you ever received speech, language, or reading therapy? Y N

If yes, did this therapy focus on a single speech sound such as a lisp

Or difficulty pronouncing “r”? Y N

Do you have a learning disability? Y N If yes, what area does this disability effect:

Reading Y N Writing Y N Math Y N

Do you have dyslexia? Y N

Does anyone in your family have any of the above learning difficulties? Y N

Do you have ADHD/ADD? Y N

Do you have normal (or corrected to normal) vision? Y N

Are you colour blind? Y N

Which hand do you use to hold a pencil when you write? Left Right Both

Which hand do you use to hold scissors? Left Right Both

Which hand do you use to throw a baseball? Left Right Both

Which hand do you use to brush your teeth? Left Right Both

Do you have anyone in your immediate family who is left-handed? Y N

Have you ever had a head trauma resulting in a loss of consciousness? Y N

Have you ever had a stroke or any other neurological conditions? Y N

Do you have (or have you ever had) any of the following medical conditions? (Please Circle)

Multiple Sclerosis	Brain Tumour
Parkinson’s Disease	Alzheimer’s Disease
High Blood Pressure	Diabetes

APPENDIX C

Written instructions for lexical decision experiments:

In this experiment you will be shown a series of letter strings. Each letter string will be presented one at a time at approximately the center of the screen.

Your task is to decide whether the letter string is an English word (e.g., lake) or a nonword (e.g., laje). To indicate your decision press one of two keys. Press the "Z" key if the letter string is a word or the "?" key if the letter string is a nonword. Before each word a cross (+) will appear briefly in the middle of the screen

Both speed and accuracy are important. Therefore, please try to make your decisions as quickly and as accurately as possible.

We will begin with a set of practice trials.

Please press the "Enter" key when you are ready to continue.

APPENDIX D

Large SN words used in Experiment 2 with their length in letters (L), orthographic frequencies, orthographic neighbourhood sizes (ON), phonological frequency and semantic neighbourhood sizes (SN)

Large SNs	Letters	OFreq	ONs	PFreq	SNs
TWIG	4	3.64	3	1.5969	612
SLICK	5	3.48	7	2.1292	237
RAMP	4	1.99	10	1.70336	283
HERB	4	3.94	7	0.958139	235
GASH	4	1.93	12	0.42584	278
COPS	4	2.17	24	1.17106	264
WAND	4	3.51	11	1.49044	393
GRAM	4	1.4	8	2.55504	264
CRYPT	5	2.6	1	0.21292	279
BREW	4	2.48	7	3.51318	358
LEAK	4	4.08	11	3.93902	383
FLAIR	5	1.59	1	0.5323	356
SLIME	5	2.4	5	0.42584	282
NUDE	4	4.49	3	1.17106	329
SIFT	4	1.22	5	0.21292	296
STALE	5	5.17	13	1.91628	594
PULP	4	2.81	4	1.17106	261
RINSE	5	1.71	0	2.23566	357
COLT	4	4.17	13	0.63876	241
CRANK	5	2.9	6	0.74522	325
GLAND	5	1.82	3	0.958139	338
SHACK	5	2.71	9	1.80982	235
PANE	4	3.6	20	0.5323	386
BLINK	5	3.22	5	1.38398	244
SPICE	5	3.77	7	3.08734	302
MOOSE	5	3.91	6	1.17106	261
VEST	4	4.31	11	3.30026	314
FLAX	4	2.13	9	0.10646	291
DODGE	5	4.6	2	0.958139	301
FREAK	5	3.79	3	1.38398	229
BOOZE	5	2.04	1	4.57778	306
LISP	4	1.42	3	0.21292	434
LARD	4	1.54	12	0.958139	282
JAZZ	4	5.19	0	3.93902	436
QUART	5	2.69	1	1.27752	436

SNACK	5	1.94	6	2.23566	342
LEASH	5	2.27	3	0.42584	315
MATH	4	1.01	11	0.31938	440
BROTH	5	3.31	4	0.42584	380
GROIN	5	2.38	3	1.5969	369

Small SN words used in Experiment 2 with their length in letters (L), orthographic frequencies, orthographic neighbourhood sizes (ON), phonological frequency and semantic neighbourhood sizes (SN)

Small SNs	Letters	OFreq	ONs	PFreq	SNs
SHRUB	5	2.74	2	2.1292	52
PLANK	5	5.79	9	2.23566	24
BRIM	4	4.72	6	0.42584	43
WHACK	5	1.65	2	2.87442	41
QUITS	5	1.9	5	0.10646	44
SCANT	5	5.46	3	0.21292	54
FLUFF	5	1.09	1	0.958139	35
CHIME	5	1.71	7	0.42584	43
CHUM	4	3.44	3	0.85168	39
RIFT	4	2.97	8	1.0646	50
SPECK	5	4.3	2	0.74522	25
WISP	4	2.07	4	0.31938	40
PECK	4	4.34	11	0.74522	46
CUSS	4	1.8	9	0.74522	42
STORK	5	1.26	5	0.21292	47
VOGUE	5	3.91	2	0.958139	39
SKIP	4	4.75	9	7.87804	34
GROPE	5	1.49	4	0.21292	51
PAVE	4	1.17	14	1.5969	26
CHUMP	5	1.57	6	0.42584	66
STEED	5	4.25	5	0.31938	34
LASH	4	4.66	14	0.5323	31
SLUNG	5	4.26	7	0.958139	43
FANG	4	3.13	10	0.74522	37
SCAB	4	1.18	6	1.0646	26
FRAY	4	4.54	7	0.958139	24
SNOB	4	2.06	6	0.85168	56
WICK	4	2.43	12	1.91628	33
FLAKE	5	1.77	5	1.5969	28
HOOF	4	3.67	8	0.5323	48
DAZE	4	1.51	13	0.21292	55
SPADE	5	5.1	6	3.83256	52
GULL	4	1.84	13	0.31938	46
MULL	4	1.38	13	0.63876	63
SLUSH	5	1.36	6	0.31938	62
DUNE	4	1.75	14	0.21292	46

CRAM	4	1.19	8	0.74522	16
REIN	4	5.87	3	0.42584	57
SPOOK	5	1.39	6	0.21292	31
CLAP	4	3.29	11	3.08734	53

APPENDIX E

Stimulus Set: Words from distributed semantic neighbourhoods used in experiment 3 with their length in letters, orthographic frequencies (OFreq), semantic neighbourhood sizes (SN), and semantic similarity (SemSim).

Distributed SNs	Letters	OFreq	SNs	SemSim
TRAY	4	1.942	317	0.24
FAINT	5	2.694	300	0.245
CREEK	5	4.101	333	0.247
MICE	4	4.712	356	0.248
BRASS	5	5.035	305	0.252
FOIL	4	4.503	315	0.256
MOIST	5	2.265	409	0.258
GRAPH	5	3.893	347	0.26
SPINE	5	3.304	339	0.261
PINE	4	4.442	336	0.262
CLOTH	5	5.089	372	0.262
CHAMP	5	1.952	403	0.262
WELSH	5	2.467	326	0.265
HOSE	4	4.842	424	0.265
SHADE	5	3.125	326	0.266
TIRE	4	5.602	377	0.266
CRUST	5	3.255	391	0.267
TREK	4	5.195	310	0.268
GRILL	5	2.518	353	0.268
STOVE	5	3.632	397	0.268
WAIST	5	4.455	442	0.269
PIER	4	1.069	302	0.27
SPICE	5	2.144	302	0.27
CHILL	5	3.565	320	0.27
GLUE	4	3.655	357	0.27
THIGH	5	3.669	393	0.27
BEAN	4	4.087	311	0.271
ROBE	4	3.17	473	0.271
SWIM	4	4.142	332	0.274
NODE	4	3.522	362	0.274
QUART	5	1.12	436	0.274
BLOND	5	2.372	316	0.276
COIL	4	3.187	433	0.276
NIECE	5	2.043	332	0.277
SNACK	5	2.309	342	0.277

Stimulus Set: Words from dense semantic neighbourhoods used in experiment 3 with their length in letters, orthographic frequencies (OFreq), semantic neighbourhood sizes (SN), and semantic similarity (SemSim).

Dense SNs	Letters	OFreq	SNs	SemSim
BRAKE	5	5.399	399	0.284
PORK	4	5.364	344	0.285
SCENT	5	2.285	306	0.286
SPEAR	5	1.918	322	0.287
GLAND	5	1.972	338	0.288
PEEL	4	2.563	303	0.289
ROAST	5	2.651	420	0.289
LOON	4	3.311	338	0.29
HERD	4	3.902	304	0.291
YACHT	5	2.311	349	0.292
ZOOM	4	1.914	338	0.295
PILL	4	5.586	315	0.296
LACE	4	1.498	369	0.299
BAKE	4	5.36	394	0.3
CLOAK	5	3.132	322	0.303
ZINC	4	1.44	323	0.303
SCARF	5	1.459	340	0.303
SILK	4	2.567	403	0.303
BROTH	5	1.527	380	0.304
DOUGH	5	4.106	359	0.307
LIME	4	2.309	368	0.307
NOUN	4	4.428	406	0.308
BRIBE	5	5.728	363	0.309
CHORD	5	3.391	341	0.31
PSALM	5	4.774	362	0.31
SAIL	4	4.806	378	0.311
BREW	4	3.25	358	0.312
STEAK	5	1.978	380	0.312
PERM	4	4.2	312	0.318
SKIRT	5	5.361	343	0.32
WAND	4	3.252	393	0.32
VERB	4	3.898	363	0.322
VOLT	4	2.488	393	0.322
FLUTE	5	1.076	303	0.333
HOUND	5	3.229	347	0.339

APPENDIX F

Stimulus Set: Target words and three prime types used in experiment 4.

Target	Close Prime	Distant Prime	Unrelated Prime
BAKE	loaf	bun	winch
BRAKE	clutch	winch	heat
BROTH	boil	heat	theme
CHORD	bass	theme	drape
CLOAK	wand	drape	waltz
FLUTE	harp	waltz	brood
HERD	sheep	brood	brake
HOUND	breed	brake	wool
LACE	blouse	wool	fruit
LIME	pulp	fruit	pun
NOUN	verb	pun	glue
PEEL	rind	glue	nurse
PILL	dose	nurse	lard
PORK	beef	lard	dose
ROAST	steak	steam	knot
SAIL	boat	knot	bath
SCENT	smell	bath	slip
SILK	gown	slip	smell
SKIRT	hem	sleeve	pierce
SPEAR	axe	pierce	hem
STEAK	pork	lean	ship
VOLT	watt	prong	bay
YACHT	ship	bay	shoot
ZOOM	lens	shoot	mint
BEAN	pea	mint	tool
BRASS	drum	tool	chess
CHAMP	match	chess	ice
CHILL	cool	ice	shirt
CLOTH	gauze	shirt	bolt
COIL	fuse	bolt	duck
CREEK	lake	duck	fuse
CRUST	pie	mousse	lake
GLUE	foam	wire	sphere
GRAPH	curve	sphere	spray
HOSE	valve	spray	geese
MICE	rat	geese	heir
NIECE	aunt	heir	bridge
PIER	wharf	bridge	root
PINE	oak	root	milk
QUART	pint	milk	blush

SHADE	hue	blush	drink
SNACK	meal	drink	hue
SPICE	blend	mix	brain
SPINE	bone	brain	blend
SWIM	dive	sport	meal
THIGH	knee	brace	steer
TIRE	wheel	steer	knee
WAIST	skirt	sheer	bun

VITA AUCTORIS

Name:	Gillian Macdonald
Place of Birth:	Windsor, Ontario
Year of Birth:	1980
Education:	F.J. Brennan Catholic High School, Windsor, ON 1994-1999
	University of Windsor, Windsor, ON 1999-2003 Hons. B.A. Psychology
	Wilfrid Laurier University, Waterloo, ON 2003-2005 M.A. Psychology
	University of Windsor, Windsor, ON 2005-2013 Ph.D. Clinical Neuropsychology