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The relationship between semantic and episodic memory: Exploring the effect of semantic neighbourhood density on episodic memory

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The relationship between semantic and episodic memory: Exploring the effect of semantic neighbourhood density on episodic memory

by

Daniela Wong Gonzalez

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The relationship between semantic and episodic memory: Exploring the effect of semantic neighbourhood density on episodic memory

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ABSTRACT

Semantic and episodic memory have been traditionally conceptualized as distinct memory systems (Tulving, 1972). Recent research emphasizes that these systems are interdependent, and many studies have found that semantic memory influences episodic memory (Graham et al., 2000; Greenberg & Verfaellie, 2010; Takashima et al., 2014). This dissertation expands this area of research by examining a question that had not been explored to date. The main objective was to examine the influence of semantic neighbourhood density on explicit and implicit episodic memory. Semantic neighbourhood density is a measure that captures the degree of semantic relationship between words in semantic memory (Buchanan et al., 2001). This variable has been shown to influence language processing, but it has not been studied in the context of episodic memory (Buchanan et al., 2001; Danguecan & Buchanan, 2016). Four experiments were designed to explore the effect of semantic neighbourhood density on a variety of episodic memory tasks. The results indicate that high semantic neighbourhood density facilitates both explicit and implicit episodic memory. These findings contribute to our current understanding about the influence of semantic factors on episodic memory for words.

DEDICATION

This work is dedicated to my parents.

Without you, it would not have been possible!

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To my family and friends, thank you for your support and reassurance. To my wonderful parents, thank you for your unconditional love and constant curiosity about my work. I am grateful to have you in my life.

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CHAPTER 1

INTRODUCTION

Overview of the Current Study

Memory serves a crucial function in our everyday experiences, as it enables us to learn and retain information about the world. Traditionally, memory has been divided into multiple systems, each seemingly governed by unique neural substrates, reflecting the complexity of this cognitive process (Graham, Simons, Pratt, Patterson, & Hodges, 2000; Schacter & Tulving, 1994; Wiggs, Weisberg, & Martin, 1998). Two memory systems, semantic and episodic memory, play a vital role in the acquisition and retention of knowledge. Briefly, semantic memory stores facts and knowledge about the world, including our knowledge of language, whereas episodic memory stores temporally-dated information about personally experienced events (Conway, 2009; Greenberg & Verfaellie, 2010; Tulving, 1972; Tulving & Thomson, 1973; Schacter & Tulving, 1994). For example, when we remember that the tip of a shoelace is called an *aglet* we are drawing from semantic memory. However, when we remember that we learned that on an episode of the Big Bang Theory we are drawing from episodic memory.

Theories of episodic and semantic memory typically conceptualized them as distinct systems (Tulving, 1972). This distinction is supported by the disassociation between semantic and episodic memory caused by brain damage. Medial temporal lobe damage often results in impairment of episodic memory while semantic memory remains relatively intact (Graham et al., 2000; Greenberg & Verfaellie, 2010). On the other hand, anterior and lateral temporal lobe damage, which is seen in semantic dementia, results in impairment of semantic memory while episodic memory remains relatively intact (Graham et al., 2000; Greenberg & Verfaellie, 2010). Even though this distinction is useful because it helps us understand the unique characteristics of each system, semantic and episodic memory are not entirely independent systems (Graham et al., 2000; Greenberg & Verfaellie, 2010; Takashima, Bakker, van Hell, Janzen, & McQueen, 2014). Our previous knowledge about the world (semantic memory) influences our ability to learn and remember new experiences (episodic memory; Craik & Lockhart, 1990; Graham et al., 2000; Greenberg & Verfaellie, 2010; Greve, Rossum, & Donaldson, 2007; Lee, Robbins, Graham, & Owen, 2002; Prior & Bentin, 2008; Takashima et al., 2014). For example, individuals who are considered experts have better memory for new information specifically related to their field when compared to novices (Bein et al., 2015). Expert chess players are better at remembering the location of pieces on a chessboard when compared to novice chess players (Alba & Hasher, 1983). The relationship between semantic and episodic memories is further supported by neuroimaging findings that suggest both unique and common neural correlates of the two memory systems (Rugg & Vilberg, 2013; Takashima et al., 2014; Wiggs et al., 1998).

This dissertation expands our current understanding about the influence of semantic memory on episodic memory by examining a topic that has not received a lot of attention. This study focused on how semantic richness, which captures how much semantic information is associated with specific words, influences explicit and implicit episodic memory. Semantic richness refers to how much variability is associated with a word’s meaning (Pexman, Hargreaves, Siakaluk, Bodner, & Pope, 2008). Words with high semantic richness are associated with more meaning-related information and will elicit more of that information than words with low semantic richness. Only a few studies have examined the effects of semantic richness on episodic memory (Hargreaves et al., 2012; Nelson et al., 2013; Rabovsky et al., 2012). One measure of semantic richness that is known to influence language processing, called semantic neighbourhood density, has not been studied in the context of episodic memory (Buchanan, Westbury, & Burgess, 2001; Danguecan & Buchanan, 2016; Mirman & Magnuson, 2008). Semantic neighbourhood density is a measure of how word representations are organized in semantic memory and it captures the degree of semantic relationship between words and their semantic neighbours (Buchanan et al., 2001). The main objective of this study is to address this gap in the literature and examine the influence of semantic neighbourhood density on both explicit and implicit episodic memory. To do this, the first chapter will review theoretical information about semantic and episodic memory. The following chapters will describe the methodology, results, and implications of four experiments designed to examine the effects of semantic neighbourhood density on a variety of explicit and implicit episodic memory tasks.

General Principles of Memory Systems

All memory systems receive and encode information, store aspects of this information as memory representations, and transfer information to other cognitive systems if required (Schacter & Tulving, 1994; Tulving, 1972; 1986). The main operations of memory systems include encoding, rehearsing, storing, and retrieving; the act of remembering is a combination of all these (Tulving & Thomson, 1973; Tulving, 1972; 1986). The concept of memory is broad and complex. For instance, a “good memory” can be characterized as recalling a very detailed personal event, memorizing the capitals of all countries, or knowing how to fix a bike. Given the diversity in these examples, definitions of memory necessarily include different cognitive systems (Tulving, 1972; 1986; Tulving & Thomson, 1973; Schacter & Tulving, 1994).

In the past few decades, many studies have investigated the cognitive and neural organization of different memory systems, and it is currently recognized that these systems are functionally distinct (Graham et al., 2000; Greenberg & Verfaellie, 2010; Schacter & Tulving, 1994; Takashima et al., 2014; Tulving, 2002; Squire, 1992). Memory systems vary depending on the type of information being processed, the brain mechanisms that support them, and the execution of their main operations (Schacter & Tulving, 1994; Tulving, 1972; 1986). A comprehensive theory of memory that recognizes different memory systems provides a framework to describe and understand the unique characteristics of each system.

There are several well-established distinctions regarding memory systems (Schacter & Tulving, 1994). One of these distinctions is between short-term and long-term memory. This distinction is based on the capacity and duration of memory representations. Short-term memory is a system that can store limited amounts of information for a brief period of time (Baddeley, 2000; Cowan, 2009; Schacter & Tulving, 1994). In contrast, long-term memory stores vast amounts of information for extended periods of time (Cowan, 2009; Schacter & Tulving, 1994).

One distinction in long-term memory is between explicit and implicit memory, also referred to as declarative and non-declarative memory, respectively (Squire, 1992; Schacter, Chiu, & Oschsner, 1993; Schacter & Tulving, 1994). This distinction is based on how memory representations are retrieved (Squire, 1992; Schacter et al., 1993; Ward, Berry, & Shanks, 2013) and it will be reviewed in more detail below. Another distinction that is relevant to this dissertation is between semantic and episodic memory. These two memory systems are distinguished on the basis of the type of information they store (Conway, 2009; Takashima et al., 2014; Tulving, 1972; Schacter & Tulving, 1994). These differences are essential to this paper and will be reviewed in detail in the following sections.

Explicit and Implicit Memory

Explicit and implicit memory are distinguished by the ways in which the memories are retrieved (Schacter et al., 1993; Schacter & Tulving, 1994). Explicit memory refers to conscious and intentional recollection of knowledge and past events (Squire, 1992; Schacter et al., 1993;

Schacter & Tulving, 1994; Ward et al., 2013). When we consider the act of remembering, we usually think of explicit memory or conscious recollection of experiences (Squire, 1992). Remembering what you had for breakfast after someone asks you about it is an example of an explicit memory.

In experimental studies of explicit memory, participants are typically given a list of items to study (e.g., words, pictures). Retrieval of the previously presented items is frequently measured with recall or recognition tasks (Criss, Aue, & Smith, 2011; Glanzer, Adams, Iverson, & Kim, 1993). In a recall task, individuals are asked to retrieve as many of the previously presented items as possible. In a recognition task, participants are shown a test list and they must discriminate between previously studied (old) and not previously studied items (new). In an explicit memory task, whether recall or recognition, participants are intentionally trying to remember the studied items.

In contrast, implicit memory refers to unconscious or unintentional demonstrations of recollection of previously acquired information (Squire, 1992; Schacter et al., 1993; Schacter & Tulving, 1994; Ward et al., 2013). For instance, tasks such as driving or typing on a keyboard can be performed successfully without consciously recalling all the steps involved in the process. In experimental studies of implicit memory, participants are given a list of items to study. After, they are required to perform a task that seems unrelated to memory performance. To perform this task accurately, participants do not have to intentionally remember the previously studied items. Nonetheless, having studied the items can influence performance on the task. Implicit recollection can be inferred if there is a change in performance that can be attributed to the information previously presented, even though there is no intention to recollect such information

(Graf & Schacter, 1985; Squire, 1992; Schacter & Graf, 1986; Schacter, Harbluk, & McLachlan, 1984).

A common task used to measure implicit memory in experimental studies is a lexical decision task (Graf & Schacter, 1985; Squire, 1992). In a lexical decision task, participants are required to make word/nonword lexical decisions to a series of letter strings that are words or nonwords. Lexical decision times are faster for items previously studied than not previously studied (Graf & Schacter, 1985; Squire, 1992). This advantage in lexical decision reaction times can be attributed to the previous presentation of items. This effect is called repetition priming and it occurs when exposure to an item makes it easier to process that same item later (Squire, 1992). Priming effects are frequently used as a measure of implicit memory (Squire, 1992). Semantic categorization tasks can also be used to measure implicit memory. In this task, participants are asked to categorize words according to a semantic category (e.g., Is this item animate or inanimate?), and on average, participants produce faster reaction times to previously studied words than to new words (Schacter et al., 1993; Schacter & Graf, 1986). Another task used to measure implicit memory is a word-fragment completion task, in which participants are asked to complete word fragments (e.g., W_ _ D) with the first word that comes to mind (Schacter et al., 1993; Schacter & Graf, 1986). Participants are more likely to complete the word fragments with previously studied words (Schacter et al., 1993; Schacter & Graf, 1986). For instance, after reading a list of words that contains the word *wood*, participants are more likely to complete the fragment W _ _ D with *wood* than with *wand*.

There is evidence suggesting that explicit and implicit memory operate independently and rely on separate brain mechanisms (Squire, 1992; Schacter, 1992; Schacter & Graf, 1986). For instance, individuals with amnesia often have impaired performance on explicit memory tasks; however, they can show intact or near-intact performance on tasks of implicit memory (Squire, 1992; Schacter & Graf, 1986). An individual with medial temporal lobe amnesia will likely have difficulty recalling a list of words previously studied (impaired explicit memory) but will have faster lexical decision reaction times for words previously studied compared to new words they have not seen before (intact implicit memory; Schacter, 1992). Priming effects are present even though these individuals have no conscious recollection of previously studying the words.

Several clinical cases have been used to demonstrate this disassociation between explicit and implicit memory. One of the most well-known cases in the study of memory is the case of H.M. H.M underwent surgical resection of his medial temporal lobes bilaterally to treat intractable epilepsy, and as a result developed severe anterograde amnesia (Scoville & Milner, 1957). Despite having average intellectual abilities, H.M was unable to form new memories after the surgery. For instance, he demonstrated very poor performance on tests of explicit memory in which he was asked to remember stories, shapes, and word pairs that were presented to him approximately 20 minutes before. However, he was able to learn and perform novel motor sequences, a task which relies on implicit memory. The same pattern has been observed in individuals with other amnestic syndromes; for instance, individuals with Korsakoff's syndrome perform very poorly in tasks of word recall and recognition (explicit memory tasks), but their performance is relatively intact in word-fragment completion tasks (implicit memory task; Warrington & Weiskrantz, 1970). The independence of explicit and implicit memory has also been supported by the finding that after a time interval, explicit memory accuracy typically decreases, but priming effects remain the same (Tulving, Schacter, & Stark, 1982).

Regarding the neuroanatomical correlates of explicit and implicit memory, explicit recognition produces increased activation in bilateral parietal and prefrontal cortices, in addition to increased activation in the posterior cingulate, bilateral hippocampus and parahippocampal regions (Schott et al., 2005; Voss & Paller, 2008). On the other hand, implicit memory as shown by priming effects produce reduced activity in bilateral parietal, occipital, prefrontal, inferior temporal, and left fusiform gyrus regions. This pattern suggests that explicit and implicit memory may be supported by distinct neural processes (Schott et al., 2005; 2006; Voss & Paller, 2008).

Distinction between Semantic and Episodic Memory

As previously mentioned, knowing that the tip of a shoelace is called an *aglet* is a semantic memory, but knowing that you learned that on an episode of the Big Bang Theory is an episodic memory. The main distinction between semantic and episodic memory systems is the type of information that is stored as memory representations (Conway, 2009; Graham et al., 2000; Tulving, 1972; 2002; Tulving & Thomson, 1973; Schacter & Tulving, 1994). Semantic memory stores facts and knowledge about the world (Graham et al., 2000; Martin & Chao, 2001; Tulving, 1972; Schacter & Tulving, 1994). In addition, semantic memory is essential for language use because it stores the meaning of words and the rules governing their use (Collins & Quillian, 1969; Kutas & Federmeier, 2000; Martin & Chao, 2001; Tulving, 1972; 2002; Schacter & Tulving, 1994). On the other hand, episodic memory stores information about personally experienced events and their temporal relations (Conway, 2009; Tulving, 1972; 2002; Schacter & Tulving, 1994). Remembering the meaning of words and which months are the summer months in the Northern hemisphere are examples of semantic memory representations.

Remembering which words were seen in a list of words thirty minutes ago and which courses one took last summer are examples of episodic memory representations.

Another difference between these two systems is the time it takes for memory representations to be consolidated, and the susceptibility of these representations to interference, change, or loss (Conway, 2009; Tulving, 2002; Schacter & Tulving, 1994). Episodic memory is a rapidly working system that encodes and stores most incoming information, while semantic information is consolidated more slowly over time (Takashima et al., 2014). Furthermore, episodic memory representations are believed to be more susceptible to interference and change than semantic memory representations (Conway, 2009; Schacter & Tulving, 1994).

Tulving proposed a model conceptualizing semantic and episodic memory as cognitively and neurologically distinct systems (1972). Brain injured individuals with impaired episodic memory can show intact access to semantic memory representations, suggesting a disassociation between these two systems (Graham et al., 2000; Greve et al., 2007; Schacter & Tulving, 1994; Takashima et al., 2014; Tulving, 2002). Previous findings suggest that episodic memory relies heavily on the medial temporal lobes, particularly on the hippocampus, while semantic memory relies on distributed cortical networks (Burgess, Maguire, & O'Keefe, 2002; Shimamura, 2014; Takashima et al., 2014). Access to semantic memory representations, which makes language processing possible, is often intact in individuals with medial temporal lobe damage (Takashima et al., 2014; Moscovitch, Cabeza, Winocour, & Nadel, 2016). In contrast, individuals with semantic dementia, a neurodegenerative disease characterized by progressive degeneration of the semantic memory system, can show relatively spared episodic memory skills (Graham et al., 2000; Greenberg & Verfaellie, 2010).

Semantic Memory

Research on semantic memory has focused on discovering its structure and organizational principles (Collins & Quillian, 1969; Collins & Loftus, 1975; Kintsch, 1974; Tulving, 1986). Language processing tasks, such as lexical decision and semantic categorization, are often used to explore how information from semantic memory is processed and/or retrieved. Quillian proposed one of the first theories about the structure and organization of semantic memory (1967). This theory proposes that semantic memory has a hierarchical structure in which concepts are organized according to the categories they belong to (Collins & Quillian, 1969; Quillian, 1967). For instance, the concept of *dolphin* would be connected to a general concept, like *animal*, and to its properties, like *has fins* and *swims.* General concepts would be stored near the top of the hierarchy and properties would be located toward the bottom of the hierarchy. In this model, concepts are represented by nodes, and related nodes are connected to each other through associative links (Collins & Quillian, 1969; Quillian, 1967).

Collins and Loftus (1975) elaborated on this model and proposed that the greater the similarity between concepts, the greater the relative weight of the associative link between the nodes that represent them (Collins & Loftus, 1975). In their view, concepts are connected to each other according to semantic similarity, but there is no specific hierarchy in the system (Collins & Loftus, 1975). Similarly, more recent models of semantic memory propose that the system is organized according to semantic similarity, so that meaning-related concepts are close to each other in semantic space (Buchanan et al., 2001). However, different models of semantic memory propose slightly different organizational principles for the system (Buchanan et al., 2001; Danguecan & Buchanan, 2016; Lund & Burgess, 1996).

Models of semantic memory can be classified into two main categories: object-based vs. language-based (Buchanan et al., 2001; Danguecan & Buchanan, 2016). An object-based view defines semantic similarity according to the similarity of concepts' physical properties (Buchanan et al., 2001; Pexman et al., 2008). As one example, a feature-based model, proposes that concepts are organized according to the number of shared features (McRae, Cree, Seidenberg, & McNorgan, 2005). In this view, the words *dolphin* and *whale* are semantically similar concepts and are close to each other in semantic space because they share many features, such as *having fins*, *living in water*, and *swimming*. It is important to mention that some words are associated with more features than others; for instance, if you ask participants to list the features of concepts, on average they would list 20 features for *couch*, but only 9 features for *leopard* (McRae et al., 2005).

Counting the number of features of concepts brings attention to the construct of semantic richness. Semantic richness is broadly defined as the variability in information associated with a word's meaning (Pexman et al., 2008; Yap, Tan, Pexman, & Hargreaves, 2011). When one considers the meaning of words, some words elicit more meaning-related information than others (Pexman, Hargreaves, Edwards, Henry, & Goodyear, 2007). Words are considered semantically rich when they are associated with large amounts of semantic information. Words with high semantic richness are thought to have better-specified semantic representations in semantic memory than words associated with less semantic information (Pexman et al., 2008). Semantically rich words are recognized faster and more accurately across a variety of language processing tasks, including lexical decision and semantic categorization (Danguecan & Buchanan, 2016; Pexman et al., 2008; Yap et al., 2011). In a feature-based model, semantic richness is defined as the number of features associated with a word. In the previous example, the word *couch* is more semantically rich than *leopard* because it is associated with more features (McRae et al., 2005).

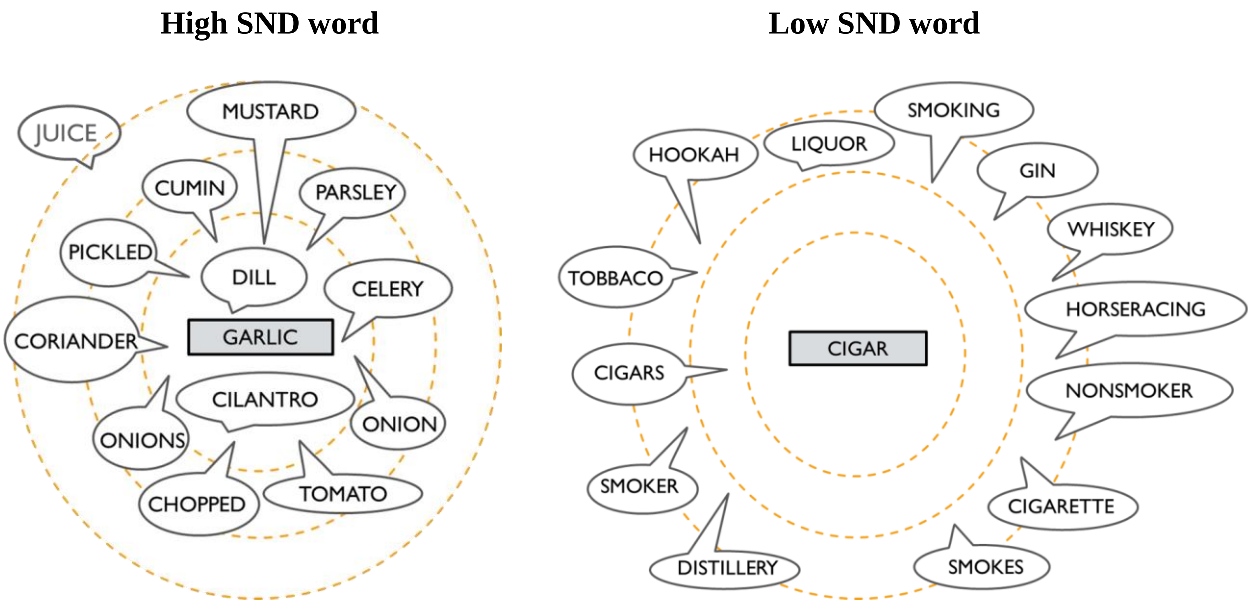
In contrast to object-based views, language-based models propose that concepts are organized according to how they are used in language (Buchanan et al., 2001; Danguecan & Buchanan, 2016; Pexman et al., 2008). For example, words like *sea* and *water* are semantically related and close to each other in semantic space because they are frequently used together in linguistically similar contexts. Language-based models use different methods to uncover the structure of semantic memory. An association model uses a free-association task that involves giving a target word to many individuals and asking them to name the first word that comes to mind (Nelson, McEvoy, Schreiber, 2004; Nelson, McKinney, Gee, & Janczura, 1998). The responses are coded as the *semantic associates* of the target word. For example, if given the word *potato*, an individual may say *fries*, another may say *skin*, and another may say *salad*. In this case, *fries, skin,* and *salad* would be considered semantic associates of *potato* (Nelson et al., 1998). In this model, semantic richness is defined as the number of semantic associates. On a free-association task, individuals produce 23 semantic associates for *potato* but only 8 for *pumpkin* on average (Nelson et al., 2004; Pexman et al., 2007). As such, one can conclude that *potato* is associated with more semantic information than *pumpkin*.

Another type of language-based models are computational co-occurrence models (Burgess, 2008; Buchanan et al., 2001; Durda & Buchanan, 2008; Landauer & Dumain, 1997; Lund & Burgess, 1996). Co-occurrence models have the same goal as association models, that is to describe how words are organized in semantic memory according to how they are used in language. The difference is that co-occurrence models use computational analysis of written text to come up with words' semantic associates, as opposed to using human judgments on a free-association task. The advantage of computational co-occurrence models over models that rely on human judgements is that computational models are less taxing and time-consuming (Lund & Burgess, 1996).

Co-occurrence models use computational analysis of large bodies of text to calculate how frequently pairs of words occur near one another (Buchanan et al., 2001; Durda & Buchanan, 2008; Lund & Burgess, 1996). This analysis produces a lexical co-occurrence matrix where words are represented as vectors. Vectors contain co-occurrence values between a target word and neighbouring words. Words that frequently co-occur together are related in meaning and are considered *semantic neighbours*. For example, the word *sea* co-occurs with semantically related neighbours like *ocean, waters,* and *coast* (Durda & Buchanan, 2008). A *semantic neighbourhood* refers to a hypothetical space within semantic memory that includes a target word surrounded by its semantic neighbours. Words that tend to co-occur with many other words have large neighbourhoods with many *semantic neighbours* and words that tend to co-occur with fewer other words have smaller neighbourhoods with few *semantic neighbours* (Buchanan et al., 2001; Danguecan & Buchanan, 2016). Semantic richness is captured by the size of the semantic neighborhood; words are considered semantically rich if they have large neighbourhoods with many semantic neighbours (Buchanan et al., 2001; Danguecan & Buchanan, 2016; Pexman et al., 2008).

In addition to providing the semantic neighbours of a target word, co-occurrence models also provide a measure of the distance between the word and its neighbours. Even when semantic neighbourhoods have the same size (i.e., have the same number of neighbours), the distribution of semantic neighbours around the target word varies. Some words have on average more near than distant neighbours, and vice versa (Buchanan et al., 2001; Danguecan & Buchanan, 2016).

The distance between a target word and a neighbour reflects how related the words are in meaning; near neighbours are more closely related in meaning to the target word than distant neighbours. Semantic neighbourhood density (SND) is a variable that captures the variability in the distribution of *semantic neighbours* (Buchanan et al., 2001; Danguecan & Buchanan, 2016; Durda & Buchanan, 2008). SND is operationalized as the average distance between a target words and its semantic neighbours, and thus, it captures the degree of semantic relationship between words (Buchanan et al., 2001; Danguecan & Buchanan, 2016). Target words with high SND have on average more near than distant neighbours that are organized tightly around it, and thus, have a dense semantic neighbourhood. In contrast, words with low SND have on average more distant than near neighbours scattered around it, forming a sparsely distributed semantic neighbourhood (Buchanan et al., 2001; Danguecan & Buchanan, 2016). Figure 1 shows a simplified illustration of the semantic neighbourhood distribution of a high SND and a low SND word based on WINDSORS, a computational global co-occurrence model which will be used in this study (Durda & Buchanan, 2008). Only the first thirteen neighbours of each word are represented in Figure 1 due to space restrictions.


High SND word

Low SND word

Figure 1. Illustration of the semantic neighbourhood distribution of high and low SND words.

As previously mentioned, the size of the semantic neighbourhood provides information about semantic richness. Words with large semantic neighbourhoods (i.e., many neighbours) are semantically rich (Pexman et al., 2008), but SND provides additional information about the distribution of those *semantic neighbours*. SND captures the degree of semantic relationship between words because the distance between a target word and a neighbour reflects how related they are in meaning. Near neighbours are more closely related in meaning to the target word than distant neighbours. As such, high density words have neighbours that are closely related to it, while low density words have neighbours that are relatively less related to it. Measures of semantic neighbourhood size and density predict performance on language processing tasks (Buchanan et al., 2001; Danguecan & Buchanan, 2016; Mirman & Magnuson, 2008; Pexman et al., 2008). Regarding semantic neighbourhood size, words with large neighbourhoods (i.e., many neighbours) generate faster response times than words with small neighbourhoods (i.e., few neighbours; Buchanan et al., 2001; Siakulak, Buchanan, & Westbury, 2003; Pexman et al., 2008). On the other hand, low semantic neighbourhood density words (i.e., more distant than near neighbours) are processed faster than high density words (i.e., more near than distant neighbours) on lexical decision and semantic categorization tasks (Danguecan & Buchanan, 2016; Mirman & Magnuson, 2008).

Episodic Memory

Historically, research on episodic memory has focused on factors that influence encoding and retrieval processes (Conway, 2009; Craik & Lockhart, 1990; Glanzer et al., 1993; Tulving, 2002; Schacter & Tulving, 1994). A typical experimental task of episodic memory has a study phase and a test phase. In the study phase, participants are presented with a series of items. In the test phase, they are asked to retrieve as many items as possible from the study phase (Tulving, 2002; Tulving & Thomson, 1973). The main question addressed in these experimental designs is whether participants can accurately remember the learning episode. Participants' accuracy remembering the items is a proxy for episodic memory encoding and retrieval processes. As previously mentioned, explicit retrieval of previously presented information is frequently measured with recall or recognition tasks, whereas implicit retrieval can be measured with a variety of tasks such as lexical decision, semantic categorization, and word-fragment completion tasks (Criss et al., 2001; Glanzer et al., 1993; Schacter et al., 1993; Schacter & Graf, 1986).

The manner by which information is processed during encoding is a factor known to influence episodic memory (Atienza, Crespo-Garcia, & Cantero, 2011; Craik & Lockhart, 1972; 1990; Crail & Tulving, 1975; Glanzer et al., 1993; Schott et al., 2011). The levels-of-processing framework postulates that deeper processing of the stimulus at the time of encoding facilitates memory retrieval (Bein et al., 2015; Craik & Lockhart, 1972; 1990; Craik & Tulving, 1975;

Galli, 2014). Depth of processing can take several forms, but one of the most effective strategies is processing the semantic content of the stimulus (i.e., semantic elaboration). Many studies have found that focusing on the meaning of the to-be-remembered stimuli leads to more accurate retrieval than focusing on other, more surface level, features (e.g., orthographic features; Craik & Lockhart, 1972; Craik & Tulving, 1975; Galli, 2014; Greve et al., 2007; Prior & Bentin, 2008; Schacter & Graf, 1986; Schott et al., 2013; Seamon, 1976). Deeper processing leads to elaborate and lasting memory representations that can be easily retrieved from memory storage (Craik & Lockhart, 1972; 1990; Craik & Tulving, 1975; Galli, 2014; Schott et al., 2013).

The nature of the to-be-remembered items is also known to influence episodic memory. Words are frequently used as stimuli in episodic memory tasks, and the effects of word frequency on episodic retrieval have been extensively studied (de Zubicaray, McMahon, Eastburn, Finnigan, Humphreys, 2005; Diana & Reder, 2006; Freeman, Heathcote, Chalmers, & Hockley, 2010; Glanzer et al., 1993; Glanzer & Adams, 1990; Shiffrin & Steyvers, 1997). The word frequency effect refers to the finding that low frequency words are more accurately remembered than high frequency words in recognition memory tasks (de Zubicaray et al., 2005; Diana & Reder, 2006; Freeman et al., 2010; Glanzer & Adams, 1990; Glanzer et al., 1993; Shiffrin & Steyvers, 1997). On the other hand, high frequency words are more accurately remembered than low frequency words in free-recall tasks (Glanzer & Adams, 1990; Glanzer et al., 1993).

Other item-specific variables such as word length, word class (nouns vs. verbs), imagability (degree to which the word evokes a mental image), concreteness (degree to which the word can be experienced by the senses), and contextual diversity (how many different types of contexts a word appears in linguistic corpora) also influence episodic memory (Criss et al., 2011; Earles & Kersten, 2000; Fliessbach, Weis, Klaver, Elger, & Weber, 2006; Hamilton & Rajaram, 2001; Hicks, Marsh, & Cook, 2006; Jalbert, Neath, Bireta, & Surprenant, 2011; Madan, Glaholt, & Caplan, 2010).

Remembering individual items is important, but another very important memory process is memory for associations or associative memory (Bader, Mecklinger, Hoppstädter, & Meyer, 2010; Hockley, 1994; Troyer et al., 2008). Associative memory is important because our entire knowledge network is based on associations between individual units of information; for example, we learn the associations between words with their meaning and between events and their context. Experimental associative memory tasks typically require participants to study a list of word pairs and are later asked to recollect them. The key difference between an associative and a single-item memory task, is that in the associative task participants have to correctly remember the link between the words. If they recall the words that made up the studied word pairs but do not recall their correct associations, their performance would be incorrect.

Research has demonstrated that there are some differences between single-item and associative memory (Hockley & Consoli, 1999). For instance, rate of forgetting has been found to be greater for single words than for associations between words (Hockley, 1992). In addition, associative memory is more susceptible to aging and mild cognitive impairment than memory for single items (Old & Nave-Benjamin, 2008; Troyer et al., 2008). Despite this distinction, research on associative memory has found that factors that influence memory for single words, such as depth of processing and word frequency, can also influence the ability to remember associations (Arnon et al., 2010; Hockley, 1994; Schacter & Graf, 1986).

The Relationship between Semantic and Episodic Memory

Although it is useful to study the dissociation between semantic and episodic memory to understand their unique characteristics, there is evidence that these two systems are interdependent and do not operate in isolation (Graham et al., 2000; Lee et al., 2002; Schacter & Tulving, 1994; Takashima et al., 2014). Many studies have examined how semantic knowledge facilitates learning and memory of new information (Atienza et al., 2011; Bein et al., 2015; Craik & Lockhart, 1990; Greve et al., 2007; Prior & Bentin, 2008; Staresina, Gray, & Davachi, 2009). For example, individuals who are considered experts have better memory for information specific to their field when compared to novices (Bein et al., 2015).

The levels-of-processing framework is another example of how activation of pre-existing semantic knowledge facilitates memory retrieval. Deeper processing, such as focusing on the meaning of the to-be-remembered stimuli (i.e., semantic elaboration) at encoding increases the probability of accurate retrieval (Craik & Lockhart, 1990; Craik & Tulving, 1975). In addition, memory retrieval is facilitated when the to-be-remembered items are presented within a context (e.g., sentence) at encoding (Prior & Bentin, 2008). This context-dependent facilitation is only observed when the context is compatible with pre-existing semantic knowledge (Atienza et al., 2011; Bein et al., 2015; Moscovith & Craik, 1976; Staresina et al., 2009). The congruency effect refers to the finding that items are remembered better when presented with information that is compatible, rather than incompatible, with pre-existing knowledge (Bein et al., 2015; Moscovith & Craik, 1976; Staresina et al., 2009). For example, the probability of remembering the word *lettuce* is higher when presented with a semantically congruent adjective, such as *leafy*, than when presented with a semantically incongruent adjective, such as *crazy* (Bein et al., 2015). Depth of processing has been suggested as a possible mechanism for this finding (Bein et al., 2015; Prior & Bentin, 2008). Reading semantically congruent sentences is thought to elicit a process similar to semantic elaboration (Prior & Bentin, 2008; Schacter & Graf, 1986). Words that form semantically congruent sentences usually have strong associations between them. Thus, when a target word is presented in a semantically congruent sentence, related words also get activated because of their pre-existing semantic associations with the target word (Bein et al., 2015; Prior & Bentin, 2008). This greater level of activation is similar to deeper processing and could be the mechanism behind better retrieval of target words (Prior & Bentin, 2008).

Another example revealing the role for semantic representations in episodic memory is that presenting semantically related cues increases the probability of accurate retrieval of target items (Nelson, Kitto, Galea, McEvoy, & Bruza, 2013). The extralist cued-recall task has been used to study this phenomenon. In this task, participants see a list of target words. After, they must recall as many target words as possible while being presented with a number of extralist cues (words not previously presented). Cues that are semantically related to target words elicit more accurate retrieval of target words than unrelated cues (Nelson et al., 2013). One possible explanation for this effect is that semantically related cues and targets may share a semantic neighbourhood. Therefore, the presentation of semantically related cues could facilitate the retrieval of target words because of their associations in the semantic neighborhood (Nelson et al., 2013).

Pre-existing semantic information not only influences memory for single items, it also plays a role in associative memory (Greve et al., 2007; Nelson et al., 2013; Prior & Bentin, 2003). Semantically related words pairs (e.g., word pairs that share features, belong to the same category, or have a temporal, functional, or spatial relationship) are better remembered than semantically unrelated word pairs (Atienza et al., 2011; Bader et al., 2010; Greve et al., 2007;

Kriukova, Bridger, & Mecklinger, 2013). For example, a related word pair such as *dancer – ballet* is remembered better than an unrelated word pair like *dancer – building* (Bader et al., 2010). Similarly, associative memory is better for compound word constituents (e.g., *pin* and *point* are constituents of the compound word *pinpoint*) than for unrelated word pairs (Ahmad & Hockley, 2014; Ahmad, Fernandes, & Hockley, 2015; Hockley, Ahmad, & Nicholson, 2016). Constituents of compounds words have a pre-existing semantic relationship that is thought to facilitate associative memory (Ahmad & Hockley, 2014; Ahmad et al., 2015; Hockley et al., 2016).

Taken together, these findings indicate that pre-existing semantic associations facilitate encoding and retrieval of episodic associations. Spreading of activation in the semantic network has been proposed as a mechanism for this effect (Bader et al., 2010; Bein et al., 2015; Kriukova et al., 2013). When two related words are presented, in addition to the activation created by studying each word, activation also spreads between the semantic neighbourhoods of both words in a bidirectional fashion (Bader et al., 2010; Bein et al., 2015; Kriukova et al., 2013). The overall increased level of activation facilitates retrieval of the association.

Effects of Semantic Richness on Episodic Memory

Most research on the relationship between semantic and episodic memory has focused on the effects of explicit encoding and retrieval manipulations, such as task instructions that elicit semantic elaboration (Hargreaves, Pexman, Johnson, and Zdrazilova, 2012; Schacter & Tulving, 1994). All the examples presented in the previous section involve explicit strategies that experimenters impose on a memory task to activate semantic knowledge. However, another way of looking at this relationship is to examine the influence of semantic richness, which captures the degree of semantic information associated with specific words, on episodic memory. As previously mentioned, semantic richness captures the variability in information associated with a word’s meaning (Pexman et al., 2008). The effects of item-specific semantic characteristics (e.g., semantic richness) on episodic memory are often less studied than the effects of explicit encoding and retrieval manipulations (Hargreaves et al., 2012). This is surprising given that words are frequently used in memory research, and they can be used to explore both semantic and episodic memory (Freeman et al., 2010).

A few studies have explored the effects of item-specific semantic richness on episodic memory (Hargreaves et al., 2012; Nelson et al., 1998; Nelson et al., 2013). In a series of experiments, Nelson and colleagues found that the number of semantic associates of target words had dissociable effects on recall and recognition tasks (1998). Words with few, as opposed to many, associates were more likely to be recalled in an extralist cued-recall task, but not in a free-recall task (Nelson et al., 1998; Nelson et al., 2013). In contrast, words with many associates were better remembered than words with few associates in a recognition memory task (Nelson et al., 1998; Nelson et al., 2013). This pattern suggests that the effects of semantic richness on memory for words could vary depending on task requirements.

In addition, Hargreaves and colleagues studied the effects of semantic richness, as measured by the number of features, on an episodic recall task (2012). They found that free recall was better for words with many features than for words with few features (Hargreaves et al., 2012). The authors proposed the levels-of-processing framework as an explanation for this finding; that is, explicit semantic elaboration at encoding leads to deep and rich processing that facilitates memory retrieval (Craik & Lockhart, 1972; 1990; Craik & Tulving, 1975). It is possible that deep and rich processing could also be elicited by item-specific semantic richness (Hargreaves et al., 2012). The semantic neighbourhood of a target word gets activated when the word is encountered. The richer the semantic representation of a target word, the greater the level of activation in the neighbourhood. It is possible that semantically rich words elicit deep processing at encoding even without explicit semantic elaboration strategies because of their rich semantic representations (Hargreaves et al., 2012). The activation of semantically rich neighbourhoods may act as an equivalent to deep processing and facilitate episodic memory retrieval (Hargreaves et al., 2012).

In another study, the number of features associated with words had a significant repetition priming effect on a lexical decision task (Rabovsky, Sommer, & Rahman, 2012). Repetition priming effects are observed when processing of a stimulus is facilitated after being presented repeatedly (e.g., faster lexical decisions for repeated versus non-repeated words; Rabovsky et al., 2012). Priming effects are considered to represent increased accessibility to representations and are considered a measure of implicit encoding (Graf & Mandler, 1984; Ratcliff, Hockley, & McKoon, 1985; Rabovsky et al., 2012; Schacter & Graf, 1986). Rabovsky and colleagues found that words with many features had an enhanced repetition priming effect, which suggested that previously known semantic information influences encoding of episodic events (Rabovsky et al., 2012).

Nelson and colleagues developed a model called Processing Implicit and Explicit Representations (PIER-2) to account for the role of pre-existing knowledge in episodic memory performance (1998). This model proposes that encoding target words in an episodic memory task produces two representations. The first is an implicit representation of the target word and its semantically related associates (Nelson et al., 1998). Semantic associates are automatically activated when the target word is encountered. This activation of semantic associates creates an implicit memory representation that allows parallel access to semantic information associated with the target word (Nelson et al., 1998). The size and strength of the associations in the semantic neighbourhood of the target word influences this implicit representation. The second is an explicit representation that includes the target word and the context of study (e.g., encoding conditions; Nelson et al., 1998). The explicit processing strategies used during encoding (e.g., semantic elaboration) influence the explicit representation (Nelson et al., 1998).

This model assumes that explicit and implicit representations are independent memory traces and both play a role in retrieval of episodic events (Nelson et al., 1998). According to this account, semantic information associated with the target word (e.g., semantically related associates) influence the implicit representation, and encoding and retrieval strategies influence the explicit representation. Similar to the way that semantic elaboration as an encoding strategy increases the strength of the explicit representation, stronger connections between the target and its semantic associates increase the strength of the implicit representation. Stronger explicit and implicit representations facilitate memory retrieval. In a series of experimental episodic memory tasks, words with strong as opposed to weak target-associate connections were more accurately retrieved in recall and recognition memory tasks (Nelson et al., 1998). According to this view, encoding and retrieval are dependent on both explicit encoding and retrieval strategies and implicitly activated semantic information.

To summarize, episodic and semantic memory are interdependent systems (Graham et al., 2000; Greenberg & Verfaellie, 2010; Takashima et al., 2014). Most research examining the relationship between these two systems has focused on explicit encoding and retrieval strategies, such as semantic elaboration, task instructions, and testing conditions (Bein et al., 2015; Craik & Lockhart, 1972; 1990; Craik & Tulving, 1975; Hargreaves et al., 2012; Nelson et al., 1998). However, less attention has been given to word-specific semantic variables. Research indicates that item-specific semantic richness influences language processing (Buchanan et al., 2001; Danguecan & Buchanan, 2016; Pexman et al., 2008; Yap et al., 2011), but it is less clear how this richness influences episodic memory for words. The few studies that have looked at semantic richness effects on episodic memory have focused on two measures: number of semantic associates and number of features (Hargreaves et al., 2012; Nelson et al., 1998; 2013; Rabovsky et al., 2012). They have found that words with high semantic richness are better remembered than words with low semantic richness (Hargreaves et al., 2012; Nelson et al., 1998; 2013; Rabovsky et al., 2012).

The facilitatory effect of semantic richness on episodic memory is thought to be the result of a greater level of activation in the semantic neighbourhood of target words (Hargreaves et al., 2012; Nelson et al., 1998; 2013). That is, semantically rich words are associated with more semantic information (e.g., semantic features, associates) all of which get activated when the word is encountered. This increased level of semantic activation translates into better episodic memory for target words. However, no study to date has examined the effects of semantic neighbourhood density on episodic memory. The overall goal of this dissertation is to address this gap in the literature. Semantic neighbourhood density is a unique variable because it captures the variability in the distribution of semantic neighbours around a target word (Buchanan et al., 2001; Danguecan & Buchanan, 2016). Target words with high semantic neighbourhood density have on average more near than distant semantic neighbours. In contrast, words with low semantic neighbourhood density have on average more distant than near neighbours (Danguecan & Buchanan, 2016). The distance between a target word and its neighbours reflects the degree of semantic relatedness; thus, semantic neighbourhood density captures the degree of semantic relationship between a target word and its neighbours (Buchanan et al., 2001; Danguecan & Buchanan, 2016; Durda & Buchanan, 2008). When it comes to language processing tasks, both the number of semantic neighbours and their density around the target word predict performance (Buchanan et al., 2001; Danguecan & Buchanan, 2016; Pexman et al., 2008; Yap et al., 2011), but the effects of semantic density on episodic memory have not been investigated. As in language processing, it may be that the distribution of semantic neighbours also plays a role in episodic memory performance. This dissertation tests that possibility.

Research Objectives

The first main objective of this dissertation is to explore the effects of semantic neighbourhood density (SND) on memory for single words. To gain a better understanding of the influence of SND on memory, it is important to first test its effects using a commonly used memory task. The most commonly used procedure to assess verbal memory abilities is a list-learning task with single words as the stimuli (Lezak, Howieson, Bigler, & Tranel, 2012). List-learning tasks are explicit memory tasks because they require participants to intentionally recollect previously presented information. As such, Experiment 1 was designed to test the effect of SND on explicit memory for single words.

When we think of memory abilities, we usually think of explicit memory or conscious recollection of experiences (Squire, 1992). Another important memory process that often receives less attention is implicit memory. For instance, although several amnestic syndromes show a pattern of impaired explicit memory and intact implicit memory, implicit memory is typically not assessed at all in clinical populations (Graf & Schacter, 1985; Scoville & Milner, 1957; Squire, 1992; Warrington, & Weiskrantz, 1970). There are several factors, such as depth of encoding and word frequency, which have been found to influence both explicit and implicit memory (Gomez, 2002; Schachter et al., 2003). To expand our understanding of the effects of SND on episodic memory, Experiment 2 was designed to test the effect of SND on implicit memory for single words.

As previously mentioned, the most common procedure to assess episodic memory in general is to use single words as the stimuli. In neuropsychological assessment, an individual's verbal memory abilities are often inferred based on their performance on a task of memory for single words (Lezak et al., 2012; Snyder, Nussbaum, & Robins, 2006). However, another very important memory process is memory for associations. The ability to learn and remember associations is essential to the acquisition and retention of knowledge. Both differences and similarities between single-item and associative memory have been reported (Graf & Schacter, 1985; Hockley, 1992; Old & Nave-Benjamin, 2008; Troyer et al., 2008). Given the relevance of associative memory, the second main objective of this dissertation is to explore whether the effects of SND on memory for single words extend to memory for associations between words. Experiment 3 was designed to test the effect of SND on explicit memory for word associations and Experiment 4 was designed to test the effect of SND on implicit memory for word associations.

To summarize, the specific research questions addressed by Experiments 1 to 4 respectively are as follows: 1) Does SND influence explicit memory for single words? 2) Does SND influence implicit memory for single words? 3) Does SND influence explicit memory for word associations? and 4) Does SND influence implicit memory for word associations? Given that words with high semantic richness are remembered better than words with low semantic richness (Hargreaves et al., 2012; Nelson et al., 1998; 2013; Rabovsky et al., 2012), it was predicted that high semantic density would also have a faciliatory effect across episodic memory tasks.

Understanding the factors that influence memory processes of words and their associations, such as SND, has important implications. First, this research will contribute to our theoretical understanding of a major topic of interest in cognitive psychology, that is, how words are stored and retrieved from memory. As previously mentioned, traditional models of memory conceptualized semantic and episodic memory as distinct systems, but more recent research has focused on how these two systems interact (Graham et al., 2000; Lee et al., 2002; Nelson et al., 1998; Schacter & Tulving, 1994; Tulving, 1972; 2002; Takashima et al., 2014). This study contributes to this area of research by examining how semantic information associated with specific words influence both explicit and implicit episodic memory. In addition, by focusing on a co-occurrence-derived semantic richness variable (i.e., semantic neighbourhood density) this study will address a research question that has not been examined before in the context of episodic memory.

In addition, understanding whether word characteristics, such as SND, influence episodic memory can be beneficial to those with impaired episodic memory. For example, a common compensatory strategy for memory impairment is the use of reminders (Cicerone et al., 2011; Velikonja et al., 2014). Reminders can take the form of written words/sentences in post-it notes, calendars, or agendas. When choosing the words to write reminders for those with memory impairment, one could choose words that are more likely to be remembered, and semantic density may help guide our choices. Additionally, individuals with moderate to severe memory impairment should be repeatedly reminded of certain information, such as their location and daily schedule, in order to prevent disorientation and confusion (Lezak et al., 2012; Velikonja et al., 2014). Disorientation can increase negative psychological symptoms such as anxiety and irritability in this population (Lezak et al., 2012). When communicating with individuals with memory impairment it would be beneficial to choose words that are more likely to be remembered correctly. This research can also have implications for those learning or teaching a second language. If semantically rich words are remembered better, then teachers could initially focus on those words to help students build a bigger vocabulary faster. Similarly, teachers could provide students who have difficulties acquiring the new vocabulary with words that are high as opposed to low in semantic richness to aid with their learning.

CHAPTER 2

DESIGN AND METHODOLOGY

Participant Recruitment and Inclusion Criteria

Participants were University of Windsor undergraduate students recruited through the Psychology department participant pool. They received partial course credits for their participation. Participants met the following inclusion criteria: reported English as their first language and had normal or corrected-to-normal vision. Separate samples of 32 participants were recruited for each experiment.

Operational Definitions

Semantic Neighbourhood Density (SND)

Semantic neighbourhood density (SND) captures the variability in the distribution of semantic neighbours in a target word's semantic neighbourhood (Buchanan et al., 2001; Danguecan & Buchanan, 2016; Durda & Buchanan, 2008). SND is derived from a global co-occurrence model called Windsor improved norms of distance and similarity of representations of semantics (WINDSORS; Durda and Buchanan, 2008). SND is operationalized as the average distance between a target word and its semantic neighbours and is expressed as a mathematical value (Durda and Buchanan, 2008). To manipulate SND as a factor, words were categorized as high or low SND. High SND words were selected from the top 1/3 of the WINDSORS database distribution and low SND words were selected from the bottom 1/3 of the distribution. Target words with high SND have on average more near than distant neighbours and thus, have a dense semantic neighbourhood. In contrast, words with low SND have on average more distant than near neighbours scattered around it, forming a sparsely distributed semantic neighbourhood (Buchanan et al., 2001; Danguecan & Buchanan, 2016).

SND values capture the degree of semantic relationship between words (Buchanan et al., 2001; Danguecan & Buchanan, 2016). Low SND words have low SND values indicating that they have weakly related semantic neighbours that are organized relatively distant around the target. In contrast, high SND words have high SND values indicating that they have closely related semantic neighbours that are organized closely around it. Refer to *Figure 1* for an illustration of the distribution of semantic neighbours for words with low and high SND.

Stimulus Development

The stimulus set consisted of 96 experimental words, 48 control words, and 96 control pronounceable nonwords. The 96 experimental words were concrete nouns 4 to 8 letters in length. Forty-eight experimental words had high SND and the other 48 had low SND values. The difference in mean SND values between high and low SND words was statistically significant ($t = 31.62$, $p < .001$). Word frequency and orthographic neighbourhood size were controlled because they are known to influence memory and language processing (Colheart, Davelaar, Janasson, & Besner, 1977; Glanzer & Adams, 1990; Shiffrin & Steyvers, 1997). Word frequency refers to how frequently a word occurs in a language, and orthographic neighbourhood size is defined as the number of words that can be created by changing a single letter while maintaining all letter positions (KALE is an orthographic neighbour of MALE; Colheart et al., 1977). All experimental words had low frequency values (equal to or less than 10 per million occurrences) and orthographic neighbourhood sizes of 0, 1 or 2 as measured by WINDSORS database (Durda & Buchanan, 2008). Table 1 summarizes the lexical characteristics of the experimental words. All the experimental words and their lexical characteristics are presented in Appendix A.

Table 1. *Means and Standard Deviations for Word Length, Frequency (Freq), Orthographic Neighborhood Size (ON), and Semantic Neighbourhood Density (SND) of Experimental and Control Words.*

Experimental Words	***Length***	***Freq***	***ON***	***SND***
High SND	6.58 (1.09)	1.56 (2.29)	0.58 (0.71)	0.43 (0.02)
Low SND	6.16 (1.19)	3.17 (2.62)	1.00 (0.84)	0.27 (0.01)
Control Words				
High SND	6.95 (0.89)	3.78 (2.70)	0.20 (0.62)	0.40 (0.03)
Low SND	6.85 (1.04)	2.92 (2.22)	0.60 (0.75)	0.31 (0.02)

The 48 control words had the same lexical characteristics as the experimental words. They were concrete nouns 4 to 8 letters in length. Twenty-four control words had high SND values and the other 24 had low SND values. All control words had low frequency values (equal to or less than 10 per million occurrences) and orthographic neighbourhood sizes of 0, 1 or 2 (WINDSORS; Durda & Buchanan, 2008). See Table 1 for a summary of the lexical characteristics of the control words. The 96 control nonwords were formed using the nonword generator Wuggy (Keuleers & Brysbaert, 2010). To generate nonwords, this program takes real words and changes one to two of their letters while maintaining their length and syllabic structure (Keuleers & Brysbaert, 2010). The real words inputted into the program to generate nonwords were matched to the experimental and control words on their lexical characteristics (i.e., length, frequency, orthographic neighbourhood size). They had 4 to 8 letters in length (M = 5.20), frequencies equal to or less than 10 per million occurrences (M = 2.97), and orthographic neighbourhood sizes of 0, 1 or 2 (M = 0.50). Control words and nonwords are presented in Appendices B and C.

Task Software and Display Details

The experimental tasks were administered using Direct RT (Version v2012; Empirisoft Corporation) on a Dell PC with Windows XP operating system. Words were presented in capital letters, with font size 30, of turquoise color against a black background in the center of the monitor.

Experimental Procedure

Four experiments are described below. All four experiments shared a critical experimental stimulus set (described above) and all four had the same basic structure. The experimental structure consisted of a study phase in which participants were presented with a study list in a computer screen and asked to remember the items as best as possible. In Experiments 1 and 2, the study list consisted of single words presented one at a time for 1.5 seconds. In Experiments 3 and 4, the study list consisted of word pairs presented one at a time for 2 seconds. The study list items were presented in a random order in all experiments.

The study phase was followed by a 5-minute distractor phase during which participants completed mazes on paper. The final stage in all experiments was a test phase. In Experiments 1 and 3, the test phase consisted of an explicit recognition memory task. In the explicit memory task, participants were presented with old items and new items one at a time (single words in Experiment 1 and words pairs in Experiment 3). Old test items were those presented in the study list and new items were control items not previously presented in the study list. Participants were asked to discriminate between old and new items by pressing the YES key for old items or the NO key for new items. They were allowed as much time as needed to make their responses.

In Experiments 2 and 4, the test phase consisted of an implicit memory task. The implicit memory task was a lexical decision task. In this task, participants were presented with letter strings one at a time and were required to indicate with a key press whether the letter string formed a real English word or a nonword. The letter strings presented were either old items presented in the study list, new items not previously presented in the study list, or pronounceable nonwords. They were asked to make their responses as quickly and as accurately as possible. The test items were presented in a random order in all experiments. Table 2 presents a summary of the experimental procedure for each experiment. More details about the specific procedure of each experiment is provided in the following chapters.

Table 2. *Phases of experimental procedure and stimulus set for all experiments.*

Experiment	**Study Phase**	**Distraction Phase**	**Test Phase**
1	Single Words	Mazes (5 minutes)	Explicit Test Recognition Memory Test Old/New Responses
2	Single Words	Mazes (5 minutes)	Implicit Test Lexical Decision Task Word/Nonword Responses
3	Word Pairs	Mazes (5 minutes)	Explicit Test Recognition Memory Test Old/New Responses
4	Word Pairs	Mazes (5 minutes)	Implicit Test Lexical Decision Task Word/Nonword Responses

Outlier identification

The following procedure was used to identify outliers for Experiments 1 and 3. Participants and stimulus items with less than 50% accuracy (less than chance) were excluded from subsequent statistical analyses. For Experiments 2 and 4 the following steps were taken.

First, all incorrect responses and reaction times faster than 200 ms were removed. Then, reaction times deviating more than 2.5 standard deviations from the mean were removed.

General Statistical Procedures

For Experiments 1 and 3 (explicit memory test), after outliers were removed, mean hit rates and false alarm rates were calculated for each participant per condition. In both experiments, SND was manipulated as a within-subjects variable. Hit rates were the proportion of correct responses to target items (old) and false alarm rates were the proportion of incorrect responses to nontarget items (new). Using these values, *d'* (index of discriminability) was calculated for each participant per condition using the following formula: $d' = Z_{hit} - Z_{FA}$ (Z represents the z transformation of a probability value based on the normal distribution; Leeuw, 2015). *D'* is the preferred statistic in recognition memory research because it calculates the relative proportion of hits minus false alarms. The use of *d'* is based on signal detection theory, which stipulates that individuals have different response criteria; some people are more likely to say *yes* regardless of whether the stimulus is present (hit rate) or absent (false alarm rate; Macmillan & Creelman, 2004; Swets, 1964). For instance, if an individual is very likely to always respond with *yes*, they would obtain a high hit rate but also a high false alarm rate in a recognition memory task. Accordingly, analyzing the hits alone does not provide information about participants' ability to discriminate between old and new items. As such, *d'* is an unbiased measure because it takes into consideration both the hits and the false alarms. Higher *d'* values indicate that participants can easily discriminate old from new items. In Experiment 1, differences in *d'* between high and low SND words were compared using a paired-samples t-test. In Experiment 3, differences in *d'* between SND groups were analyzed using a repeated-measures analysis of variance (ANOVA).

For Experiments 2 and 4 (implicit memory test), after outliers were removed, mean reaction times were calculated for each participant per condition. In both experiments, SND was manipulated as a within-subjects variable. In Experiment 2, the type of test word (old, new) was also manipulated as a within-subjects variable. Differences in reaction times between groups were analyzed using a repeated measures ANOVA. In Experiment 4, in addition to SND, the type of test word (prime, target) was also manipulated as a within-subjects variable. Differences in reaction times between groups were analyzed using repeated measures ANOVAs. More details about the specific procedures and analyses for each experiment are provided in the following chapters.

CHAPTER 3

Experiment 1: Single Word Explicit Recognition Memory Task

Participants

Thirty-Two University of Windsor undergraduate students participated in Experiment 1 (23 females and 9 males; mean age = 20.37 years). Two participants were excluded due to insufficient accuracy rates (< 50%).

Procedure

The objective of Experiment 1 was to determine whether SND influences explicit memory for single words. In the study phase participants were presented with a study list consisting of the 96 experimental words (48 per SND condition). Following the completion of the distraction phase, they completed an explicit recognition memory task (test phase). In this task, participants were presented with 80 test items. Forty test items were experimental words from the study list (20 per SND condition), and the other 40 were new control words not previously presented in the study list (20 per SND condition). As previously mentioned, the new words (control) were matched to the old words (experimental) on their lexical characteristics.

Statistical analysis

The SND of the experimental words (high, low) was manipulated as a within-subjects variable. The mean proportion of accurate responses to old items (hit rate) and mean proportion of inaccurate responses to new items (false alarm rate) were calculated per participant for each condition. In addition, the statistic *d'* was calculated per participant for each condition using the following formula: ($d' = Z_{hit} - Z_{FA}$; Leeuw, 2015; Macmillan & Creelman, 2004). Given that high semantic richness has been found to facilitate memory, it was predicted that high SND words would produce higher *d'* values (higher hit rates and lower false alarm rates) when compared to low SND words. The effect of SND on mean *d'* was tested using a paired samples t-test.

Results

The outlier analysis revealed that 2 participants had insufficient accuracy rates (< 50%), and as such, were excluded from subsequent analysis. Mean hit rate and false alarm rate for each condition were calculated and are displayed in Table 3. A paired-samples t-test revealed that high SND words (d' = 2.47) were discriminated better than low SND words (d' = 1.73; t = 2.99, p < .01, Cohen's d = 0.62). Figure 2 and 3 present the hits and false alarms of Experiment 1.

Table 3. *Mean Hit Rates, False Alarm Rates, and Standard Errors in Experiment 1.*

	SND	
	High SND	**Low SND**
Hits	.84 (.03)	.71 (.03)
False Alarms	.12 (.03)	.15 (.02)

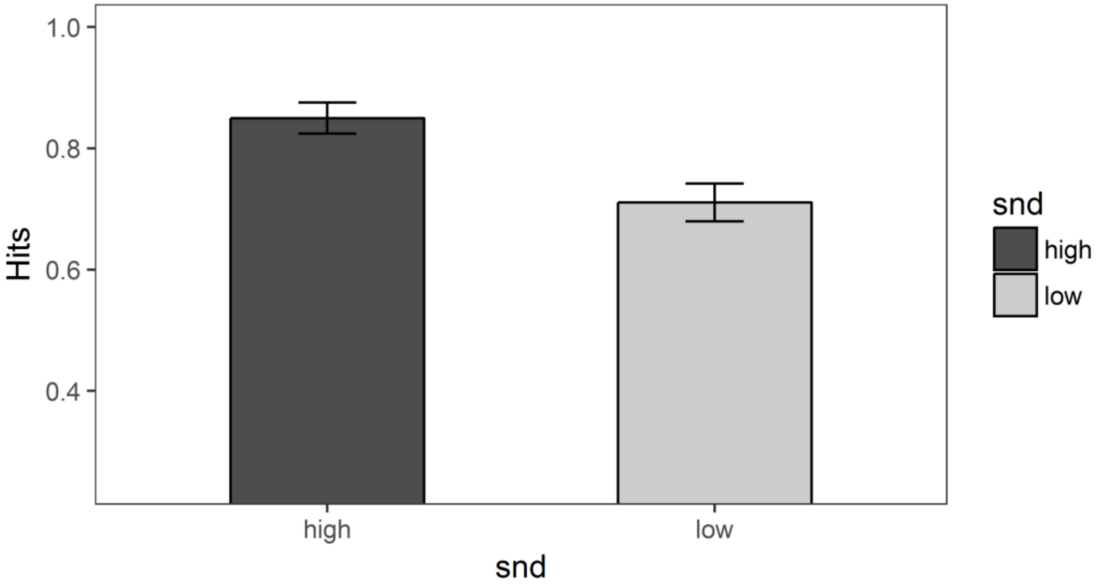


Figure 2. Experiment 1 hit rates. Error bars represent standard error.

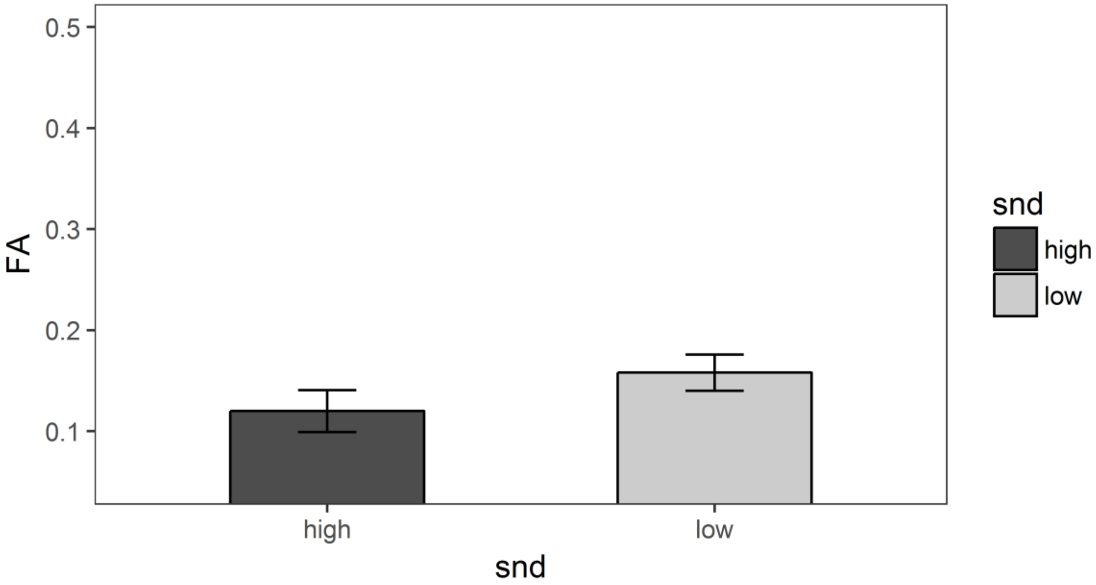


Figure 3. Experiment 1 false alarm rates. Error bars represent standard error.

Discussion

The objective of Experiment 1 was to determine whether SND influences explicit memory for single words. Given that high semantic richness has been found to facilitate memory, it was predicted that high SND words would be remembered better than low SND words. The results supported this prediction and showed that high SND words produced higher *d'* values than low SND words. Higher *d'* values indicate that high SND words were discriminated better than low SND words in the memory test; that is, high SND words had on average higher hits and lower false alarm rates than low SND words. Previous research has found that words with many as opposed to few semantic features or associates are remembered more accurately (Hargreaves et al., 2012; Nelson et al., 2008). The results of Experiment 1 show that the distribution of semantic neighbours also plays a role in explicit memory for single words. Words with dense neighbourhoods (i.e., many near neighbours) were remembered better than words with sparse neighbourhoods (i.e., few near neighbours) in an explicit memory task.

CHAPTER 4

Experiment 2: Single Word Implicit Memory Task

Participants

Thirty-Two University of Windsor undergraduate students participated in Experiment 2 (29 females and 3 males; mean age = 20.75 years).

Procedure

The objective of Experiment 2 was to determine whether SND influences implicit memory for single words. In the study phase participants were presented with a study list consisting of 48 experimental words (24 per SND condition). After the distraction phase, they completed the implicit memory task, which was a lexical decision task with 192 trials in total (test phase). In each trial they were presented with one letter string at a time and were required to indicate with a key press whether the letter string formed a real English word or a nonword. Participants were asked to make their responses as quickly and as accurately as possible. The letter strings presented in the lexical decision task were the 48 old words from the study list (24 per SND condition), 48 new control words not presented in the study list (24 per SND condition), and 96 pronounceable nonwords.

Statistical analysis

The aim of this task was to determine whether SND influences implicit memory for single words. As such, the first question was whether there is evidence of repetition priming. As previously mentioned, repetition priming would be evident if lexical decisions are faster for words that were previously presented than for new words. Because this procedure has been used in the past to elicit repetition priming, it was predicted that old words would produce faster reaction times then new words in the lexical decision task (Squire, 1992; Schacter et al., 1993).

The same effect of SND was expected in the explicit and implicit memory tasks; thus, it was predicted that high SND words would facilitate implicit memory and produce a larger priming effect than low SND words. The pronounceable nonwords were required for the lexical decision task, but given the research question, they were not of interest and were not included in subsequent analyses. Mean lexical decision times for test items were calculated per participant for each condition. The SND of the experimental words (high, low) and the type of test item (old, new) were manipulated as within-subjects variables. The effects of SND and type of test item on lexical decision times were analyzed using a repeated-measures analysis of variance (ANOVA).

Results

Reaction time outliers were identified across conditions and this resulted in removal of 1.8% of the data. After removal of outliers, mean reaction times were calculated across participants for each condition and are presented in Table 4.

Table 4. *Mean Reaction Times (ms) and Standard Errors in Experiment 2*.

	SND of test item	
	High SND	**Low SND**
New Items	806 (22)	768 (22)
Old Items	734 (18)	736 (21)

The analysis revealed a priming effect in which old words produced faster reaction times than new words [$F(1,31) = 39.73$, $p < .001$, $\omega^2 = .54$]. There was also a main effect of SND [$F(1, 31) = 5.54$, $p = .02$, $\omega^2 = .12$] whereby low SND words produced faster reaction times than high SND words. There was an interaction between SND and type of item type [$F(1,31) = 6.96$, $p < .001$, $\omega^2 = .15$] whereby reaction times were faster for old versus new words only within the high

SND word group (*M* = 72 ms) but not within the low SND group (*M* = 32 ms). Mean reaction times per condition are presented in Figure 4.

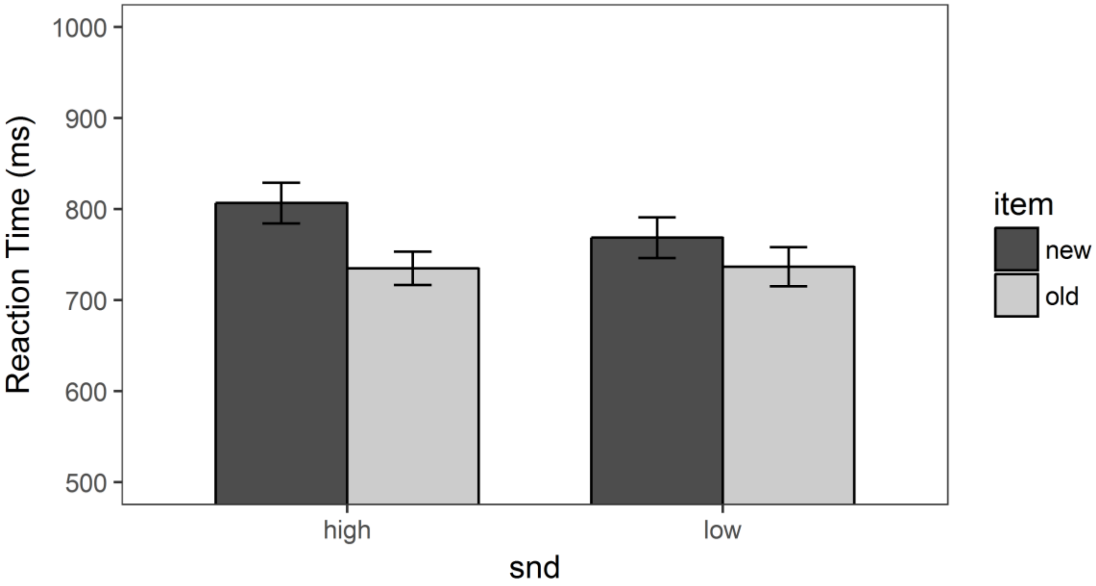


Figure 4. Experiment 2 mean reaction times. Error bars represented standard error.

Discussion

The objective of Experiment 2 was to extend the findings of Experiment 1 and determine whether SND influences implicit memory for single words. The first prediction was that there would be a priming effect whereby old words would be processed faster than new words in the lexical decision task. The second prediction was that high SND words would produce a greater priming effect than low SND words, which would indicate that they are remembered better than low SND words. The results revealed a priming effect in which old words were processed faster than new words. This result indicates that participants had an implicit memory representation of the old words which facilitated their processing in the lexical decision task.

There was also a main effect of SND whereby on average, low SND words were processed faster than high SND words. This finding is consistent with previous research reporting that words with sparse neighbourhoods (low SND) are processed faster than words with dense neighbourhoods (high SND) in language processing tasks (Buchanan et al., 2001; Danguecan & Buchanan, 2016; Mirman & Magnuson, 2008; Pexman et al., 2008). Most importantly, the interaction showed that the priming effect was evident only for high SND words. High SND old words were recognized 72 milliseconds faster than high SND new words. Low SND old words were recognized 32 milliseconds faster than low SND new words, but this difference was not statistically significant. This pattern suggests that in implicit memory tasks, high SND words benefit more than low SND words from a previous learning episode. The processing advantage that is conferred by repeated exposure to words is thought to be the result of increased accessibility to word representations (McNamara, 1992; Rabovsky et al., 2012). Experiment 2 suggests that high SND enhances, or can benefit from, the effect of repeated exposure through increased accessibility to word representations via an implicit memory task. Consistent with Experiment 1, these results indicate that the distribution of semantic neighbours influences memory performance.

CHAPTER 5

Experiment 3: Word Pairs Explicit Recognition Memory Task

Participants

Thirty-Two University of Windsor undergraduate students participated in Experiment 3 (25 females and 7 males; mean age = 20.67 years). One participant was excluded due to insufficient accuracy rates (< 50%).

Procedure

The objective of Experiment 3 was to determine whether SND influences explicit memory for word associations. In the study phase, participants were presented with a study list consisting of 48 word pairs. The word pairs were classified into four conditions and had the following format: high SND/high SND, low SND/low SND, high SND/low SND, low SND/high SND. There were 12 word pairs per SND condition. The words forming each pair were semantically unrelated to each other. Following the distraction phase, participants completed the explicit recognition memory task (test phase). In this task, participants were presented with 24 intact word pairs (6 per SND condition) and 24 rearranged word pairs (6 per SND condition). Intact word pairs were word pairs previously presented in the study list. Rearranged word pairs were word pairs not presented in the study list; however, they were formed using words that were part of different pairs in the study list. For example, two word pair examples from the study list are *garlic-violin* and *aspirin-muffin*. In the test list, *garlic-violin* would be considered an intact pair, but *aspirin-violin* would be considered a rearranged pair.

Participants were required to press the YES key for intact pairs and the NO key for rearranged pairs. They were instructed to press the YES key only for word pairs formed with two words that were presented together in the study list (intact pairs). This procedure was used to test whether participants remembered the associations between the studied words. They were allowed as much time as needed to make their responses.

Statistical analysis

It has been argued that the effect of semantic richness on memory has a similar mechanism as the effect of depth of processing at encoding (Hargreaves et al., 2012). Accordingly, the effect of semantic richness should extend to memory for associations, as is the case for the effect of depth of processing (Schacter & Graf, 1986). As such, it was predicted that the effect of SND would be similar between single-item and associative memory. That is, word pairs with two high SND words were expected to be remembered better than pairs with two low SND words. Pairs consisting of one high and one low SND word were expected to produce accuracy rates lower than pairs with two high SND words, but higher than pairs with two low SND words.

The SND of the experimental word pairs was manipulated as a within-subjects variable (high SND/high SND, low SND/low SND, high SND/low SND, low SND/high SND). The mean proportion of accurate responses to intact pairs (hit rate) and mean proportion of inaccurate responses to rearranged pairs (false alarm rate) were calculated per participant for each condition. In addition, *d’* was calculated per participant for each condition. The effect of SND on mean *d’* was analyzed using a repeated-measures analysis of variance (ANOVA).

Results

The outlier analysis revealed that one participant had insufficient accuracy rates (< 50%), and as such, their data was excluded from subsequent analyses. The mean hit rate and false alarm rate for each condition are displayed in Table 5.

Table 5. *Mean Hit Rates, False Alarm Rates, and Standard Errors in Experiment 3.*

	Word Pair SND			
	High High	**High Low**	**Low High**	**Low Low**
Hits	.85 (.03)	.65 (.04)	.63 (.05)	.73 (.04)
False Alarms	.24 (.04)	.38 (.05)	.43 (.04)	.27 (.03)

The hit rates and false alarm rates across participants were used to calculate mean *d’* for each SND condition. The analysis revealed that SND had an effect on *d’* [$F(3, 30) = 10.89$, $p = .001$, $\omega^2 = .46$]. Post-hoc tests (Tukey’s HSD) revealed that High High pairs (*d’* = 2.23) were discriminated better than High Low pairs (*d’* = 0.96, $t = 3.61$, $p < .01$) and Low High pairs (*d’* = 0.74, $t = 4.24$, $p < .01$). However, there was no difference between High High (*d’* = 2.23) and Low Low pairs (*d’* = 1.62; $t = 1.74$, $p = .30$). No other comparison was statistically significant ($p > .05$). Mean hits and false alarm rates for each condition are presented in Figures 5 and 6.

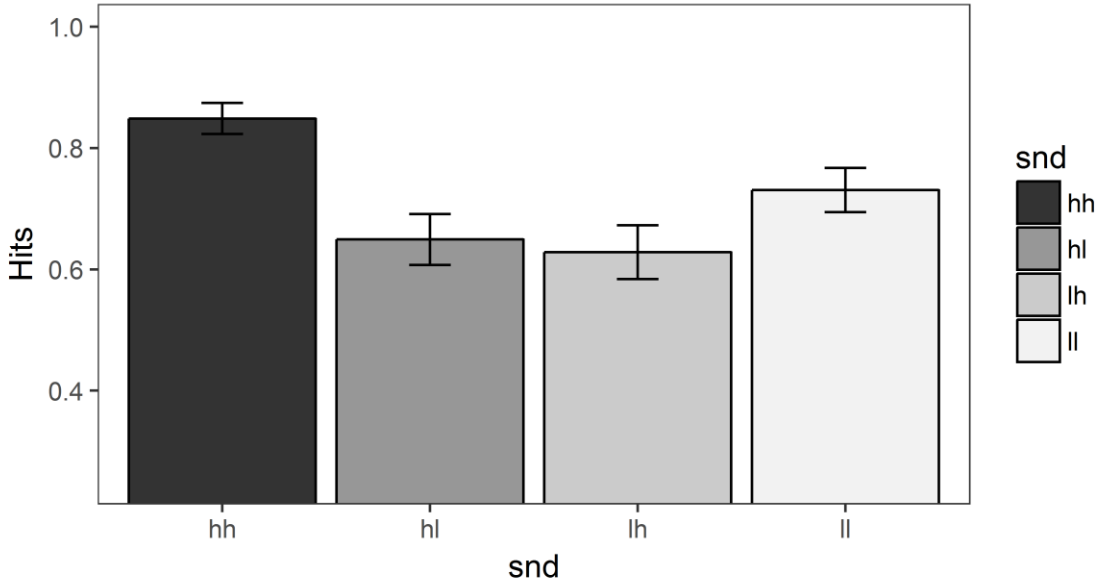


Figure 5. Experiment 3 mean hit rates. Error bars represent standard error.

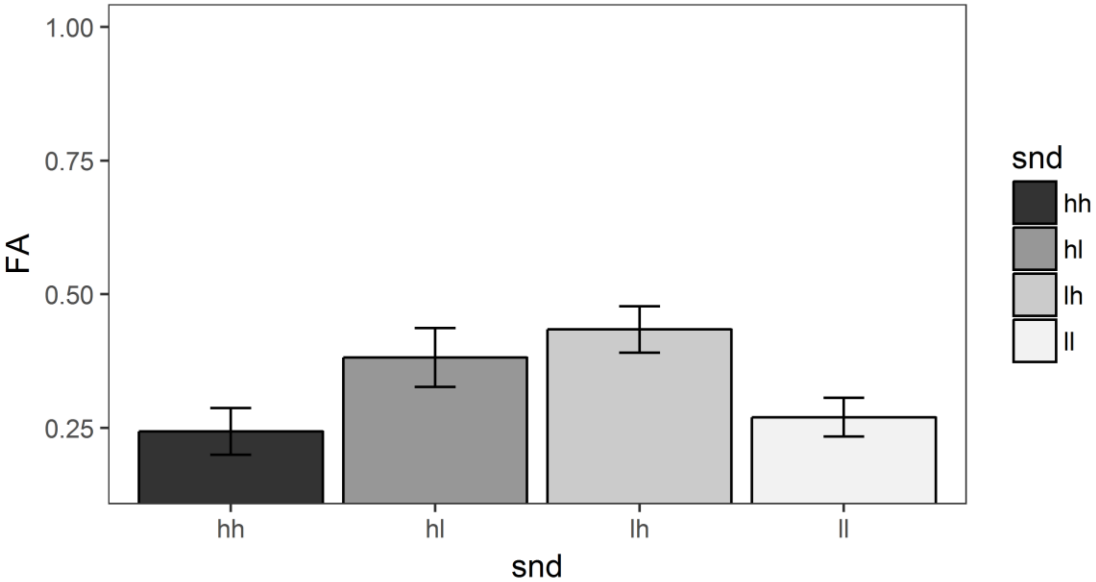


Figure 6. Experiment 3 false alarm rates. Error bars represent standard error.

Discussion

The objective of Experiment 3 was to determine whether SND influences explicit memory for word associations. Consistent with the previous predictions, it was expected that high SND would facilitate explicit memory for word associations. More specifically, it was predicted that word pairs with high SND words would be remembered better than pairs with low SND words. The results showed that pairs with two high SND words were discriminated better than pairs with one high and one low SND word. Pairs with two high SND words had a higher discriminability rate (*d'*) than pairs with two low SND words, but this difference was not statistically significant. Despite that, the overall pattern of results suggests that pairs with two high SND words had the highest hits and lowest false alarm rates of all pairs. Consistent with the results from Experiments 1 and 2, this finding suggests that high SND facilitates memory for words.

Although not statistically significant, pairs with one high SND and one low SND word had lower hits and higher false alarm rates than pairs with two low SND words. This pattern was not consistent with the prediction that high SND words would lead to overall higher discriminability than low SND words. Based on the finding from Experiment 1 that high SND words were discriminated better than low SND words, one could expect that pairs with one high and one low SND word would have discriminability rates somewhere between pairs with two high SND words and pairs with two low SND words. However, pairs with one high and one low SND word had the lowest discriminability rates of all pairs. One possible explanation for this finding could be drawn from research on the process of unitization and associative memory. Unitization refers to the process by which multiple items can be encoded as a single unit or as a whole (Ahmad & Hockley, 2014; Bader et al., 2010; Bastin et al., 2013; Quamme, Yonelinas, &

Norman, 2007). This idea is similar to gestalt psychology principles that explain how the perceptual system organizes multiple visual stimuli into a coherent whole (Graf & Schacter, 1989). It has been argued that word pairs can be encoded as a single unit (unitized word pairs) or as two individual words associated with each other (non-unitized word pairs; Ahmad & Hockley, 2014; Bader et al., 2010; Tibon, Vakil, Goldstein, & Levy, 2012).

Different manipulations have been used to promote unitization of word pairs. For instance, studies have used words pairs made up with either constituents of compound words or words that form common idioms (Ahmad & Hockley, 2014; Schacter & McGlynn, 1989). In another study, participants saw word pairs made up with two unrelated words presented above fictional definitions for the word pairs (Bader et al., 2010). As a result of these manipulations, word pairs can be unitized (encoded as a single unit). Ahmad and Hockley examined both single-item and associative recognition of word pairs that were formed with either constituents of compound words (unitized pairs) or unrelated words (non-unitized pairs; 2014). They found greater single-item recognition accuracy for non-unitized pairs than for unitized pairs, but greater associative recognition accuracy for unitized pairs than for non-unitized pairs (Ahmad & Hockley, 2014). These findings support the idea that the words from unitized pairs are encoded as a single unit but words from non-unitized pairs are encoded as two units (Ahmad & Hockley, 2014). Several studies suggest that unitized pairs are discriminated better than non-unitized pairs in associative recognition memory tasks (Ahmad & Hockley, 2014; Greve et al., 2007; Winograd, Karchmer, & Russell, 1971). Unitization also decreases deficits in associative memory that are commonly seen in older adults and amnestic patients (Ahmad et al., 2015; Bastin et al., 2013; Giovanello, Keane, & Verfaellie, 2006; Quamme et al., 2007).

Returning to the results of Experiment 3, it could be argued that pairs with two high SND words and pairs with two low SND words were unitized better than pairs with one high and one low SND word. Pairs with one high and one low SND word had the highest false alarm rates of all pairs. False alarms were based on incorrect *yes* responses to rearranged pairs, which were made up with the first word of a studied pair and the second word of another pair. If pairs with one high and one low SND word were poorly unitized and encoded as two individual words, the words of rearranged pairs would have seemed equally familiar to participants, and this would increase false alarms. On the other hand, if pairs with two high or two low SND words were unitized and encoded as single unit, then the corresponding rearranged pairs would not have seemed highly familiar and this would decrease false alarms. This could explain why pairs with one high and one low SND word had the lowest discriminability rates of all pairs.

CHAPTER 6

Experiment 4: Word Pairs Implicit Memory Task

Participants

Thirty-Two University of Windsor undergraduate students participated in Experiment 4 (24 females, 5 males, and 3 who identified their gender as other; mean age = 20.65 years).

Procedure

The objective of Experiment 4 was to determine whether SND influences implicit memory for word associations. The study phase of Experiment 4 was the same as in Experiment 3 – participants were presented with a study list consisting of 48 word pairs (12 per SND condition: high SND/high SND, low SND/low SND, high SND/low SND, low SND/high SND). After the distraction phase, they completed the implicit memory task, which was a lexical decision task with 192 trials in total. For the purposes of this experiment, each trial of the lexical decision task was divided into two parts; in the first part participants saw one letter string and were required to indicate with a key press whether the letter string formed a real English word or a nonword. The second part was the same, with the exception that a different letter string was presented. The letter string in the first part was called the *prime* and the one in the second part the *target.* See Figure 7 for an example of a lexical decision trial in Experiment 4. From the perspective of the participants there was no tangible difference between primes and targets – all items were presented in exactly the same way.

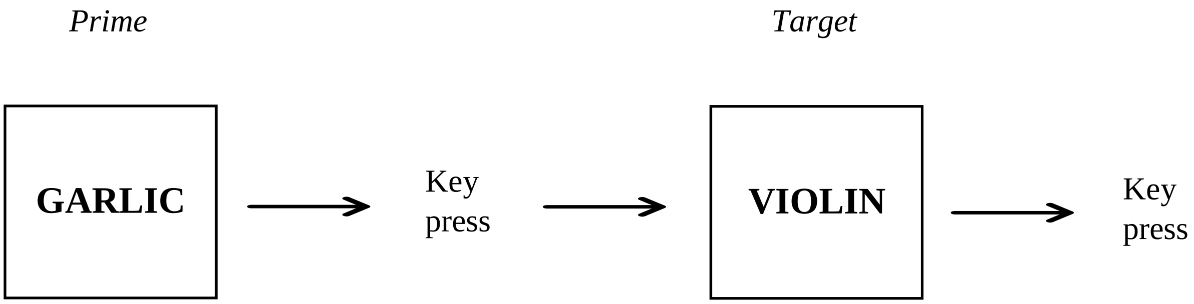


Figure 7. Example of a test trial from Experiment 4.

Test items were organized in prime-target pairs to test whether the prime facilitated processing of the target (priming effect). Prime-target pairs were either intact pairs, rearranged pairs, or control pairs. The prime and the target of intact pairs were words from the 24 word pairs presented in the study list. The prime was presented before the target, but the prime was the first word of a study list pair and the target was the second word of the same pair. For example, if a study list word pair was *garlic-violin*, an intact test pair would have *garlic* as the prime and *violin* as the target. The prime and the target of intact pairs were presented together as part of the same word pair in the study phase.

The prime and the target of rearranged word pairs were words from the other 24 word pairs presented in the study list, but they were presented in a rearranged order. In this case, the prime was the first word of a study list pair, but it was followed by a target that was the second word of a different pair. That means that the prime and target of rearranged pairs were not seen together in the study phase. For example, if two pairs from the study list were *garlic-violin* and *aspirin-muffin*, a rearranged test pair would have *garlic* as the prime followed by *muffin* as the target.

The remaining pairs were control pairs consisting of 48 new words not presented in the study list and 48 pronounceable nonwords. These items were organized in the following manner: 24 control nonwords followed by 24 control new words, and 24 control new words followed by 24 control nonwords. The *prime* and *target* words used in Experiment 4 are presented in Appendix C.

Statistical analysis

As previously mentioned, the aim of this task was to determine whether SND influences implicit memory for word associations. Like Experiment 2, the first question was whether there was evidence of priming. If participants have an implicit memory representation of the associations between the words of studied word pairs, the prime of intact pairs should facilitate processing of the target. That is, reaction times should be faster for targets than for primes of intact pairs. This processing advantage should not be observed in rearranged pairs because the two words of rearranged pairs were not presented together in the study phase. Thus, there is no reason to expect that the prime of rearranged pairs would facilitate processing of the target. Accordingly, a priming effect was predicted for intact pairs but not for rearranged pairs. In addition, if SND influences implicit memory for word associations, reaction times to target words from intact pairs should vary by SND condition. Consistent with the previous hypotheses, it was predicted that high SND words would facilitate implicit memory for associations and produce a larger priming effect than low SND words.

The type of word (prime, target) and the SND of the experimental word pairs (high SND/high SND, low SND/low SND, high SND/low SND, low SND/high SND) were manipulated as within-subjects variables. Mean lexical decision reaction times were calculated per participant for each condition. The effects of type of word and SND of word pairs on reaction times of intact and rearranged pairs were analyzed using a repeated-measures analysis of variance (ANOVA).

Results

The outlier analysis revealed outlier reaction times across conditions, which resulted in removal of 1.4% of the data. After removal of outliers, mean reaction times across participants for each condition were calculated. Mean reaction times per condition for intact pairs are presented in Table 6.

Table 6. Mean Reaction Times (ms) and Standard Error for Intact Pairs.

Intact	**High-High SND**	**High-Low SND**	**Low-High SND**	**Low-Low SND**
Prime	784 (46)	761 (37)	686 (28)	685 (31)
Target	672 (31)	695 (28)	678 (28)	657 (29)

Within intact pairs, there was a priming effect whereby targets were recognized faster ($M = 675$ ms) than primes [$M = 729$ ms; $F(1, 31) = 15.12$, $p < .001$, $\omega^2 = .31$]. There was also a main effect of SND [$F(3, 31) = 4.07$, $p < .01$, $\omega^2 = .21$]. Most importantly, there was an interaction between the type of word and SND [$F(3, 31) = 3.71$, $p = .01$, $\omega^2 = .19$] whereby the difference in reaction time between targets and primes was significant only for pairs with two high SND words (112 ms; $t = 2.36$, $p = .01$; see *Figure 8* below). The difference in reaction time between targets and primes was not significant in all the other pairs ($p > .05$).

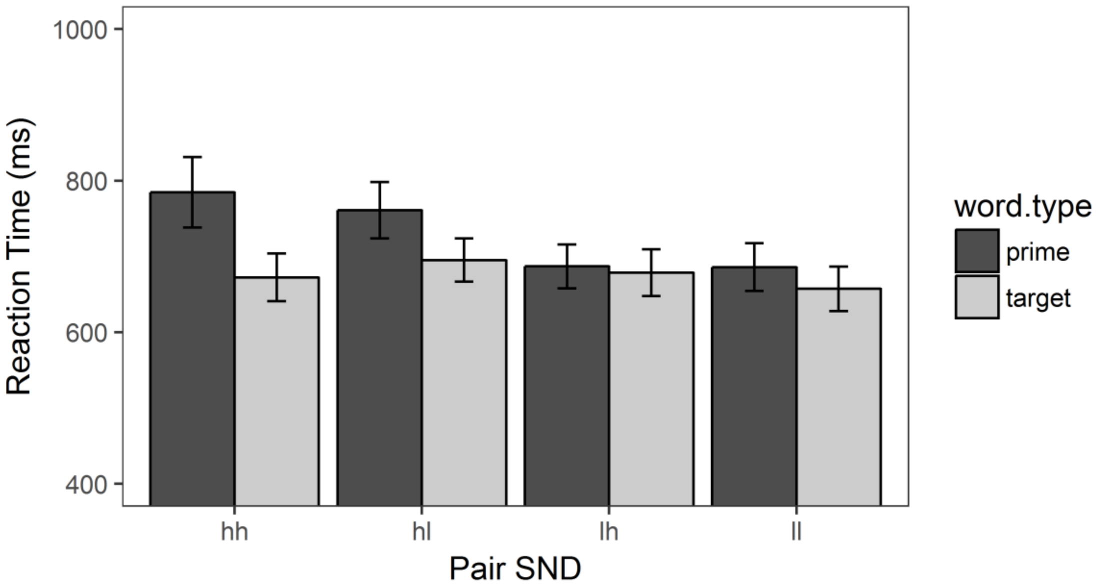


Figure 8. Mean reaction time per SND condition. Error bars represent standard error.

However, analyzing the difference in reaction times between primes and targets in pairs with one high and one low SND word does not actually give an indication of whether priming occurred. This is because there is already a difference in how fast participants process high and low SND words on lexical decision tasks in the absence of any priming effects. As previously mentioned, several studies have reported that words with sparse neighbourhoods (low SND) are processed faster than words with dense neighbourhoods (high SND) in language processing tasks (Buchanan et al., 2001; Danguecan & Buchanan, 2016; Mirman & Magnuson, 2008). Consistent with these findings, Experiment 2 also found that low SND words were recognized faster than high SND words.

In the current analysis, the reaction time difference between primes and targets from pairs with a high SND prime and a high SND target was 112 milliseconds. One could conclude that seeing the prime facilitated processing of the target. On the other hand, the reaction time difference between a low SND prime and a high SND target was just eight milliseconds, from which one would conclude that there was no priming effect. The limitation of this analysis is that low SND words are recognized faster than high SND words on average, which would reduce any reaction time difference between a low SND prime and a high SND target. In fact, high SND targets preceded by low SND primes (*M* = 678) have a similar reaction time to high SND targets preceded by a high SND prime (*M* = 672). The same rationale can be applied to the difference in reaction time between a high SND prime and a low SND target. The average reaction time difference for those pairs was 60 milliseconds, but this difference is not necessarily the result of priming effects as it could be the result of low SND words being recognized faster than high SND words on average.

This limitation was not anticipated while designing the experiment and planning the analysis. To address this limitation, the levels of SND (high SND/high SND, low SND/low SND, high SND/low SND, low SND/high SND) were collapsed, and then the effects of type of word (prime, target) and SND of the individual words (high, low) on reaction times for intact and rearranged pairs were analyzed. Mean reaction times per condition for intact and rearranged pairs of the follow-up analysis are presented in Table 7.

Table 7. Mean Reaction Times (ms) and Standard Error for Experiment 4.

	High SND		**Low SND**	
Intact Pairs	Prime	Target	Prime	Target
	772 (29)	675 (21)	686 (21)	676 (20)
Rearranged Pairs	**High SND**		**Low SND**	
	Prime	Target	Prime	Target
	762 (25)	727 (22)	711 (27)	700 (19)

Within intact pairs, there was a priming effect in which targets (*M* = 675 ms) were recognized faster than primes [*M* = 729 ms; *F*(1, 31) = 15.12, $p < .001$, $\omega^2 = .30$]. Low SND words (*M* = 681 ms) were recognized faster than high SND words (*M* = 724 ms; *F*(1, 31) = 16.19, $p < .001$, $\omega^2 = .32$). In addition, there was an interaction between the type of word and SND [*F*(1, 31) = 7.69, $p < .01$, $\omega^2 = .17$] whereby the difference in reaction time between primes and targets was significant for high SND words but not for low SND words (see *Figure 9* below).

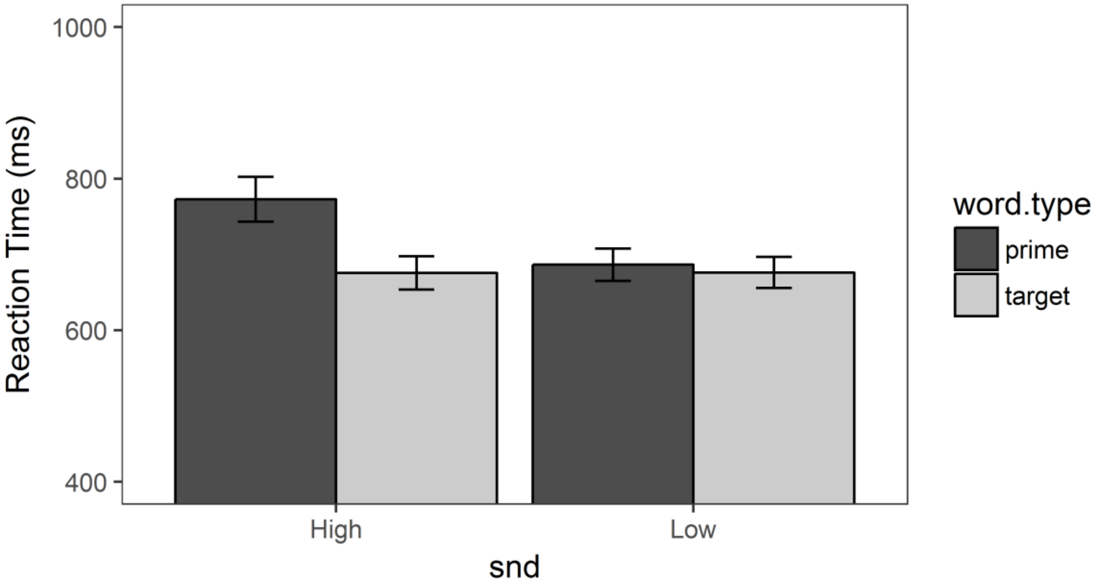


Figure 9. Mean reaction times for intact pairs. Error bars represent standard error.

In contrast, there was no difference in reaction time between primes (*M* = 737 ms) and targets [*M* = 714; *F*(1, 31) = 2.25, *p* = .14, ω^2= .03] of rearranged pairs. Low SND words (*M* = 706 ms) were recognized faster than high SND words (*M* = 745 ms; *F*(1, 31) = 9.66, *p* < .01, ω^2= .21). There was no interaction between type of word and SND [*F*(1, 31) = 0.72, *p* = .41, ω^2= .001; see *Figure 10* below].

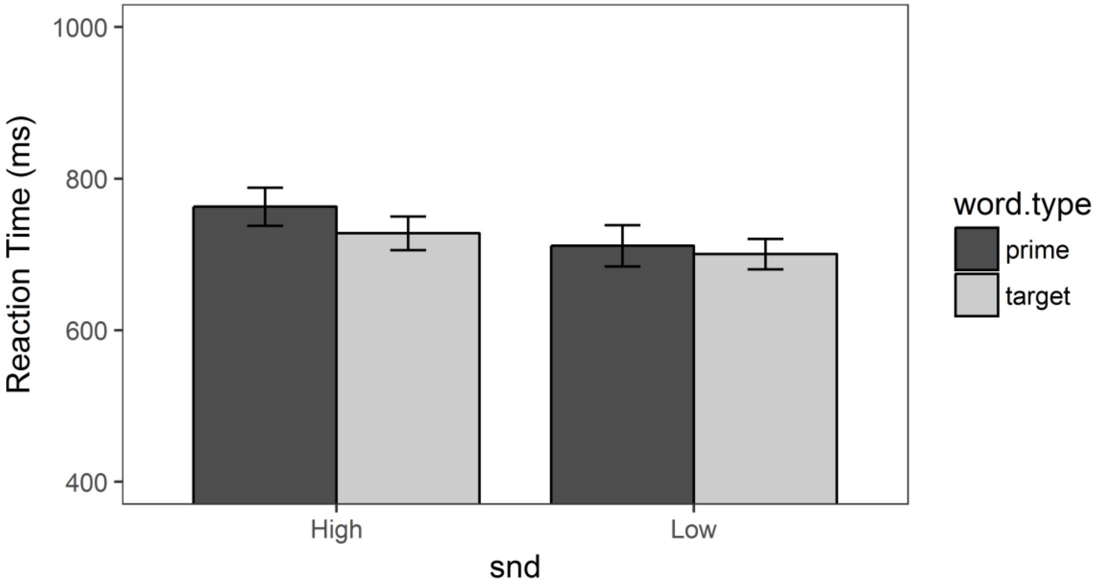


Figure 10. Mean reaction times for rearranged pairs. Error bars represent standard error.

Discussion

The objective of Experiment 4 was to determine whether SND influences implicit memory for word associations. One prediction was that if participants have an implicit memory representation of the association between the words of studied word pairs; then the first word of intact word pairs (prime) should prime the second word (target). If that is the case, lexical decision reaction times should be faster for targets than for primes of studied pairs (intact), but this pattern should not emerge for not studied pairs (rearranged). Consistent with this prediction, a priming effect (faster reaction time for targets than for primes) was found in intact pairs, but not in rearranged pairs. This finding indicates that participants had an implicit memory representation of the association between the studied words, whereby presentation of the first word facilitated processing of the second word of the pair. The fact that there was no priming effect in rearranged pairs strengthens the conclusion that the previously learned association of studied word pairs facilitated processing of the targets in the lexical decision task.

In addition, it was predicted that high SND words would facilitate implicit memory for word associations and produce a larger priming effect than low SND words. The initial analysis manipulating the SND of the word pairs (high SND/high SND, low SND/low SND, high SND/low SND, low SND/high SND) showed a reaction time difference for high SND targets preceded by high SND primes. However, a close examination of the means revealed that analyzing the difference between primes and targets for pairs with one high SND and one low SND word did not provide a conclusive answer about priming. That is because on average, low SND words are recognized faster than high SND words on lexical decision tasks in the absence of any other manipulation (Buchanan et al., 2001; Danguecan & Buchanan, 2016; Mirman &

Magnuson, 2008). To address this limitation, the levels of SND of word pairs were collapsed, and the effect of SND of the individual words (high, low) was analyzed.

This follow-up analysis showed that the priming effect was evident for high SDN words but not for low SND words. This reaction time advantage for high SND targets compared to primes was evident regardless of whether they were preceded by a high SND or a low SND prime. These results are consistent with the results of Experiment 2, which found a priming advantage for high SND words when compared to low SND words. This pattern suggests that high SND words benefit more than low SND words from a previous learning episode in implicit associative memory tasks. High SND words have an advantage over low SND words when it comes to being associated with unrelated words. Interestingly, these associations can be learned and retrieved after a single learning episode. We know that processing of a target word is faster when it is preceded by a semantically related prime than an unrelated prime (Balota, 1983; Burgess & Lund, 2000; McNamara, 1992; Ratcliff & McKoon, 1994), but in this study, it was found that newly learned associations involving high SND words can have priming effects similar to those seen due to pre-existing semantic associations.

As a summary, Table 8 presents the memory tasks, independent variables, dependent variables, and hypotheses for all experiments.

Table 8. *Summary of memory tasks, independent variables (IV), dependent variable (DV), and hypotheses for all experiments.*

Experiment	**Test Phase**	**IV**	**DV**	**Hypotheses**
1. Single Word Explicit Recognition Memory Task	Discriminate old/new words	SND *(high, low)*	*d'* (Hits/FA)	1. Higher *d'* for high SND words
2. Single Word Implicit Memory Task	Word/nonword lexical decision	Item *(old, new)* SND *(high, low)*	RT	2a. Faster RT for old words 2b. Larger priming effect for high SND words
3. Word Pairs Explicit Recognition Memory Task	Discriminate old/new word pairs	SND *(high/high, high/low, low/high, low/low)*	*d'* (Hits/FA)	3a. Higher *d'* for high/high SND word pairs 3b. Lowest *d'* for low/low SND word pairs
4. Word Pairs Implicit Memory Task	Word/nonword lexical decision	Word *(prime, target)* SND *(high, low)*	RT	4a. Faster RT for targets than primes of intact pairs 4b. Faster RT for high than low SND targets of intact pairs

Note. RT = reaction time.

CHAPTER 7

DISCUSSION

General Discussion

This dissertation was motivated by the literature that has examined semantic and episodic memory; two memory systems that play a vital role in the acquisition and retention of knowledge. Traditionally, theories of episodic and semantic memory conceptualized them as distinct systems (Tulving, 1972). Semantic memory stores facts and knowledge about the world, including our knowledge of language, whereas episodic memory stores temporally-dated information about personally experienced events (Conway, 2009; Greenberg & Verfaellie, 2010; Tulving, 1972; 1986; Tulving & Thomson, 1973; Schacter & Tulving, 1994). This distinction is supported by the disassociation between semantic and episodic memory caused by brain damage (Graham et al., 2000; Greenberg & Verfaellie, 2010). At the same time, there is a growing literature indicating that these two systems interact (Graham et al., 2000; Greenberg & Verfaellie, 2010; Lee et al., 2002; Schacter & Tulving, 1994; Takashima et al., 2014). That is, the information stored in semantic memory is known to influence how well we learn and remember episodic memories (Atienza et al., 2011; Bein et al., 2015; Graham et al., 2000; Greve et al., 2007; Lee et al., 2002; Prior & Bentin, 2008; Staresina et al., 2009; Takashima et al., 2014). This dissertation focused on the contemporary view of semantic and episodic memory as interdependent memory systems.

The current study aimed to further investigate the relationship between semantic and episodic memory by examining a research topic that has not received a lot of attention. That is – how does semantic information associated with specific words, as captured by a semantic richness measure, influence episodic memory? Only a few studies have examined the effects of semantic richness on episodic memory (Hargreaves et al., 2012; Nelson et al., 2013; Rabovsky et al., 2012). These studies have found that words associated with more semantic information are remembered better than words associated with less semantic information (Hargreaves et al., 2012; Nelson et al., 2013; Rabovsky et al., 2012). However, one measure of semantic richness that is known to influence language processing called semantic neighbourhood density has not been studied in the context of episodic memory. This study has argued that semantic neighbourhood density is a unique measure because it captures the degree of semantic relationship between a target word and its surrounding neighbours (Buchanan et al., 2001; Danguecan & Buchanan, 2016; Durda & Buchanan, 2008). However, whether this measure has an influence on episodic memory performance has not been examined to date. The aim of this dissertation was to address that gap in the literature.

Accordingly, the overall goal of this study was to examine the influence of semantic neighbourhood density on episodic memory. To do this, the first main objective was to test the effects of semantic neighbourhood density on memory for single words using both explicit and implicit memory tasks. Given that words with many as opposed to few semantic features or associates are remembered better (Hargreaves et al., 2012; Nelson et al., 2013), it was predicted that words with many near neighbours would lead to better episodic memory than words with few near neighbours. The results of Experiments 1 and 2 supported this prediction and revealed that high semantic neighbourhood density words were remembered better than low density words in both explicit and implicit memory tasks. By manipulating semantic neighbourhood density, Experiments 1 and 2 showed that the distribution of semantic neighbours also plays a role in memory for single words.

The facilitatory effect of semantic richness on episodic memory is thought to be the result of a greater level of activation in the semantic neighbourhood of target words (Hargreaves et al., 2012; Nelson et al., 1998; 2013). That is, semantically rich words are associated with more semantic information (e.g., semantic neighbours, features, associates) all of which get activated when the word is encountered. This increased level of semantic activation translates into better episodic memory for target words. Hargreaves and colleagues used the levels-of-processing framework to explain the effects of semantic richness on episodic memory (2012). As previously mentioned, the levels-of-processing framework postulates that deeper processing of the stimulus at the time of encoding facilitates memory retrieval (Craik & Lockhart, 1972; 1990; Craik & Tulving, 1975; Galli, 2014). One of the most common procedures to elicit deeper processing is to focus on the meaning of words, which leads to elaborate memory representations that can be easily retrieved from memory later (Craik & Lockhart, 1972; Craik & Tulving, 1975; Galli, 2014; Greve et al., 2007; Prior & Bentin, 2008; Schacter & Graf, 1986; Schott et al., 2013; Seamon, 1976). Hargreaves and colleagues argued that activation in the semantic neighbourhood of words can also produce deep processing (2012). This is a reasonable argument given that activation in the semantic neighbourhood represents activation of pre-existing semantic knowledge, which is known to facilitate memory performance (Atienza et al., 2011; Craik & Tulving, 1975; Moscovith & Craik, 1976; Prior & Bentin, 2008; Staresina et al., 2009). Words with high semantic richness can elicit deep processing because of their rich semantic representations, even in the absence of explicit semantic elaboration strategies (Hargreaves et al., 2012). As a result, the activation of semantically rich neighbourhoods facilitates episodic memory retrieval.

The effect of semantic neighbourhood density on memory for single words could be supported by a similar mechanism. According to models of semantic memory organization, semantic neighbourhoods are organized according to semantic similarity, so that meaning-related words are close to each other in semantic space (Buchanan et al., 2001; Burgess, 2008; Durda & Buchanan, 2008; Landauer & Dumain, 1997; Loftus & Collins, 1975; Lund & Burgess, 1998; Nelson et al., 1998). More specifically, co-occurrence models of semantic memory propose that the distance between a word and its neighbours represents the degree of semantic relatedness (Burgess, 2008; Durda & Buchanan, 2008; Lund & Burgess, 1998). That means that words that are highly related in meaning will be near each other, while words that are less related will be farther apart. Accordingly, when the semantic neighbourhood area that is nearest to a target word is activated, the information that is activated will be information that is highly related in meaning to the target word. It is possible that the activation of near semantic neighbours elicits deeper processing than distant neighbours because near neighbours are highly related in meaning to the target word. As a result, activation in the near semantic neighbourhood area could facilitate retrieval better than activation of the distant neighbourhood area.

Experiments 1 and 2 found that high semantic neighbourhood density words were remembered better than low semantic neighbourhood density words in both explicit and implicit memory tasks. As previously mentioned, high semantic neighbourhood density words have on average more near than distant neighbours, while low semantic neighbourhood density words have on average more distant than near neighbours (Buchanan et al., 2001; Danguecan & Buchanan, 2016). Consequently, when high density words are encountered, they produce a greater level of activation in their near neighbourhood area when compared to low density words. This process could elicit deeper processing at encoding and better memory retrieval for high semantic neighbourhood density words.

To gain a better understanding of how semantic neighbourhood density influences episodic memory, this dissertation also examined whether the effects of semantic neighbourhood density on memory for single words extend to memory for word associations. Associative memory is important because our entire knowledge network is based on associations between individual units of information. Experiment 3 was designed to test the effects of semantic neighbourhood density on explicit memory for word associations and Experiment 4 was designed to test the effects of semantic neighbourhood density on implicit memory for word associations. Word pairs with two high semantic neighbourhood density words had the highest hits and lowest false alarm rates of all pairs in an explicit memory task. The associative memory advantage of high density words could be supported by the same mechanism used to explain the effects of semantic neighbourhood density on memory for single words. When two high density words are encountered in the study phase, both of their near semantic neighbourhoods receive high levels of activation because of their many near neighbours. The activation of many near semantic neighbours translates into deep processing and better retrieval of associations between high density words.

An unexpected finding of Experiment 3 was that pairs with two low semantic neighbourhood density words did not have the lowest discriminability rate of all pairs; instead pairs with one high and one low density word were the most difficult pairs to remember. Based on the results of Experiment 1, it was predicted that pairs with one high and one low density word would have discriminability rates somewhere between pairs with two high density words and pairs with two low density words. However, this prediction was not supported. It is possible that in addition to the activation in the semantic neighbourhood of words, there was another process influencing associative memory. In the discussion section of Experiment 3, it was proposed that pairs with one high and one low density word may have been more difficult to unitize than other pairs. Poor unitization means that these pairs were likely encoded as two individual items, which could have resulted in the observed high false alarm rates. Future research could examine whether semantic neighbourhood density influences unitization and whether these two factors have an impact on associative memory performance.

In addition, Experiment 4 showed that newly learned word associations resulted in a priming effect whereby the first word of a pair facilitated processing of the second word in a lexical decision task. Consistent with the previous findings, there was a larger priming effect for high semantic neighbourhood density words than for low density words. This pattern suggests that high density words benefit more than low density words from a previous learning episode in implicit associative memory tasks. An interesting observation about this finding is that newly learned word associations can act in a similar way to pre-existing associations. It has been established that processing of a target word on a lexical decision task is faster when it is preceded by a semantically related prime than an unrelated prime (Balota, 1983; Burgess & Lund, 2000; McNamara, 1992; Ratcliff & McKoon, 1994). Spreading-of-activation models explain this effect by stipulating that the representation of a prime is activated when it is first encountered, and this activation spreads along semantically related words in semantic memory, one of which will be the target word (Anderson, 1983; McNamara, 1992; Ratcliff & McKoon, 1994). As such, a target word will be processed faster when it is preceded by a semantically related prime because its representation has been pre-activated. Interestingly, we found that the learned association between high density words after a single learning episode, lead to a priming effect similar to the priming effect seen between semantically related words. A potential future study could examine whether priming effects that result from novel word associations have the same strength as priming effects from pre-existing semantic associations.

Overall, the pattern of findings suggests that high semantic neighbourhood density facilitates memory performance on both explicit and implicit memory tasks. Words with many near neighbours and dense neighbourhoods are remembered better than words with few near neighbours and sparse neighbourhoods. This facilitatory effect was observed for memory for words and for word associations. It is possible that high semantic neighbourhood density facilitates memory because these words produce a high level of activation in their near semantic neighbourhood when they are encountered. The activation in the near semantic neighbourhood represents activation of pre-existing semantic information related to the target word. Based on the levels-of-processing framework, one can argue that this activation translates into deeper and more elaborate processing of target words at encoding, which facilitates memory retrieval.

This account is consistent with the Processing Implicit and Explicit Representations model which attempts to account for the role of pre-existing semantic information in episodic memory (Nelson et al., 1998). This model proposes that encoding target words in an episodic memory task produces an implicit and an explicit memory representation. The implicit representation consists of the target word and its automatically activated semantic associates, while the explicit representation consists of the target word and the context of study. According to this model, episodic memory accuracy could be improved by strengthening either the implicit or the explicit representation. The explicit representation can be influenced by using intentional processing strategies during encoding, such as semantic elaboration. The implicit representation is influenced by the size and strength of the associations in the semantic neighbourhood of the target word. Stronger connections between the target and its semantic associates strengthen the implicit representation like semantic elaboration strengthens the explicit representation, and both can improve episodic memory performance (Nelson et al., 1998). This study found that words with many as opposed to few near semantic neighbours facilitated episodic memory in the absence of explicit encoding strategies. It can be argued that near semantic neighbours have strong connections to the target word because they are highly related in meaning to it. It is possible that the activation of near semantic neighbours improves episodic memory because this process strengthens the implicit representation of the encoding episode.

This dissertation contributes to the literature that has investigated how semantic knowledge influences learning and memory of new information (Atienza et al., 2011; Bein et al., 2015; Graham et al., 2000; Greve et al., 2007; Prior & Bentin, 2008; Staresina et al., 2009; Takashima et al., 2014) by examining a topic that had not been addressed before in episodic memory research. More specifically, this study showed that a co-occurrence-derived semantic neighbourhood density measure (WINDSORS; Durda & Buchanan, 2008) influences episodic memory. Finding that high semantic neighbourhood density facilitates episodic memory supports previous studies reporting that semantically rich words facilitate memory (Hargreaves et al., 2012; Nelson et al., 2013; Rabovsky et al., 2012). Overall, the current findings are consistent with the account that semantic memory influences episodic memory (Atienza et al., 2011; Graham et al., 2000; Greenberg & Verfaillie, 2010; Lee et al., 2002; Prior & Bentin, 2008; Schacter & Tulving, 1994; Takashima et al., 2014).

The current study also contributes to our theoretical understanding of how words are stored in semantic memory. Models of semantic memory agree that the system is organized according to semantic similarity; however, there is some debate over what is the best definition of semantic similarity (Buchanan et al., 2001; Danguecan & Buchanan, 2016; Pexman et al., 2008). For instance, some models define semantic similarity according to the similarity of concepts' physical features, but others define similarity based on how words are used in language (Buchanan et al., 2001; Danguecan & Buchanan, 2016; Pexman et al., 2008). Computational global co-occurrence models, like the one used in this study (WINDSORS; Durda & Buchanan, 2008), propose that words that frequently co-occur together in linguistically similar contexts are related in meaning and considered semantic neighbours. This study shows evidence that a semantic neighbourhood density measure derived from a global co-occurrence model (WINDSORS; Durda & Buchanan, 2008) captures unique variability related to episodic memory performance. Previous research has found that semantic neighbourhood density plays a role in how information is processed and retrieved from semantic memory (Buchanan et al., 2001; Danguecan & Buchanan, 2016; Mirman & Magnuson, 2008). The current study supplements those findings by showing that semantic neighbourhood density not only influences language processing, but also plays a role in episodic memory performance. As such, the influence of co-occurrence derived measures of semantics on episodic memory are a topic worth examining. Future research could extend the current findings by investigating how semantic density influences episodic memory in the context of other variables known to be relevant for memory performance.

Understanding the influence of semantic factors on episodic memory performance has important real-world implications. For instance, the current findings can be applicable to those learning or teaching English as a second-language. The process of learning a new vocabulary in a second-language is influenced by a number of psycholinguistic factors, such as the phonological, orthographic, and semantic features of words (Ellis & Beaton, 1993). For instance, word frequency, concreteness, imagability, word class, and word length can all influence how easily we learn words in a second language (Ellis & Beaton, 1993). In addition, strategies that increase depth of processing, such as semantic elaboration, can facilitate second-language vocabulary learning (Bancroft, 2004; Joe, 2010). Interestingly, it has been argued that the facilitatory effect of semantic richness on memory is supported by a similar mechanism as the effect of semantic elaboration (Hargreaves et al., 2012); thus, semantic richness may facilitate second-language vocabulary acquisition as well. As such, given that this study found that high semantic density words are remembered better among a group of English native speakers, it is possible that high semantic density also facilitates word retrieval among learners of English as a second-language. Teachers could use this knowledge about word characteristics and memory to plan the content of their courses. For instance, teachers could initially focus on high semantic density words to help students build a bigger vocabulary faster.

Another recommended technique that helps with second-language vocabulary acquisition is to form an association between the new word in the second language and the word with the same meaning in the native language (Coady & Huckin, 1997). This recommendation is supported by the semantic-transfer hypothesis, which proposes that the use of words in a second language is mediated by activation of their translation in the native language in the early stages of second-language acquisition (Jiang, 2004). As such, learners associate the new words in the second language with their translation in the native language (Jiang, 2004). Since high semantic density words were found to have an advantage over low density words in associative memory tasks, it is possible that high density words are better associated with their translations, which could facilitate word retrieval among second-language learners.

In addition, knowing that high semantic richness facilitates memory can also be beneficial to those with impaired episodic memory. Cognitive rehabilitation guidelines indicate that the most effective intervention for memory deficits is the use of compensatory strategies (Cicerone et al., 2011; Velikonja et al., 2014). To compensate for memory deficits, it is recommended that individuals use reminders such as written words in post-it notes, calendars, and/or agendas. The current findings can guide our choices about which are the best words to use in reminders. This study found that high semantic neighbourhood density words are remembered better; thus, it is possible that these words are also more effective reminders for those with impaired memory. When preparing written reminders, individuals with memory impairment or their caregivers could choose high semantic density words over low density words because these words are more likely to be remembered correctly. These compensatory memory strategies do not only target memory functioning, but they also improve self-efficacy, self-reported daily functioning, and overall well-being (Belleville et al., 2006; Sitzer, Twamley, & Jeste, 2006).

Future directions

To further expand our understanding about the effects of the distribution of semantic neighbours on episodic memory, one could examine interference effects of near versus distant neighbours on retrieval of target words. In addition, it would be interesting to test whether the distance between a target word and its semantic neighbours influences how well word associations are remembered. Given that semantic relatedness facilitates associative memory, one could argue that the distance between a target word and a semantic neighbour would influence associative memory accuracy.

The current study presents evidence that words with many as opposed to few near semantic neighbours are remembered better by neurologically-intact and relatively young individuals. Another potentially fruitful area of future research would be to examine whether the effects of semantic neighbourhood density on episodic memory are the same in other populations, such as individuals with memory impairment. In addition, given that older adults show a relative deficit in associative memory when compared to single-item memory (Old & Nave-Benjamin, 2008; Troyer et al., 2008), another potential study could examine whether high semantic neighbourhood density can ameliorate age-related deficits in associative memory.

Given that the influence of semantic factors on episodic memory performance can be applicable to those learning English as a second-language, future studies could focus on formally examining whether word-specific semantic richness influences second language acquisition. For instance, it would be interesting to investigate whether semantic neighbourhood density influences word retrieval among individuals learning English as a second language.

In conclusion, this dissertation described the effects of semantic neighbourhood density on explicit and implicit memory for single words and for word associations. It was found that high semantic neighbourhood density facilitates episodic memory. Words with many near neighbours have a memory advantage over words with few near neighbours. These findings support the account that semantic memory influences episodic memory; and more specifically, that semantic richness facilitates episodic memory performance (Graham et al., 2000; Greenberg & Verfaellie, 2010; Hargreaves et al., 2012; Lee et al., 2002; Nelson et al., 1998; 2013; Takashima et al., 2014).

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APPENDICES

Appendix A

Characteristics of Experimental Stimulus Words: Length, Frequency (Freq), Orthographic Neighbourhood Size (ON), and Semantic Neighbourhood Density (SND).

		High SND Words		
Word	***Length***	***Freq***	***ON***	***SND***
ALMOND	6	0.666	0	0.428
ASPIRIN	7	2.112	0	0.434
BAGEL	5	0.316	0	0.426
BEVERAGE	8	3.822	1	0.408
BLOUSE	6	6.632	0	0.495
ATTIRE	6	5.586	0	0.434
FOSSILS	7	6.306	0	0.409
GARLIC	6	4.871	2	0.424
HYENA	5	0.185	0	0.426
JELLYFISH	9	0.328	0	0.408
SQUIRREL	8	5.713	0	0.400
LEGUMES	7	0.264	0	0.422
MINIVAN	7	0.628	0	0.446
MUFFIN	6	0.711	1	0.428
PISTOL	6	5.088	2	0.421
OREGANO	7	0.317	0	0.434
RIFLE	5	8.387	0	0.419
DESSERT	7	3.420	0	0.417
SPINACH	7	0.676	0	0.439
TENDON	6	0.509	0	0.405
TOMATO	6	2.384	0	0.403
VIOLIN	5	1.788	0	0.403
VODKA	5	1.686	0	0.422
WRESTLER	8	1.062	2	0.431

Appendix A (continued)

Characteristics of Experimental Stimulus Words: Length, Frequency (Freq), Orthographic Neighbourhood Size (ON), and Semantic Neighbourhood Density (SND).

		High SND Words		
Word	***Length***	***Freq***	***ON***	***SND***
OMELET	6	0.500	0	0.465
BISCUIT	7	5.385	0	0.452
RAISIN	6	0.855	0	0.428
CUCUMBER	8	0.683	0	0.438
CLARINET	8	1.594	0	0.450
STALLION	8	3.07	1	0.441
FEMUR	5	0.266	2	0.407
EGGPLANT	8	0.138	0	0.456
NOTEPAD	7	3.279	0	0.454
OATMEAL	7	1.359	0	0.450
PONYTAIL	8	0.215	0	0.408
SALAD	5	7.894	0	0.436
SAUSAGE	7	1.669	0	0.46
PRETZEL	7	0.082	0	0.430
PECAN	5	0.220	0	0.430
AVOCADO	7	0.519	0	0.419
LEMONADE	8	2.352	0	0.413
LASAGNA	7	0.089	0	0.465
TELESCOPE	9	3.831	0	0.400
WAFFLE	6	0.478	2	0.435
SALAMI	6	0.496	0	0.473
WAIST	5	4.455	2	0.405
WARSHIP	7	0.639	1	0.406
CIDER	5	3.99	2	.443

Appendix A (continued)

Characteristics of Experimental Stimulus Words: Length, Frequency (Freq), Orthographic Neighbourhood Size (ON), and Semantic Neighbourhood Density (SND).

		Low SND Words		
Word	***Length***	***Freq***	***ON***	***SND***
ANACONDA	8	0.325	0	0.249
ARMCHAIR	8	6.837	0	0.255
BACKYARD	8	1.101	1	0.245
CORDON	6	1.826	0	0.243
CRIB	4	0.904	1	0.264
DIARY	5	4.202	1	0.258
CURTAIN	7	4.644	2	0.253
GRAFFITI	8	1.008	0	0.258
DRESSER	7	0.93	2	0.265
FOUNTAIN	8	2.134	1	0.261
CEMETERY	8	8.324	0	0.291
KEYHOLE	7	1.882	0	0.235
NICHE	5	3.367	0	0.253
PALACE	6	7.986	1	0.263
QUILL	5	1.504	2	0.238
PEBBLE	6	0.678	1	0.262
PIRATE	6	3.376	0	0.248
PUPIL	5	2.345	1	0.257
RAINBOW	7	6.241	0	0.260
SCRATCH	7	9.227	0	0.242
STAPLE	6	1.66	1	0.260
THUNDER	7	5.326	0	0.261
TRUNK	5	3.574	2	0.261
UMBRELLA	8	2.465	0	0.255

Appendix A (continued)

Characteristics of Experimental Stimulus Words: Length, Frequency (Freq), Orthographic Neighbourhood Size (ON), and Semantic Neighbourhood Density (SND).

		Low SND Words		
Word	***Length***	***Freq***	***ON***	***SND***
SOAPBOX	7	0.250	0	0.256
BROACH	6	0.221	2	0.277
CIGAR	5	2.691	0	0.269
COMPASS	7	4.239	0	0.27
CUSHION	7	1.615	0	0.277
DONOR	5	2.987	1	0.283
ELEVATOR	8	4.826	0	0.277
FIREFLY	7	2.307	0	0.27
LISTENER	8	1.378	1	0.257
GARAGE	6	8.617	0	0.265
ICEBERG	7	3.172	0	0.266
JEWEL	5	1.56	1	0.267
ARCHER	6	7.827	2	0.255
METEOR	6	1.599	0	0.277
CITADEL	7	3.245	0	0.277
PACIFIER	8	0.201	2	0.279
PARCEL	6	2.732	0	0.269
PEACOCK	7	1.122	0	0.277
DIAMOND	7	8.634	0	0.256
TORCH	5	2.816	2	0.27
TOTEM	5	0.566	2	0.266
TRIANGLE	8	5.045	0	0.278
VEIL	4	3.409	2	0.267
VIPER	5	0.899	2	0.269

Appendix B

Characteristics of Control Words: Length, Frequency (Freq), Orthographic Neighbourhood Size (ON), and Semantic Neighbourhood Density (SND).

		High SND Words		
Word	***Length***	***Freq***	***ON***	***SND***
BOOKLET	7	4.32	0	0.37
ABDOMEN	7	4.23	0	0.37
AMMONIA	7	3.65	0	0.43
AMULET	6	3.85	0	0.44
ARMOUR	6	10.85	2	0.44
BAZOOKA	7	0.06	0	0.38
BUNGALOW	8	4.49	0	0.36
CAFFEINE	8	0.70	0	0.39
CAROTID	7	0.31	0	0.39
CEMETERY	8	1.75	0	0.38
CRUMBS	6	4.00	0	0.44
EARDRUM	7	0.10	0	0.38
FLAMINGO	8	0.47	0	0.38
GORILLA	7	2.36	0	0.38
HORMONE	7	1.93	0	0.38
JAGUAR	6	2.48	0	0.46
JUPITER	7	6.40	0	0.42
MOSQUITO	8	3.46	0	0.39
NECKLACE	8	5.40	0	0.38
PARTICLE	8	6.25	0	0.40
PHARMACY	8	1.04	0	0.38
STABLES	6	7.80	2	0.37
TADPOLE	7	0.84	0	0.38
YATCH	5	2.83	0	0.42

Appendix B (continued)

Characteristics of Control Words: Length, Frequency (Freq), Orthographic Neighbourhood Size (ON), and Semantic Neighbourhood Density (SND).

		Low SND Words		
Word	***Length***	***Freq***	***ON***	***SND***
AQUARIUM	8	3.85	1	0.31
BAYONET	7	2.41	1	0.31
CAMEL	5	5.56	1	0.30
CANISTER	8	0.75	1	0.34
CERAMIC	7	1.65	0	0.31
CUTLERY	7	1.50	1	0.34
CYCLIST	7	1.18	0	0.32
DRESSER	7	3.51	2	0.26
DOMINOES	8	0.92	1	0.31
FREEZER	7	2.00	1	0.31
HAREM	5	2.46	2	0.27
KANGAROO	8	4.29	0	0.32
LIPSTICK	8	1.85	2	0.32
MOSAIK	6	2.70	0	0.28
NARRATOR	8	2.71	0	0.26
NOSTRIL	7	1.12	0	0.30
OBELISK	7	0.78	0	0.32
PRAIRIE	7	8.33	0	0.30
SPIDER	6	7.05	0	0.30
SUBTITLE	8	0.26	0	0.33
TROPHY	6	6.16	0	0.27
VOLCANO	7	5.2	0	0.34
VOMIT	5	1.47	0	0.33
ZOMBIE	6	0.59	0	0.32

Appendix C

Experiment 4 Trials and Corresponding Test Items.

Trial #			**Test Trials**	
	Prime-Target Pair Type	***SND***	***Prime***	***Target***
			(1st word)	***(2nd word)***
1	Intact	High/High	GARLIC	VIOLIN
2			BLOUSE	LEGUMES
3			JELLYFISH	BEVERAGE
4			SALAMI	RIFLE
5			HYENA	BAGEL
6			SPINACH	MINIVAN
7	Intact	High/Low	PISTOL	VEIL
8			TOMATO	PUPIL
9			BISCUIT	ANACONDA
10			SQUIRREL	ARMCHAIR
11			WRESTLER	FIREFLY
12			DESSERT	UMBRELLA
13	Intact	Low/Low	TRUNK	LISTENER
14			TRIANGLE	METEOR
15			CRIB	THUNDER
16			STAPLE	ICEBERG
17			TOTEM	SCRATCH
18			DIARY	PIRATE
19	Intact	Low/ High	FOUNTAIN	SALAD
20			SOAPBOX	PONYTAIL
21			COMPASS	LEMONADE
22			ELEVATOR	AVOCADO
23			PACIFIER	WARSHIP
24			VIPER	TELESCOPE

Appendix C (continued)

Experiment 4 Trials and Corresponding Test Items.

Trial #			**Test Trials**	
	Prime-Target Pair Type	***SND***	***Prime***	***Target***
			(1st word)	***(2nd word)***
25	Rearranged	High/High	OREGANO	MUFFIN
26			ALMOND	TENDON
27			WAIST	FOSSILS
28			STALLION	EGGPLANT
29			ASPIRIN	LASAGNA
30			ATTIRE	VODKA
31	Rearranged	High/Low	NOTEPAD	CIGAR
32			WAFFLE	GRAFFITI
33			SAUSAGE	NICHE
34			OATMEAL	PEBBLE
35			PECAN	JEWEL
36			PRETZEL	QUILL
37	Rearranged	Low/ High	BROACH	CIDER
38			TORCH	FEMUR
39			DRESSER	CUCUMBER
40			BACKYARD	OMELET
41			KEYHOLE	CLARINET
42			DONOR	RAISIN
43	Rearranged	Low/Low	RAINBOW	CURTAIN
44			GARAGE	CORDON
45			CUSHION	PEACOCK
46			PARCEL	ARCHER
47			CITADEL	DIAMOND
48			CEMETERY	PALACE

Appendix C (continued)

Experiment 4 Trials and Corresponding Test Items.

Trial #			**Test Trials**	
	Prime-Target Pair Type	***Real Word SND***	***Prime***	***Target***
			(1st word)	***(2nd nonword)***
49	Control	High	BOOKLET	RASSALS
50			ABDOMEN	MILLEN
51			AMMONIA	LAVELL
52			AMULET	REMIPE
53			ARMOUR	REGIVA
54			BAZOOKA	PAGRIL
55			BUNGALOW	RADLAL
56			CEMETERY	PIRATS
57			CRUMBS	UNADRE
58			EARDRUM	TASELS
59			FLAMINGO	PIVALS
60			GORILLA	ARSHES
			(1st nonword)	***(2nd word)***
61	Control	High	LISALS	JAGUAR
62			REDISE	JUPITER
63			FLOONS	CAFFEINE
64			UNEINS	CAROTID
65			EATLIT	PHARMACY
66			NUBUUM	HORMONE
67			RAVANT	MOSQUITO
68			PANDOT	NECKLACE
69			GROOSE	PARTICLE
70			SCRAME	STABLES
71			THOINS	TADPOLE
72			MUCCER	YATCH

Appendix C (continued)

Experiment 4 Trials and Corresponding Test Items.

Trial #			**Test Trials**	
	Prime-Target Pair Type	***Real Word SND***	***Prime***	***Target***
			(1st word)	***(2nd word)***
73	Control	Low	AQUARIUM	WOSCER
74			BAYONET	SOTTON
75			CAMEL	PADNET
76			CANISTER	MANONE
77			CUTLERY	RUTPLE
78			DRESSER	REBETS
79			FREEZER	SINTABLE
80			HAREM	LAWFEL
81			KANGAROO	LADEIN
82			LIPSTICK	OZANT
83			MOSAIK	RAJAR
84			NARRATOR	DRUNKARK
			(1st nonword)	***(2nd word)***
85	Control	Low	WAIRE	NOSTRIL
86			PLAJO	OBELISK
87			EMAND	PRAIRIE
88			QUACE	TROPHY
89			DISPERMED	SPIDER
90			PIRKA	SUBTITLE
91			TOBIZ	VOLCANO
92			BOOGE	CERAMIC
93			STROKID	DOMINOES
94			ZECLO	VOMIT
95			GAIRE	CYCLIST
96			BANZA	ZOMBIE

Appendix D

Experimental Word Pairs by Semantic Neighbourhood Density.

Word Pair Type by SND

High/High SND		***High/Low SND***	
GARLIC	VIOLIN	PISTOL	VEIL
BLOUSE	LEGUMES	TOMATO	PUPIL
JELLYFISH	BEVERAGE	BISCUIT	ANACONDA
SALAMI	RIFLE	SQUIRREL	ARMCHAIR
HYENA	BAGEL	WRESTLER	FIREFLY
SPINACH	MINIVAN	DESSERT	UMBRELLA
OREGANO	TENDON	NOTEPAD	GRAFFITI
ALMOND	FOSSILS	WAFFLE	NICHE
WAIST	EGGPLANT	SAUSAGE	PEBBLE
STALLION	VODKA	OATMEAL	JEWEL
ASPIRIN	MUFFIN	PECAN	QUILL
ATTIRE	LASAGNA	PRETZEL	CIGAR
Low/Low SND		***Low/High SND***	
TRUNK	LISTENER	FOUNTAIN	SALAD
TRIANGLE	METEOR	SOAPBOX	PONYTAIL
CRIB	THUNDER	COMPASS	LEMONADE
STAPLE	ICEBERG	ELEVATOR	AVOCADO
TOTEM	SCRATCH	PACIFIER	WARSHIP
DIARY	PIRATE	VIPER	TELESCOPE
RAINBOW	CORDON	BROACH	FEMUR
GARAGE	PEACOCK	TORCH	CUCUMBER
CUSHION	ARCHER	DRESSER	OMELET
PARCEL	DIAMOND	BACKYARD	CLARINET
CITADEL	PALACE	KEYHOLE	RAISIN
CEMETERY	CURTAIN	DONOR	CIDER

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