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Processing Concrete and Abstract Relationships in Word Pairs

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By

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Processing Concrete and Abstract Relationships in Word Pairs

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DECLARATION OF CO-AUTHORSHIP / PREVIOUS PUBLICATION

I. Co-Authorship

I hereby declare that this thesis incorporates material that is result of joint research, as follows: Chapters 1 and 4 of this dissertation were co-authored with Lori Buchanan. The key ideas, primary contributions, experimental designs, data analysis, interpretation, and writing were performed by the author, and the contribution of the co-author was primarily through the provision of supervision and providing feedback on refinement of ideas and editing of the manuscript.

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This thesis includes 1 original paper that have been previously published/submitted for publication in peer reviewed journals, as follows:

Thesis Chapter	Publication title/full citation	Publication status*

Chapters 1 and 4	Malhi, S. K., & Buchanan, L. (2018). A test of the symbol interdependency hypothesis with both concrete and abstract stimuli. *PLoS ONE*, *13*(3), e0192719. doi: 10.1371/journal.pone.0192719	Published

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ABSTRACT

Malhi (2015) found a reverse concreteness, or abstractness, effect for word pairs in an iconicity judgment task. Per Vigliocco et al.'s (2009) *theory of embodied abstract semantics*, Malhi and Buchanan (2017) hypothesized that participants were taking a visualization approach (time-costly) towards the concrete word pairs and an emotional valence approach (time-efficient) towards the abstract word pairs. It was also hypothesized that the abstractness effect emerged not by considering single words in isolation but rather by considering the relationship between them. The goal of the present study was to test these hypotheses and to further investigate this reverse concreteness, or abstractness, effect. Results generally provided support for these hypotheses. An event-related potential (ERP) experiment revealed a dissociation between behavioural abstractness and neural concreteness. The results are interpreted using a proposed *theory of flexible abstractness and concreteness effects* (FACE).

DEDICATION

To my mother, Jaspal Kaur Malhi, the Dr. Malhi who inspired me to become a Dr. Malhi.

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LIST OF ABBREVIATIONS/SYMBOLS

ACE - Action-Sentence Compatibility Effect 7
ANOVA - Analysis of Variance 30
BEAGLE - Bound Encoding of the Aggregate Language Environment 3
BOI - Body-Object Interaction 7
ERP - Event-Related Potentials 11
FACE - Flexible Abstractness and Concreteness Effects 52, 76
fMRI - Functional Magnetic Resonance Imaging 8
HAL - Hyperspace Analogue to Language 3
HiDEx - High Dimensional Explorer 3
Hz - Hertz 32
kOhms - Kiloohms 32
LASS - Language and Situated Simulation Theory 13
LDA - Latent Dirichlet Allocation 3
LSA - Latent Semantic Analaysis 3
mm - millimeter 46
ms - millisecond 32
PET - Positron Emission Tomography 20
RT - Reaction Time 4
SD - Standard Deviation 31
WINDSORS - Windsor Improved Norms of Distance and Similarity of Representations of Semantics 4

CHAPTER I

INTRODUCTION

Understanding the differential processing of concrete and abstract words has been an ongoing pursuit of psycholinguistics researchers. One challenge in this pursuit is differentiating concrete versus abstract words and developing stimuli reflecting this differentiation. Unfortunately, neither agreed-upon criteria for the creation of concrete/abstract stimuli (Borghi & Binkofski, 2014), nor tasks to measure the processing of these items have been established. Another challenge is how to measure the processing of concrete and abstract stimuli (i.e., selecting tasks that tap into concreteness and abstractness). Over the years, various theories have been proposed to explain how we process and obtain meaning from words, in general. A review of these general psycholinguistic theories as well as more specific theories of concrete and abstract word processing follows. This will set the stage for the present study, which measures the processing of concrete and abstract relationships in word pairs.

Symbolic Representation Theory

Language comprehension has been explained through symbolic – also referred to as linguistic, distributional, computational, or amodal – theories (Markman & Dietrich, 2000). Note that symbolic approaches to cognition in general are not under discussion, but rather, a constrained definition of symbolic theory is being used to discuss a particular type of symbolic theory relevant to the semantic processing literature. Symbolic theories of language maintain that words map onto internal symbolic representations of word meaning (Buchanan, Westbury, & Burgess, 2001). There is an arbitrary relationship between symbols and what they represent in the real world, and the meaning of a linguistic symbol is understood by how it is related to other linguistic symbols (Meteyard, Cuadrado, Bahrami, & Vigliocco, 2012). Thus, words are understood via rule-governed manipulation of symbols (Weiskopf, 2010). Notably, perceptual inputs are transduced into symbols so that the process of understanding words does not necessitate perceptual experience, nor does it recruit the brain's sensorimotor system (Meteyard et al., 2012; Weiskopf, 2010). In other words, sophisticated capacities such as language comprehension are viewed as being different from lower level perceptual processes (Jirak, Menz, Buccino, Borghi, & Binkofski, 2010). It is important to note that proponents of the symbolic theory (Fodor, 1975; Mahon, 2015; Pylyshyn, 1984) do not necessarily agree on the characteristics described (i.e., whether or not symbols are used, whether word meanings are inferred from experience, and whether people rely on rules). There is considerable variation in how the symbolic theory is defined, and as such, a description is being provided that captures the essence of the symbolic theory as opposed to providing a unitary definition of the theory.

Collins and Quillian (1969) introduced a symbolic, hierarchical model of semantic knowledge in which concepts were represented as nodes, with general concepts (e.g., *animal*) located at the top of the hierarchy, and more specific concepts (e.g., *robin*) located at the bottom. Collins and Loftus (1975) revised the earlier hierarchical model by introducing a spreading activation model wherein concept activation proceeds or spreads from the target concept to related concepts. Both the hierarchical and the spreading activation model assume localist representation such that each concept corresponds to a single node. On the other hand, in distributed representation models (Hinton, McClelland, & Rumelhart, 1986), concepts are represented as unique patterns of activation among common nodes. Distributed representation models also symbolize concepts through the activation of representations of the individual features of the concept (e.g., connectionist feature-based approaches to semantic memory; McRae, 2004).

While some symbolic views of language are feature-based, other symbolic views of language are use-based ones that rely on statistical regularities. As such, researchers from the symbolic orientation have aimed to capture the meaning of words by computationally studying word usage in large bodies of text. Computational analyses have been used to develop lexical co-occurrence models. One such co-occurrence model is the Hyperspace Analogue to Language (HAL; Lund & Burgess, 1996). In HAL, the different contexts in which a word appears in a large body of text are analyzed and meaning is derived from the number of times that certain pairs of words co-occur. Words are represented in the form of vectors in a high-dimensional semantic space. In this semantic space, word vectors with smaller distances between them are deemed to be more similar in meaning than word vectors located farther apart. Consistent with the symbolic view, the meaning of a word is obtained from its relationship to other words as opposed to the referent of the word. For example, the word *flower* is understood because it is related to other words such as *plant*, *garden*, and *nature*. These latter words are considered to be the semantic neighbours of *flower*.

Other lexical co-occurrence models include Latent Semantic Analysis (LSA; Landauer & Dumais, 1997), Bound Encoding of the Aggregate Language Environment (BEAGLE; Jones & Mewhort, 2007), Latent Dirichlet Allocation (LDA; Blei, Ng, & Jordan, 2003), Topic Model (Griffiths, Steyvers, & Tenenbaum, 2007), and High Dimensional Explorer (HiDEx; Shaoul & Westbury, 2006). Although there are subtle differences among models, the overarching commonality is that word meaning is derived through an analysis of the words that a target word associates with at either the sentence level or in some larger context.

Unfortunately, co-occurrence in both HAL and LSA is influenced by word frequency, such that two words with a high frequency are more likely to co-occur by chance than are two words with a low frequency. This is unfortunate because it makes the metrics derived from those models less useful in psycholinguistic experiments because frequency is a confound. As psycholinguistic tasks are highly sensitive to frequency effects, spurious frequency effects may hide less robust co-occurrence effects. Durda and Buchanan (2008) were able to remove the influence of word frequency by obtaining frequency-free measures of word co-occurrence (using log-relative frequency ratios to address high-frequency values and scaling procedures to address low-frequency values; see Durda and Buchanan (2008) for the algorithm) and introduced an adaptation of HAL called Windsor Improved Norms of Distance and Similarity of Representations of Semantics (WINDSORS).

Lexical co-occurrence models produce results that correlate with human performance on various psycholinguistic tasks (Buchanan et al., 2001; Burgess & Conley, 1998; Burgess & Lund, 1997; Foltz, Kintsch, & Landauer, 1998; Kintsch, 2000; Landauer & Dumais, 1997; Louwerse, Cai, Hu, Ventura, & Jeuniaux, 2006; Lund & Burgess, 1996; Siakaluk, Buchanan, & Westbury, 2003). For example, in HAL, distances between vectors can explain human reaction time (RT) on a single-word priming experiment (Lund & Burgess, 1996), vectors can distinguish between semantic and grammatical concepts (Burgess & Lund, 1997), vectors can distinguish between proper names, famous proper names, and common nouns (Burgess & Conley, 1998), and semantic density can influence the type of semantic errors produced by those with deep dyslexia (Buchanan, Burgess, & Lund, 1996). LSA was shown to both contain spatial knowledge and have the ability to temporally order units of time, days of the week, and months of the year (Louwerse et al., 2006), perform analogously to non-native English speakers on a synonym selection task of the Test of English as a Foreign Language (Landauer & Dumais, 1997), pick up on changes in content within a text and predict the effect of text coherence on comprehension (Foltz et al., 1998), as well as mimic experimental findings concerning human metaphor comprehension (Kintsch, 2000). Louwerse (2008) found that iconic word pairs (e.g., *attic-basement*) were more frequent in language than reverse-iconic word pairs (e.g., *basement-attic*), accounting for shorter human RTs during semantic judgments of iconic word pairs compared to reverse-iconic word pairs. Louwerse and Connell (2011) demonstrated that word co-occurrences could be used to categorize words into their perceptual modalities. Durda, Buchanan, and Caron (2009) showed that co-occurrence rankings included featural information such that there could be a reliable mapping from co-occurrence vectors to featural information.

To summarize, symbolic views of word meaning based on lexical co-occurrence models understand meaning as being derived from the linguistic context in which the word occurs. A number of models have been introduced over the years and they differ with respect to how the linguistic units are assumed to be represented but in all cases the representations are, in some way, a reflection of the linguistic context.

Embodied Cognition Theory

On the opposite end of a semantic model continuum are embodied theories, also known as perceptual, grounded, or modal theories. Historically, this etymological debate between conventionalism (i.e., symbolism) and naturalism (i.e., embodied cognition) traces back to Plato’s *Cratylus* (Fowler, 1921). In conventionalism, names are arbitrarily adopted with local or national convention determining which names are attached to objects. In naturalism, names are adopted in a specific way, such that names encode descriptions of their objects. Embodied theories maintain that language comprehension is grounded in sensorimotor interactions with the environment. As such, the embodied cognition approach addresses an inherent problem in the symbolic approach – the symbol grounding problem (Harnad, 1990; Searle, 1980). It is important to note that embodied theories range on a continuum of being weakly embodied to strongly embodied (see Meteyard et al. (2012) for a discussion of this continuum). In contrast to the symbolic view, real world perceptual experiences as opposed to symbolic representation form the basis of understanding words. Unlike symbolic theories, which separate language comprehension and lower level perceptual processes, embodiment theories postulate that both are intertwined. Barsalou (1999), in his *perceptual symbols systems* theory, states that during direct perceptual experience, sensorimotor regions of the brain are activated in a bottom-up fashion. Perceptual symbols, or representations of the experience, then become encoded in the brain. Later, sensorimotor regions of the brain are partially reactivated in a top-down manner in the absence of direct perceptual experience. That is, when words are encountered, a mental simulation occurs, and that indirect experience facilitates comprehension. Similarly, Glenberg and Robertson (1999) proposed the *indexical hypothesis* which states that sentences are understood by simulating the actions that underlie them. Returning to the *flower* example, the embodied theory would suggest that we understand this word through our experience of seeing, touching, and smelling flowers, whereas from a symbolic co-occurrence perspective, one need not have actual experience with a flower to understand its meaning.[1] Therefore, according to the embodied cognition account, words are understood via simulated perceptual, motor, and emotional experiences.

[1] This is not to say that symbolic theories are nativist. With symbolic theories, linguistic experience, rather than perceptual experience forms the basis of understanding words.

Numerous studies have provided support for the embodied view of language. At the level of individual words, researchers have found a *body-object interaction* (BOI) effect (Siakaluk, Pexman, Aguilera, Owen, & Sears, 2008). Words with a high BOI, that is, words whose referents with which the body can physically interact with ease, facilitate responding on lexical and phonological decision tasks when compared to words with a low BOI. At the level of sentences, Glenberg and Kaschak (2002) found an interaction between performing an action and sentence comprehension which they coined the *action-sentence compatibility effect* (ACE). In their study, participants were asked to judge the sensibility of sentences describing both the transfer of concrete objects (e.g., *Andy delivered the pizza to you; you delivered the pizza to Andy*) and the transfer of abstract information (e.g., *Liz gave you the news; you gave Liz the news*). Participants responded by either pressing a button close to them, or far away from them. Results indicated that for both concrete and abstract sentences, sensibility judgments were faster when the action in the sentence matched the action required for responding. In a follow-up study, Glenberg et al. (2008) found activation of the corticospinal motor pathways to the hand muscles when reading both the concrete and abstract transfer sentences. Other studies have demonstrated the ACE when a physical movement such as turning a knob in a clockwise direction interferes with participants' understanding of sentences describing an opposite movement (e.g., *Eric turned down the volume*; Zwaan & Taylor, 2006). Lugli, Baroni, Anelli, Borghi, and Nicoletti (2013) found congruency effects between adding and going up a lift and subtracting and going down a lift. The ACE has also been studied in the context of conceptual metaphors where orientational literal sentences (e.g., *she climbed up the hill*), metaphors (e.g., *she climbed up in the company*), and abstract sentences with similar meaning to the metaphors (e.g., *she succeeded in the company*) all elicit faster hand motion responses when the direction implied in the sentence matches the direction of hand movement (Santana & de Vega, 2011). Moreover, asking participants to move their hands in an upward direction while reading sentences compatible with 'more' is easier than asking participants to move their hands downwards (Guan, Meng, Yao, & Glenberg, 2013). Research also reports that sensory metaphors (e.g., *cold person*) are used more frequently and are better remembered than their semantic equivalents (e.g., *unfriendly person*) given that sensory metaphors are stored with both semantic and sensory cues (Akpinar & Berger, 2015). Similar to the ACE, Chen and Bargh (1999) found an *approach-avoidance effect* where RTs were shorter when participants had to pull a lever towards their body in response to positive words and to push a lever away from their body in response to negative words. Remarkably, the ACE is not limited to actual physical movement, but also occurs with imagined physical movement (Wilson & Gibbs, 2007). The embodied cognition theory suggests that mental imagery activates sensorimotor systems (Binkofski et al., 2000; Jeannerod & Decety, 1995) and that imagery and action have shared neural substrates (Jeannerod, 1995).

The embodied view of language has also gained support from neuroimaging and patient investigations. Functional magnetic resonance imaging (fMRI) has been used to show that when participants listen to, read, or generate action-related words, the same regions of the brain are activated as if they were actually performing the action (Esopenko et al., 2012; Hauk, Johnsrude, & Pulvermuller, 2004; Tettamanti et al., 2005). Moreover, brain regions activated during the observation of hand, foot, and mouth actions are also activated when participants read sentences associated with these words (Aziz-Zadeh, Wilson, Rizzolatti, & Iacoboni, 2006). Boulenger, Hauk, and Pulvermuller (2009) also used fMRI and found that reading sentences – both literal and idiomatic – containing arm and leg related action words activated areas of the brain responsible for motor functioning. Notably, these studies have established that neural activation occurs somatotopically. Patient studies have provided support for embodiment by showing that an intact motor system is necessary for verb processing. Researchers have found selective impairments of verb processing in patients with motor neuron disease (Bak, O'Donovan, Xuereb, Boniface, & Hodges, 2001). Other researchers have failed to find a priming effect of verbs for patients with Parkinson disease off of their medication relative to Parkinson disease patients on medication and controls (Boulenger et al., 2008).

Iconicity has also been used to support the embodied cognition theory. Iconicity occurs when a linguistic symbol matches its referent. There are different forms of iconicity (e.g., onomatopoeia represents an auditory form of iconicity when words sound like their referent). Spatial iconicity, hereafter referred to as iconicity, has been the focus of prior research and refers to when the spatial positions of words match how their referents appear. In research, this is whether the relative positions of words on a computer screen match the relative positions of their referents (Zwaan & Yaxley, 2003). Studies of iconicity find a processing advantage for words that are spatially presented in a manner that reflects their meaning. In keeping with Barsalou's (1999) *perceptual symbols systems* theory, according to the embodied cognition theory, there is a processing advantage for words presented in their referents' typical locations because of our sensorimotor history with such an arrangement in our world. For example, Setic and Domijan (2007) found that RTs for judging the names of flying animals were shorter when displayed at the top of a computer screen and names of non-flying animals were judged faster when displayed at the bottom of a computer screen. These results were replicated when the names of animals were replaced with non-living things typically associated with either upper or lower space. Similarly, Estes, Verges, and Barsalou (2008) found that words representing objects associated with high or low space stalled subsequent identification of unrelated visual targets presented in the object’s typical location.

This ability for the meaning of a word to orient spatial attention has been referred to as conceptual cuing (Goodhew, McGaw, & Kidd, 2014). Zwaan and Yaxley (2003) demonstrated the iconicity effect with word pairs. Participants saw word pairs either in an iconic relationship (e.g., the word *attic* presented above the word *basement*) or in a reverse-iconic relationship (e.g., the word *basement* presented above the word *attic*) and were asked to indicate whether the two words were semantically related. Results revealed that RTs were shorter when word pairs were displayed in an iconic relationship compared to when word pairs were displayed in a reverse-iconic relationship. This iconicity effect disappeared when the word pairs were presented horizontally. Louwerse and Jeuniaux (2010) and Louwerse and Hutchinson (2012) extended this work by asking participants to make both judgments about semantic relatedness (i.e., is the word pair related or unrelated) as well as judgments about iconicity (i.e., is the word pair in an iconic or reverse-iconic relationship). These researchers found shorter RTs for iconic word pairs compared to reverse-iconic word pairs only in the iconicity judgment task.

Iconicity has been demonstrated with both concrete and abstract stimuli. For example, when participants are asked to judge which of two social groups (e.g., *masters* and *servants*) have more power, RTs are shorter when the more powerful group is displayed at the top of the screen. Conversely, when asked to judge which group has less power, RTs are shorter when the less powerful group is at the bottom of the screen (Schubert, 2005). Moreover, when participants are asked to make evaluations of words presented on a computer screen, evaluations of positive words are faster when the words are displayed at the top of the screen, whereas evaluations of negative words are faster when the words are displayed at the bottom of the screen (Meier &

Robinson, 2004). Positive evaluations also tend to draw visual attention to higher areas of visual space and negative evaluations tend to draw visual attention to lower areas of visual space (Meier & Robinson, 2004). Xie, Wang, and Chang (2014) found that the processing of affective words also produces spatial information which can subsequently influence performance on unrelated tasks. Chasteen, Burdzy, and Pratt (2010) found that in addition to the top and the bottom of the screen, the right and the left of the screen also activate positive and negative associations, respectively. For example, participants had shorter RTs when asked to detect above and right targets following a God-related word (e.g., *Lord*) presented in the middle of the computer screen and shorter RTs when asked to detect below and left targets following a Devil-related word (e.g., *Satan*). These findings can be explained by the *conceptual metaphor theory* in which concepts are embedded in spatial relations (e.g., *up* represents power and happiness; Lakoff & Johnson 1980; Gibbs 1994).

Event-related potentials (ERP) studies also show the iconicity effect. For example, Zhang, Hu, Zhang, and Wang (2014) primed participants with either up or down arrows and then presented them with neutral words or target emotional words that were either positive (e.g., *happy*) or negative (e.g., *sad*). Results showed that N400 amplitudes were greater when target words were primed by incongruent spatial information (e.g., up arrow priming the word *sad*). Similarly, in line with the ACE, research has found a greater N400 when the action required for responding is incongruent with target stimuli (Aravena et al., 2010; Glenberg & Kaschak, 2002; Guan et al., 2013).

Combined Theories

While symbolic and embodied theories tend to be viewed as being at odds with one another, historical and recent attempts to reconcile these theories have been documented

(Andrews, Frank, & Vigliocco, 2014). Paivio's (1971) *dual coding theory* advocated for separate cognitive subsystems for verbal and nonverbal information. Paivio (1971) described different types of processing including representational (direct activation of the verbal or non-verbal system), referential (activation of the verbal system by the non-verbal system or vice versa), and associative (activation of representations within the same verbal or nonverbal system). According to the *dual coding theory*, depending on task requirements, one or multiple types of processing would be activated. Dove (2009) proposed *representational pluralism*, in which the meaning of a word results from diverse semantic codes. Some codes are perceptual (i.e., embodied, modal) and others are non-perceptual (i.e., symbolic, amodal). Therefore, for any given word, both sensorimotor simulations and linguistic representations are activated (Dove, 2011). Louwerse (2007) proposed the *symbol interdependency hypothesis*, in which the linguistic system serves as a shortcut to the perceptual system. Symbols are grounded in embodied experiences such that language encodes relations in the world, including embodied relations. That is, language is structured in such a way that it encodes perceptual information (Louwerse, 2011). However, language comprehension for the most part uses symbolic representation and the embodied representations of words do not necessarily need to be accessed or fully activated. While embodied information enables a thorough understanding of words, symbolic information is more efficient and is adequate for providing most meaning. Hutchinson and Louwerse (2012) found support for the *symbol interdependency hypothesis* such that both symbolic (i.e., order frequency of the word pair) and embodied (i.e., positivity or negativity of the word pair) factors were involved in conceptual metaphor comprehension, with the symbolic factor most salient for positive-negative word pairs presented horizontally, and the embodied factor most salient for positive-negative word pairs presented vertically. In addition to the *dual coding theory*, *representational pluralism*, and the *symbol interdependency hypothesis*, the *language and situated simulation theory* (LASS; Barsalou, Santos, Simmons, & Wilson, 2008) proposes that language and situated simulation both play a role in conceptual processing. The LASS theory incorporates a temporal component such that both symbolic and embodied factors are activated immediately, but symbolic activation reaches its peak earlier than embodied activation. Parallel to the claims of the *symbol interdependency hypothesis*, symbolic factors are believed to be less precise than embodied factors, providing quick approximate representations, which the perceptual system then refines. The notion that symbolic factors tend to dominate early on in a language comprehension task has been linked to depth of processing. When symbolic processing is sufficient for the task at hand, the embodied system may not be recruited. As the linguistic system evolved later than the simulation system, it does not necessarily provide access to deep conceptual information. Therefore, in LASS, symbolic factors are presumed to be most important for shallow tasks, with embodied factors coming into play for tasks involving deeper processing.

The LASS theory has received empirical support. In an fMRI experiment, participants were asked to perform a property generation task. The early phase of conceptual processing during the property generation was set as the first 7.5 seconds of each trial, and the late phase was set as the last 7.5 seconds. In a later session, participants were asked to perform word associations for a concept and they were asked to generate a situation in which one commonly experiences a concept. Results demonstrated that word associations activated areas involved in linguistic tasks such as Broca’s area, whereas situation generations activated areas involved in mental imagery tasks such as bilateral posterior areas. Critically, in the property generation task, the former linguistic areas were more active in the early phase and the latter imagery areas were more active in the late phase (Simmons, Hamann, Harenski, Hu, & Barsalou, 2008). Similarly, Louwerse and Connell (2011) found that symbolic activation reached an earlier peak in a modality-shifting experiment. In their study, the effect of symbolic factors on RT preceded the effect of embodied factors. Fast responses were best explained by symbolic factors and slow responses by embodied factors, such that language statistics were used to make quick decisions and perceptual simulations were engaged for slower decisions. Similarly, an EEG experiment revealed that while conceptual processing involved neural activation associated with both symbolic and embodied processing, effect sizes for symbolic areas were larger earlier on in a trial and effect sizes for perceptual areas were larger towards the end of a trial (Louwerse & Hutchinson, 2012). Therefore, in addition to task characteristics, timing seems to play a role.

In summary, combined theories argue that meaning is derived from words by accessing both symbolic and embodied information. However, the relative influence of either symbolic or embodied information depends on timing and task. Combined theories also argue that symbolic information is more readily accessible than embodied information and can serve as a shortcut. That is, embodied information does not always need to be accessed or fully activated.

With respect to task, Louwerse and Jeuniaux (2010) found that tasks with a linguistic focus, e.g. semantic relatedness judgments, highlight the role of symbolic information and tasks with an embodied focus, e.g. iconicity judgments, highlight the role of embodied information. In their study, participants were asked to make speeded judgments about semantic relatedness or iconicity for word pairs or pictures. The symbolic factor was operationalized as frequency of word order, that is, whether word pairs were presented in the order in which they typically occur in language, and the embodied factor was operationalized as iconicity, that is, whether word pairs were presented in the spatial relationships in which their referents typically occur. An analysis of RTs and error rates revealed that the symbolic factor dominated in the semantic relatedness task for word pairs (the shallower processing) and the embodied factor dominated in the iconicity judgment task for pictures (the deeper processing). Louwerse and Jeuniaux (2010) concluded that this study provided support for the *symbol interdependency hypothesis*.

Malhi (2015) tested the *symbol interdependency hypothesis* (Louwerse, 2007) in a study similar to Louwerse and Jeuniaux (2010). The same semantic relatedness and iconicity judgment tasks and the same embodied factor (i.e., iconicity) was used. Note that while the format of iconic or reverse-iconic information is not in and of itself sensory or embodied, seeing words presented in such a format activates their corresponding perceptual representations and thus has been used as a proxy of embodiment. While the same embodied factor as previous research was used, a novel symbolic factor was introduced (i.e., semantic neighbourhood distance between word pairs, where distance between semantic neighbours was determined by the WINDSORS lexical co-occurrence model; Durda & Buchanan, 2008). Malhi (2015) also included abstract word pairs in addition to concrete word pairs. Results supported the *symbol interdependency hypothesis* in that the symbolic factor (i.e., semantic neighbourhood distance) was recruited for the semantic relatedness task and the embodied factor (i.e., iconicity) was recruited for the iconicity judgment task. Results also demonstrated that across tasks, and especially for the iconicity judgment task, abstract stimuli (e.g., *beauty-ugly*) led to shorter RTs compared to concrete stimuli (e.g., *desk-carpet*). This reverse concreteness, or abstractness, effect was interpreted in the context of abstract words not affording the mental images available from concrete words (Malhi & Buchanan, 2017). In judging iconicity, with concrete word pairs, the first step is visualization and the second step is mental manipulation. In contrast, because abstract word pairs cannot be visualized, there is only the single step of mental manipulation. As an alternative and more efficient means of judging iconicity, it was proposed that for the abstract word pairs, participants were tagging upper and lower space with emotions. Therefore, utilizing Vigliocco, Meteyard, Andrews, and Kousta's (2009) *theory of embodied abstract semantics*, Malhi and Buchanan (2017) concluded that sensorimotor information was contributing to understanding concrete words and emotional information was contributing to understanding abstract words (see Sheik and Titone (2013) for another example). The next section will describe theories of concrete and abstract word processing.

Theories of Concrete and Abstract Word Processing

Concrete words (e.g., *apple*) are words that have direct sensory referents and words that can be easily visualized. Concreteness is related to a variable known as imageability. Concreteness and imageability have been found to be highly correlated, with imageability accounting for 72% of the variability in concreteness (Kousta, Vigliocco, Vinson, Andrews, & Del Campo, 2011). While concreteness and imageability are related, they are not the same. Whereas imageability is defined as whether the word can conjure an image, concreteness is defined as whether the referent of the word can be situated in time and space. Abstract words are, words that do not have direct sensory referents and words that cannot be easily visualized (e.g., *respect*; Schwanenflugel & Stowe, 1989). Many studies have found a concreteness effect (Pavio, 1991), whereby when presented with both concrete and abstract stimuli, participants more quickly recognize (Kroll & Merves, 1986) and better remember (Paivio, 1971) concrete stimuli compared to abstract stimuli. With the concreteness effect, concrete words are also better preserved after neurological impairment (e.g., Coltheart, Patterson, & Marshall, 1980; Franklin, Howard, & Patterson, 1995; Katz & Goodglass, 1990; Martin & Saffran, 1992). For example, in the case of deep dyslexia, individuals are better able to read aloud concrete compared to abstract words (Coltheart et al., 1980). However, this concreteness advantage in deep dyslexia may be limited to oral-word reading (Boumaraf & Macoir, 2016; Malhi, McAuley, Lansue, & Buchanan, submitted; Newton & Barry, 1997).

The concreteness effect has been explained by various theories. The *dual coding theory* (Paivio, 1971) explains the concreteness effect in terms of the type of information available. That is, concrete words have a processing advantage because they activate both the linguistic (verbal) and imagistic (nonverbal) systems, whereas abstract words only activate the linguistic (verbal) system. For example, participants produce comparable RTs for concrete and abstract words when asked to generate word associates. However, they produce shorter RTs for concrete words than abstract words when asked to generate mental imagery (Ernest & Paivio, 1971). The *dual coding theory* has also received empirical support from visual field studies in which concrete words presented to the left visual field (right hemisphere) are processed faster than those presented to the right visual field. This supports the *dual coding theory* to the extent that the right hemisphere is dominant for visual processing (Levine & Banich, 1982; Shibaraha & Lucero-Wagoner, 2002). Imaging studies also provide support for the *dual coding theory* as areas involved in perception and imagery have more activation for concrete compared to abstract words (Binder, Westbury, McKiernan, Possing, & Medler, 2005; Wang, Conder, Blitzer, & Shinkareva, 2010). On the other hand, the *context availability theory* (Schwanenflugel, Harnishfeger, & Stowe, 1988; Schwanenflugel & Shoben, 1983; Schwanenflugel & Stowe, 1989) explains the concreteness effect with respect to how much information is available. According to this theory, concrete words are strongly associated with a few contexts, whereas abstract words are weakly associated with many contexts. Concrete words thus have more easily accessible and richer contextual information, which facilitates processing. Another theory to explain the concreteness effect and one that integrates the *dual coding theory* with the *context availability theory* is the *context extended dual coding theory* (Holcomb, Kounios, Anderson, & West, 1999). This theory proposes that concrete words have a processing advantage because of both their ability to generate mental images as well as more semantic activity within a verbal system. Crutch and Warrington's (2005) *different representational frameworks model* proposes that concrete words are represented in a categorical framework (i.e., based on semantic similarity) and abstract words are represented mainly by semantic association (i.e., linguistics contexts). This theory maintains that concrete words share more representations with other similar words (e.g., *cow-sheep*) than with other associated words (e.g., *cow-barn*) whereas abstract words share more representations with other associated words (e.g., *robbery-punishment*) than with other similar words (e.g., *robbery-theft*).

Much theorizing on concrete and abstract word processing focuses on what concreteness is as opposed to what abstractness is. Abstract words are not defined by what they are but instead by what they lack relative to concrete words. Recognizing this problem, Borghi and Binkofski (2014) outline, in their view, the main characteristics of abstract concepts. First, they describe that abstract concepts are not grounded in physical entities. However, they argue that this does not mean that abstract concepts are ungrounded. Rather, abstract concepts have a different grounding, such that they are grounded in mental states, situations, events, and in complex relations between objects. Whereas concrete concepts evoke more perceptual properties, abstract concepts evoke more properties that are situational and introspective (Barsalou & Wiemer-Hastings, 2005; Wiemer-Hastings & Xu, 2005). Similarly, Barsalou (2003) argues that concepts become more and more abstract as they become more detached from physical entities and more linked with mental states. Another component of their definition of abstract concepts is that abstract concepts are more complex than concrete ones. Finally, they argue that abstract concepts are characterized by greater meaning variability, such that the meaning of abstract concepts is more changeable than the meaning of concrete concepts. Borghi and Binkofski (2014) also make a distinction between the terms abstractness and abstraction. For instance, concepts such as *animal* and *furniture* are at the top of the abstraction hierarchy and more abstract than *dog* or *chair*, but all are concrete concepts. Iliev and Axelrod (2017) make a distinction between abstractness based on precision (how much overall information is available) and abstractness based on concreteness (how much sensorimotor information is available). They suggest that, in a lexical decision task, greater precision slows down RTs but greater concreteness facilitates them.

Considering theories of concrete and abstract word processing in relation to symbolic and embodied theories, concrete word processing has been explained using both symbolic and embodied theories. Abstract word processing, in contrast, has typically been explained through symbolic theories. While embodied theories address the symbol grounding problem (Harnad, 1990; Searle, 1980) inherent in symbolic theories, the grounding of abstract words is a challenge to the embodied theory (see Dove (2016) for a discussion of these challenges). However, proposals have pointed out how embodied theories can also explain abstract word processing. For example, the *affective embodiment account* (Kousta et al., 2011) proposes that concrete concepts are externally embodied in our experience with the physical environment and abstract concepts are internally embodied through emotional states. Similarly, Vigliocco et al.'s (2009) *theory of embodied abstract semantics* proposes that sensorimotor information contributes to concrete word processing and emotional information contributes to abstract word processing. Another proposal of the embodied view of abstract concepts is the *conceptual metaphor theory* (Lakoff & Johnson 1980; Gibbs 1994) in which abstract concepts such as metaphors, like concrete concepts, are embedded in spatial relations. The *words as tools* (Borghi & Binkofski, 2014) proposal states that like concrete concepts, abstract concepts are embodied, with language being more important for abstract concepts, and sensorimotor information for concrete concepts. Finally, *hub-and-spoke models* (Lambon Ralph, 2014; Lambon Ralph, Sage, Jones, & Mayberry, 2010; Patterson, Nestor, & Rogers, 2007), where the bilateral anterior temporal lobes (hub) integrate white matter connections (spokes) can also account for the representation and embodiment of abstract concepts. In this model, abstract concepts are the result of crossmodal conjunctive representation (Binder, 2016) in which input is integrated crossmodally at convergence zones or association areas (Damasio, 1989; Simmons & Barsalou, 2003).

In addition to behavioural studies, concreteness has also been investigated using measures such as ERPs (see Huang and Federmeier (2015) for a review). ERPs are measures of electrical activity from the brain, time-locked to an event, such as the presentation of a stimulus or a participant's response to a stimulus. They are recorded from the scalp using electrodes and signals are compared to the stimuli that participants viewed or the responses that they made (Huang & Federmeier, 2015). ERPs reflect neurotransmission in the cortical pyramidal cells (Luck, 2014). The advantage of ERPs over other measures of neural activity is that they provide high temporal resolution, with millisecond-level precision. Moreover, ERPs provide a continuous measure of processing, such that neural activity is measured both before the stimulus is presented and after the participant has made their response (Luck, 2014). Hemodynamic measures such as positron emission tomography (PET) and fMRI are different from ERPs as they have poor temporal resolution but high spatial resolution (Luck, 2014). As language processing is rapid, ERPs are useful in monitoring the time-course of language processing (Huang & Federmeier, 2015).

ERP studies report a greater N400 (300-500 ms) amplitude for concrete words compared to abstract words, with this finding most prominent at central and posterior electrode sites (Dhond, Witzel, Dale, & Halgren, 2007; Holcomb et al., 1999; Kounios & Holcomb, 1994; Lee & Federmeier, 2008; Nittono, Suehiro, & Hori, 2002; Sysoeva, Ilyuchenok, & Ivanitsky, 2007; van Schie, Wijers, Mars, Benjamins, & Stowe, 2005; West & Holcomb, 2000). The N refers to a negative component and the 400 refers to the time at which it occurs, with N400 representing a negative component peaking at 400 ms. ERP studies also report a greater N700 (300-900 ms) amplitude for concrete words compared to abstract words, with this finding most prominent at anterior electrodes (Holcomb et al., 1999; Huang, Lee, & Federmeier, 2010; Lee & Federmeier, 2008; Nittono et al., 2002; Shen, Tsai, & Lee, 2015; West & Holcomb, 2000). Similarly, the N700 is a negative component peaking at 700 ms. Researchers have conceptualized the anterior N700 as an index of imagery (Gullick, Mitra & Coch, 2013; Welcome, Paivio, McRae, & Joanisse, 2011; West & Holcomb, 2000).

The N400 and anterior N700 have been demonstrated across a range of tasks. In a classic ERP study, Kounios and Holcomb (1994) used both a lexical decision task and a concrete versus abstract categorization task and found that concrete words had a greater N400 amplitude compared to abstract words, with this finding stronger in the categorization task (which required a deeper level of processing). Holcomb et al. (1999) used a congruency judgment task where participants read sentences ending in either a concrete or an abstract word. Results demonstrated a greater N400 and a frontal N700 towards concrete words in the incongruent condition, implying the role of sentence context in producing the concreteness effect. To further study the role of task demands in the N400 and N700, West and Holcomb (2000) used a sentence verification task where, again, the final word of the sentence was either concrete or abstract.

Critically, there were three conditions, with the verification involving generating an image, making a semantic decision, or evaluating the surface characteristics of the word (i.e., whether a probe letter was present in the target word). These researchers found N400 and anterior N700 concreteness effects only in the semantic decision and image generation conditions. Notably, the anterior N700 effect was most robust in the imagery task. This led the researchers to conceptualize the anterior N700 as an index of imagery.

In another ERP study, Welcome et al. (2011) asked participants to generate a word that was associated with the target word or to generate a mental image of the target word. Results showed that during word associate generation, but not mental image generation, concrete words had a greater N400 than abstract words. However, around 800 ms, a concreteness effect occurred in the mental image generation task, again providing support for a later negativity towards concrete words as an index of imagery. In another related study, Gullick et al. (2013) asked participants to make a decision about surface characteristics or whether it was easy to make a mental image for the word. Similar to the results of Welcome et al. (2011), these researchers found an anterior N700 to concrete words only in the mental image task. However, somewhat contrary to the results of Welcome et al. (2011), they found a larger N400 to concrete words in the mental image task compared to the surface task. Nittono et al. (2002) asked participants to rate imageability and found that concrete words elicited both a larger N400 and a later going negativity (N800) than abstract words. While these ERP studies generally provide support for the *context extended dual coding theory*, ERP support is also available for the *context availability theory*. For example, Laszlo and Federmeier (2011) found a greater N400 for words with more orthographic neighbors and for words with more lexical associates in long-term memory, suggesting greater activity in the semantic system and richer semantic associations.

Overall, the anterior N400 component has been proposed to reflect processing of visual semantic information in the form of high-level descriptions of the visual properties of concrete objects (van Schie et al., 2005). The anterior N700 has been proposed to reflect activation in a more frontal brain region, such as the prefrontal cortex, and as such, is implicated in higher cognitive functions such as working memory (i.e., mental images are held in mind to make a judgment; West & Holcomb, 2000) and executive functioning (Barber, Otten, Kousta, & Vigliocco, 2013). Concreteness effects to words and object working memory have been proposed to have overlapping neural structures. Research supporting this proposal has found suppression of visualization to concrete words by a concurrent (non-semantic) object working memory task, with the requirement of maintaining an object in working memory affecting the amplitude to concrete words (van Schie et al., 2005). The link between visual working memory and concrete word processing has also been demonstrated in behavioural studies. For example, in one study, participants listened to recordings of concrete and abstract words while looking at a computer that displayed either dynamic visual noise or static visual noise. Concrete words were better recalled only in the static visual noise condition, whereas, in the dynamic visual noise condition abstract words were better recalled (Parker & Dagnall, 2009). Mate, Allen and Baques (2012) found interference in remembering visual items while participants repeated aloud concrete word pairs, but not abstract word pairs. Similarly, Kellogg, Olive, and Piolat (2007) found interference on a visual working memory task when participants wrote down definitions of concrete words, but not abstract words.

Abstractness Effects

Abstractness effects, while less commonly found than concreteness effects, have been documented in the literature. Malhi (2015) reported a reverse concreteness, or abstractness, effect in an iconicity judgment task. Kousta et al. (2011) reported an abstractness effect in a lexical decision task after controlling for context availability and imageability among other variables. This abstractness effect was reported to be the result of abstract words being more emotionally valenced than concrete words. Similarly, Barber et al. (2013) reported an abstractness effect in a lexical decision task after controlling for context availability and imageability. These researchers suggested that the abstractness effect was a result of abstract words activating superficial linguistic associations that were used to make quick responses. In addition to finding that abstract words had shorter RTs compared to concrete words, they also found that, despite the faster behavioural responses to the abstract words, concrete words still had greater N400 and N700 responses. Considering that concrete and abstract words were matched for both context availability and imageability, the *context extended dual coding theory* was judged inadequate to explain the results. Instead, N400 differences were proposed to be the result of greater semantic processing (integration of multimodal information) for concrete words compared to abstract words and N700 differences were proposed to be the result of concrete words activating the executive control system.

Pexman, Hargreaves, Edwards, Henry, & Goodyear (2007) collected both behavioural and fMRI data while participants completed a semantic categorization task. They found that abstract words had both shorter RTs and more widespread cortical activation than concrete words. These researchers also argued against *dual coding* and *context availability* explanations and suggested that their results were compatible with Barsalou's (1999) *perceptual symbol systems* theory, and that abstract words, compared to concrete words, were more richly represented. Danguecan and Buchanan (2016) similarly found that linguistic associative information (i.e., semantic neighbourhood density) was more important for abstract words compared to concrete words. This is consistent with the definition of abstract concepts outlined by Borghi and Binkofski (2014) that abstract concepts are more complex than concrete ones. Patient studies have also revealed abstractness effects in semantic dementia not fully accounted for by the *dual coding* and *context availability* theories (e.g., Bonner et al., 2009; Breedin, Saffran, & Coslett, 1994; Macoir, 2009; Yi, Moore, & Grossman, 2007). While Paivio's (1971) *dual coding theory* has typically been cited to explain the concreteness effect, Paivio (2013) recently described that the *dual coding theory* can allow for abstractness effects depending on the stimuli and task. For example, Paivio (2013) recalls a study where Paivio and O'Neill (1970) found that at tachistoscopic word recognition thresholds, concreteness had no effect (and there was actually an abstractness effect) because the stimuli first had to be recognized before they could be visualized.

Overview of Present Study

Malhi (2015) asked participants to complete a semantic relatedness task and an iconicity judgment task for both concrete and abstract word pairs. Results demonstrated that across tasks, and especially in the iconicity judgment task, abstract stimuli facilitated shorter RTs. Consistent with Vigliocco et al.'s (2009) *theory of embodied abstract semantics*, it was hypothesized that, in the iconicity judgment task, participants were taking a visualization approach (time-costly) towards the concrete word pairs and an emotional valence approach (time-efficient) towards the abstract word pairs. The goal of the present study was to further investigate this reverse concreteness, or abstractness, effect found for word pairs. As this effect is opposite from the concreteness effect (Paivio, 1991) found for single words, Malhi and Buchanan (2017) hypothesized that the abstractness effect emerged not by considering the single words in isolation but rather by considering the relationship between them. If the two single words that make up the word pair were read in isolation, there would be no reason to expect a deviation from the concreteness effect as two, three, four, etc. concrete words should be processed faster than two, three, four, etc. abstract words. Concrete and abstract words are better conceptualized as occurring on a continuum rather than as binary constructs, such that highly abstract concepts have concrete aspects and vice versa. In that respect, while the concrete words in the Malhi (2015) stimulus set fell on the concrete end of the continuum, and most of the abstract words fell on the abstract end of the continuum, some of the abstract words were not as clear cut (e.g., *teacher*). However, the manipulation circumvented this potential problem, as the task aimed to capture the abstract relationship between the words as opposed to the abstractness of the individual word (e.g., *teacher* above *student* as representing an abstract concept of power).

This novel task and method of studying abstractness helps tackle a fundamental problem in psycholinguistic research – the concretizing of abstract words. Prinz (2002) argued that words are arbitrary symbols and to be understood they must be linked to perceivable features via *sign-tracking*. Therefore, abstract concepts are understood by grounding them in concrete concepts. By definition, abstract words lack sensory referents and cannot be easily visualized (Schwanenflugel & Stowe, 1989). However, considering our tendency towards parsimony (Epstein, 1984), when we see abstract words, we may be reducing them to a sensory referent that can be easily visualized (e.g., imagining a *church* for *religion*). In other words, we indirectly imagine abstract words by directly imagining their concrete associates. Undoubtedly, some abstract words lend themselves to being more easily concretized than others (e.g., *democracy* can be imagined as a voting ballot, whereas *truth*, may be more difficult to imagine). Prinz (2002, p. 148) has argued ‘‘…the failure to see how certain properties can be perceptually represented is almost always a failure of the imagination.” Directly imagining concrete words has been argued to facilitate processing by the *dual coding theory* (Paivio, 1971) and being unable to imagine abstract words has been argued to slow down its processing. While this is reasonable, the confound is that participants may be indirectly imagining abstract words and it is this indirect imagination that is slowing down processing, rather than not imagining the abstract words at all. Thus, what appears to be a concreteness effect is confounded by the concretizing of abstract words. In in the case of a reverse concreteness, or abstractness, effect this could be seen as a problem. However, in developing the stimulus set, Malhi (2015) ensured that, according to their definitions (Schwanenflugel & Stowe, 1989), concrete words were imaginable (e.g., *nose-tongue*), while abstract words (e.g., *accept-reject*) were not. This was possible by activating the relationship between the word pairs as opposed to activation at the level of the individual words. That is, participants were attending to the abstract relationship between the individual words rather than attending to the abstract words themselves. Therefore, this serves as a purer measure of abstractness and helps circumvent the confound of concretizing abstract words.

CHAPTER 2

DESIGN AND METHODOLOGY

Hypotheses

Two hypotheses motivated the present study:

H1: In the iconicity judgment task, participants take a visualization/imagining approach towards the concrete word pairs and an emotional/intuitive approach towards the abstract word pairs.

The goal of Experiment 1 was to test this hypothesis by asking participants questions regarding strategy use. The goal of Experiment 3 was also to test this hypothesis by showing pictures prior to the word pairs. If iconicity judgments of concrete word pairs are taking longer because participants are visualizing them, then providing pictures prior to the concrete words should contribute to shorter RTs. The goal of Experiment 2 was also to test this hypothesis by replicating the iconicity judgment task in an ERP paradigm. If participants are taking a visualization approach towards the concrete word pairs, then neural markers of imagery (e.g., N700) should be observed for the concrete word pairs.

H2: Abstractness effects will be found in tasks where participants attend to the relationship between the words (e.g., in Experiment 1's iconicity judgment task) and abstractness effects will not be found in tasks where participants do not attend to the relationship between the words (e.g., in Experiment 4 and 5's lexical decision tasks).

The goal of Experiment 1 was also to test this hypothesis by asking participants to provide ratings. When the single words making up the abstract word pair are rated individually, they should be rated as less abstract than when rated together while considering the relationship between them.

In sum, a series of experiments both subjectively and objectively tested the hypotheses that participants were taking a visualization approach towards the concrete word pairs and that participants were attending to the relationship between the words. Experiment 1 included subjective strategy use questions that tested the hypothesis that participants were taking a visualization approach towards the concrete word pairs. The tasks in Experiments 2 (ERP iconicity judgment task) and 3 (picture iconicity judgment task) tested this hypothesis objectively. Experiment 1 included ratings that tested the hypothesis that participants were attending to the relationship between the words. The tasks in Experiments 4 (non-pronounceable lexical decision task) and 5 (pronounceable lexical decision task) tested this hypothesis objectively.

Operational Definitions

Close Versus Distant Semantic Neighbours

The symbolic factor was operationalized using semantic neighbourhood distance between word pairs, with close semantic neighbours defined as less than 50 words away from one another, and distant semantic neighbours defined as greater than 200 words away from one another (Durda & Buchanan, 2008). Semantic neighbourhood distance was an ordinal measurement with the target word located X words away from its neighbour of interest. For example, *nose* is the 9^{th} neighbour of *tongue* and *tongue* is the 22^{nd} neighbour of *nose*, making them close semantic neighbours.

Concreteness

Consistent with Schwanenflugel and Stowe (1989), concreteness was operationalized as word pairs representing physical objects whose relationships could be easily visualized, while abstractness was operationalized as word pairs representing intangible constructs whose relationships could not be visualized.

Method

Stimulus Development

The full stimulus set is presented in Appendix A. The stimulus set was developed using WINDSORS (Durda & Buchanan, 2008) and Wordmine2 (Durda & Buchanan, 2006). The stimulus set contained 40 concrete word pairs and 40 abstract word pairs. As expected, the mean imageability ratings for the concrete word pairs were higher than the mean imageability ratings for the abstract word pairs [$F(1, 32) = 87.05$, $p < .001$] (Altarriba, Bauer, & Benvenuto, 1999; Bennett, Burnett, Siakaluk, & Pexman, 2011; Bird, Franklin, & Howard, 2001; Stadthagen-Gonzalez & Davis, 2006). Also as expected, the abstract word pairs were more emotionally valenced compared to the concrete word pairs [$F(1, 73) = 66.28$, $p < .001$] (Warriner, Kuperman, & Brysbaert, 2013). Half of the word pairs in the stimulus set were close semantic neighbours and half were distant semantic neighbours. Moreover, half of the close and distant semantic neighbours were presented in an iconic relationship and half were presented in a reverse-iconic relationship. The stimulus set was counterbalanced so that the word pairs were presented in both iconic and reverse-iconic form. However, no participant saw the same word pair in both iconic and reverse-iconic form.

To avoid low and high extremes, orthographic frequency values were restricted to a range of 10-200 per million words of text. An analysis of variance (ANOVA) was conducted to ensure that the word pairs' average orthographic frequencies (mean orthographic frequency of the word pair) [$F(1, 79) = 1.33$, $p = .25$] and average number of letters (mean number of letters in the word pair) [$F(1, 79) = 2.06$, $p = .059$] did not differ across conditions. An ANOVA was also conducted to ensure that semantic neighbourhood distance did not differ between the concrete and abstract stimuli [$F(1, 79) = .35$, $p = .55$]. To avoid an alliteration effect, no two words in the pairs begins with the same letter. Age of acquisition was the higher age associated with the word pair. For example, for the word pair *flower-vase*, the word *flower* is acquired at age 3.11 and the word *vase* is acquired at age 7.89, and thus the age of acquisition for the entire word pair was entered as 7.89. The higher age was selected rather than the mean age because participants are encoding the word pair, and the word pair would only have meaning if both words are known. As expected, the age of acquisition for concrete words pairs differed from the age of acquisition for abstract word pairs [$F(1, 79) = 14.048$, $p < .001$], such that abstract word pairs were acquired at a later age. The means and standard deviations (SD) for number of letters, orthographic frequencies, and age of acquisition (Kuperman, Stadthagen-Gonzalez, & Brysbaert, 2012) per condition are displayed in Table 1.

Table 1 *Means and SDs for Word Length, Frequency, and Age of Acquisition (AoA) Per Condition in the Stimulus Set*

Condition	Word Length	Frequency	AoA
Abstract			
Close	12.15(2.68)	44.81(17.65)	7.68(2.07)
Distant	11.9(3.23)	41.73(20.07)	8.12(1.67)
Concrete			
Close	10.9(2.17)	37.81(28.14)	6.15(1.55)
Distant	10(1.86)	35.14(23.09)	6.19(1.39)

Participant Recruitment and Inclusion Criteria

University of Windsor undergraduate students were recruited from the psychology department's participant pool. Participants received partial course credit for their involvement in the study. For each experimental condition, at least 25 students were recruited, exceeding the numbers suggested by a power analysis using a large effect size (partial $\eta^2 = .14$) and an alpha level of .05 (Faul, Erdfelder, Buchner, & Lang, 2009). In total, for Experiments 1 and 3-5, 125 students were recruited. For Experiment 2, 23 students were recruited, a sample size comparable to that used in a similar ERP study of the iconicity judgment task (i.e., Louwerse & Hutchinson, 2012). For Experiments 1 and 3-5, all participants were at least 18 years of age, had learned English as their first language, and had normal or corrected-to-normal vision. For Experiment 2, all participants were also right-handed and reported no neurologic or psychiatric history.

Task Software and Display Details

The experiments were run using DirectRT (Jarvis, 2012) on a PC running Windows 7. Word pairs were presented in the middle of a black background in all capital letters, size 24, bold-faced font with turquoise coloured letters. Each word pair appeared one at a time in random order and the pair remained on the screen until the participant gave their response by pressing either the “z” key or the “/” key. These response keys were covered with “Yes” and “No” stickers to simplify responding and were counterbalanced across participants to avoid any confound of dominant hand responding. For Experiment 3, picture pairs were presented in the middle of a black background and remained on the screen for 1000 milliseconds (ms)

For the ERP, scalp and mastoid electrode impedances were maintained below 5 kiloohms (kOhms) and eye electrode impedances below 10 kOhms. The data was continuously sampled at a rate of 1000 hertz (Hz) per channel. The signals were amplified by SynAmps^2 amplifiers (Neuroscan Inc.). The data was low-pass filtered (half-amplitude cut-off = 40 Hz, slope = 24 decibels per octave). Data was recorded and stored on a computer running Neuroscan Acquire 4.5 software.

Outlier Analyses

A minimum accuracy rate of 70% was used for both participants and words. The criteria for removing a whole participant was an overall error rate greater than 30%. All incorrect responses, as well as responses faster than 300 ms (considered to be invalid; 200 ms for the picture iconicity judgment task), were removed. For behavioral data, after model fitting, data was trimmed using the LMERConvenienceFunctions package (Tremblay & Ransijn, 2015). Outliers with a standardized residual at a distance greater than 2.5 SD from 0 were excluded from the fitted model. Data was trimmed after the model was fitted as invalid data was already removed and the linear mixed effects analysis (statistical analysis used) does not assume a normal distribution. Moreover, RT was log transformed to approach normality. For the ERP results, data was baseline corrected and trials contaminated by eye movements, muscular activity, or electrical noise were excluded from the analyses.

Statistical Analyses

Data was analyzed using R (R Core Team, 2016) version 3.4.3 and the lme4 and lmerTest packages (Kuznetsova, Brockhoff, & Christensen, 2013). RTs were log transformed. Correct responses were analyzed in a linear mixed effects analysis. As random effects, subjects and items were entered into the model. The model was fitted with random slopes by subject and by item. P-values (probability values) were obtained for the fixed effects using the lmerTest package with Satterthwaite approximations to degrees of freedom (Kuznetsova et al., 2013).

For accuracy, the binomial dependent variable (i.e., correct or incorrect) was analyzed using a mixed logit model (generalized linear mixed model; Jaeger, 2008). As random effects, subjects and items were entered into the model. The model was fitted with random slopes by subject and by item.

For data from the strategy questions in Experiment 1, a qualitative analysis was performed on the open-ended responses (Berg, 2009). This analysis will be described in more detail below. For the rating data, a one-way ANOVA compared the mean ratings across the conditions. For the ERP data, for every subject, statistical analyses were conducted on the peak amplitude of electrode sites within the N400 (300-500 ms) time window and on the peak amplitude of anterior electrode sites within the N700 (500-800 ms) time window using ERPScore (Segalowitz, 1999). Peak amplitudes to correct responses were analyzed using repeated measures ANOVAs. Greenhouse-Geisser corrected p-values are reported due to violations of sphericity common in ERP data (Luck, 2014).

CHAPTER 3

EXPERIMENT 1: ICONICITY JUDGMENT TASK WITH STRATEGY QUESTIONS AND CONCRETENESS RATINGS

The goal of Experiment 1 was to address the hypothesis that, in an iconicity judgment task, participants take a visualization/imagining approach towards the concrete word pairs and an emotional/intuitive approach towards the abstract word pairs, via both open-ended and forced choice questions regarding strategy use. Another goal of this experiment was to address the hypothesis that the abstractness effect emerges from participants attending to the relationship between the words, via ratings. If it is not the words themselves that are being activated as abstract, but the relationship between them, when the single words making up the abstract word pair are rated individually, they should be rated as less abstract (or more concrete) than when rated together while considering the relationship between them. In contrast, ratings of concreteness for the concrete words should be comparable regardless of whether they are rated together or in isolation.

Method

Participants

Fifty (11 males, 39 females, M_{age} = 20.5 years, age range: 18–38 years) University of Windsor undergraduate students participated for partial course credit. All participants were at least 18 years of age, had learned English as their first language, and had normal or corrected-to-normal vision.

Materials

The same stimulus set from the iconicity judgment task in Malhi (2015) was used. See Chapter 2 for details regarding stimulus development. The full stimulus set is provided in Appendix A.

Procedure

Participants provided written informed consent. The iconicity judgment task instructions were explained with examples and an opportunity for questions. Participants first completed a practise session with four trials, including two concrete and two abstract word pairs not on the experimental list. The practise session included corrective feedback. Participants then completed the iconicity judgment task. In this task they were asked to indicate whether the positions of the words matched how their referents appear, either in everyday objects (for concrete words) or in relationships (for abstract words) by pressing the “Yes” key if the word pair was iconic (e.g., *stove*-*oven*) and pressing the “No” key if the word pair was reverse-iconic (e.g., *oven*-*stove*). For concrete words, participants were given the example of *pot* and *plant*, where one would expect to see a *plant* above a *pot*. For abstract words, participants were given the example of *doctor* and *patient*, where because of their greater authority and power, *doctor* would be above *patient*. To illustrate the different kinds of abstract relationships, participants were also given the example of *happy* and *sad*, where because of its positive and uplifting associations, *happy* would be above *sad*. Participants were advised not to make moral judgments and instead, to consider how concepts stereotypically appear. Participants were informed that RTs were being measured and that they should use both index fingers to make their responses as quickly as possible but not at the expense of accuracy. Following completion of the iconicity judgment task, participants answered questions regarding strategy use. The first two questions were open-ended, and the third question was forced choice. While it was possible that participants did not have insight into their own strategy use during the task, asking the open-ended questions ensured that all possible strategies were considered before biasing responses in the forced choice question. The strategy questions were followed by participants providing concreteness ratings for the stimuli. Instructions for concreteness ratings were based on the instructions in Altarriba et al. (1999), with ratings made on a scale ranging from 1 to 7. Participants were randomly assigned to one of two conditions. In condition one, participants rated the concreteness of the single words that made up the word pair. In this condition, single words, as opposed to the word pair, were presented to participants. In condition two, participants saw the word pairs together and were asked to rate the concreteness of the relationship between the word pair. All task instructions are provided in Appendix B.

Results

Data Cleaning

There were no responses faster than a preselected minimum cut-off of 300 ms and outliers with a standardized residual at a distance greater than 2.5 SD from 0 were removed during analyses (see next section). A minimum accuracy rate of 70% was used for both participants and words. This resulted in the removal of four participants (320 observations) and three word pairs (*boot – heel*, *lend – borrow*, and *host – guest*; 138 observations). All incorrect responses were removed, resulting in the removal of 262 observations (7.3% of the remaining data).

RT Analysis

Data was analyzed using R and the lmerTest package. Correct responses were analyzed in a linear mixed effects analysis. RTs were log transformed. As fixed effects, the factors concreteness, semantic neighbours, and iconicity were considered for the model. As random effects, subjects with random slopes for concreteness, semantic neighbours and iconicity, and items with random slopes for iconicity were considered for the model. Using forward and backward fitting, variables were removed, and the final model included fixed effects for concreteness, semantic neighbours, and iconicity, random slopes for concreteness by subject, and random slopes for item. After the model was fitted, data was trimmed using the LMERConvenienceFunctions package. Outliers with a standardized residual at a distance greater than 2.5 SD from 0 were excluded. This resulted in the removal of 60 observations (1.8% of the data). Skewness was .45 and kurtosis was -.094. Participant mean RTs, SDs, and error rates per condition for the final data set are displayed in Table 2. A caveat is that log and raw RTs are not on the same scale – however, all analyses were on log transformed RTs.

Table 2 *Mean RTs (with SDs) and Error Rates Per Condition in the Iconicity Task*

Condition	Mean Log RT (ms)	Mean Raw RT (ms)	Mean Error Rate (%)
Abstract-Close-Iconic	7.29 (.47)	1652.72 (954.99)	1.93
Abstract-Close-Reverse Iconic	7.38 (.42)	1772.68 (946.72)	6.28
Abstract-Distant-Iconic	7.39 (.43)	1786.39 (888.30)	3.48
Abstract-Distant-Reverse Iconic	7.5 (.46)	2027.47 (1120.38)	7.83
Concrete-Close-Iconic	7.62 (.44)	2268.89 (1120.73)	5.87
Concrete- Close-Reverse Iconic	7.81 (.42)	2693.59 (1284.68)	10.87
Concrete-Distant-Iconic	7.69 (.47)	2442.90 (1292.06)	8.70
Concrete-Distant-Reverse Iconic	7.84 (.49)	2875.61 (1587.51)	12.83

P-values were obtained for the fixed effects using the lmerTest package with Satterthwaite approximations to degrees of freedom. There was a main effect of concreteness [$b = -.35$, $t(88.5) = -10.06$, $p < .001$], with abstract word pairs yielding shorter RTs than concrete word pairs. There was a main effect of semantic neighbours [$b = -.083$, $t(74.8) = -2.58$, $p = .012$], with close semantic neighbours yielding shorter RTs than distant semantic neighbours. There was a main effect of iconicity [b = -.13, t(3104) = -10.3, p < .001], with iconic word pairs yielding shorter RTs than reverse-iconic word pairs. See Figure 1 for a graphical depiction of the effects of concreteness and iconicity. Error bars represent the standard error.

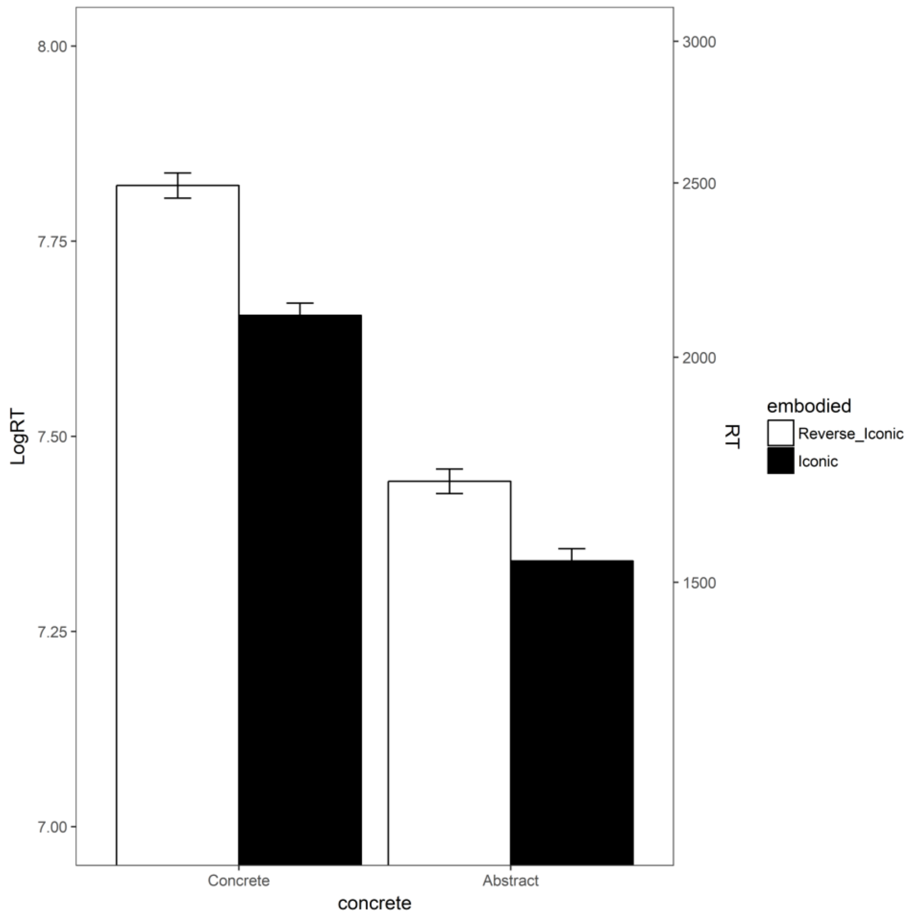


Figure 1. Concreteness and iconicity factors in the iconicity task (RTs).

Error Analysis

For accuracy, the binomial dependent variable (i.e., correct or incorrect) was analyzed using a mixed logit model (generalized linear mixed model). As fixed effects, the factors concreteness, semantic neighbours, and iconicity were considered for the model. As random effects, subjects with random slopes for concreteness, semantic neighbours and iconicity, and items with random slopes for iconicity were considered for the model. Using forward and backward fitting, variables were removed, and the final model included fixed effects for concreteness and iconicity, random slopes for subject, and random slopes for iconicity by item. There was a main effect of concreteness [b = -.71, z = -3.26, p = .0011], with abstract word pairs yielding fewer errors than concrete word pairs. There was a main effect of iconicity [b = -1.13, z = -4.88, p < .001], with iconic word pairs yielding fewer errors than reverse-iconic word pairs. There were no other effects to report as the semantic neighbours variable was removed during the model fitting procedure. See Figure 2 for a graphical depiction of the effects of concreteness and iconicity. Error bars represent the standard error.

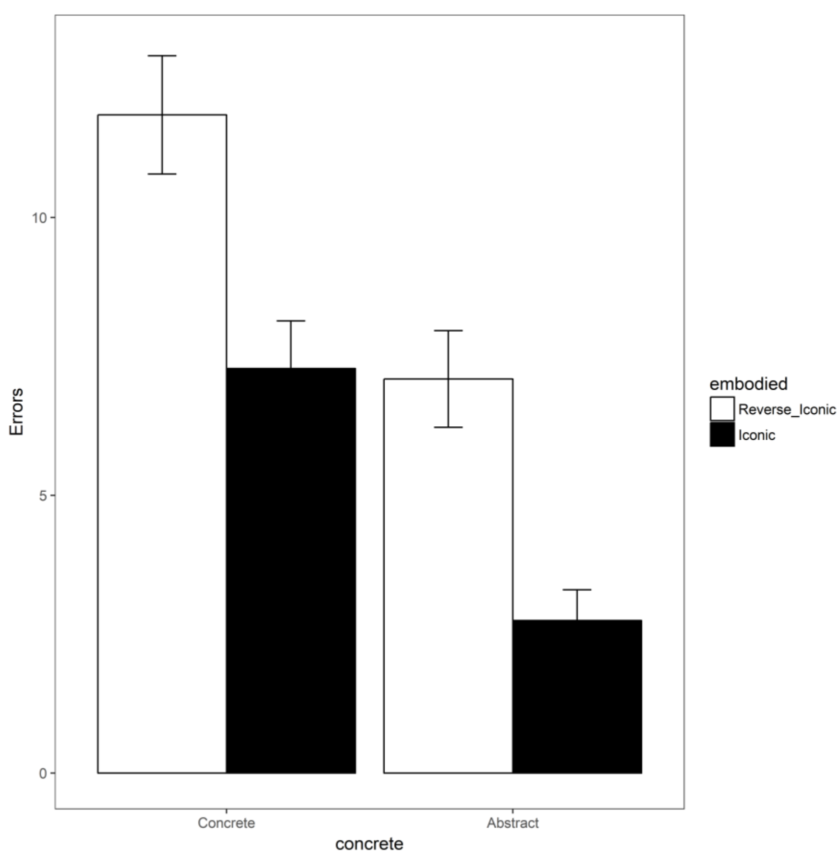


Figure 2. Concreteness and iconicity factors in the iconicity task (errors).

Strategy Questions Analysis

Open-ended responses were analyzed using a qualitative analysis of the text (Berg, 2009). First, three independent coders analyzed the text and came up with themes that represented ways of labelling all the unique content in the text. Different ways of expressing the same idea were combined (e.g., *authority*, *power*, *status*, and *in-charge* were combined into one theme). The content must have also been endorsed by more than one person. Next, the themes were compared and themes that reached agreement from the coders were selected. Finally, the coders completed a frequency count of the themes and rank ordered the themes based on which occurred most often. This analysis yielded *visual-spatial reasoning* as the major theme and *real-life experience* as the minor theme for the question, “What strategy did you use in responding to the concrete word pairs?” An example of how the visual-spatial reasoning theme was expressed by the participants is, “Made a picture in my mind.” An example of how the real-life experience theme was expressed is, “What things go on top were YES. Looked to see if the word on top was spatially on top in real life situations.” This analysis also yielded *social norms* as the major theme and *values* as the minor theme for the question, “What strategy did you use in responding to the abstract word pairs?” An example of how the social norms theme was expressed is, “Based answer on authority/position in society.” An example of how the values theme was expressed is, “What I considered better than the other I thought should be listed first.” Forced choice responses revealed that, for the concrete word pairs, 100% of participants used a visualization/imagining strategy and 0% of participants used an emotional/intuitive strategy. For the abstract word pairs, 26% of participants used a visualization/imagining strategy and 74% of participants used an emotional/intuitive strategy. See Figure 3 for a graphical depiction of the forced choice responses to strategy use.

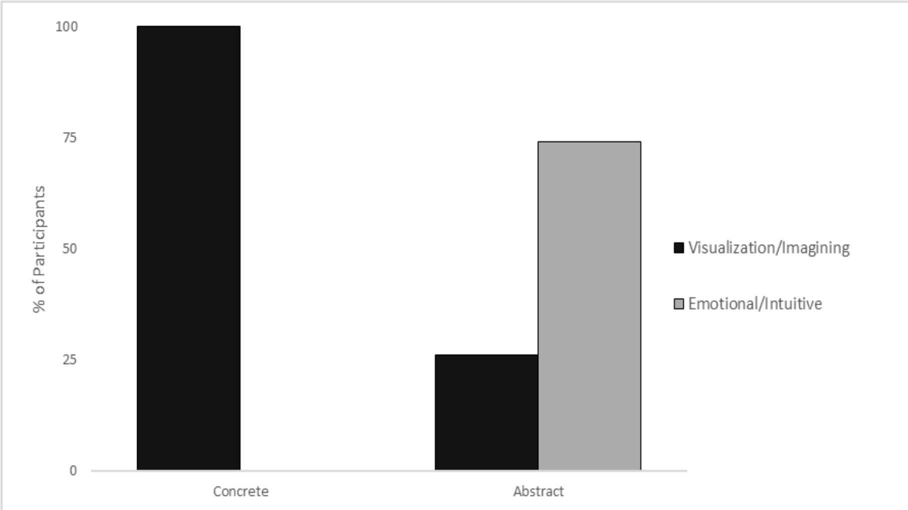


Figure 3. Strategy use for concrete and abstract word pairs in the iconicity task.

Ratings Analysis

A one-way repeated measures ANOVA revealed a main effect of concreteness [$F(1, 24) = 353.48$, $p < .001$], with concrete stimuli receiving a higher mean rating of concreteness compared to abstract stimuli. There was no main effect of presentation [$F(1, 25) = .18$, $p = .67$], such that there was no difference in the mean ratings of concreteness based on whether the words were presented as pairs or individually. There was also no interaction between concreteness and presentation [$F(1, 25) = .39$, $p = .54$]. Participant mean concreteness ratings and SD per condition are displayed in Table 3. See Appendix A for concreteness ratings of all word pairs.

Table 3 *Mean Concreteness Ratings (with SDs) Per Condition in the Ratings Task*

Condition	Mean Ratings
Abstract-Individual	3.13 (.85)
Abstract-Pair	2.94 (1.05)
Concrete-Individual	6.26 (.65)
Concrete-Pair	6.32 (.82)

Discussion

Experiment 1 was motivated by two hypotheses. The first hypothesis was that, in an iconicity judgment task, participants take a visualization/imagining approach towards the concrete word pairs and an emotional/intuitive approach towards the abstract word pairs. The second hypothesis was that the abstractness effect emerges from participants attending to the relationship between the words. Results provided support for only the first hypothesis. Responses to forced choice and open-ended questions about strategy use for the concrete word pairs were consistent. That is, all participants reported using a visualization/imagining strategy in the forced choice question, and visual-spatial reasoning emerged as the major theme in the qualitative analysis of the open-ended responses. While about a quarter of participants endorsed taking a visualization/imagining approach towards the abstract word pairs, no participant reported taking an emotional/intuitive approach towards the concrete word pairs. While the manipulation attempted to eliminate indirect visualizing/imagining of concrete associates by using abstract word pairs instead of abstract words, as some participants still reported visualizing/imagining the abstract word pairs, this suggests that the manipulation was successful in reducing rather than eliminating the tendency to concretize abstract words.

While there was consistency in the responses to open-ended and forced choice questions about strategy use for concrete word pairs, the open-ended question for the abstract word pairs revealed a more nuanced idea of what may constitute the emotional/intuitive approach. Specifically, participants described using social norms and values to make their decisions about the iconicity of abstract word pairs. Interestingly, values emerged as a theme, despite participants being instructed to withhold moral judgments. It may be that judgments on these tasks to the abstract word pairs unintentionally tap into implicit biases much like the implicit association task (IAT) intentionally does (Greenwald, McGhee, & Schwartz, 1998). With respect to the second hypothesis, ratings of the abstract word pairs did not significantly differ when the words were rated together compared to when they were rated individually. However, means were in the hypothesized direction, such that the mean concreteness ratings for abstract word pairs rated together were lower than the mean concreteness ratings for abstract words rated individually, whereas mean concreteness ratings for concrete word pairs showed the opposite pattern. One potential explanation for a lack of significant findings may be floor effects for the concreteness ratings of the abstract words and word pairs. However, the ratings showed partial support for the second hypothesis such that when abstract *words* were rated individually, some of them were rated to be concrete, i.e., above the midpoint of 4. However, no abstract *word pairs* were rated to be above the midpoint of 4. Moreover, the ratings confirmed the validity of the stimulus set with respect to concreteness, as concrete words received a mean concreteness rating of 6.29 and abstract words received a mean concreteness rating of 3.03.

CHAPTER 4

EXPERIMENT 2: EVENT-RELATED POTENTIALS ICONICITY JUDGMENT TASK

The goal of Experiment 2 was to replicate the iconicity judgment task from Experiment 1 in an ERP paradigm in order to investigate the neural underpinnings of the reverse concreteness, or abstractness, effect. More specifically, the goal of this experiment was to address the hypothesis that, in an iconicity judgment task, participants visualize the concrete word pairs but not the abstract word pairs. As concrete words elicit a larger N400 amplitude than abstract words and the N700 is considered to be an index of imagery, it was predicted that both components would be greater for the concrete word pairs, despite the absence of a behavioural concreteness effect.

Method

Participants

Twenty-three (six males, 17 females, M_{age} = 20.4 years, age range: 18–35 years) University of Windsor undergraduate students participated for partial course credit. All participants were at least 18 years of age, had learned English as their first language, were right-handed, and had normal or corrected-to-normal vision. Additionally, all participants were in good health, and none reported neurologic or psychiatric history.

Materials

The same stimulus set as Experiment 1 was used.

Procedure

Participants provided written informed consent. Horizontal eye movements were monitored using an electrode placed 1 cm lateral to the outer canthus of the right eye and vertical eye movements and blinks were monitored by an electrode placed above the center of the left eye. ERP data was recorded using an electrocap from 30 scalp sites (Fp1, Fp2, F7, F8, F3, F4, FT7, FT8, FC3, FC4, C3, C4, CP3, CP4, TP7, TP8, T7, T8, P3, P4, P7, P8, O1, O2, Fz, FCz, Cz, CPz, Pz, Oz) referenced to two electrodes on the left and right mastoids. The ground electrode was located 10 millimeters (mm) anterior to Fz. See Figure 4 for the electrode montage.

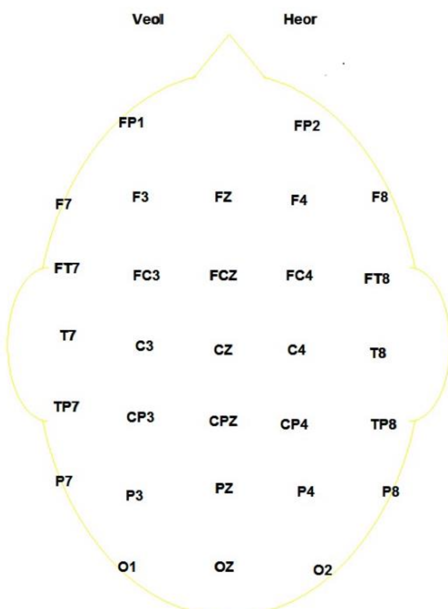


Figure 4. Montage of electrode placements on the scalp.

Following the set-up, participants were shown a monitor with the ERP signals. Participants were asked to scrunch up their face and were shown how signals could be affected with changes in facial expressions. Participants were then instructed not to move, make facial expressions, or blink excessively while completing the task in order to reduce artifacts. Next, a 5-minute baseline was established while participants looked at a black computer screen with their index fingers positioned on the response keys. The rest of the procedure was identical to the iconicity judgment task procedure from Experiment 1.

Results

Behavioural Data Cleaning

There were no responses faster than a preselected minimum cut-off of 300 ms and outliers with a standardized residual at a distance greater than 2.5 SD from 0 were removed during analyses (see next section). A minimum accuracy rate of 70% was used for both participants and words. This resulted in the removal of responses from one participant (80 observations) and two word pairs (*ferry – ocean* and *jockey – horse*; 46 observations). All incorrect responses were removed, resulting in the removal of 117 observations (6.52% of the remaining data).

RT Analysis

Data was analyzed using R and the lmerTest package. Correct responses were analyzed in a linear mixed effects analysis. RTs were log transformed. As fixed effects, the factors concreteness, semantic neighbours, and iconicity were considered for the model. As random effects, subjects with random slopes for concreteness, semantic neighbours and iconicity, and items with random slopes for iconicity were considered for the model. Using forward and backward fitting, variables were removed, and the final model included fixed effects for concreteness, random slopes for concreteness by subject, and random slopes by item. After the model was fitted, data was trimmed using the LMERConvenienceFunctions package. Outliers with a standardized residual at a distance greater than 2.5 SD from 0 were excluded. This resulted in the removal of 37 observations (2.21% of the data). Skewness was .40 and kurtosis was .017. Participant mean RTs, SDs, and error rates per condition for the final data set are displayed in Table 4. A caveat is that log and raw RTs are not on the same scale – however, all analyses were on log transformed RTs.

Table 4 *Mean RTs (with SDs) and Error Rates Per Condition in the ERP Iconicity Task*

Condition	Mean Log RT (ms)	Mean Raw RT (ms)	Mean Error Rate (%)
Abstract-Close-Iconic	7.31 (.51)	1732.61 (1086.13)	3.48
Abstract-Close-Reverse Iconic	7.38 (.45)	1777.23 (910.15)	5.65
Abstract-Distant-Iconic	7.34 (.42)	1699.93 (820.62)	3.91
Abstract-Distant-Reverse Iconic	7.46 (.39)	1873.51 (795.26)	6.52
Concrete-Close-Iconic	7.70 (.45)	2462.23 (1344.42)	8.26
Concrete- Close-Reverse Iconic	7.76 (.48)	2654.49 (1551.10)	8.70
Concrete-Distant-Iconic	7.78 (.44)	2644 (1335.75)	5.65
Concrete-Distant-Reverse Iconic	7.79 (.42)	2639.82 (1264.79)	10.63

There was a main effect of concreteness, with participants responding faster to abstract stimuli than concrete stimuli [b = -.38, t(72.09) = -7.24, p < .001]. There were no other effects to report as semantic neighbours and iconicity variables were removed during the model fitting procedure. To determine whether the additional instructions for the ERP design (e.g., asking participants to remain still) slowed down RTs, RTs from this experiment were compared with RTs from Experiment 1 and there were no significant differences [t(22) = .12, p = .91]

Error Analysis

For accuracy, the binomial dependent variable (i.e., correct or incorrect) was analyzed using a mixed logit model (generalized linear mixed model). As fixed effects, the factors concreteness, semantic neighbours, and iconicity were considered for the model. As random effects, subjects with random slopes for concreteness, semantic neighbours and iconicity, and items with random slopes for iconicity were considered for the model. Using forward and backward fitting, variables were removed, and the final model included fixed effects for concreteness, random slopes for subject, and random slopes for item. There was a main effect of concreteness [$b = -.62$, $z = -2.41$, $p = .016$], with abstract word pairs yielding fewer errors than concrete word pairs. There were no other effects to report as semantic neighbours and iconicity variables were removed during the model fitting procedure.

ERP Data Cleaning

Data was baseline corrected and trials contaminated by eye movements, muscular activity, or electrical noise were excluded from the analyses.

ERP Results

Grand average waveforms for concrete and abstract conditions across all scalp electrodes are presented in Figure 5 with Figure 6 zooming into electrode FCZ to show the scale. For each averaged ERP waveform, amplitude and latency of the N400 (300-500 ms) and N700 (500-800 ms) components were measured using a computer program, ERPScore, which enabled both the automatic scoring of peak amplitude and latency within a predefined time window as well as visual inspection of the average waveform (Segalowitz, 1999). For every subject, statistical analyses were conducted on the peak amplitude of 6 central electrode sites (C3, C4, CP3 CP4, T7, T8) and 8 posterior electrode sites (O1, O2, P3, P4, P7, P8, TP7, TP8) within the N400 epoch, and on the peak amplitude of 10 anterior electrode sites (FP1, FP2, F3, F4, F7, F8, FC3, FC4, FT7, FT8) within the N700 epoch. Peak amplitudes to correct responses were analyzed using repeated measures ANOVAs. Greenhouse-Geisser corrected p-values are reported due to violations of sphericity common in ERP data (Luck, 2014). For the N400 epoch, there was an interaction between concreteness and electrode site [$F(1, 22) = 4.41$, $p = .047$]. Follow-up analyses revealed that, toward more central scalp locations concrete stimuli were associated with a more negative waveform than were abstract stimuli [$t(22) = 2.75$, $p = .012$]. The voltage difference between concrete and abstract stimuli was not significant at posterior scalp locations [$t(22) = 1.99$, $p = .059$]. There were no main effects of semantic neighbours [$F(1, 22) = .97$, $p = .34$] or iconicity [$F(1, 22) = .025$, $p = .88$] and no interactions between these factors and electrode site. For the N700 epoch, an omnibus ANOVA of the peak amplitudes showed that, overall, concrete stimuli were associated with a more negative waveform than were abstract stimuli [$F(1, 22) = 9.09$, $p = .006$]. There were no main effects of semantic neighbours [$F(1, 22) = .35$, $p = .56$] or iconicity [$F(1, 22) = .1$, $p = .76$]. There were no significant findings with respect to latencies.

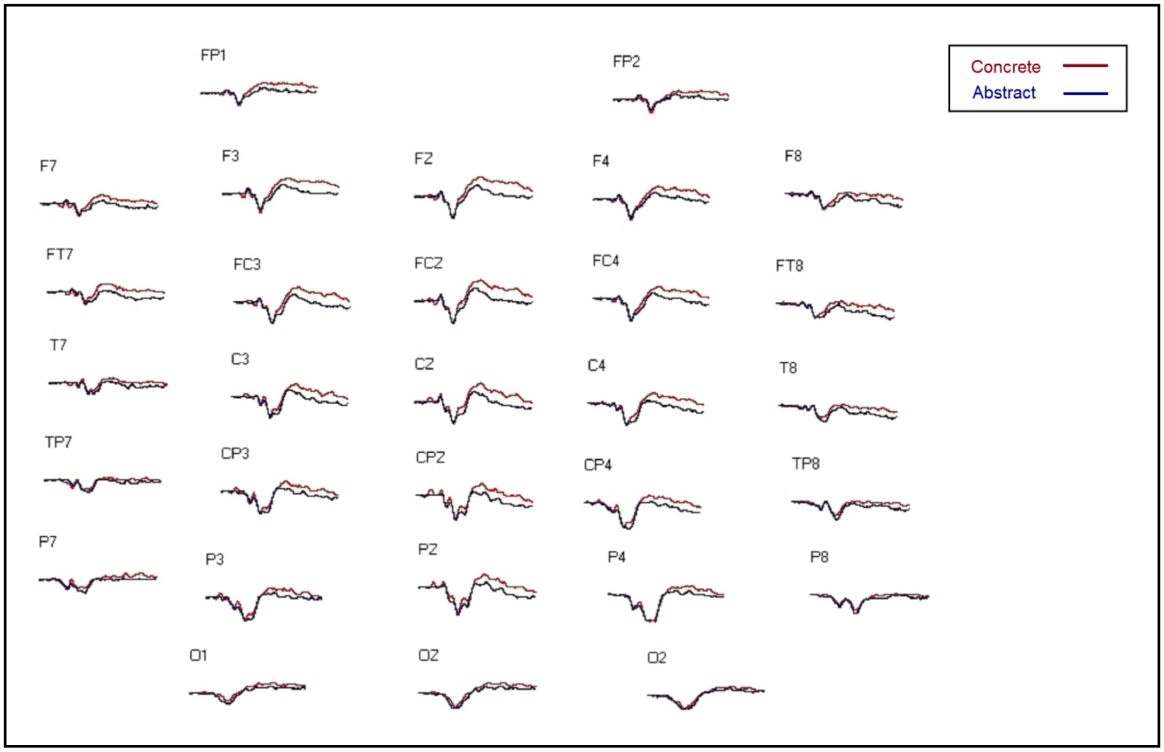


Figure 5. Grand average waveforms (negative amplitudes peak upwards) for concrete and abstract conditions.

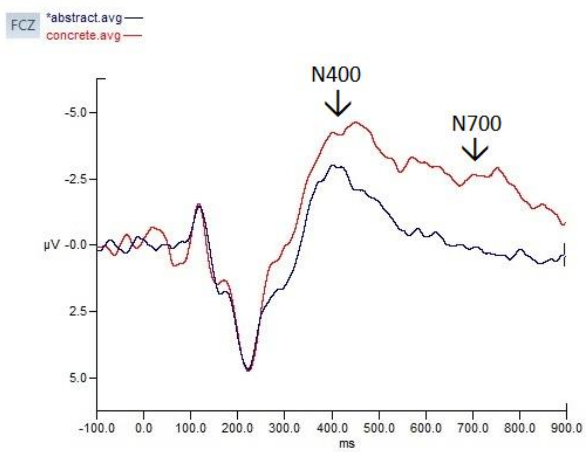


Figure 6. Electrode FCZ zoomed in.

Discussion

The results of Experiment 2 provided support for the hypothesis that in an iconicity judgment task, participants visualize the concrete word pairs but not the abstract word pairs. The goal of this experiment was to replicate the iconicity judgment task from Experiment 1 in an ERP paradigm. The central N400, which is generated in response to concrete words, and the anterior N700, which is considered to be an index of imagery, were greater for the concrete word pairs, despite a behavioural abstractness effect. The anterior N700 also suggests that responding to concrete words in an iconicity judgment task involves visual working memory and activates the executive control system. The results of this experiment support the successful development of a stimulus set that measures abstractness while circumventing the confound of concretizing via indirect visualization of abstract words. As RTs were shorter for the abstract word pairs, there was a dissociation between RTs and ERP waveforms, with the outcome of behavioural abstractness with neural concreteness. This demonstrates that the same neural activity (i.e., N400 and anterior N700) can behaviourally manifest differently (i.e., as concreteness or as abstractness) based on task demands.

At this point, I propose a *flexible abstractness and concreteness effects* (FACE) theory to integrate and account for the findings in Experiments 1 and 2 and elsewhere in the literature. See Figure 7 for a visual presentation of the FACE theory. Bidirectional arrows represent a reciprocal relationship (i.e., task influences how stimuli are processed, and stimuli influences how the task is performed). The tenets and predictions of the FACE theory are as follows:

1. **Abstractness and concreteness effects are task-dependent** (Paivio & O'Neill, 1970; Malhi, 2015). Task factors may include task demands, instructions, depth of processing (Barsalou et al., 2008; Louwerse & Jeuniaux, 2010), timing (i.e., early in a task or late in a task; Barsalou et al., 2008), etc.
2. **Even in cases where an impairment for abstract words is predicted, such as in deep dyslexia, tasks should be able to demonstrate both abstractness and concreteness effects.** For example, both abstractness and concreteness effects have been demonstrated depending on implicit (i.e., iconicity judgment) versus explicit (i.e., oral word-reading) task demands in deep dyslexia (Boumaraf & Macoir, 2016; Malhi et al., submitted; Newton & Barry, 1997).
3. **Abstractness and concreteness effects depend on the proxy used for measuring the concept.** As Borghi et al. (2017) notes "We do not intend to equate concepts and words... Where possible, we will distinguish between concepts and word meanings and focus on concepts; in most of the cases, however, it is impossible, because tasks on conceptual representation in human adults usually involve the use of words." Therefore, whether abstractness and concreteness is measured using pictures, words, word pairs, etc. will influence the conclusions drawn. The study of abstract word pairs and the relationship of

the words in the word pair may allow getting closer to measuring the concept of abstractness while helping circumvent the problem of concretizing abstract words.

4. **Stimuli characteristics interact with task to produce FACE.** For example, the greater imageability of concrete words compared to abstract words may facilitate RTs for concrete words in one task (e.g., image generation task; Ernest & Paivio, 1971) but hinder them in another (e.g., iconicity judgment task; Malhi, 2015; current study). The literature describes imageability using a dichotomy of high and low, with concrete words high on imageability and abstract words low on imageability. However, with the concretizing of abstract words through indirect visualization (i.e., visualization of concrete associates), the concrete associates of abstract words may be highly imageable. As such, I propose a novel dichotomy when considering imageability for concrete and abstract words: **direct and indirect imageability**. Direct imageability refers to the idea that when we visualize a concrete word (e.g., apple), we directly visualize the concrete word itself (e.g., *apple*). Indirect imageability refers to the idea that when we visualize an abstract word (e.g., *education*), we indirectly visualize the abstract word by visualizing a concrete associate (e.g., *teacher*). Related to that, I propose a second dichotomy of imageability: **confined and free imageability**. The latter proposal is based on the idea that the images of concrete words are confined such that there are a limited number of ways in which one can visualize a concrete word. However, there are infinite ways in which one can visualize an abstract word as the visualization of an abstract words depends on the concrete associate one visualizes and there can be considerable variation in the concrete associate one links to the abstract word. Borghi and Binkofski (2014), in a somewhat similar vein, argued that abstract concepts are characterized by greater

meaning variability, such that the meaning of abstract concepts is more changeable than the meaning of concrete concepts. These stimuli characteristics (direct-indirect imageability and confined-free imageability) interact with task to produce FACE.

5. There are FACE such that there may be abstractness behaviourally and concreteness with respect to neural markers (i.e., N400 and anterior N700), or vice versa. In other words, **there may be a dissociation between behavioural and neural data** (Barber et al., 2013; current study) **and this may be a result of task demands.**
6. **Symbolic and embodied information is available for both concrete and abstract words, but such information is flexibly recruited.**
7. **Some factors that drive FACE are implicitly processed** (e.g., semantic neighbourhood distance is a numerical value which influences participants' performance, but it is outside of participants' awareness) **and some are both implicit and explicit** (e.g., iconicity can be implicit if it is not relevant to the task such as in a semantic relatedness task or it can be explicit if it is relevant to the task such as in an iconicity judgment task).

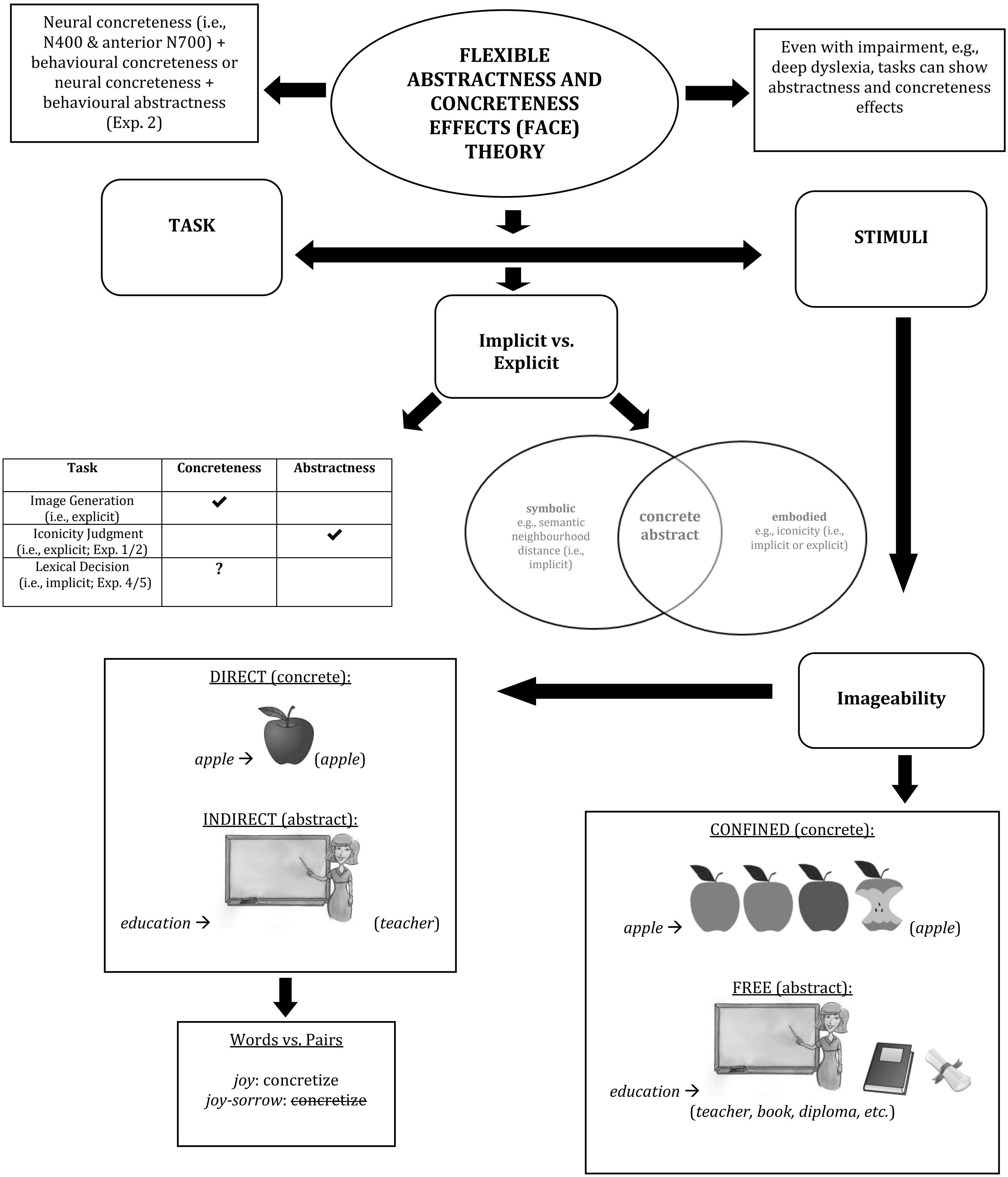


Figure 7. Visual presentation of the FACE theory.

CHAPTER 5

EXPERIMENT 3: ICONICITY JUDGMENT TASK FOR CONCRETE WORD PAIRS AND PICTURES

The goal of Experiment 3 was to address the hypothesis that if iconicity judgments of concrete word pairs take longer because participants first visualize the words, then providing pictures prior to the concrete words should facilitate processing.

Method

Participants

Twenty-five (four males, 21 females, M_{age} = 21.6 years, age range: 19–38 years) University of Windsor undergraduate students participated for partial course credit. All participants were at least 18 years of age, had learned English as their first language, and had normal or corrected-to-normal vision.

Materials

The concrete word pairs from Experiment 1’s stimulus set were used along with pictures to match the words. Pictures were either obtained from the Internet under creative commons licenses or drawn and coloured by artists from our lab. All pictures were drawings as opposed to photographs depicting real objects. Pictures were standardized in size. The stimulus set of picture and word pairs is provided in Appendix C.

Procedure

Participants provided written informed consent. The picture iconicity judgment task instructions were explained with examples and an opportunity for questions. Participants first completed a practise session with four trials of word pairs primed by picture pairs not on the experimental list. The practise session included corrective feedback. Each picture pair was presented for 1000 ms before the word pair appeared. Participants then made their iconicity judgment, as in Experiment 1, to the word pair. Task instructions are provided in Appendix D.

Results

Data Cleaning

There were no responses faster than a preselected minimum cut-off of 200 ms (adjusted from the 300 ms from prior tasks to reflect the lower difficulty level of this task) and outliers with a standardized residual at a distance greater than 2.5 SD from 0 were removed during analyses (see next section). A minimum accuracy rate of 70% was used for both participants and words. This resulted in the removal of one participant (40 observations). All incorrect responses were removed, resulting in the removal of 47 observations (5.04% of the remaining data).

RT Analysis

Data was analyzed using R and the lmerTest package. Correct responses were analyzed in a linear mixed effects analysis. RTs were log transformed. As fixed effects, the factors semantic neighbours and iconicity were considered for the model. As random effects, subjects with random slopes for semantic neighbours and iconicity, and items with random slopes for iconicity were considered for the model. Using forward and backward fitting, variables were removed, and the final model included fixed effects for iconicity, random slopes for subject, and random slopes for item. After the model was fitted, data was trimmed using the LMERConvenienceFunctions package. Outliers with a standardized residual at a distance greater than 2.5 SD from 0 were excluded. This resulted in the removal of 12 observations (1.35% of the data). Skewness was -

.078 and kurtosis was -.094. Participant mean RTs, SDs, and error rates per condition for the final data set are displayed in Table 5. A caveat is that log and raw RTs are not on the same scale – however, all analyses were on log transformed RTs.

Table 5 *Mean RTs (with SDs) and Error Rates Per Condition in the Picture Iconicity Task*

Condition	Mean Log RT (ms)	Mean Raw RT (ms)	Mean Error Rate (%)
Close-Iconic	6.95 (.77)	1430.55 (1429.91)	1.72
Close-Reverse Iconic	7.18 (.75)	1693.49 (1256.92)	7.73
Distant-Iconic	7.12 (.73)	1593.06 (1181.60)	3.43
Distant-Reverse Iconic	7.26 (.73)	1843.23 (1480.65)	7.26

P-values were obtained for the fixed effects using the lmerTest package with Satterthwaite approximations to degrees of freedom. There was a main effect of iconicity [b = -.19, t(810.7) = -5.4, p < .001], with iconic word pairs yielding shorter RTs than reverse-iconic word pairs. There were no other effects to report as the semantic neighbours variable was removed during the model fitting procedure.

Error Analysis

For accuracy, the binomial dependent variable (i.e., correct or incorrect) was analyzed using a mixed logit model (generalized linear mixed model). As fixed effects, the factors semantic neighbours and iconicity were considered for the model. As random effects, subjects with random slopes for semantic neighbours and iconicity, and items with random slopes for iconicity were considered for the model. Using forward and backward fitting, variables were removed, and the final model included fixed effects for iconicity, random slopes for subject, and random slopes for item. There was a main effect of iconicity [b = -1.15, z = -3.31, p < .001], with iconic word pairs yielding fewer errors than reverse-iconic word pairs. There were no other effects to report as the semantic neighbours variable was removed during the model fitting procedure.

Experiment 1 and Experiment 3 Combined Results

RT Analysis

Data was analyzed using R and the lmerTest package. Correct responses were analyzed in a linear mixed effects analysis. RTs were log transformed. As fixed effects, the factors task, semantic neighbours, and iconicity were considered for the model. As random effects, subjects with random slopes for semantic neighbours and iconicity, and items with random slopes for task and iconicity were considered for the model. Using forward and backward fitting, variables were removed, and the final model included fixed effects for task, semantic neighbours, and iconicity, random slopes for semantic neighbours by subject and random slopes for item. After the model was fitted, data was trimmed using the LMERConvenienceFunctions package. Outliers with a standardized residual at a distance greater than 2.5 SD from 0 were excluded. This resulted in the removal of 45 observations (1.76% of the data). Skewness was -.44 and kurtosis was .66. Participant mean RTs, SDs, and error rates per condition for the final data set are displayed in Table 6.

A second model was added post-hoc to compare responses to the abstract word pairs in the iconicity judgment task with the concrete word pairs in the picture iconicity judgment task. As fixed effects, the factors task/concreteness, semantic neighbours, and iconicity were considered for the model. As random effects, subjects with random slopes for semantic neighbours and iconicity, and items with random slopes for iconicity were considered for the model. Using forward and backward fitting, variables were removed, and the final model included fixed effects for task/concreteness, semantic neighbours, and iconicity, random slopes for subject, and random slopes for iconicity by item. After the model was fitted, data was trimmed using the LMERConvenienceFunctions package. Outliers with a standardized residual at a distance greater than 2.5 SD from 0 were excluded. This resulted in the removal of 54 observations (2.12% of the data). Skewness was -.13 and kurtosis was .72. Participant mean RTs, SDs, and error rates per condition for the final data set are displayed in Table 6. A caveat is that log and raw RTs are not on the same scale – however, all analyses were on log transformed RTs.

Table 6 *Mean RTs (with SDs) and Error Rates Per Condition in the Picture and Iconicity Tasks*

Condition	Mean Log RT (ms)	Mean Raw RT (ms)	Mean Error Rate (%)
Iconicity-Close-Iconic (Abstract)	7.30 (.48)	1687.68 (1027.70)	1.93
Iconicity-Close-Reverse Iconic (Abstract)	7.38 (.42)	1776.85 (948.99	6.28
Iconicity-Distant-Iconic (Abstract)	7.41 (.45)	1846.70 (1078.26)	3.48
Iconicity-Distant-Reverse Iconic (Abstract)	7.51 (.47)	2063.56 (1197.46)	7.83
Iconicity-Close-Iconic (Concrete)	7.64 (.46)	2317.57 (1244.38)	5.87
Iconicity-Close-Reverse Iconic (Concrete)	7.82 (.44)	2770.89 (1494.54)	10.87
Iconicity-Distant-Iconic (Concrete)	7.69 (.47)	2456.61 (1308.89)	8.70
Iconicity-Distant-Reverse Iconic (Concrete)	7.84 (.50)	2905.87 (1655.69)	12.83
Picture-Close-Iconic	6.98 (.71)	1380.46 (1111.72)	1.72
Picture- Close-Reverse Iconic	7.18 (.71)	1651.03 (1110.73)	7.73
Picture-Distant-Iconic	7.11 (.71)	1562.18 (1144.40)	3.43
Picture-Distant-Reverse Iconic	7.28 (.70)	1836.16 (1370.02)	7.26

P-values were obtained for the fixed effects using the lmerTest package with Satterthwaite approximations to degrees of freedom. For the first model, there was a main effect of task [b = -.64, $t(68)$ = -6.88, p < .001], with the picture iconicity task yielding shorter RTs compared to the iconicity task. There was a main effect of semantic neighbours [b = -.15, $t(166.1)$ = -6.08, p < .001], with close semantic neighbours yielding shorter RTs than distant semantic neighbours. There was a main effect of iconicity [b = -.17, $t(2333.1)$ = -10.52, p < .001], with iconic word pairs yielding shorter RTs than reverse-iconic word pairs. See Figure 8 for a graphical depiction of the results. Error bars represent the standard error. For the second model, there was a main effect of task/concreteness [b = .28, $t(92.89)$ = 2.8, p = .0063], with concrete words in the picture iconicity task yielding shorter RTs compared to abstract words in the iconicity task. There was a main effect of semantic neighbours [b = -.13, $t(70.87)$ = -2.88, p = .0053], with close semantic neighbours yielding shorter RTs than distant semantic neighbours. There was a main effect of iconicity [b = -.12, $t(61.85)$ = -5.84, p < .001], with iconic word pairs yielding shorter RTs than reverse-iconic word pairs.

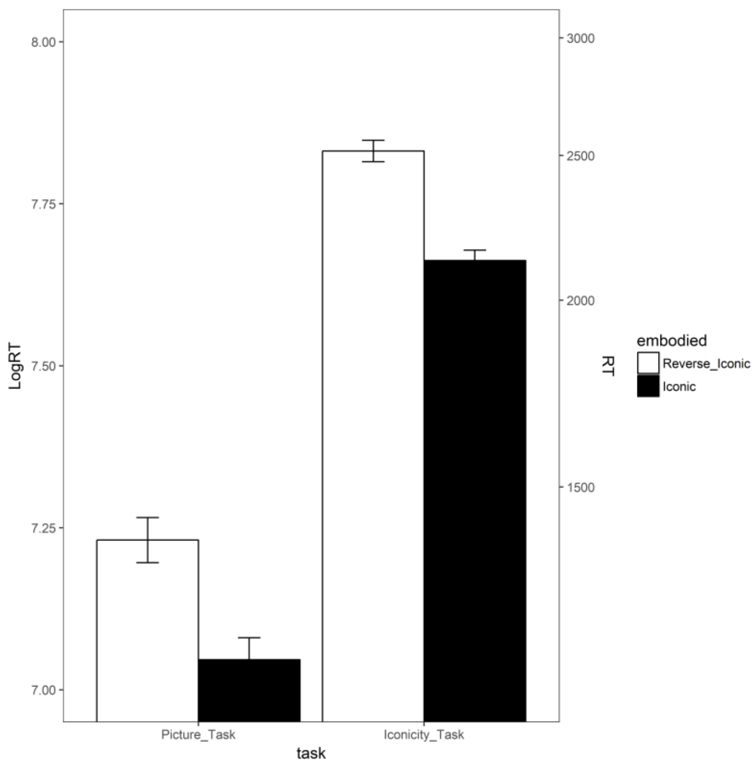


Figure 8. Iconicity factor in the iconicity and picture iconicity tasks (RTs).

Error Analysis

For accuracy, the binomial dependent variable (i.e., correct or incorrect) was analyzed using a mixed logit model (generalized linear mixed model). As fixed effects, the factors task, semantic neighbours, and iconicity were considered for the model. As random effects, subjects with random slopes for semantic neighbours and iconicity, and items with random slopes for task and iconicity were considered for the model. Using forward and backward fitting, variables were removed, and the final model included fixed effects for task and iconicity, random slopes for subject, and random slopes for item. There was a main effect of task [$b = -.72$, $z = -3.25$, $p = .0012$], with the picture iconicity task yielding fewer errors compared to the iconicity task. There was a main effect of iconicity [$b = -.70$, $z = -4.81$, $p < .001$], with iconic word pairs yielding fewer errors than reverse-iconic word pairs. There were no other effects to report as the semantic neighbours variable was removed during the model fitting procedure. See Figure 9 for a graphical depiction of the results. Error bars represent the standard error. For the second model, as fixed effects, the factors task, semantic neighbours, and iconicity were considered for the model. As random effects, subjects with random slopes for semantic neighbours and iconicity, and items with random slopes for iconicity were considered for the model. Using forward and backward fitting, variables were removed, and the final model included iconicity as a fixed effect, random slopes for subject, and random slopes for iconicity by item. There was a main effect of iconicity [$b = -1.77$, $z = -4.51$, $p < .001$], with iconic word pairs yielding fewer errors than reverse-iconic word pairs. There were no other effects to report as task and semantic neighbours variables were removed during the model fitting procedure.

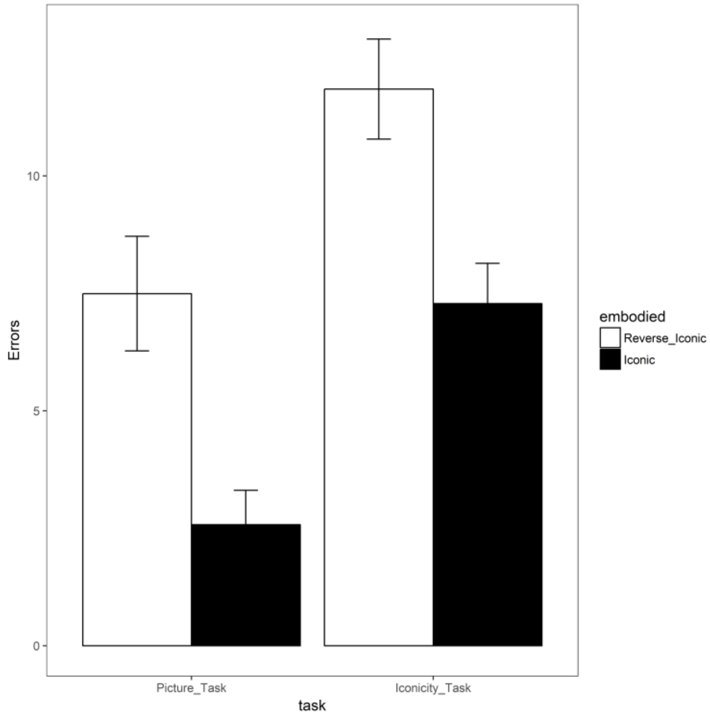


Figure 9. Iconicity factor in the iconicity and picture iconicity tasks (errors).

Discussion

The results of Experiment 3 supported the hypothesis that iconicity judgments of concrete word pairs take longer than iconicity judgments of abstract word pairs because participants take a visualization/imagining approach to the concrete word pairs. As hypothesized, RTs were longer in the original iconicity judgment task to concrete word pairs compared to RTs in the picture iconicity judgment task, where participants were provided with pictures prior to seeing each word pair. As the only difference between the two tasks was that participants were provided with pictures in the picture iconicity judgment task, it can be inferred that the longer RTs in the original iconicity judgment task were the result of a lack of pictures, and consequently, participants having to visualize/imagine the concrete word pairs on their own. Providing pictures not only facilitated processing in terms of RTs, but there were also fewer errors in the picture iconicity judgment task compared to the number of errors to concrete word pairs in the original iconicity judgment task. Providing further support for the hypothesis, RTs were shorter to concrete words in the picture iconicity judgment task when compared to abstract words in the iconicity judgment task. However, a limitation of this comparison is that it confounds task and stimuli effects. In order to disentangle these effects, the abstract words would also have to be presented in the picture iconicity judgment task, but this would not be feasible.

CHAPTER 6

EXPERIMENT 4: NON-PRONOUNCEABLE LEXICAL DECISION TASK

The goal of Experiment 4 was to address the second hypothesis that the abstractness effect will not be found in tasks where participants do not attend to the relationship between the words. In a lexical decision task, participants make speeded judgments about whether a letter string is a word or a nonword. While the meaning of the words may be activated, lexical decision tasks, especially with non-pronounceable nonwords as foils, are considered to be a shallow form of processing. As such, it is less likely that a lexical decision task would activate the relationship between the words (however, the task may still activate the meaning of the individual words). Consequently, if the second hypothesis is correct, then the results should demonstrate a concreteness effect (consistent with the literature on single-word processing) and not an abstractness effect.

Method

Participants

Twenty-five (nine males, 16 females, M_{age} = 21.2 years, age range: 18–31 years) University of Windsor undergraduate students participated for partial course credit. All participants were at least 18 years of age, had learned English as their first language, and had normal or corrected-to-normal vision.

Materials

The real word pairs were all of the words from Experiment 1’s stimulus set. There were 40 nonsense word pairs consisting of both nonwords matched on word length to 20 concrete and 20 abstract word pairs. There were also 20 nonsense word pairs consisting of one nonword matched on word length to a concrete word and one real concrete word matched on both word length and orthographic frequency to a concrete word. As well, there were 20 nonsense word pairs consisting of one nonword matched on word length to an abstract word and one real abstract word matched on both word length and orthographic frequency to an abstract word. Twenty of the 40 nonsense word pairs consisting of one nonword and one real word had the nonword presented first and 20 had the real word presented first. The stimulus set is provided in Appendix E.

Procedure

Participants provided written informed consent. The non-pronounceable lexical decision task instructions were explained with examples and an opportunity for questions. Participants first completed a practise session with eight trials, including two concrete word pairs, two abstract word pairs, and four nonsense word pairs, all not on the experimental list. The practise session included corrective feedback. Participants then saw word pairs (stimulus set from Experiment 1) and nonsense word pairs and were asked to indicate whether the pair of words were both words or not. Task instructions are provided in Appendix F.

Results

Data Cleaning

Only responses to target word pairs were included in the analysis. There were no responses faster than a preselected minimum cut-off of 300 ms and outliers with a standardized residual at a distance greater than 2.5 SD from 0 were removed during analyses (see next section). A minimum accuracy rate of 70% was used for both participants and words. This did not result in the removal of any responses. All incorrect responses were removed, resulting in the removal of 29 observations (1.45% of the remaining data).

RT Analysis

Data was analyzed using R and the lmerTest package. Correct responses were analyzed in a linear mixed effects analysis. RTs were log transformed. As fixed effects, the factors concreteness, semantic neighbours, and iconicity were considered for the model. As random effects, subjects with random slopes for concreteness, semantic neighbours and iconicity, and items with random slopes for iconicity were considered for the model. Using forward and backward fitting, variables were removed, and the final model included an intercept model with random slopes for subject and item. After the model was fitted, data was trimmed using the LMERConvenienceFunctions package. Outliers with a standardized residual at a distance greater than 2.5 SD from 0 were excluded. This resulted in the removal of 47 observations (2.39% of the data). Skewness was .73 and kurtosis was .60. Participant mean RTs, SDs, and error rates per condition for the final data set are displayed in Table 7. A caveat is that log and raw RTs are not on the same scale – however, all analyses were on log transformed RTs.

Table 7 *Mean RTs (with SDs) and Error Rates Per Condition in the Non-Pronounceable Lexical Decision Task*

Condition	Mean Log RT (ms)	Mean Raw RT (ms)	Mean Error Rate (%)
Abstract-Close-Iconic	6.75 (.35)	910.29 (373.87)	2.0
Abstract-Close-Reverse Iconic	6.75 (.33)	906.14 (342.90)	1.6
Abstract-Distant-Iconic	6.77 (.33)	921.70 (362.65)	1.2
Abstract-Distant-Reverse Iconic	6.76 (.34)	915.24 (366.37)	1.2
Concrete-Close-Iconic	6.70 (.33)	864.86 (344.06)	.80
Concrete- Close-Reverse Iconic	6.72 (.33)	880.73 (329.66)	2.0
Concrete-Distant-Iconic	6.73 (.32)	887.63 (333.52)	1.2

Concrete-Distant-Reverse Iconic	6.71 (.30)	861.92 (283.93)	1.6

There were no effects to report as concreteness, semantic neighbours, and iconicity variables were removed during the model fitting procedure.

Error Analysis

For accuracy, the binomial dependent variable (i.e., correct or incorrect) was analyzed using a mixed logit model (generalized linear mixed model). As fixed effects, the factors concreteness, semantic neighbours, and iconicity were considered for the model. As random effects, subjects with random slopes for concreteness, semantic neighbours and iconicity, and items with random slopes for iconicity were considered for the model. Using forward and backward fitting, variables were removed, and the final model included an intercept model with random slopes for subject and item. There were no effects to report as concreteness, semantic neighbours, and iconicity variables were removed during the model fitting procedure.

Discussion

The goal of Experiment 4 was to test the hypothesis that the abstractness effect will not be found when participants do not attend to the relationship between the words. Compared to an iconicity judgment task, a lexical decision task with non-pronounceable words requires shallower processing. Making speeded judgments about whether words are real words, unlike the iconicity judgment task, does not necessitate attending to the relationship between the words, although the task may still activate the meaning of the individual words. If the abstractness effect is found in tasks where participants attend to the relationship between the words, then a lexical decision task with non-pronounceable words should not show an abstractness effect as it does not require participants to attend to the relationship between the words. In contrast, results should show a concreteness effect consistent with the literature on single-word processing.

Consistent with the hypothesis, results from Experiment 4 showed that the abstractness effect was not found when participants did not attend to the relationship between the words. A lexical decision task with non-pronounceable words using the same stimuli as the iconicity judgment task failed to show an abstractness effect. However, inconsistent with the hypothesis, there was no concreteness effect. Moreover, there were no main effects at all (i.e., no effects of semantic neighbours or iconicity). One explanation is that the lexical decision task with non-pronounceable words was so shallow, that not only did participants not attend to the relationship between the words, but the task also did not activate the meaning of the individual words. The goal of Experiment 5 was to investigate this possibility by replicating Experiment 4 with pronounceable nonwords.

CHAPTER 7

EXPERIMENT 5: PRONOUNCEABLE LEXICAL DECISION TASK

Like Experiment 4, the goal of Experiment 5 was to address the second hypothesis that the abstractness effect will not be found in tasks where participants do not attend to the relationship between the words. Pronounceable lexical decision tasks involve deeper processing compared to non-pronounceable lexical decision tasks. Considering that the non-pronounceable lexical decision task from Experiment 4 found no main effects, it may have been the case that the task was too shallow to even activate the meaning of the individual words. To investigate this possibility, Experiment 5 included a pronounceable lexical decision task.

Method

Participants

Twenty-five (eight males, 17 females, M_{age} = 20.4 years, age range: 18–24 years) University of Windsor undergraduate students participated for partial course credit. All participants were at least 18 years of age, had learned English as their first language, and had normal or corrected-to-normal vision.

Materials

The real word pairs were all of the words from Experiment 1's stimulus set. There were 40 pronounceable nonword pairs consisting of both nonwords matched on word length to 20 concrete and 20 abstract word pairs. There were also 20 pronounceable pairs consisting of one nonword matched on word length to a concrete word and one real concrete word matched on both word length and orthographic frequency to a concrete word. As well, there were 20 pronounceable pairs consisting of one nonword matched on word length to an abstract word and one real abstract word matched on both word length and orthographic frequency to an abstract word. Twenty of the 40 pronounceable pairs consisting of one nonword and one real word had the nonword presented first and 20 had the real word presented first. The stimulus set is provided in Appendix G.

Procedure

Participants provided written informed consent. The pronounceable lexical decision task instructions were explained with examples and an opportunity for questions. Participants first completed a practise session with eight trials, including two concrete word pairs, two abstract word pairs, and four nonsense pronounceable word pairs, all not on the experimental list. The practise session included corrective feedback. Participants then saw word pairs (stimulus set from Experiment 1) and nonsense pronounceable word pairs and were asked to indicate whether the pair of words were both words or not. Task instructions are provided in Appendix H.

Results

Data Cleaning

Only responses to target word pairs were included in the analysis. There were no responses faster than a preselected minimum cut-off of 300 ms and outliers with a standardized residual at a distance greater than 2.5 SD from 0 were removed during analyses (see next section). A minimum accuracy rate of 70% was used for both participants and words. This resulted in the removal of responses from one word pair (*meek* – *bold*; 25 observations). All incorrect responses were removed, resulting in the removal of 51 observations (2.57% of the remaining data).

RT Analysis

Data was analyzed using R and the lmerTest package. Correct responses were analyzed in a linear mixed effects analysis. RTs were log transformed. As fixed effects, the factors concreteness, semantic neighbours, and iconicity were considered for the model. As random effects, subjects with random slopes for concreteness, semantic neighbours and iconicity, and items with random slopes for iconicity were considered for the model. Using forward and backward fitting, variables were removed, and the final model included fixed effects for semantic neighbours and random slopes for subject and item. After the model was fitted, data was trimmed using the LMERConvenienceFunctions package. Outliers with a standardized residual at a distance greater than 2.5 SD from 0 were excluded. This resulted in the removal of 49 observations (2.54% of the data). Skewness was .84 and kurtosis was .64. Participant mean RTs, SDs, and error rates per condition for the final data set are displayed in Table 8. A caveat is that log and raw RTs are not on the same scale – however, all analyses were on log transformed RTs.

Table 8 *Mean RTs (with SDs) and Error Rates Per Condition in the Pronounceable Lexical Decision Task*

Condition	Mean Log RT (ms)	Mean Raw RT (ms)	Mean Error Rate (%)
Abstract-Close-Iconic	6.83 (.33)	976.644 (372.28)	1.2
Abstract-Close-Reverse Iconic	6.84 (.34)	999.13 (428.60)	2.8
Abstract-Distant-Iconic	6.97 (.35)	1142.90 (479.71)	1.69
Abstract-Distant-Reverse Iconic	6.88 (.31)	1027.65 (364.46)	.84
Concrete-Close-Iconic	6.86 (.31)	1000.97 (361.05)	2.4
Concrete- Close-Reverse Iconic	6.85 (.33)	997.10 (387.62)	3.2
Concrete-Distant-Iconic	6.92 (.35)	1084.12 (438.42)	2
Concrete-Distant-Reverse Iconic	6.93 (.33)	1085.44 (419.67)	3.2

P-values were obtained for the fixed effects using the lmerTest package with Satterthwaite approximations to degrees of freedom. There was a main effect of semantic neighbours [b = -.083, t(75.69) = -3.25, p = .0017], with close semantic neighbours yielding shorter RTs than distant semantic neighbours. There were no other effects to report as concreteness and iconicity variables were removed during the model fitting procedure. See Figure 10 for a graphical depiction of the results. Error bars represent the standard error.

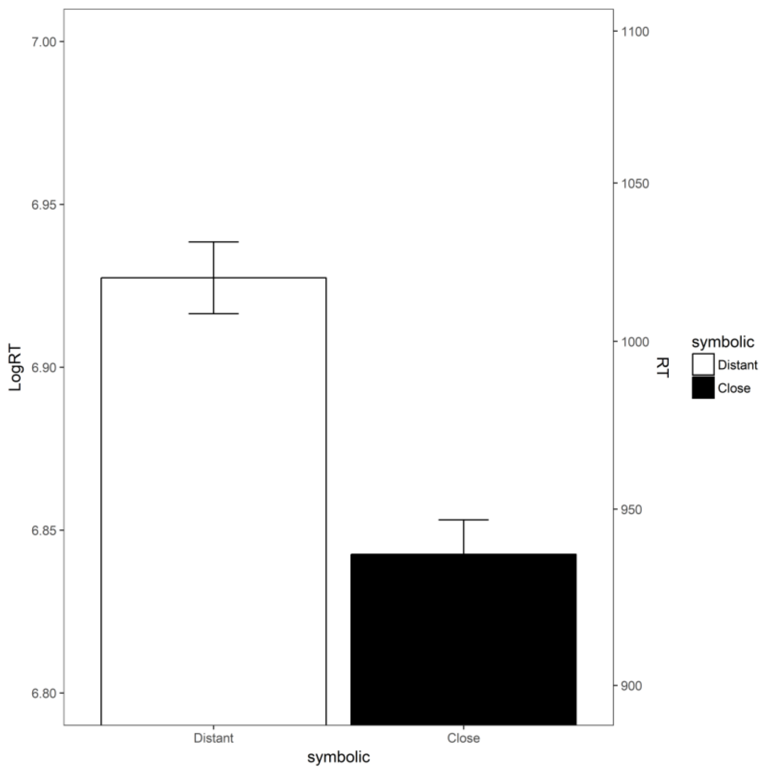


Figure 10. Semantic neighbours factor in the pronounceable lexical decision task (RTs).

Error Analysis

For accuracy, the binomial dependent variable (i.e., correct or incorrect) was analyzed using a mixed logit model (generalized linear mixed model). As fixed effects, the factors concreteness, semantic neighbours, and iconicity were considered for the model. As random effects, subjects with random slopes for concreteness, semantic neighbours and iconicity, and items with random slopes for iconicity were considered for the model. Using forward and backward fitting, variables were removed, and the final model included an intercept model with random slopes for subject and item. There were no effects to report as concreteness, semantic neighbours, and iconicity variables were removed during the model fitting procedure.

Discussion

The results of Experiment 4, using a non-pronounceable lexical decision task, supported the hypothesis that the abstractness effect is not found in tasks where participants do not attend to the relationship between the words. Experiment 5 included a pronounceable lexical decision task and again, the results supported this hypothesis, as no abstractness effects were found. While the results of Experiment 4 failed to find any main effects, the results of Experiment 5 found that RTs were shorter for close semantic neighbours compared to distant semantic neighbours. As the pronounceable lexical decision task from Experiment 5 requires a deeper level of processing than the non-pronounceable lexical decision task from Experiment 4, it may be that the task in Experiment 5 activated the meaning of the individual words to some degree (i.e., as captured by the differences in semantic neighbourhood distance).

CHAPTER 8

CONCLUSIONS

General Discussion

The overall goal of this study was to investigate the origins of a reverse concreteness, or abstractness, effect found for word pairs in an iconicity judgment task. The results of this study supported the first hypothesis that participants were taking a visualization and imagining approach (2-steps; time-costly) towards the concrete word pairs and an emotional and intuitive approach (1-step; time-efficient) towards the abstract word pairs. When participants were supplied with pictures, they became more time-efficient at completing the task as they no longer had the additional step of generating a mental image for the concrete word pairs before mentally manipulating them. When comparing performance on the picture iconicity judgment task with performance to abstract words on the iconicity judgment task, supplying pictures increased efficiency such that the abstractness advantage disappeared. The results of the study also offered new insights beyond the hypothesized visualization/imagining and emotional/intuitive strategies, showing that participants also used real-life experiences for the concrete word pairs and social norms and values for the abstract word pairs. Moreover, the results of the ERP study indicated the role of visual working memory (i.e., holding mental images in mind to make a judgment) and executive functioning (i.e., mentally manipulating the images) in the iconicity judgment task for the concrete word pairs.

The results of this study also supported the second hypothesis that the abstractness effect will be found in tasks where participants attend to the relationship between the words and will not be found in tasks where participants do not attend to the relationship between the words. While there was no difference in the concreteness ratings of words rated individually or in pairs, both lexical decision tasks showed the absence of an abstractness effect. Taken together, the results of this study suggest that abstractness effects are task-dependent. In an iconicity judgment task, abstractness effects were observed, whereas in a lexical decision task, they were not. Integrating findings in the literature where the majority of studies report concreteness effects and some report abstractness effects, this study offers a methodological contribution such that abstractness effects were enhanced by participants attending to the relationship between the words.

Not only are abstractness effects task-dependent, but the role of symbolic and embodied factors is similarly task-dependent. Considering the symbolic and embodied factors as a function of task, the pronounceable lexical decision task showed an effect of the symbolic factor, semantic neighbourhood distance, whereas the iconicity and the picture iconicity judgment tasks showed the effect of the embodied factor, iconicity. This is consistent with the *symbol interdependency hypothesis* and previous work (i.e., Malhi, 2015), where the symbolic factor was recruited for the semantic relatedness task and the embodied factor was recruited for the iconicity judgment task.

Overall, the results of this study are consistent with the proposed *flexible abstractness and concreteness effects* (FACE) theory.

1. Abstractness and concreteness effects are task-dependent. The results of Experiments 1 and 2 using an iconicity judgment task revealed abstractness effects whereas the results of Experiments 4 and 5 with the same stimuli but using a lexical decision task showed no advantage for abstract stimuli. While not tested as part of this study, the FACE theory would give rise to the prediction that using the same stimuli in an image generation task (e.g., Ernest & Paivio, 1971) would reveal concreteness effects.

2. Even in cases where an impairment for abstract words is predicted, such as in deep dyslexia, tasks should be able to demonstrate both abstractness and concreteness effects. This was not tested as part of the present study but is a prediction of the FACE theory that has been supported elsewhere (e.g., Boumaraf & Macoir, 2016; Malhi et al., submitted; Newton & Barry, 1997).

3. Abstractness and concreteness effects depend on the proxy used for measuring the concept. The results of Experiment 3 showed that RTs were shorter to concrete word pairs preceded by picture pairs when compared to concrete word pairs presented alone. Experiments 1 and 2 provided support for the idea that participants were not visualizing the abstract word pairs, suggesting that the study of abstract word pairs may allow getting closer to measuring the concept of abstractness while avoiding the concretizing of abstract words.

4. Stimuli characteristics interact with task to produce FACE. The results of Experiments 1 and 2 (iconicity judgment tasks; abstractness effects) versus the results of Experiments 4 and 5 (lexical decision tasks; no abstractness effects) demonstrates that the task influences how the stimuli are processed (i.e., advantage for abstract stimuli or not) and the stimuli influences how the task is processed (e.g., concrete words in the iconicity judgment task are visualized whereas abstract words are not). While the constructs of direct vs. indirect and confined vs. free imageability were introduced, they were not tested as part of this study. Future research can study the validity of these constructs. For example, for confined vs. free imageability, future research can examine the extent of agreement among participants for the concrete associates generated in response to visualizing abstract words. Future research can also study the interaction between these constructs (e.g., some abstract words may be indirect but highly confined such as visualizing the *statue of liberty* for the abstract word *liberty*).

5. There may be a dissociation between behavioural and neural data and this may be a result of task demands. While the literature reports the N400 and anterior N700 along with behavioural concreteness, the results of Experiment 2 showed the N400 and anterior N700 along with behavioural abstractness.

6. Symbolic and embodied information is available for both concrete and abstract words, but such information is flexibly recruited. The availability of embodied information for abstract words has been questioned. The results from the strategy questions from Experiment 1 suggest that concrete words may be grounded in sensorimotor information and real-life experiences and abstract words may be grounded in emotions, values, and social norms. For the latter, I propose using the term <u>sociocultural norms</u> as social norms are not universal, but rather rooted in culture. Slang words like “sick” illustrate how abstract words may be grounded in society and culture as such word meanings are derived from the cultures and subcultures in which one is socialized. Furthermore, even conceptual metaphors may be culturally based (e.g., languages that read right to left may differ on their positive and negative associations with right and left dimensions). This is not to say that sensorimotor information does influence abstract word processing or that sociocultural factors do not influence concrete word processing. Rather, sensorimotor information is more salient for grounding concrete words than abstract words, and sociocultural factors are more salient for grounding abstract words than concrete words.

7. Some factors that drive FACE are implicitly processed and some are both implicit and explicit. For example, in Experiments 1, 2, and 3, semantic neighbourhood distance was an implicit factor, but iconicity was an explicit factor, however, in Experiments 4 and 5, both semantic neighbourhood distance and iconicity were implicit factors.

The FACE theory adds to the existing literature by extending theories that integrate symbolic and embodied accounts (e.g., LASS; Barsalou et al., 2008; *representational pluralism*; Dove, 2009; *symbol interdependency hypothesis*; Louwerse, 2007). The FACE theory not only integrates symbolic and embodied accounts, but it also considers their relationship to concrete and abstract word processing. Similarly, the FACE theory also extends theories of concrete and abstract word processing (e.g., *dual coding theory*; Paivio, 1971 and *context-availability theory*; Schwanenflugel et al., 1988; Schwanenflugel & Shoben, 1983; Schwanenflugel & Stowe, 1989), by considering their relationship to symbolic and embodied factors. For theories that already consider these components (e.g., *words as tools*; Borghi & Binkofski, 2014; *affective embodiment account*; Kousta et al., 2011; *theory of embodied abstract semantics*; Vigliocco et al., 2009), the FACE theory extends these theories by grounding abstract words in emotion (Kousta et al., 2011; Vigliocco et al., 2009) and sociality (Borghi et al., 2017), and also in values, social norms, and culture. In addition to including a sociocultural component, some other novel propositions of the FACE theory include ideas of direct/confined and indirect/free imageability, implicit versus explicit symbolic and embodied influences, and using word pairs to get closer to the measurement of the concept of abstractness. Moreover, the FACE theory offers both an account of normal and impaired processing (i.e., deep dyslexia). The FACE theory also attempts to integrate abstractness and concreteness effects in both behavioural and neural data. Overall, the FACE theory attempts to answer recent calls for theories that include flexibility in conceptual processing and explain the grounding of abstract concepts (Barsalou, 2016), as well as theories that emphasize the social dimension for concepts and language (Borghi et al., 2017).

Limitations

The FACE theory is not without its limitations, of course. For example, it is unable to account for abstractness effects despite the later acquisition of these words relative to concrete words. Moreover, its account of impaired processing is limited to deep dyslexia. Finally, it does not explain how abstractness and concreteness effects may manifest in bilingualism. These are areas for future directions.

Future Directions

Other areas for future research include further exploration of the link between visual working memory and concreteness during an iconicity judgment task. Based on prior research (Kellogg et al., 2007; Mate et al., 2012; Parker & Dagnall, 2009; van Schie et al., 2005), occupying one's visual working memory while they simultaneously complete the iconicity judgment task should selectively interfere with iconicity judgments for concrete word pairs but not for abstract word pairs. Future research can investigate the role of sensory modality presentation on the results. In other words, how would the results change if the iconicity judgment task was presented auditorily instead of visually. Similarly, what if a phonological working memory task was used as opposed to a visual working memory task. The N400 and the N700 appear to be reliable ERP components of concreteness and imagery, respectively. Future research can explore whether abstractness and emotion can similarly be mapped onto ERP components. Future research can also explore individual differences in emotionality and performance for abstract word pairs.

REFERENCES

Akpinar, E., & Berger, J. (2015). Drivers of cultural success: The case of sensory metaphors. *Journal of Personality and Social Psychology, 109*(1), 20-34. doi:10.1037/pspa0000025

Altarriba, J., Bauer, L. M., & Benvenuto, C. (1999). Concreteness, context availability, and imageability ratings and word associations for abstract, concrete, and emotion words. *Behavior Research Methods, Instruments, and Computers, 31*(4), 578-602. doi:10.3758/BF03200738

Andrews, M., Frank, S., & Vigliocco, G. (2014). Reconciling embodied and distributional accounts of meaning in language. *Topics in Cognitive Science, 6*(3), 359-370. doi:10.1111/tops.12096

Aravena, P., Hurtado, E., Riveros, R., Cardona, J. F., Manes F., & Ibanez, A. (2010). Applauding with closed hands: Neural signature of action-sentence compatibility effects. *PLoS ONE, 5*(7), e11751. doi:10.1371/journal.pone.0011751

Aziz-Zadeh, L., Wilson, S. M., Rizzolatti, G., & Iacoboni, M. (2006). Congruent embodied representations for visually presented actions and linguistic phrases describing actions. *Current Biology, 16,* 1-6. doi:10.1016/j.cub.2006.07.060

Bak, T. H., O'Donovan, D. G., Xuereb, J. H., Boniface, S., & Hodges, J. R. (2001). Selective impairment of verb processing associated with pathological changes in Brodmann areas 44 and 45 in the motor neurone disease-dementia-aphasia syndrome. *Brain, 124*, 103-120. doi:10.1093/brain/124.1.103

Barber, H. A., Otten, L. J, Kousta, S. T., & Vigliocco, G. (2013). Concreteness in word processing: ERP and behavioral effects in a lexical decision task. *Brain & Language, 125*, 47-53. doi:10.1016/j.bandl.2013.01.005

Barsalou, L. W. (1999). Perceptual symbol systems. *Behavioral and Brain Sciences, 22*, 577-660. doi:10.1017/S0140525X99002149

Barsalou, L. W. (2003). Abstraction in perceptual symbol systems. *Philosophical Transactions of the Royal Society of London: Biological Sciences, 358*(1435), 1177-1187. doi: 10.1098/rstb.2003.1319

Barsalou, L. W. (2016). On staying grounded and avoiding quixotic dead ends. *Psychonomic Bulletin and Review, 23*, 1122-1142. doi:10.3758/s13423-016-1028-3

Barsalou, L. W., & Wiemer-Hastings, K. (2005). Situating abstract concepts. In D. Pecher & R. Zwaan (Eds.), Grounding cognition: The role of perception and action in memory, language, and thought (pp. 129-163). New York: Cambridge University Press.

Bennett, S., Burnett, N., Siakaluk, P. D., & Pexman, P. (2011). Imageability and body – object interaction ratings for 599 multisyllabic nouns. *Behavior Research Methods, 43*(4), 1100-1109. doi:10.3758/s13428-011-0117-5

Berg, B. (2009). *Qualitative research methods for the social sciences*. Boston, MA: Allyn and Bacon.

Binder, J. R. (2016). In defense of abstract conceptual representations. *Psychonomic Bulletin and Review, 23*(4), 1096-1108 doi:10.3758/s13423-015-0909-1.

Binder, J. R., Westbury, C. F., McKiernan, K. A., Possing, E. T., & Medler, D. A. (2005). Distinct brain systems for processing concrete and abstract concepts. *Journal of Cognitive Neuroscience*, *17*(6), 905-917. doi:10.1162/0898929054021102

Binkofski, F., Amunts, K., Stephan, K. M., Posse, S., Schormann, T., Freund, H.-J., et al. (2000). Broca’s region subserves imagery of motion: A combined cytoarchitectonic and fMRI study. *Human Brain Mapping*, *11*(4), 273-285. doi:10.1002/1097-0193

Bird, H., Franklin, S., & Howard, D. (2001). Age of acquisition and imageability ratings for a large set of words, including verbs and function words. *Behavior Research Methods, Instruments, and Computers, 33*(1), 73-79. doi:10.3758/BF03195349

Blei, D., Ng, A., & Jordan, M. (2003). Latent Dirichlet allocation. *Journal of Machine Learning Research, 3*, 993-1022. Retrieved from https://www.cs.princeton.edu/~blei/papers/BleiNgJordan2003.pdf

Bonner, M. F., Vesely, L., Price, C., Anderson, C., Richmond, L., Farag, C., . . . Grossman, M. (2009). Reversal of the concreteness effect in semantic dementia. *Cognitive Neuropsychology, 26*(6), 568-579. doi:10.1080/02643290903512305

Borghi, A. M., Binkofski, F., Castelfranchi, C., Cimatti, F., Scorolli, C., & Tummolini, L. (2017). The challenge of abstract concepts. *Psychological Bulletin, 143*(3), 263-292. doi:10.1037/bul0000089

Borghi, A. M., & Binkofski, F. (2014). *Words as social tools: An embodied view on abstract concepts.* New York: Springer.

Boulenger, V., Hauk, O., & Pulvermuller, F. (2009). Grasping ideas with the motor system: Semantic somatotopy in idiom comprehension. *Cerebral Cortex, 19*, 1905-1914. doi:10.1093/cercor/bhn217

Boulenger, V., Mechtouff, L., Thobois, S., Broussolle, E., Jeannerod , M., & Nazir, T. A. (2008). Word processing in Parkinson’s disease is impaired for action verbs but not for concrete nouns. *Neuropsychologia, 46*(2), 743-756. doi:10.1016/j.neuropsychologia.2007.10.007

Boumaraf, A., & Macoir, J. (2016). The influence of visual word form in reading: Single case study of an Arabic patient with deep dyslexia. *Reading and Writing, 29*, 137-158. doi:10.1007/s11145-015-9583-y

Breedin, S. D., Saffran, E. M., & Coslett, H. B. (1994). Reversal of the concreteness effect in a patient with semantic dementia. *Cognitive Neuropsychology, 11*(6), 617-660. doi:10.1080/02643299408251987

Buchanan, L., Burgess, C., & Lund, K. (1996). Overcrowding in semantic neighborhoods: Modeling deep dyslexia. *Brain and Cognition, 32*(2), 111-114.

Buchanan, L., Westbury, C., & Burgess, C. (2001). Characterizing semantic space: Neighbourhood effects in word recognition. *Psychonomic Bulletin and Review, 8*(3), 531-544. doi:10.3758/BF03196189

Burgess, C., & Conley, P. (1998). Representing proper names and objects in a common semantic space: A computational model. *Brain and Cognition*, *40*, 67-70. doi:10.1.1.8.3089

Burgess, C., & Lund, K. (1997). Modelling parsing constraints with high-dimensional context space. *Language and Cognitive Processes, 12*(2/3), 177-210. doi:10.1080/016909697386844

Chasteen, A. L., Burdzy, D. C., & Pratt, J. (2010). Thinking of God moves attention. *Neuropsychologia, 48*(2), 627-630. doi:10.1016/j.neuropsychologia.2009.09.029

Chen, M., & Bargh, J. A. (1999). Consequences of automatic evaluation: Immediate behavioral predispositions to approach or avoid the stimulus. *Personality and Social Psychology Bulletin*, *25*, 215-224.

Collins, A. M., & Loftus, E. F. (1975). A spreading-activation theory of semantic processing. *Psychological Review, 82*(6), 407-428. doi:10.1037/0033-295X.82.6.407

Collins, A. M., & Quillian, M. R. (1969). Retrieval time from semantic memory. *Journal* *of Verbal Learning and Verbal Behavior, 8,* 240-247. doi:10.1016/S0022-5371(69)80069-1

Coltheart, M., Patterson, K. E., & Marshall, J. C. (1980). *Deep dyslexia*. London, UK: Routledge & Kegan Paul.

Crutch, S. J., & Warrington, E. K. (2005). Abstract and concrete concepts have structurally different representational frameworks. *Brain, 128*, 615-627. doi:10.1093/brain/awh349

Damasio, A. R. (1989). The brain binds entities and events by multiregional activation from convergence zones. *Neural Computation*, *1*(1), 123-132. doi:10.1162/neco.1989.1.1.123

Danguecan, A. N., & Buchanan, L. (2016). Semantic neighborhood effects for abstract versus concrete words. *Frontiers in Psychology, 7*, 1034. doi:10.3389/fpsyg.2016.01034

Dhond, R. P., Witzel, T., Dale, A. M., & Halgren, A. (2007). Spatiotemporal cortical dynamics underlying abstract and concrete word reading. *Human Brain Mapping, 28*, 355-362. doi:10.1002/hbm.20282

Dove, G. (2009). Beyond perceptual symbols: A call for representational pluralism. *Cognition, 110*(3), 412-431. doi:10.1016/j.cognition.2008.11.016

Dove, G. (2011). On the need for embodied and dis-embodied cognition. *Frontiers in Psychology, 1*, 242. doi:10.3389/fpsyg.2010.00242

Dove, G. (2016). Three symbol ungrounding problems: Abstract concepts and the future of embodied cognition. *Psychonomic Bulletin & Review*, *23*(4), 1109-1121. doi:10.3758/s13423-015-0825-4

Durda, K., & Buchanan, L. (2008). WINDSORS: Windsor improved norms of distance and similarity of semantics. *Behavior Research Methods*, *40*(3), 705-712. doi:10.3758/BRM.40.3.705

Durda, K., Buchanan, L., & Caron, R. (2009). Grounding co-occurrence: Identifying features in a lexical co-occurrence model of semantic memory. *Behavior Research Methods*, *41*(4), 1210-1223. doi:10.3758/BRM.41.4.1210

Durda, K., & Buchanan, L. (2006). *WordMine2* [Online] Available: http://web2.uwindsor.ca/wordmine

Epstein, R. (1984). The principle of parsimony and some applications in psychology. *Journal of Mind and Behavior*, *5*(2), 119-130. doi:

Ernest C. H., & Paivio, A. (1971). Imagery and verbal associative latencies as a function of imagery ability. *Canadian Journal of Psychology*, *25*(1), 83-90. doi:10.1037/h0082371

Esopenko, C., Gould, L., Cummine, J., Sarty, G. E., Kuhlmann, & Borowsky, R. (2012). A neuroanatomical examination of embodied cognition: Semantic generation to action-related stimuli. *Frontiers in Human Neuroscience, 6*, 84. doi:10.3389/fnhum.2012.00084

Estes, Z., Verges, M., & Barsalou, L. W. (2008). Head up, foot down: Object words orient attention to the objects' typical location. *Psychological Science, 19*(2), 93-97. doi:10.1111/j.1467-9280.2008.02051.x

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, *41*, 1149-1160.

Fodor, J.A. (1975). *The language of thought*. Cambridge, MA: Harvard University Press.

Foltz, P. W., Kintsch, W. & Landauer, T. K. (1998). The measurement of textual coherence with Latent Semantic Analysis. *Discourse Processes, 25*(2/3), 285-307. doi:10.1.1.21.1029

Franklin, S., Howard, D., & Patterson, K. (1995). Abstract word anomia. *Cognitive Neuropsychology, 12*, 549-566. doi:10.1080/02643299508252007

Gibbs, R. W. J. (1994). *The poetics of mind: Figurative thought, language, and understanding*. New York: Cambridge University Press.

Glenberg, A. M., & Kaschak, M. P. (2002). Grounding language in action. *Psychonomic Bulletin and Review, 9,* 558-565. doi:10.3758/BF03196313

Glenberg, A. M., & Robertson, D. A. (1999). Indexical understanding of instructions. *Discourse Processes, 28*, 1–26. doi:10.1080/01638539909545067

Glenberg, A. M., Sato, M., Cattaneo, L., Riggio, L., Palumbo, P., & Buccino, G. (2008). Processing abstract language modulates motor system activity. *The Quarterly Journal of Experimental Psychology, 61*(6), 905-919. doi:10.1080/17470210701625550

Goodhew, S. C., McGaw, B., & Kidd, E. (2014). Why is the sunny side always up? Explaining the spatial mapping of concepts by language use. *Psychonomic Bulletin and Review, 21*, 1287-1293. doi:10.3758/s13423-014-0593-6

Greenwald, A. G., McGhee, D. E., & Schwartz, J. L. K. (1998). Measuring individual differences in implicit cognition: The Implicit Association Test. *Journal of Personality and Social Psychology, 74*(6), 1464-1480. doi:10.1037/0022-3514.74.6.1464

Griffiths, T. L., Steyvers, M., & Tenenbaum, J. B. (2007). Topics in semantic representation. *Psychological Review, 114*, 211-244. doi:10.1037/0033-295X.114.2.211

Guan, C. Q., Meng, W., Yao, R., & Glenberg, A. M. (2013). The motor system contributes to comprehension of abstract language. *PLoS ONE, 8*(9), e75183. doi:10.1371/journal.pone.0075183

Gullick, M. M., Mitra, P., & Coch, D. (2013). Imagining the truth and the moon: An electrophysiological study of abstract and concrete word processing. *Psychophysiology, 50*, 431-440. doi:10.1111/psyp.12033

Hauk, O., Johnsrude, I., & Pulvermuller, F. (2004). Somatotopic representation of action words in human motor and premotor cortex. *Neuron, 41*, 301-307. doi:10.1016/S0896-6273(03)00838-9

Harnad, S. (1990). The symbol grounding problem. *Physica D, 42*, 335-346. doi: 10.1016/0167-2789(90)90087-6

Hinton, G. E., McClelland, J. L., & Rumelhart, D. E. (1986). Distributed representations. In D. E. Rumelhart & J. L. McClelland (Eds.), *Parallel distributed processing: Explorations in the microstructure of cognition Vol. 1: Foundations* (pp. 77-109). Cambridge, MA: MIT Press.

Holcomb, P. J., Kounios, J., Anderson, J. E., & West, W. C. (1999). Dual-coding, context-availability, and concreteness effects in sentence comprehension: An electrophysiological investigation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *25*, 721-742. doi:10.1037/0278-7393.25.3.721

Huang, H., & Federmeier, K. D. (2015). Imaginative language: What event-related potentials have revealed about the nature and source of concreteness effects. *Language and Linguistics*, *16*(4), 503-515. doi:10.1177/1606822X15583233

Huang, H., Lee, C., & Federmeier, K. D. (2010). Imagine that! ERPs provide evidence for distinct hemispheric contributions to the processing of concrete and abstract concepts. *NeuroImage*, *49*(1), 1116-1123. doi:10.1016/j.neuroimage.2009.07.031

Hutchinson, S., & Louwerse, M. M. (2012). The upbeat of language: Linguistic context and embodiment predict processing valence words. *Proceedings of the Annual Meeting of the Cognitive Science Society, 34*(34), 1709-1714.

Iliev, R., & Axelrod, R. (2017). The paradox of abstraction: Precision versus concreteness.

Journal of Psycholinguist Research, 46, 715-729. doi:10.1007/s10936-016-9459-6

Jaeger, T. F. (2008). Categorical data analysis: Away from ANOVAs (transformation or not) and towards logit mixed models, *Journal of Memory and Language*, *59*, 434-446. doi:10.1016/j.jml.2007.11.007

Jarvis, B. G. (2012). DirectRT (Version 2012) [Computer Software]. New York, NY: Empirisoft Corporation.

Jeannerod, M. (1995). Mental imagery in the motor context. *Neuropsychologia, 33*(11), 1419-1432. doi:10.1016/0028-3932(95)00073-C

Jeannerod, M., & Decety, J. (1995). Mental motor imagery: A window into the representational stages of action. *Current Opinion in Neurobiology, 5*(6), 727-732. doi:10.1016/0959-4388(95)80099-9

Jirak, D., Menz, M. M., Buccino, G., Borghi, A. M., & Binkofski, F. (2010). Grasping language - a short story on embodiment. *Consciousness and Cognition, 19*(3), 711-720. doi:10.1016/j.concog.2010.06.020

Jones, M. N., & Mewhort, D. J. K. (2007). Representing word meaning and order information in a composite holographic lexicon. *Psychological Review, 114*(1), 1-37. doi:10.1037/0033-295X.114.1.1

Katz, R. B., & Goodglass, H. (1990). Deep dysphasia: Analysis of a rare form of repetition disorder. *Brain and Language, 39*, 153-185. doi:10.1016/0093-934X(90)90009-6

Kellogg, R.T., Olive, T., & Piolat, A. (2007). Verbal, visual, and spatial working memory in written language production. *Acta Psychologica, 124,* 382-397. doi:10.1016/j.actpsy.2006.02.005

Kintsch, W. (2000). Metaphor comprehension: A computational theory. *Psychonomic*

Bulletin and Review, *7*(2), 257-266. doi:10.3758/BF03212981

Kounios, J., & Holcomb, P. J. (1994). Concreteness effects in semantic processing: ERP evidence supporting dual-coding theory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *20*, 804-823. doi:10.1037/0278-7393.20.4.804

Kousta, S. T., Vigliocco, G., Vinson, D., Andrews, M., & Del Campo, E. (2011). The representation of abstract words: Why emotion matters. *Journal of Experimental Psychology: General, 140,* 14-34. doi:10.1037/ a0021446

Kroll, J. F., & Merves, J. S. (1986). Lexical access for concrete and abstract words. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12*(1), 92-107. doi:10.1037/0278-7393.12.1.92

Kuperman, V., Stadthagen-Gonzalez, H., & Brysbaert, M. (2012). Age-of-acquisition ratings for 30,000 English words. *Behavioural Research, 44,* 978-990. doi:10.3758/s13428-012-0210-4

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2013). lmerTest: Tests for random and fixed effects for linear mixed effect models (lmer objects of lme4 package). *R package version*, *2*(6).

Lakoff, G., & Johnson, M. (1980). *Metaphors we live by*. Chicago: Chicago University Press.

Lambon Ralph, M. A. (2014). Neurocognitive insights on conceptual knowledge and its breakdown. *Philosophical Transactions of the Royal Society B: Biological Sciences, 369*(1634), 20120392. doi:10.1098/rstb.2012.0392.

Lambon Ralph, M. A., Cipolotti, L., Manes, F., & Patterson, K. (2010). Taking both sides: Do unilateral anterior temporal lobe lesions disrupt semantic memory? *Brain, 133*(11), 3243-3255. doi:10.1093/brain/awq264

Landauer, T. K., & Dumais, S. T. (1997). A solution to Plato's problem: The latent semantic analysis theory of acquisition, induction, and representation of knowledge. *Psychological Review*, *104*(2), 211-240. doi:10.1.1.184.4759

Laszlo, S. & Federmeier, K. D. (2011). The N400 as a snapshot of interactive processing: Evidence from regression analyses of orthographic neighbor and lexical associate effects. *Psychophysiology*, *48*, 176-186. doi:10.1111/j.1469-8986.2010.01058.x

Lee, C. & Federmeier, K.D. (2008). To watch, to see, and to differ: an event-related potential study of concreteness effects as a function of word class and lexical ambiguity. *Brain and Language, 104*(2), 145-158. doi:10.1016/j.bandl.2007.06.002

Levine, S. C., & Banich, M. T. (1982). Lateral asymmetries in the naming of words and corresponding line drawings. *Brain and Language*, *17*, 34-43. doi:10.1016/0093-934X(82)90003-7

Louwerse, M. M. (2007). Symbolic or embodied representations: A case for symbol interdependency. In T. Landauer, D. McNamara, S. Dennis, & W. Kintsch (Eds.), *Handbook of latent semantic analysis* (pp. 107-120). Mahwah, NJ: Erlbaum.

Louwerse, M. M. (2008). Embodied relations are encoded in language. *Psychonomic Bulletin and Review, 15*(4), 838-844. doi:10.3758/PBR.15.4.838

Louwerse, M. M. (2011). Symbol interdependency in symbolic and embodied cognition. *Topics in Cognitive Science, 3*(2), 273-302. doi:10.1111/j.1756-8765.2010.01106.x

Louwerse, M. M., Cai, Z., Hu, X., Ventura, M., & Jeuniaux, P. (2006). Cognitively inspired natural-language based knowledge representations: Further explorations of latent semantic analysis. *International Journal of Artificial Intelligence Tools*, *15*, 1021-1039. doi:10.1.1.99.2211

Louwerse, M. M., & Connell, L. (2011). A taste of words: Linguistic context and perceptual simulation predict the modality of words. *Cognitive Science*, *35*(2), 381-398. doi:10.1111/j.1551-6709.2010.01157.x

Louwerse, M. M., & Hutchinson, S. (2012). Neurological evidence linguistic processes precede perceptual simulation in conceptual processing. *Frontiers in Psychology*, *3*, 385. doi:10.3389/fpsyg.2012.00385

Louwerse, M. M., & Jeuniaux, P. (2010). The linguistic and embodied nature of conceptual processing. *Cognition*, *114*, 96-104. doi:10.1016/j.cognition.2009.09.002

Luck, S. (2014). *An introduction to the event-related potential technique*. Cambridge: MIT Press.

Lugli, L., Baroni, G., Anelli, F., Borghi, A. M., & Nicoletti, R. (2013). Counting is easier while experiencing a congruent motion. *PLoS ONE*, *8*(5), e64500. doi:10.1371/journal.pone.0064500

Lund, K., & Burgess, C. (1996). Producing high-dimensional semantic spaces from lexical co-occurrence. *Behaviour Research Methods, Instruments, and Computers*, *28*(2), 203-208. doi:10.3758/BF03204766

Macoir, J. (2009). Is a plum a memory problem?: Longitudinal study of the reversal of the concreteness effect in a patient with semantic dementia. *Neuropsychologia*, *47*(2), 518-535. doi:10.1016/j.neuropsychologia.2008.10.006

Mahon, B. Z. (2015). What is embodied about cognition? *Language, Cognition and Neuroscience, 30*(4), 420-429. doi:10.1080/23273798.2014.987791

Malhi, S. K. (2015). Symbolic representations versus embodiment: A test using semantic neighbours and iconicity (Master's thesis). Retrieved from ProQuest Dissertations and Theses Database. (UMI No. 1602969)

Malhi, S. K., & Buchanan, L. (2017, June). *A test of the symbol interdependency hypothesis with both concrete and abstract stimuli*. Paper presented at the 27th Annual Meeting of the Canadian Society for Brain, Behaviour, and Cognitive Science, Regina, SK, CA

Malhi, S. K., McAuley, T. L, Lansue, B., & Buchanan, L. (submitted). Concrete and abstract word processing in deep dyslexia.

Markman, A. B., & Dietrich, E. (2000). Extending the classical view of representation. *Trends in Cognitive Sciences, 4,* 470-475. doi:10.1016/S1364-6613(00)01559-X

Martin, N., & Saffran, E. M. (1992). A computational account of deep dysphasia: Evidence from a single case study. *Brain and Language, 43,* 240-274. doi:10.1016/0093-934X(92)90130-7

Mate, J., Allen, R.J., & Baques, J. (2012). What you say matters: Exploring visual-verbal interactions in visual working memory. *The Quarterly Journal of Experimental Psychology, 65*(3), 395-400. doi:10.1080/17470218.2011.644798

McRae, K. (2004). Semantic memory: Some insights from feature-based connectionist attractor networks. In B. H. Ross (Editor), *The Psychology of Learning and Motivation: Advances in Research and Theory, Vol. 45* (pp. 41-86). San Diego, CA: Academic Press.

Meier, B. P., & Robinson, M. D. (2004). Why the sunny side is up: Associations between affect and vertical position. *Psychological Science, 15*(4), 243-247. doi:10.1111/j.0956-7976.2004.00659.x

Meteyard, L., Cuadrado, S. R., Bahrami, B., & Vigliocco, G. (2012). Coming of age: A review of embodiment and the neuroscience of semantics. *Cortex, 48*, 788-804. doi:10.1016/j.cortex.2010.11.002

Newton, P. K., & Barry, C. (1997). Concreteness effects in word production but not word comprehension in deep dyslexia. *Cognitive Neuropsychology, 14*(4), 481-509. doi:10.1080/026432997381457

Nittono, H., Suehiro, M., & Hori, T. (2002). Word imageability and N400 in an incidental memory paradigm. *International Journal of Psychophysiology*, *44*, 219-229. doi:10.1016/0093-934X(82)90088-8

Paivio, A. (1971). *Imagery and verbal processes*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Paivio, A. (1991). Dual coding theory: Retrospect and current status. *Canadian Journal of Psychology*, *45*, 255-287. doi:10.1037/h0084295

Paivio, A. (2013). Dual coding theory, word abstractness, and emotion: a critical review of Kousta et al. (2011). *Journal of Experimental Psychology: General, 142*(1), 282-287. doi:10.1037/a0027004

Paivio, A., & O'Neill, B. J. (1970). Visual recognition thresholds and dimensions of word meaning. *Perception and Psychophysics, 8*, 273-275.

Parker, A. & Dagnall, N. (2009). Concreteness effects revisited: The influence of dynamic visual noise on memory for concrete and abstract words. *Memory*, *17*(4), 397-410. doi:10.1080/09658210902802967

Patterson, K., Nestor, P. J., & Rogers, T. T. (2007). Where do you know what you know? The representation of semantic knowledge in the human brain. *Nature Reviews Neuroscience, 8*(12), 976-987. doi:10.1038/nrn2277.

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

Neural correlates of concreteness in semantic categorization. *Journal of Cognitive Neuroscience*, *19*, 1407-1419. doi:10.1162/jocn.2007.19.8.1407

Plato. Plato in Twelve Volumes, Vol. 12 translated by Harold N. Fowler. Cambridge, MA, Harvard University Press; London, William Heinemann Ltd. 1921.

Prinz, J. J. (2002). *Furnishing the mind: Concepts and their perceptual basis*. Cambridge: MIT Press.

Pylyshyn, Z. (1984). *Computation and cognition*. Cambridge, MA: MIT Press.

R Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Santana, E., & de Vega, M. (2011). Metaphors are embodied, and so are their literal counterparts. *Frontiers in Psychology*, *2*, 90. doi:10.3389/fpsyg.2011.00090

Schubert, T. W. (2005). Your highness: Vertical positions as perceptual symbols of power. *Journal of Personality and Social Psychology, 8*9(1), 1-21. doi:10.1037/0022-3514.89.1.1

Schwanenflugel, P. J., Harnishfeger, K. K., & Stowe, R.W. (1988). Context availability and lexical decisions for abstract and concrete words. *Journal of Memory and Language*, *27*, 499-520. doi:10.1016/0749- 596X(88)90022-8

Schwanenflugel, P. J., & Shoben, E. J. (1983). Differential context effects in the comprehension of abstract and concrete verbal materials. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *9*, 82-102. doi:10.1037/0278-7393.9.1.82

Schwanenflugel, P. J., & Stowe, R. W. (1989). Context availability and the processing of abstract and concrete words in sentences. *Reading Research Quarterly*, *24*(1), 114-126. doi:10.2307/748013

Searle, J. R. (1980). Minds, brains, and programs. *The Behavioral and Brain Sciences, 3*(3), 417-457. doi: 10.1017/S0140525X00005756

Segalowitz, S. J. (1999). *ERPScore Program: Peak and Area Analysis of Event-Related Potentials*. St. Catharines, ON: Brock University.

Šetić, M., & Domijan, D. (2007). The influence of vertical spatial orientation on property verification. *Language and Cognitive Processes*, *22*(2), 297-312. doi:10.1080/01690960600732430

Shaoul, C., & Westbury, C. (2006). Word frequency effects in high-dimensional co-occurrence models: A new approach. *Behavior Research Methods*, *38*, 190-195. doi:10.3758/BRM.42.2.393

Sheikh, N. A., & Titone, D. A. (2013). Sensorimotor and linguistic information attenuate emotional word processing benefits: An eye-movement study. *Emotion*, *13*(6), 1107-21. doi:10.1037/a0032417

Shen, Z., Tsai, Y., & Lee, C. (2015). Joint influence of metaphor familiarity and mental imagery ability on action metaphor comprehension: An event-related potential study. *Language and Linguistics*, *16*(4), 615-637. doi:10.1177/1606822X15583241

Shibahara, N., & Lucero-Wagoner, B. (2002). Hemispheric asymmetry in accessing word meanings: Concrete and abstract nouns. *Perceptual and Motor Skills*, *94*, 1292-1300. doi:10.2466/PMS.94.4.1292-1300

Siakaluk, P., Buchanan, L., & Westbury, C. (2003). The effect of semantic distance in yes/no and go/no-go semantic categorization tasks. *Memory and Cognition, 31*(1), 100-113. doi:10.3758/BF03196086

Siakaluk, P. D., Pexman, P. M., Aguilera, L., Owen, W. J., & Sears, C. (2008). Evidence for the activation of sensorimotor information during visual word recognition: The body–object interaction effect. *Cognition*, *106*, 433-443. doi:10.1016/j.cognition.2006.12.011

Simmons,W. K., & Barsalou, L.W. (2003). The similarity-in-topography principle: Reconciling theories of conceptual deficits. *Cognitive Neuropsychology, 20*(3), 451-486. doi:10.1080/02643290342000032.

Simmons, W. K., Hamann, S. B., Harenski, C. L., Hu, X. P., & Barsalou, L. W. (2008). fMRI evidence for word association and situated simulation in conceptual processing. *Journal of Physiology Paris*, *102*(1-3), 106-119. doi:10.1016/j.jphysparis.2008.03.014

Stadthagen-Gonzalez, H., & Davis C. J. (2006). The Bristol norms for age of acquisition, imageability, and familiarity. *Behaviour Research Methods, 38*(4), 598-605. doi: 10.3758/BF03193891

Sysoeva, O. V., Ilyuchenok, I. R., & Ivanitsky, A. M. (2007). Rapid and slow brain systems of abstract and concrete words differentiation. *International Journal of Psychophysiology*, *65*, 272-283. doi:10.1016/j.ijpsycho.2007.05.003

Tettamanti, M., Buccino, G., Saccuman, M. C., Gallese, V., Danna, M., Scifo, P., … Perani, D. (2005). Listening to action-related sentences activates fronto-parietal motor circuits. *Journal of Cognitive Neuroscience, 17*(2), 273-281. doi:10.1162/0898929053124965

Tremblay, A. & Ransijn, J. (2015). LMERConvenienceFunctions: Model selection and post-hoc analysis for (G)LMER models. *R package version*, *2*(10).

van Schie, H. T., Wijers, A. A., Mars, R. B., Benjamins, J. S., & Stowe, L. A. (2005). Processing of visual semantic information to concrete words: Temporal dynamics and neural mechanisms indicated by event-related brain potentials. *Cognitive Neuropsychology*, *22*, 364-386. doi:10.1080/02643290442000338

Vigliocco, G., Meteyard, L., Andrews, M., & Kousta, S. (2009). Toward a theory of semantic representation. *Language and Cognition, 1*(2), 219-247. doi:10.1515/LANGCOG.2009.011

Wang, J., Conder, J. A., Blitzer, D. N., & Shinkareva, S. V. (2010). Neural representation of abstract and concrete concepts: A meta-analysis of neuroimaging studies. *Human Brain Mapping, 21*(10), 1459-1468. doi:10.1002/hbm.20950

Warriner, A. B., Kuperman, V., & Brysbaert, M. (2013). Norms of valence, arousal, and dominance for 13,915 English lemmas. *Behavior Research Methods, 45*(4), 1191-1207. doi: 10.3758/s13428-012-0314-x

Weiskopf, D. A. (2010). Embodied cognition and linguistic comprehension. *Studies in History and Philosophy of Science, 41*(3), 294-304. doi:10.1016/j.shpsa.2010.07.005

Welcome, S. E., Paivio, A., McRae, K., & Joanisse, M. F. (2011). An electrophysiological study of task demands on concreteness effects: Evidence for dual coding theory. *Experimental Brain Research, 212*, 347-358. doi:10.1007/s00221-011-2734-8

West, W. C., & Holcomb, P. J. (2000). Imaginal, semantic, and surface-level, processing of concrete and abstract words: An electrophysiological investigation. *Journal of Cognitive Neuroscience, 12*(6), 1024-1037. doi:10.1162/08989290051137558

Wiemer-Hastings, K., & Xu, X. (2005). Content differences for abstract and concrete concepts. *Cognitive Science, 29*, 719-736. doi:10.1207/s15516709cog0000_33

Wilson, N. L., & Gibbs, R. W. (2007). Real and imagined body movement primes metaphor comprehension. *Cognitive Science, 31*, 721-731. doi:10.1080/15326900701399962

Yi, H. A., Moore, P., & Grossman, M. (2007). Reversal of the concreteness effect for verbs in patients with semantic dementia. *Neuropsychology, 21*(1), 9-19. doi:10.1037/0894-

4105.21.1.9

Zhang, Y., Hu, J., Zhang, E., & Wang, G. (2014). The influence of spatial representation on valence judgements: An event-related potential study. *Journal of Cognitive Psychology*, *27*(2), 218-226. doi: 10.1080/20445911.2014.995667

Zwaan, R. A., & Taylor, L. J. (2006). Seeing, acting, understanding: Motor resonance in language comprehension. *Journal of Experimental Psychology: General, 135*, 1-11. doi:10.1.1.64.8506

Zwaan, R. A., & Yaxley, R. H. (2003). Spatial iconicity affects semantic-relatedness judgments. *Psychonomic Bulletin and Review, 10*(4), 954-958. doi:10.3758/BF03196557

APPENDICES

Appendix A: Experimental Word Pairs (with Semantic Neighbourhood Distance) with their Lengths (Len.) Frequencies (Freq.), and Age of Acquisition (AoA)

Condition	Word Pair	Len.	Freq.	AoA	Concreteness Rating
CONCRETE					
Close	NOSE(9) – TONGUE(22)	10	61.79	4.47	6.15
	FLAME(10) – CANDLE(24)	11	26.98	6.25	6.42
	HIKER(7) – TRAIL(20)	10	32.06	8.50	6.15
	KNEE(2) – ANKLE(2)	9	18.30	4.89	6.5
	BRIDGE(25) – LAKE(26)	10	61.34	5.58	6.42
	CASTLE(42) – MOAT(14)	10	30.07	9.65	5.69
	STOVE(3) – OVEN(3)	9	12.81	5.67	6.62
	SHOWER(5) – TUB(17)	9	11.92	4.72	6.62
	LID(4) – TRAY(3)	7	10.99	6.05	6.23
	LUNGS(32) – STOMACH(27)	12	19.27	7.16	6.15
	MOUSTACHE(2) – BEARD(7)	14	17.69	5.40	6.35
	JOCKEY(38) – HORSE(49)	11	81.25	8.28	5.04
	JACKET(19) – TROUSERS(2)	14	21.62	7.89	6.15
	SHIRT(9) – PANTS(4)	10	22.00	3.53	6.5
	ROOF(20) – FLOOR(48)	9	94.35	5.00	6.31
	CHIMNEY(11) – FIREPLACE(3)	16	12.74	7.37	6.58
	MOUTH(25) – THROAT(11)	11	99.39	5.09	6.04
	TRAIN(22) – RAILROAD(49)	13	55.24	6.06	6.5
	JEANS(4) – SHOES(6)	10	23.29	5.26	6.31
	SHOULDERS(8) – HIPS(6)	13	43.09	6.17	6.23
Distant	HORN(679) – TAIL(506)	8	33.52	4.84	5.88
	FOAM(3149) – BEER(3107)	8	19.98	6.15	6.27
	HOOD(1730) – ENGINE(2598)	10	25.65	6.28	6.42
	DESK(422) – CARPET(361)	10	34.11	6.05	6.65
	BOOT(797) – HEEL(866)	8	13.26	7.85	6.23
	SEAT(1881) – PEDALS(1879)	10	42.42	6.50	6.23
	BRANCH(945) – ROOT(625)	10	38.18	5.94	6.15
	AIRPLANE(2214) – CAR(2162)	11	81.03	3.94	6.46
	PAPER (3633) – CLIPBOARD(2801)	14	86.41	7.76	6.19
	HAT(904) – BELT(985)	7	54.14	4.62	6.19
	FLOWER(209) – VASE(374)	10	26.58	7.89	6.54
	HANDLE(933) – BUCKET(601)	12	26.23	6.30	6.58
	MODEL(2460) – RUNWAY(3040)	11	39.28	8.35	5.58
	SHEET(506) – MATTRESS(363)	13	19.90	5.33	6.46
	FERRY(935) – OCEAN(932)	10	23.42	8.00	6.35
	FROTH(2078) – COFFEE(3271)	11	28.45	12.56	6.04
	CART(272) – WHEELS(284)	10	21.55	6.16	6.31
	BALCONY(1388) – LAWN(1399)	11	13.55	8.10	6.35

	SKY(2112) – GRASS(2750)	8	83.85	4.17	6.38
	FLAG(665) – POLE(479)	8	24.97	5.63	6.78
ABSTRACT					
Close	COACH(14) – PLAYER(22)	11	42.13	6.89	3.69
	JOY(29) – SORROW(8)	9	60.59	8.42	2.15
	ABUNDANT(8) – SCARCE(7)	14	16.41	12.84	2.69
	TEACHER(11) – STUDENT(6)	14	51.82	5.94	3.19
	ANGEL(15) – DEVIL(17)	10	40.73	5.00	2.46
	POSITIVE(2) – NEGATIVE(2)	16	41.44	8.11	2.73
	ACCEPT(8) – REJECT(4)	12	47.41	9.53	2.23
	LANDLORD(4) – TENANT(3)	14	16.42	10.33	3.46
	LEND(4) – BORROW(2)	10	17.25	8.45	2.58
	VICTORY(2) – DEFEAT(3)	13	35.89	8.74	2.46
	BRIGHT(26) – DIM(44)	9	65.40	7.06	4.03
	HOST(30) – GUEST(40)	9	34.90	8.05	3.31
	CLEAN(19) – DIRTY(46)	10	52.14	4.55	3.54
	AGREE(11) – DISAGREE(6)	13	39.86	8.37	2.58
	SAFETY(29) – DANGER(29)	12	72.18	5.84	2.92
	INCREASE(2) – DECREASE(5)	16	50.54	8.56	2.73
	MARRIAGE(3) – DIVORCE(3)	15	53.87	8.90	3.58
	FAST(2) – SLOW(2)	8	81.92	4.15	2.88
	EXCITEMENT(48) – BOREDOM(13)	17	28.11	7.68	2.46
	SMOOTH(2) – ROUGH(3)	11	47.22	6.21	3.88
Distant	PEACE(258) – VIOLENCE(225)	13	81.90	6.39	2.46
	OWNER(1306) – PET(1035)	8	28.29	7.50	4.35
	SUCCEED(898) – FAIL(998)	11	33.98	8.16	2.23
	HEALTHY(1546) – SICK(1338)	11	51.09	7.61	3.04
	BOSS(938) – EMPLOYEE(736)	12	20.90	7.84	3.35
	ACHIEVEMENT(2088) – FAILURE(2343)	18	38.25	8.80	2.5
	CONFIDENT(525) – ARROGANT(295)	17	14.59	9.95	2
	FIX(324) – BREAK(555)	8	64.84	5.30	3.65
	ALLY(1373) – ENEMY(1519)	9	35.16	9.61	2.96
	GUARD(2095) – PRISONER(2495)	13	43.18	8.00	3.42
	THERAPIST(574) – CLIENT(1005)	15	17.80	12.05	3.85
	INTELLIGENT(1892) – STUPID(1167)	17	31.07	8.28	2.5
	GAIN(305) – LOSS(394)	8	68.13	7.11	2.73
	BLESS(522) – CURSE(992)	10	20.20	7.47	2.19
	BOLD(2797) – MEEK(1665)	8	17.40	9.70	2.5
	STRAIGHT(800) – CROOKED(1353)	15	64.70	6.80	3.58
	FRESH(2402) – STALE(1070)	10	51.82	7.61	2.85
	PURE(685) – TAINTED(478)	11	31.72	9.84	2.23
	MANAGER(498) – CASHIER(673)	14	51.86	9.40	3.62
	BEAUTY(1477) – UGLY(1094)	10	67.75	5.05	2.6

Appendix B: Instructions for Experiment 1: Iconicity Judgment Task with Strategy Questions and Concreteness Ratings

Iconicity Judgment Task

Please indicate as soon as possible whether the iconicity of the pair of words is correct or incorrect by pressing “Yes” = correct and “No” = incorrect.

Example #1:

POT

PLANT

The answer is incorrect.

Example #2:

DOCTOR

PATIENT

The answer is correct.

Iconicity refers to whether the positions of the words match how they appear in real life. For example, when you think of a pot and a plant, you would expect to see the pot on the bottom, and the plant on top. Because this example has the word *pot* on top and *plant* on the bottom, it is incorrect. In the second example, we are not talking about physical objects anymore, but about power. Doctors are typically considered to have more power than their patients. Because this example shows the word *doctor* on top and *patient* on the bottom, it is correct. We are not asking you to make moral judgments, instead, consider how these concepts stereotypically appear. We also expect happy concepts to be at the top and sad concepts to be at the bottom, so keep these relationships in mind when making your judgments. Since this is a reaction time experiment, we want you to work as fast as you can – but not at the expense of accuracy. You should use both index fingers to make your responses.

Strategy Questions

1) What strategy did you use in responding to the concrete versus abstract word pairs? Remember, the concrete word pairs were words such as *pot* and *plant*, and the abstract word pairs were words such as *doctor* and *patient*. Please type out your response below.

2) Which of these strategies did you use for the concrete word pairs and which of these strategies did you use for the abstract word pairs?

Visualization/imagining strategy:

Emotional/intuitive strategy:

Concreteness Ratings

Condition #1

Below you will see a list of words. Your task is to enter a number between “1” and “7” (you can use “1” and “7” as well) next to each word.

Please use the following scale to rate the words:

I———I———I———I———I———I———I

1 2 3 4 5 6 7

abstract concrete

This is a concreteness scale. You are to rate the words on how abstract or concrete you believe the words are. For example, you might rate the word “chair” as a 6 or 7, while the word “charity” might be rated a 1 or a 2.

Condition #2

Below you will see word pairs. Your task is to enter a number between “1” and “7” (you can use “1” and “7” as well) next to each word pair. Please rate each word pair together, considering the relationship between the words.

Please use the following scale to rate the word pairs:

I———I———I———I———I———I———I

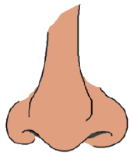
1 2 3 4 5 6 7

abstract concrete

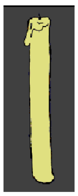
This is a concreteness scale. You are to rate the word pairs on how abstract or concrete you believe the relationship between the word pairs is. For example, you might rate the relationship between the word pair “chair-rug” as a 6 or 7, while the relationship between the word pair “parent-child” might be rated a 1 or a 2.

Appendix C: Experimental Picture and Word Pairs

NOSE – TONGUE

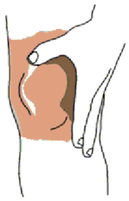


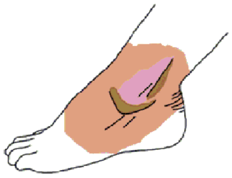
FLAME – CANDLE



HIKER – TRAIL

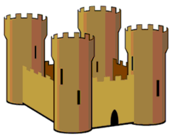
KNEE – ANKLE

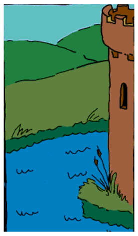




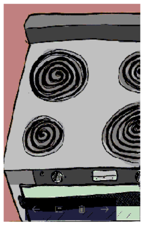
BRIDGE – LAKE

CASTLE – MOAT

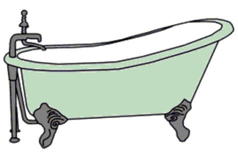




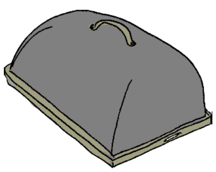
STOVE – OVEN

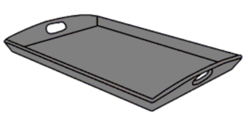


SHOWER – TUB

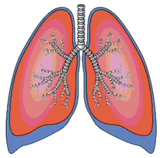


LID – TRAY

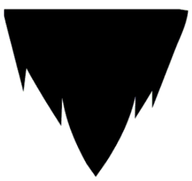




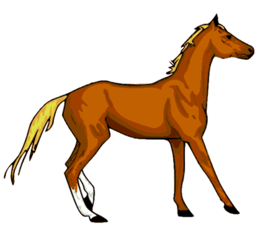
LUNGS – STOMACH



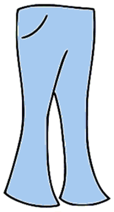
MOUSTACHE – BEARD



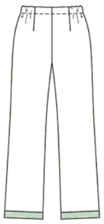
JOCKEY – HORSE



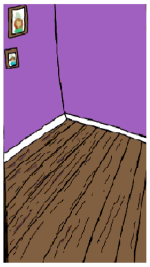
JACKET – TROUSERS



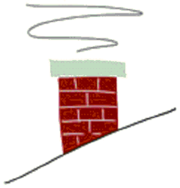
SHIRT – PANTS



ROOF – FLOOR

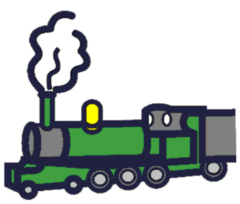


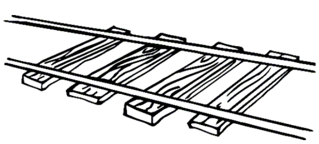
CHIMNEY – FIREPLACE



MOUTH – THROAT

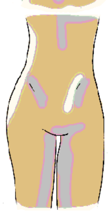
TRAIN – RAILROAD





JEANS – SHOES

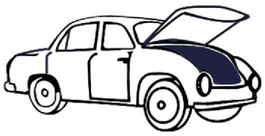
SHOULDERS – HIPS

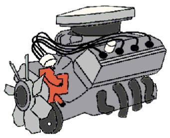


HORN – TAIL

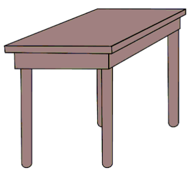
FOAM – BEER

HOOD – ENGINE

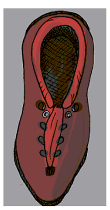


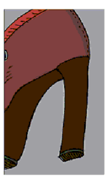


DESK – CARPET

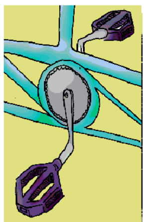


BOOT – HEEL



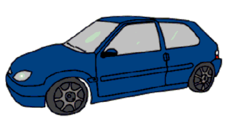


SEAT – PEDALS

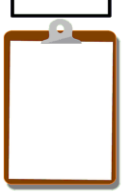


BRANCH – ROOT

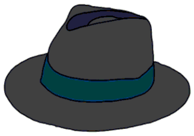
AIRPLANE – CAR



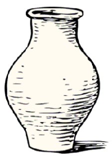
PAPER – CLIPBOARD



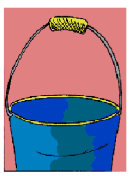
HAT – BELT



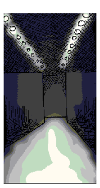
FLOWER – VASE



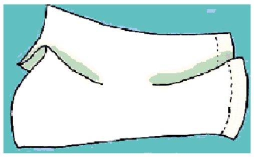
HANDLE – BUCKET



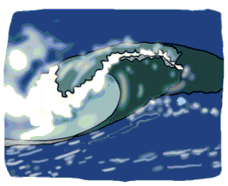
MODEL – RUNWAY



SHEET – MATTRESS

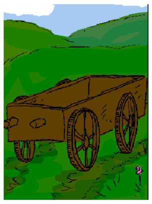


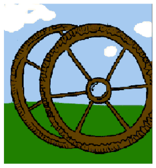
FERRY – OCEAN



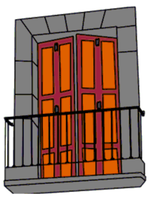
FROTH – COFFEE

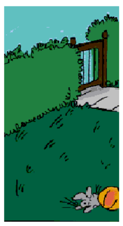
CART – WHEELS





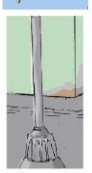
BALCONY – LAWN





SKY – GRASS

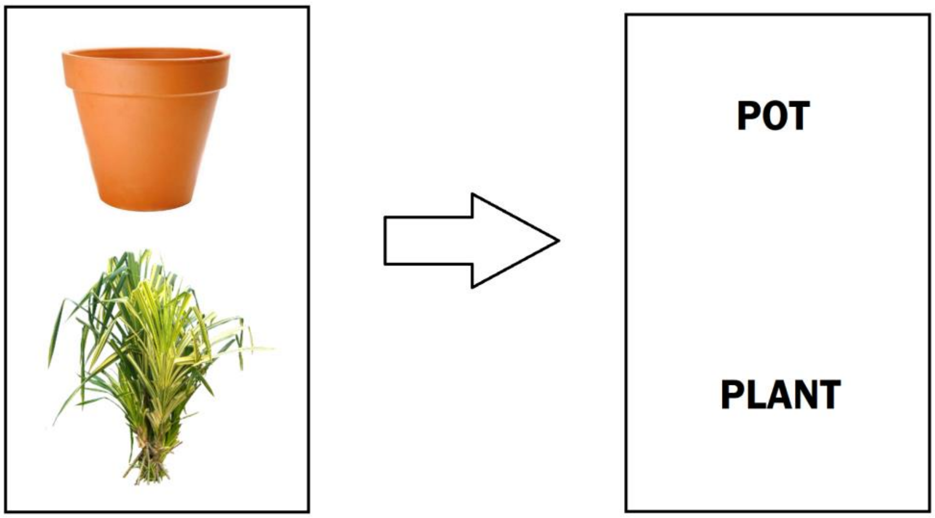
FLAG – POLE



Appendix D: Instructions for Experiment 3: Iconicity Judgment Task for Concrete Words and Pictures

Please indicate as soon as possible whether the iconicity of the pair of words is correct or incorrect by pressing "Yes" = correct and "No" = incorrect.

Example:



The answer is incorrect.

You will be first presented with the picture pair and then you will see the word pair. The picture pair will always correspond to the word pair. You are to make an iconicity judgment to the word pair. Iconicity refers to whether the positions of the words match how they appear in real life. For example, when you think of a pot and a plant, you would expect to see the pot on the bottom, and the plant on top. Because this example has the word *pot* on top and the word *plant* on the bottom, it is incorrect. Since this is a reaction time experiment, we want you to work as fast as you can – but not at the expense of accuracy. You should use both index fingers to make your responses.

Appendix E: Experimental Real Word Pairs Matched to Non-Pronounceable Nonsense Word Pairs with their Lengths (Len.) and Frequencies (Freq.)

Real Word Pair	Len.	Freq.	Nonsense Word Pair	Len.	Freq.
NOSE – TONGUE	10	61.79	NHSX – TBVSPE	10	
FLAME – CANDLE	11	26.98	FRCPE – CQTLDY	11	
HIKER – TRAIL	10	32.06	HPZXC – TWPLA	10	
KNEE – ANKLE	9	18.30	KBIH – AUTFZ	9	
BRIDGE – LAKE	10	61.34	BPCJFL – LGCT	10	
CASTLE – MOAT	10	30.07	CPWDGT – MJBS	10	
STOVE – OVEN	9	12.81	SKFGH – OPXQ	9	
SHOWER – TUB	9	11.92	SYVBCR – TLP	9	
LID – TRAY	7	10.99	LJN – TWZD	7	
LUNGS – STOMACH	12	19.27	LOGDS – SWQTZNOF	12	
MOUSTACHE – BEARD	14	17.69	MIUJNCFTS – BKJNP	14	
JOCKEY – HORSE	11	81.25	JRILTU – HVSOF	11	
JACKET – TROUSERS	14	21.62	JPOBCI – TQNZSHAX	14	
SHIRT – PANTS	10	22.00	SNKOH – PKNLA	10	
ROOF – FLOOR	9	94.35	RCHG – FTAHS	9	
CHIMNEY – FIREPLACE	16	12.74	CIRTGFS – FOYUNZCXP	16	
MOUTH – THROAT	11	99.39	MPFGS – TNJSCO	11	
TRAIN – RAILROAD	13	55.24	TPLSI – RWNQFNGH	13	
JEANS – SHOES	10	23.29	JNXBH – SYUSR	10	
SHOULDERS – HIPS	13	43.09	SYNQUKDFT – HCXI	13	
HORN – TAIL	8	33.52	HWGB – TIDE	8	29.03
FOAM – BEER	8	19.98	FLXB – BARN	8	18.92
HOOD – ENGINE	10	25.65	HIYQ – EATING	10	43.64
DESK – CARPET	10	34.11	DKSL – COPPER	10	20.66
BOOT – HEEL	8	13.26	BZGN – HAIL	8	11.72
SEAT – PEDALS	10	42.42	SKQA – POCKET	10	66.74
BRANCH – ROOT	10	38.18	BRSPVJ – ROPE	10	30.06
AIRPLANE – CAR	11	81.03	ANFHSIBO – CAT	11	45.55
PAPER – CLIPBOARD	14	86.41	PHZSR – CIGARETTE	14	24.14
HAT – BELT	7	54.14	HSG – BAND	7	57.14
FLOWER – VASE	10	26.58	FRUITS– VSRG	10	15.91
HANDLE – BUCKET	12	26.23	HAMMER – BSHKDP	12	14.08
MODEL – RUNWAY	11	39.28	MOUSE – RHSBCP	11	18.79
SHEET – MATTRESS	13	19.90	SKIRT – MSWPCLSU	13	17.22
FERRY – OCEAN	10	23.42	FENCE – OCSUH	10	26.1
FROTH – COFFEE	11	28.45	FRAME– CSHBKI	11	40.92
CART – WHEELS	10	21.55	CAGE– WRGTSU	10	13.28
BALCONY – LAWN	11	13.55	BALLOON – LNSW	11	13.65
SKY – GRASS	8	83.85	SUN – GRNSF	8	193.9
FLAG – POLE	8	24.97	FUEL – PQWO	8	22.44

COACH – PLAYER	11	42.13	CRPTF – PKIDLJ	11	
JOY – SORROW	9	60.59	JDF – SQNVWI	9	
ABUNDANT – SCARCE	14	16.41	APJNSUCP – SDRTGP	14	
TEACHER – STUDENT	14	51.82	TYSBJHN – SNKVYEO	14	
ANGEL – DEVIL	10	40.73	AKJPO – DCXET	10	
POSITIVE – NEGATIVE	16	41.44	PYHNAQST – NZPLMSTI	16	
ACCEPT – REJECT	12	47.41	ALRCUJ – RCPVBM	12	
LANDLORD – TENANT	14	16.42	LPOFDBWX – TNCKWL	14	
LEND – BORROW	10	17.25	LVBH – BQDHVP	10	
VICTORY – DEFEAT	13	35.89	VSDLFJH – DTIVBL	13	
BRIGHT – DIM	9	65.40	BJKSNV – DLH	9	
HOST – GUEST	9	34.90	HNSF – GHNXT	9	
CLEAN – DIRTY	10	52.14	CGVHS – DUIHO	10	
AGREE – DISAGREE	13	39.86	AIVBJ – DBSIJWEX	13	
SAFETY – DANGER	12	72.18	SIVBOE – DIWFBVO	12	
INCREASE – DECREASE	16	50.54	IBEJGWSE – DEICBSOK	16	
MARRIAGE – DIVORCE	15	53.87	MKSIBCWN – DEHBVUK	15	
FAST – SLOW	8	81.92	FSNI – SJNA	8	
EXCITEMENT – BOREDOM	17	28.11	EHNVBHSPNX – BSLDYVH	17	
SMOOTH – ROUGH	11	47.22	SIJCLW – RHSNO	11	
PEACE – VIOLENCE	13	81.90	PSJIC – VALUABLE	13	37.31
OWNER – PET	8	28.29	OWTYU – PAL	8	5.28
SUCCEED – FAIL	11	33.98	SKRPNW – FAIR	11	141.19
HEALTHY – SICK	11	51.09	HNSTGQY – SAGE	11	11.49
BOSS – EMPLOYEE	12	20.90	BSXO – EMOTIONS	12	24.52
ACHIEVEMENT – FAILURE	18	38.25	AHCUEBVIFJN – FARTHER	18	38.27
CONFIDENT – ARROGANT	17	14.59	CKSQVUECY – ACCURACY	17	14.68
FIX – BREAK	8	64.84	FBP – BEAST	8	31.92
ALLY – ENEMY	9	35.16	AIQE – EAGER	9	38.71
GUARD – PRISONER	13	43.18	GHBFS – POWERFUL	13	68.33
THERAPIST – CLIENT	15	17.80	TESTIMONY – CPOFLQ	15	16.98
INTELLIGENT – STUPID	17	31.07	INDIFFERENT – SRQJOV	17	19.24
GAIN – LOSS	8	68.13	GROW – LSPO	8	69.19
BLESS – CURSE	10	20.20	BLANK – CQKDE	10	23.7
BOLD – MEEK	8	17.40	BUSY – MWAE	8	59.73
STRAIGHT – CROOKED	15	64.70	SECURITY – CRPKWIH	15	75.08
FRESH – STALE	10	51.82	FALSE – STUQP	10	53.67
PURE – TAINTED	11	31.72	POEM – TSUWHCV	11	28.84
MANAGER – CASHIER	14	51.86	MISSION – CPKIUHR	14	31.49
BEAUTY – UGLY	10	67.75	BEATEN – UOKD	10	27.9

Appendix F: Instructions for Experiment 4: Non-Pronounceable Lexical Decision Task

You will be presented with letter strings that will either form real English word pairs or nonsense word pairs. For each letter string, you must decide if it is a real word pair (i.e., both are words) or a nonsense word pair (i.e., both are nonwords or only one is a real word) by pressing “Yes” = real word pair and “No” = nonsense word pair.

Example #1:

SZPDH

JLQXO

The answer is incorrect.

Example #2:

TOWEL

BLUE

The answer is correct.

Example #3:

BREAD

UHSGN

The answer is incorrect.

Appendix G: Experimental Real Word Pairs Matched to Pronounceable Nonsense Word Pairs with their Lengths (Len.) and Frequencies (Freq.)

Real Word Pair	Len.	Freq.	Nonsense Word Pair	Len.	Freq.
NOSE – TONGUE	10	61.79	NOKE – TOWSED	10	
FLAME – CANDLE	11	26.98	FLAPE – CARBLE	11	
HIKER – TRAIL	10	32.06	HEPER – TRARK	10	
KNEE – ANKLE	9	18.30	KNOU – ARTHE	9	
BRIDGE – LAKE	10	61.34	BRIRTS – LAGE	10	
CASTLE – MOAT	10	30.07	CADBLE – MOUT	10	
STOVE – OVEN	9	12.81	STONT – ORET	9	
SHOWER – TUB	9	11.92	SHASER – TOB	9	
LID – TRAY	7	10.99	LIS – TRAK	7	
LUNGS – STOMACH	12	19.27	LUTCH – STOPAFF	12	
MOUSTACHE – BEARD	14	17.69	MOOSTARCH – BEALD	14	
JOCKEY – HORSE	11	81.25	JUSHEY – HORGE	11	
JACKET – TROUSERS	14	21.62	JASHEL – TROOBERS	14	
SHIRT – PANTS	10	22.00	SHIRD – PAMED	10	
ROOF – FLOOR	9	94.35	ROUF – FLEER	9	
CHIMNEY – FIREPLACE	16	12.74	CHUMNEM – FASSPLACE	16	
MOUTH – THROAT	11	99.39	MEATH – TRATH	11	
TRAIN – RAILROAD	13	55.24	TRASP – RAILPOUD	13	
JEANS – SHOES	10	23.29	JEASH – SHEES	10	
SHOULDERS – HIPS	13	43.09	SHEAKDERS – HIDS	13	
HORN – TAIL	8	33.52	HORK– TIDE	8	29.03
FOAM – BEER	8	19.98	FOAR – BARN	8	18.92
HOOD – ENGINE	10	25.65	HOOR – EATING	10	43.64
DESK – CARPET	10	34.11	DELK – COPPER	10	20.66
BOOT – HEEL	8	13.26	BOOF – HAIL	8	11.72
SEAT – PEDALS	10	42.42	SOUT – POCKET	10	66.74
BRANCH – ROOT	10	38.18	BRAFFS – ROPE	10	30.06
AIRPLANE – CAR	11	81.03	ASHPLENE – CAT	11	45.55
PAPER – CLIPBOARD	14	86.41	POGER – CIGARETTE	14	24.14
HAT – BELT	7	54.14	HET – BAND	7	57.14
FLOWER – VASE	10	26.58	FRUITS– VAND	10	15.91
HANDLE – BUCKET	12	26.23	HAMMER – BESHET	12	14.08
MODEL – RUNWAY	11	39.28	MOUSE – RISWAY	11	18.79
SHEET – MATTRESS	13	19.90	SKIRT – MALGRESS	13	17.22
FERRY – OCEAN	10	23.42	FENCE – OBIEN	10	26.1
FROTH – COFFEE	11	28.45	FRAME– CODNEE	11	40.92
CART – WHEELS	10	21.55	CAGE– WHEEKS	10	13.28
BALCONY – LAWN	11	13.55	BALLOON – LART	11	13.65
SKY – GRASS	8	83.85	SUN – GRALE	8	193.9
FLAG – POLE	8	24.97	FUEL – PORD	8	22.44

COACH – PLAYER	11	42.13	COARD – PLEWER	11	
JOY – SORROW	9	60.59	JOK – SORRIX	9	
ABUNDANT – SCARCE	14	16.41	ADUPPANT – SCANNS	14	
TEACHER – STUDENT	14	51.82	TOULDER – SHUBENT	14	
ANGEL – DEVIL	10	40.73	ARGAL – DEPIT	10	
POSITIVE – NEGATIVE	16	41.44	PETITISM – NUCATIZE	16	
ACCEPT – REJECT	12	47.41	ACCUBE – REJIME	12	
LANDLORD – TENANT	14	16.42	LANDPIRD – TUNACK	14	
LEND – BORROW	10	17.25	LEFF – BORRIM	10	
VICTORY – DEFEAT	13	35.89	VEPPORY – DEGOOT	13	
BRIGHT – DIM	9	65.40	BRIFFS – DOM	9	
HOST – GUEST	9	34.90	HOSH – GULGE	9	
CLEAN – DIRTY	10	52.14	CHEAN – DERDY	10	
AGREE – DISAGREE	13	39.86	APRIE – DENACREE	13	
SAFETY – DANGER	12	72.18	SURKTY – DONDER	12	
INCREASE – DECREASE	16	50.54	INSPOOSE – DECHEESE	16	
MARRIAGE – DIVORCE	15	53.87	MARROUPS – DIVIRTH	15	
FAST – SLOW	8	81.92	FANE – SPOW	8	
EXCITEMENT – BOREDOM	17	28.11	EXTOSHMENT – BOREBOY	17	
SMOOTH – ROUGH	11	47.22	SMOOGE – ROURT	11	
PEACE – VIOLENCE	13	81.90	PEASE – VALUABLE	13	37.31
OWNER – PET	8	28.29	OSHES – PAL	8	5.28
SUCCEED – FAIL	11	33.98	SUYBEED – FAIR	11	141.19
HEALTHY – SICK	11	51.09	HOURTHY – SAGE	11	11.49
BOSS – EMPLOYEE	12	20.90	BOPE – EMOTIONS	12	24.52
ACHIEVEMENT – FAILURE	18	38.25	AFRUISHMENT – FARTHER	18	38.27
CONFIDENT – ARROGANT	17	14.59	CONVIDATE – ACCURACY	17	14.68
FIX – BREAK	8	64.84	FIF – BEAST	8	31.92
ALLY – ENEMY	9	35.16	ATTY – EAGER	9	38.71
GUARD – PRISONER	13	43.18	GUMPH – POWERFUL	13	68.33
THERAPIST – CLIENT	15	17.80	TESTIMONY – CRIEND	15	16.98
INTELLIGENT – STUPID	17	31.07	INDIFFERENT – STUCAD	17	19.24
GAIN – LOSS	8	68.13	GROW – LOLE	8	69.19
BLESS – CURSE	10	20.20	BLANK – CUNGE	10	23.7
BOLD – MEEK	8	17.40	BUSY – MEEF	8	59.73
STRAIGHT – CROOKED	15	64.70	SECURITY – CROOPED	15	75.08
FRESH – STALE	10	51.82	FALSE – STARD	10	53.67
PURE – TAINTED	11	31.72	POEM – TUNCHED	11	28.84
MANAGER – CASHIER	14	51.86	MISSION – CAFTEER	14	31.49
BEAUTY – UGLY	10	67.75	BEATEN – UDDY	10	27.9

Appendix H: Instructions for Experiment 5: Pronounceable Lexical Decision Task

You will be presented with letter strings that will either form real English word pairs or nonsense word pairs. For each letter string, you must decide if it is a real word pair (i.e., both are words) or a nonsense word pair (i.e., both are nonwords or only one is a real word) by pressing “Yes” = real word pair and “No” = nonsense word pair.

Example #1:

SHIFF

JINTO

The answer is incorrect.

Example #2:

TOWEL

BLUE

The answer is correct.

Example #3:

BREAD

URMER

The answer is incorrect.

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