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Support for the Right Hemisphere Hypothesis of language processing: An investigation of ambiguous word resolution in puns

Tara S. McHugh
University of Windsor

SUPPORT FOR THE RIGHT HEMISPHERE HYPOTHESIS OF LANGUAGE PROCESSING: AN INVESTIGATION OF AMBIGUOUS WORD RESOLUTION IN PUNS

by

Tara S. McHugh

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Abstract

Right frontal hemispheric stroke causes cognitive difficulties that include loss of appreciation of verbal humour (Shammi & Stuss, 1999). Although nonverbal creativity and working memory have been linked to this impairment, a deficit in the coordination and comprehension of ambiguous verbal material is likely to play a significant role. In this way, the Right Hemisphere Hypothesis of language processing (Coltheart, 1987) might contribute a plausible explanation for deficits in humour appreciation post-stroke, which would inform models of normal language processing. Through a series of four experiments, the current study contributes knowledge regarding the hemispheric specialization of processing puns. Puns were chosen for their propensity to force dual ambiguity resolution in a humourous context. Results from a single-word lexical decision task demonstrated priming for dominant associates of ambiguous targets. A centralized lexical decision task with pun primes and dominant, subordinate, and unrelated targets showed strongest priming for dominant relatives. A divided visual field study revealed that at 500 ms ISI, both hemispheres activated, but the left activated in such a way as to suggest that its pattern was driving the results for the centralized study. In contrast to the lexical decision data that favoured the dominant targets, data from a forced-choice relatedness task showed an advantage for the subordinate associates. Results from this series of experiments provide a working model of how puns are processed in neurologically intact individuals and contribute to the body of literature supporting the Right Hemisphere Hypothesis of language processing.

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Chapter 1: Introduction

Historical Background

Broca's 1861 report of his patient, Tan, who was only able to utter expletives and the morpheme *tan*, demonstrated that left inferior frontal lobe damage was responsible for severely impaired language production (Broca, 1861). Wernicke later reported that the left superior posterior temporal lobe was responsible for severely impaired language comprehension (Wernicke, 1874, as cited in Smith, 2002) and Déjérine (1891, as cited in Renier, 1994) added that alexia (i.e., inability to read) without agraphia (i.e., inability to write) resulted from isolation of the left angular gyrus from right and left occipital lobes. These combined findings led to a general acceptance of the notion that language is localized primarily in the left hemisphere (LH).

In 1874, Hughlings Jackson proposed that Tan's involuntary expletives were automatic expressions of emotion, and were thus products of an intact right hemisphere (RH). Hughlings Jackson (1873) believed that the right hemisphere was responsible for automatic language, and was equally responsible for language production and comprehension as the LH, but played a different role in processing. This early claim was later bolstered by Sperry and Gazzaniga (1967) whose experiments with "split-brain" patients showed that although participants with a disconnected RH did not have the ability to name objects, they did have the ability to make abstractions and generalizations (Sperry & Gazzaniga, 1967), perform tasks based on level of semantic relationship (Zaidel, 1982), and retained the ability to make lexical decisions (Zaidel, 1983).

Examinations of linguistic performance of patients with RH damage have uncovered a number of RH-based language functions. Participants with RH damage tend to be impaired in processing emotional information (Borod, 1992), make socially inappropriate remarks, have tangential speech, engage in circumlocutions (Joanette, Goulet & Hannequin, 1990), have trouble understanding metaphoric statements (Winner & Gardner, 1977), demonstrate poor semantic fluency (Joanette & Goulet, 1986), have difficulty processing semantic aspects of concrete words over abstract words (Villardita, Grioli, & Quattropani, 1988), and benefit less from sentence context to derive meaning (Faust, 1998).

Together, the above findings show differential responsibilities of language processing, such that the RH appears to be responsible for higher order, abstract, metaphorical, and affective language processing; whereas the LH processes concrete meanings as well as the phonetic and syntactic aspects of language. Beeman and Chiarello (1998) summarized this large body of research in their claim that the LH processes technical aspects of language (i.e., syntax, speech sounds, close semantic neighbours, and understanding grammatical sentence constraints) whereas the RH controls more holistic aspects of comprehension (i.e., prosody, emotional content, abstract semantics, and activating multiple meanings).

Research with individuals with deep dyslexia (i.e., an aphasia stemming from substantive LH damage) show a particular pattern of mistakes in reading that informs models of RH language functioning. Deep dyslexics frequently make semantic errors (e.g., *rose* is read as *tulip*), benefit from imageability and concreteness (e.g., such that *daisy* is likely to be read more accurately than abstract words like *economy*), produce morphological mistakes (e.g., *running* is read as *runner*), and make visual errors (by transposing letters, e.g., *angle* is read as *angel*). Coltheart (1987) postulated that since the

LH was damaged, these individuals rely primarily on their RH to read. Therefore, given the particular pattern of language assets and deficits displayed, the RH must carry certain specific reading responsibilities. These clinical observations of RH involvement in language functioning were incorporated into a model of reading called the Right Hemisphere Hypothesis (Coltheart, 1987).

The Right Hemisphere Hypothesis

In the development of his theory, Coltheart (1987) reviewed literature that documents the sparing of reading ability across various types of brain injury. Accounts of understanding the written word come from the study of individuals who were able to demonstrate their comprehension of written language through actions. One patient who had left hemispherectomy (see Smith, 1966) was able to select the correct colour of pen after reading the name of its colour. This patient was able to read object and colour names on occasions, but not sentences. Additionally, although he was able to write his name and copy script and designs, he was unable "to write names of objects spontaneously or from dictation" (Coltheart, 1987, p. 331). Although there are several patients without a left hemisphere described in the literature, Smith's patient was of particular interest to Coltheart because he acquired his brain injury after natural development and lateralization of language function.

Coltheart then considered the performance of individuals who had sustained brain injury early in their development, arguing that the brain's natural tendency towards plasticity would ensure RH development of language ability despite LH damage. Particularly, by tracking the recovery of individuals who experience LH-related aphasia, any language ability was assumed to be the product of intact RH functioning. This assumption came from studies of individuals with aphasia whose LH was completely anesthetized using sodium amytal, and were still able to speak (see Kinsbourne, 1971), and from observations that sustaining RH injury after initial LH damage worsened their symptoms of aphasia (see Neilsen, 1946).

Coltheart (1987) aggregated data from a variety of experiments that showed RH advantage for certain types of stimuli. For Japanese script, there is a LH advantage for the syllable based *kana* scripts and a RH advantage for the ideographic *kanji* script. The most ideographic symbols in English are numbers and patient studies have shown a RH advantage for understanding numbers (Teng & Sperry, 1973). Through experimental isolation of hemisphere with non-brain injured participants, Marcel and Patterson (1979) showed a RH ability to accurately respond to words with high imageability, but not for low imageability or abstract words. Finally, when reading fully relies on RH function in the experiments reviewed, individuals become susceptible to making many semantic errors.

Coltheart (1987) wrote that reading for an individual with deep dyslexia "is mediated by a neuroanatomical system ... which is located in the right hemisphere. This hypothesis may turn out to be wrong, but its refutation will require a detailed discussion of what is known about the right-hemisphere reading system and of how well the properties of this system correspond to the properties of the reading behaviour of the deep dyslexic" (Coltheart, 1987, p. 334).

Perhaps rising to the challenge to provide proof of veritable differences, research has emerged recounting observations of language processing lateralization. Since publishing the Right Hemisphere Hypothesis, the advent of technology has allowed more specific investigation of normal and disordered reading. A review of relevant literature will follow an introduction of the techniques used to study hemispheric specialization. This review will cover many situations in which hemispheric specialization has been demonstrated, and will finish by presenting recent studies that employ multiple methods of investigation as well as the rationale for the current series of experiments.

Investigating Hemispheric Processes

Although lesion studies initially provided the general basis for what is hypothesized about the localization of language functioning, current research techniques now afford the opportunity to study functioning in individuals who have not sustained brain injury. Results from lesion studies may be based on findings that are concomitant with damage (e.g., sustaining an injury during early stages of development may lead to functional reorganization through neuroplasticity, making generalizations about location complicated), therefore it is also logical and necessary to study the neurologically healthy. Methods such as evoked related potential (ERP), eye-tracking, divided visual field (DVF) studies, and lexical decision tasks have all been used to study healthy language processing. Studies that use the DVF technique provide data about the reaction time required to process visual information in one hemisphere discretely (Kolb & Whishaw, 1998). The DVF studies are laboratory equivalents to Sperry's split-brain investigations, and have contributed significant support for the differential responsibilities of each hemisphere within language processing. These studies will be the primary focus of the current review.

In intact visual and neural systems, the visual fields of both eyes overlap to create a binocular visual field. Information that is incorporated in binocular space is processed using both hemispheres through the transfer of signals across the corpus callosum. Visual stimuli within each half of visual space are processed in the contralateral hemisphere. Therefore, information that is separately presented to either visual hemifield is processed in isolation in the contralateral hemisphere of the visual field of presentation (Banich, 2002). For language studies, DVF tasks typically involve participants responding to single words that are flashed on a computer screen or tachistoscope. Participants' gaze is focused on the centre of the screen whilst words flash into their periphery (i.e., into either visual hemifield). In order to preclude eye movements toward the stimulus, presentations must be faster than the time required to foveate. Kolb and Whishaw (1998) suggest that stimulus presentation must be faster than 200 ms to preclude eye movements, whereas Bourne (2006) suggests 180 ms. This 20 ms disagreement notwithstanding, researchers generally agree that the rapid presentation of words to only a single visual field can shed light on asymmetrical language processing.

Behavioural studies often use DVF and primed lexical decision to investigate hemispheric processes. Priming within a lexical decision paradigm is the experimental manipulation whereby letter strings are presented to participants, who must decide as quickly and accurately as possible whether each is a real English word. Priming occurs when the response times for the "target" stimuli (e.g., *chair*) are faster when preceded by related "primes" (e.g., *table*) than for unrelated words (e.g., *river*), demonstrating an enhanced efficiency of processing. Several priming experiments have shown that depending on the strength of prime-target relationship, the hemispheres are differentially involved in language processing.

Differential hemispheric contributions were reported in a 1990 DVF study by Chiarello, Burgess, Richards and Pollock that investigated priming as a function of type of semantic relationship. Specifically, they focused on three types of associations: category/similar relations have a common semantic theme, but do not necessarily occur together in speech (e.g., *tulip* and *daisy* are both *flowers*); associates are words from different categories that commonly occur together in language (e.g., *bee* and *honey*); and category+associates are words that hold the same category membership which also frequently occur together in language (e.g. *king* and *queen*). When prime words were presented centrally, Chiarello et al. (1990) found no effect of prime-target relationship in the priming effect. However, when primes and targets were lateralized to the same visual field, category/similar priming was greater in the left visual field (i.e., RH), associate only pairs showed no priming at all, and there was equivalent bilateral priming for category+associates. Therefore, although there is spreading activation for only the most highly related words (i.e., category+associates), results showed clear evidence of automatic access to some semantic information in the RH.

Subsequent studies investigated how related words were processed within each hemisphere across time. To measure the time course of activation, studies manipulate the time between onset of prime and onset of target (Stimulus Onset Asynchrony or SOA) or the time interval between the end of the prime and the start of the target (Inter-Stimulus Interval or ISI). Investigating the time course by DVF attempts to "track" a word through the hemispheres to capture activation at discrete points along the course of processing. The more time intervals measured, the more specific the picture is painted about language comprehension. The following review of the literature organizes study outcomes by time course investigated, type of relationship manipulated, and hemispheric findings.

Bilateral Activation

Incorporating various SOAs into the investigation of language processing has allowed researchers to understand the role of each hemisphere along the time course of language processing. Although many researchers have set out to demonstrate differential processing across hemispheres, many have found bilateral activation, depending on the time course and type of relationship manipulated. Using category+associates (e.g., *king* and *queen*), Chiarello, Burgess, Richards, and Pollock (1990) found priming in both hemispheres at 600 ms SOA. Audet, Driessen, and Burgess (1998) found bilateral priming at 150 ms and 800 ms for associates and category+associates in a naming task. Coney (2002) also varied the strength of relationship between associates, such that they were weakly, moderately or highly associated. With prime-target lags of 250 and 1000 ms SOA, priming was reported in both hemispheres across all associative strengths and time conditions. Additionally, the priming effect increased as the strength of the associative relationship increased.

Keeping the depth of relationship constant (i.e., only strong associates), Richards and Chiarello (1995) manipulated the level of relationship between pairs by using direct and indirect primes. For example, WRIST and WATCH are strong direct associates that can also be mediated by a common relation. For the target WATCH, WRIST acted as a prime, but was linked indirectly by *clock* (e.g., WRIST-*clock*, *clock*-WATCH). Priming for direct and indirect pairs was measured at 50, 250 and 750 ms SOA. Although there was a stronger effect of direct priming than mediated priming, priming for both the direct and indirect associates was found bilaterally at all SOAs.

On their own, the results of these studies would be evidence that both hemispheres process associates and category+associates at similar rates. However, in light of other studies that have investigated hemispheric processing of language, these results demonstrate that for words with moderate (i.e., associates) and strong relationships (i.e., category+associates), hemispheric activation is more a function of the interaction between temporal and relational factors.

Asymmetric Activation

Chiarello, Liu, Shears, Quan, and Kacinik (2003) investigated priming over a spectrum of SOAs (i.e., 150, 225, 300, 500 and 800 ms) for strongly related pairs (i.e., category+associates). They found strong priming effects for the LH across all SOAs measured. They also found a weak RH priming effect at 150 ms, which grew to be a moderate effect over the rest of the time course investigated. These findings suggest that hemispheric processing for highly related semantic pairs differ along temporal lines.

Focusing on another type of relationship, Chiarello and Richards (1992) demonstrated hemispheric activation for words that were similarly/categorically related. High dominance word pairs were common members of a semantic category (e.g. *snow* → *hail* and *elm* → *birch*), and low dominance word pairs consisted of less common examples (e.g., *fog* → *hail* and *willow* → *birch*). Priming reliably occurred only in the RH, regardless of the dominance of the similarity of category relations. In a previous study carried out by Chiarello and Richards, words that had a stronger relationship through category, by being more representative of each category (i.e., the pair, *dog-cat* more frequently represent "*animals*" than *dog-goat*), were primed in the RH only. Based on the aggregate findings of their studies, Chiarello and Richards (1992) hypothesized that weak relationships between words (same category members, but not associated), are processed primarily in the RH. Richards and Chiarello (1995) suggested that the RH codes the broadest category of how words are related (e.g. for *tuna* and *salmon*, the broad category of *fish* is processed in the RH) whereas the LH serves the more specific function of activating a smaller subset of related words.

Beeman et al. (1994) investigated the notion of the RH as broad activator by studying how it processes multiple words within the same broad theme. Three primes were presented sequentially that were weakly related to the target, so that together they told something of a story (e.g., *candle, frost, party*: CAKE), compared to three primes that were unrelated to their target (e.g., *fever, knees, dishes*: CAKE). Results demonstrated the RH's relatively broad activation. Primes that were paired with words that told a story, despite their distant relationships, were processed faster in the RH than unrelated controls. Additionally, closely related words that were presented between two neutral words were activated most in the LH if targets were strongly related to primes. Beeman et al. (1994) also found that when the word triplets contained a direct prime between two unrelated words, (e.g., *blank, birthday, although:* CAKE) the LH produced more priming than the right. In fact, these strongly related words were primed more greatly in the LH than was the case for 'summation primes' (i.e., words that together told a story). Both direct and summation relationships were primed in the RH, suggesting a broader treatment of semantic information. Beeman et al. (1994) therefore concluded that there was a dichotomy of processing, whereby the RH was responsible for activating a broad semantic network, while the LH activates only closely related semantic neighbours.

In a series of experiments that manipulated SOA, Koivisto (1997) found that the hemispheres differentially activate along time such that the left initially activates and then fades with time, and the right takes longer to activate but remains active across time. Therefore, rather than ascribe to Beeman et al's (1994) conclusion that hemispheric contributions occur simultaneously during processing, others have proposed that the specialized work of each hemisphere complements the other along a time course (Collins, 1999; Koivisto, 1997).

Asymmetric Activation as a Function of Time Course

Koivisto (1997) examined time course by presenting similar/category pairs over 165, 250, 500, and 750 ms SOA. The LH showed a priming advantage at 165 ms (i.e., there was no RH priming at this time), whereas the RH showed an advantage for priming at the 750 ms presentation (i.e., there was no LH priming at this time). These results challenged the notion that a large range of meanings is processed in the RH over the LH. Rather, results showed that semantic activation is different in the hemispheres over time. Koivisto (1997) showed that although the LH initially activates, it decreases activation as the RH activation increases. Therefore, in contrast to Beeman et al. (1994)'s earlier conclusions, it is possible for the LH to activate weak semantic relationships (i.e., non-associated category pairs like *table* and *bed*), rather than specialize solely in activating only closely-related semantic pairs.

Other studies looked for evidence of asymmetric activation by holding depth of relationship constant while manipulating temporal factors. Nakagawa (1991) used stimuli that were associated, but not from the same category (e.g., *bees* and *honey*) and found priming at 67 ms SOA only for the LH, and bilateral priming at 750 ms SOA. Abernethy and Coney (1993) found LH priming at 250 ms and bilateral priming at 450 ms. Thus, associate pairs seem to show primary LH activation (i.e., less than 250 ms) that is maintained over the time course of processing (until 750 ms). The RH shows later initial activation (i.e. 450 ms onwards) that is maintained.

These time course investigations have lead to the consensus that each hemisphere may play a particular role at different points along the processing timeline. Given enough time, the RH is believed to activate a web of broad targets, whereas the LH initially activates a very narrow set of related information (Koivisto, 1997). That is, the LH initially activates strong relatives, but then reduces activation over time, whereas the RH is slower to activate, but remains activated longer for weaker relatives (Koivisto, 1998; Koivisto and Laine, 2000).

Given the supposition that each hemisphere has a specialized role, Chiarello, Maxfield, Liu and Kacnik (2001) investigated whether the normal role of the LH could be influenced to remain active for a longer period of time. In an attempt to show an increase in activation, items from the same semantic category were presented repeatedly at an SOA of 600 ms. Category pairs from six separate semantic neighbourhoods were used, such that the LH was exposed to words only related to *birds, vegetables,* and *body parts*, and the RH was presented with words only related to *animals, fruit,* and *clothes*. Priming was obtained in the RH, but was reduced as repetition increased. Additionally, priming did not occur in the LH, demonstrating that repetition cannot induce maintenance of category members in the LH. This finding indicates that hemispheres must maintain specific roles in processing, both in regards to time course and type of relationship.

Temporal Factors in Unilateral Language Processing

Henik, Dronkers, Knight and Osimani (1993) measured priming for strong associates in participants who had unilateral lesions. Results for participants with a functional LH matched literature that studied participants without brain injury; semantic priming occurred at 250 ms and increased by 1850 ms. For patients with a functional RH, priming did not occur at either 250 or 1850 ms time points. However, these participants were able to respond faster to the same words that had been presented earlier in the stimuli set (called identity priming), at both 250 and 1850 ms, leaving evidence of some implicit processing of language. In participants with Broca's aphasia (i.e., left frontal-temporal damage), Hagoort (1997) found that strong associates produced priming at 300 and 1400 ms. Milberg and Blumstein (1981) were unable to find priming for strong associates at 2000 ms for patients with LH damage.

The fact that patients with intact RH do not consistently show priming for strong associates is counter to the literature that demonstrates that neurologically intact individuals show sustained activation in the RH for the same type of relationship. At 1500 ms and 2500 ms SOAs, Bushell (1996) found that, when compared to healthy controls, participants with aphasia showed reaction times that were unexpectedly slowed (inhibited) for related primes. These results indicate that there appeared to be a mechanism in place that facilitated comprehension by removing irrelevant options to process.

Asymmetric Processing Results in Hemispheric Suppression

Revisiting Koivisto's (1997) time course experiment of 165, 250, 500, and 750 ms SOA, the LH showed priming after the 165 ms presentation, whereas the RH alone showed priming effects after the 750 ms presentation. At the 250 and 500 ms presentations, priming effects for each hemisphere were similar. Interestingly, a trend emerged demonstrating that the RH primed at 500 ms SOA, whereas the LH showed slower response times at this SOA. An increase in response time, so that it exceeds that for unrelated primes, is interpreted as inhibition.

Category priming in the RH at only later SOAs suggests that the initial priming that occurred in the LH becomes suppressed over time. The notion that information becomes suppressed is an interesting one. Nakagawa (1991) investigated the case of suppression by using primes that were strong associates (antonyms), distant associates, and unrelated words. Strongly associated targets primed in the LH at 67 and 750 ms. However, at 750 ms, slower response times occurred for distant and unrelated associates than to neutral trials, signifying inhibition. These results suggest that strongly associated material is rapidly activated in the LH, whereas unrelated and distant material becomes suppressed over time. In contrast, results of RH priming showed that priming strengthened from 67 to 750 ms for strong associates, and there was no inhibition for unrelated and distant associates. This finding is in keeping with the hypothesis that the RH retains its activation over time.

Summary: Bilateral and Asymmetric Processing

Manipulating the depth of relationship (i.e., similar/category members, associates, and category+associates), semantic priming research reliably demonstrates that each hemisphere initially activates a broad range of semantic information, with the RH initially activating at a later SOA than the LH. For the RH, activation is maintained for all types of relationships in normal readers and is inhibited for participants with aphasia. For the LH, semantic information is activated initially, and is maintained only for strongly related information (i.e. category+associates and associates) and is suppressed for irrelevant material. In this manner, language processing has hemispheric specialization that is complementary along the time course of language processing.

Thus far, the current literature review has presented papers that investigated how time and depth of relationship are important factors to consider in language processing. The ability to make connections between semantically relevant information reflects one aspect of language comprehension. Oftentimes, readers are called upon to not only draw upon relevant information, but also inhibit irrelevant information and make connections within context and between knowledge stored in semantic and episodic memory. Because using discourse material in the laboratory presents many methodological considerations, researchers have used words that carry more than one meaning to inform how context and frequency are employed to drive activation.

Ambiguity Resolution Specifies Processing Asymmetry

Homographs are words "where many meanings are associated with the same lexeme, though different meanings may have different pronunciations" (Hirst, 1987, p. 5). For example, *bank* could refer to a "financial institution", or the "side of a river". The meaning of a homograph is typically determined by cues (e.g., *The duck lived at the* *bank* versus *The accountant worked at the* *bank*). When presented without context, these words are disambiguated with respect to the frequency with which they appear in language[1]. The more frequent pairings (i.e., the two words with stronger association) are called *dominant* because they appear together more commonly. Pairs with lower associations are *subordinate.*

Chiarello, Maxfield and Kahan (1995) showed bilateral activation for the dominant meaning of ambiguous words at 80, 130 and 200 ms. To observe which hemisphere was more prominently activated by dominant or subordinate meanings, Burgess and Simpson (1998) presented ambiguous words at two SOAs (35 and 750 ms). In their study, the ambiguous words acted as primes (e.g., *bank*), and the targets were related to the dominant (*money*) or subordinate (*river*) meaning of each homograph. At 35 ms, there was activation in the LH for both meanings of the ambiguous word. The activation was maintained for the 750 ms interval for the dominant meaning, but not for the subordinate. Interestingly, the subordinate meanings actually showed slower response

[1] The notion that words with more than one meaning are processed using both context and the frequency of their individual meanings can lend support to an interactive model of language processing. Coney & Evans (2000) argue that if words were processed in a modular way, their meanings would be referenced from long-term memory without contextual cues. This "exhaustive access" model of language processing subsumes that all meanings of an ambiguous word are activated initially, and then inappropriate meanings are suppressed after a lexical decision has been made. In this way, context is used only to make decisions about which meanings are relevant *after* the individual words have been processed.

Coney & Evans (2000) outlined that the alternative view, a "selective access" model that proposes that context is fundamental to the processing of words, has been met with methodological limitations to measuring initial activation of semantics. In particular, it has been difficult to isolate the time participants require to process context. Criticism stems from study design in the sense that most tasks require a response *after* lexical access has occurred: "it may be that in such studies context exerts its effect, not upon the initial retrieval of meaning, but by biasing a subsequent response decision on the basis of relationships between context and target" (Coney & Evans, 2000, p. 273). Other limitations include generalizations about initial activation from long SOAs. Specifically, a response made at 1500 ms may be different from those made at 0 ms or 250 ms because the participant has had time to process many more possible meanings. Therefore, as is the case with words with singular meanings, studies that manipulate SOA and ISI provide more information about how ambiguity is resolved over time.

times than unrelated stimuli, suggesting suppression. In the RH, priming occurred at both time intervals for the dominant meaning, but only at 750 ms for the subordinate meaning.

Atchley, Burgess, Audet and Arambel (1996) performed a similar experiment, but quantified the level of dominance within the ambiguous words to include highly dominant (80% association to one meaning), and equibiased (where the dominant meaning was attributed less than 60% of the time, and the subordinate meaning was attributed more than 30% of the time). Priming occurred over 35, 300 and 750 ms SOAs. In the highly biased condition, the LH activated both dominant and subordinate meanings at 35 and 300 ms. By 750 ms, activation was maintained for the dominant meaning, and suppressed for the subordinate meaning. For the RH, both meanings were activated across all SOAs in highly biased relationships. For equitable ambiguous word pairs, bilateral activation was observed across all time intervals for dominant and subordinate meanings. As there would be no benefit in favouring one meaning over another (i.e., both senses of the word are equally probable), the balanced condition finding is logical and expected. Atchley et al. concluded that processing ambiguous words occurs such that there is an initial activation of information, which is tailored across time so that weakly related information is suppressed, and relevant information sustains activation.

Atchley, Burgess and Keeney (1999) hypothesized that compatibility might affect outcome, such that the more disparate the dominant and subordinate meanings are to one another, the more likely the irrelevant meaning will be suppressed. In order to extract the level of compatibility from association, words that had only one meaning were used and features of the words were manipulated as compatible factors. For example, if *milk* were chosen, its dominant feature relation (i.e., *liquid*) was used, as well as a compatible subordinate feature, such as *warm*. Incompatible subordinate feature words (e.g., *spoiled*) were also included. Priming was measured across 50 and 750 ms. At 50 ms, priming occurred in the LH for all relations of the word. Activation for only the dominant relative of the word was maintained over time, suggesting that the subordinate relative of the word was suppressed in the LH. The RH showed priming for dominant and incompatible subordinate words at 50 ms, but all features were primed at the later SOA, suggesting that the RH maintains more varied information.

Atchley et al. (1999) also manipulated the context qualifiers that were either congruent or incongruent with the prime. For example, *round* was compatible with *apple* but not with *liquid*. Target words were either dominant features of the words (e.g., *grow*), subordinate features (e.g., *bake*), or unrelated (e.g., *fur*). In the LH, priming occurred at 200 and 800 ms for contexts that matched dominant and subordinate meanings of the word. No priming occurred for the incongruent context and word, at either time interval. In keeping with the broad activation theory, the RH showed priming for all context combinations across both time intervals. Again, in keeping with previous findings, the LH was activated only for compatible information.

This study also contributed some understanding about what type of semantic context is used to mediate the selection of semantically relevant information in the LH. These results suggest that the RH activates both meanings of ambiguous words and maintains activation over 80, 130, 200 and 750 ms SOA. The pattern of activation for the RH indicates that it initially activates the dominant meaning, and then follows with the subordinate meaning. The LH activates both meanings simultaneously, then maintains the dominant meaning while suppressing the subordinate meaning. This is important to note, as it is possible that the LH has resources to direct which words are activated (dominant), and which are suppressed.

Faust and Lavidor (2003) suggested that the RH and LH benefit differently from meaning through their study of multiple primes that are convergent or divergent on an ambiguous target. In their research, they used dominant (e.g., *association, society -> club*), subordinate (e.g., *stick, weapon -> club*), and semantically mixed trials (e.g., *association, stick -> club*). At 800 ms SOA, the LH benefited most from multiple words that converged on the dominant meaning of the ambiguous word. The RH showed strongest activation for the words that were divergent (i.e., semantically mixed trials) on alternate meanings of the ambiguous target word. In keeping with the notion that the LH specializes in specific processing, the LH inhibited semantically mixed trials, while the RH remained active for all semantic possibilities. Priming was initially demonstrated for the LH for contextually relevant dominant meanings, and inhibition occurred later for contextually irrelevant information.

Patient Research Findings for Ambiguous Word Resolution

Regarding ambiguous word resolution in patient populations, Copland, Chenery and Murdoch (2002) compared lexical decision performance between individuals with LH damage and non-brain injured controls on words presented in the auditory modality. At ISIs of 100 and 1250 ms, participants heard two words, and were asked to make a decision about the level of relatedness of the third word. The first word provided context, the second was an ambiguous word, and the third was either related or unrelated. Four conditions were subdivided into being concordant because they converged on the dominant meaning of a word (e.g., *coin bank money*), dischordant because they contained dominant and subordinate meanings of the ambiguous word (e.g., *river bank money*), neutral (e.g., *day bank money*), or unrelated (i.e., *river day money*). Unlike neurologically intact controls, patients with LH damage were unable to suppress incongruent conditions relative to the unrelated ones (i.e., patient participants showed activation for all trials at both time intervals). These findings support the notion that the LH normally suppresses meanings that are not in keeping with the context in which ambiguous words are presented.

Atchley, Story and Buchanan (2001) found that dominant meanings influenced sustained activation in the LH for participants with aphasia and matched controls. Interestingly, subordinate meanings of ambiguous words were primed in neither hemisphere for disordered readers. Colangelo and Buchanan (2005) found a tenfold increase in semantic errors when a participant with deep dyslexia read ambiguous words grouped by semantic relation, as opposed to the same words presented randomly. Therefore, contextual cues provided by the semantic network (that would normally cue more accurate responding in an intact system), were inhibited in a case of deep dyslexia, suggesting that normal LH involvement plays a role in suppressing incorrect associates.

Summary: Hemispheric Specialization of Ambiguous Word Processing

Studies featuring patient and intact neurological participants verify differential hemispheric responsibility for language processing. Research examining the processing of similar/category members, associates, and category+associates together show that both hemispheres activate semantic information, with the RH initially activating at a later

SOA than the LH. For the RH, activation is maintained for all types of relationships. For the LH, semantic information is initially activated but is maintained only for strongly related information (i.e. category+associates and associates). Ambiguous word research in both neurologically intact participants and individuals with unilateral access further suggests that not only does the LH initially activate a broad range of information, but it quickly suppresses irrelevant information, while the RH is slower to activate all meanings initially, and sustains activation over time.

The aforementioned studies investigated hemispheric processing of single words, however research has been extended to investigate the processing of ideas as well. Of particular interest is how context influences asymmetrical processing.

Hemispheric Processing of Ideas

Faust and Babkoff (1997) performed a divided visual field study that used sentences as primes. They presented priming scripts that reflected "knowledge of the world" (e.g., *The beaches are filled with people during the summer months. Most people swim or sunbathe*), which were followed by targets. Participants made a lexical decision to one of four possible targets: related (e.g., *life guard*), unrelated (e.g., *window*), or one of two types of nonwords (i.e., stimuli created by rearranging letters from word targets). Although the greatest amount of facilitation was found for targets presented to the LH for related words, scripts facilitated lexical decisions for related word targets presented to the RH, too. The authors concluded that the priming advantage demonstrated by the LH suggests that either the LH must be more efficient in processing scripts, or that each hemisphere processes knowledge differently.

In this vein, Brownell, Potter, Bihrie and Gardner (1986) have specifically investigated the processing of inferences within neurologically intact and injured populations. Participants were asked to connect two parts of a story with an inference they generated on their own. For *the shuttle that was on the ground is now in space*, for example, neurologically intact controls made the inference that the shuttle was launched; patients with RH lesions did not. Likewise, in a similar experiment, Beeman (1993) reported that individuals with RH damage showed no priming for words that tested connective inferences (i.e., *launch*).

When neurologically intact participants were involved in a similar study, inference-related priming occurred for sentences that predicted outcome (i.e., *the shuttle sat on the ground waiting for the signal…*). That is, words that predicted outcome (i.e., *launch*) had faster response times than for unrelated words. This priming effect was only shown for words that were presented to the RH, and not the LH. During the second part of the study, when it was necessary to conclude the stories (i.e., *after a huge roar, the shuttle disappeared into space…*), priming only occurred for words that were presented to the LH. Beeman and Chiarello (1998) believed these results show that the hemispheres play complementary roles in drawing inferences. The RH initially activates related information, but the strength of this activation is too weak to draw conclusions. When a break or new direction in the story is provided, then the LH is called upon to bridge the gap in understanding, and it searches for a specific inference to make the entire story understandable. In this way, inferences are drawn through cooperative processing of both hemispheres, such that the RH excels at making predictive inferences, and the LH makes connective inferences.

Beeman, Bowden, and Gernsbacher (2000) also found that stories presented to the RH and LH were processed differentially. Priming for inferences about the stories was shown for predictive target words presented to the RH, where participants plugged in target words that predicted an event. Priming for coherence was shown for LH, where participants filled in a word to make an inference make sense, given a premise (e.g., *the shuttle sat on the ground waiting for the signal*) and a changed state (e.g., *the shuttle that was on the ground is now in space*). These results support the notion that the RH is engaged with more broad activation (i.e., possibilities and hypotheses) while the LH is primarily engaged with comprehension (i.e., making sense and drawing conclusions).

The ability to test semantic hypotheses and draw relevant conclusions has been studied with particular interest in individuals who acquire a deficit in either of these skills. Amongst otherwise seemingly unimpaired language ability, Hough (1990) reported that RH damage resulted in confabulations and difficulty depicting themes from stories. Brownell, Potter, Bihrle, and Gardner (1986) noted that individuals with RH damage had particular difficulty revising previously acquired information, in light of new knowledge. Pimental and Kingsbury (1989) reported that individuals with RH damage had difficulty understanding metaphors and that they typically render more concrete and literal interpretations. Examining the performance of individuals without brain injury, Kacinik and Chiarello (2007) discovered that each hemisphere has the ability to prime for literal and metaphoric meanings in sentences. However, unlike the LH, the RH maintained activation for meanings that were inconsistent with sentence constraints.

Another type of figurative speech, verbal humour, has also received some attention in clinical literature. Understanding verbal jokes requires inference-making in language processing. For jokes, inferences that connect premises and changed states are provided by a punchline, which often catches readers/listeners by surprise[2]. Several researchers have investigated the loss of humour appreciation in individuals who experience RH stroke (Brownell, Michel, Powelson & Gardner, 1983; Cheang & Pell, 2005; Heath & Blonder, 2005; Shammi & Stuss, 1999).

Brownell, Michel, Powelson and Gardner (1983) read jokes (minus the punchline) to individuals with RH lesions and asked them to select the most appropriate ending from 4 options:

The neighbourhood borrower approached Mr. Smith on Sunday afternoon and inquired: "Say Smith, are you using your lawnmower this afternoon?"

"Yes, I am," Smith replied warily.

The neighbourhood borrower then answered:

1. Correct ending: *"Fine, then you won't be needing your golf clubs, I'll just borrow them."*
2. Non-sequitur/surprise ending: *"You know, the grass is greener on the other side."*
3. Straightforward neutral ending: *"Do you think I could use it when you are done?"*
4. Straightforward sad ending: *"Gee, if only I had enough money, I could buy my own."*

Individuals with RH lesions tended to choose an ending that had an element of surprise, but was not otherwise congruent with the rest of the joke. That is, patients were

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[2] "A joke begins by establishing expectancy in the opening lines. Listening to the beginning of a joke, a subject uses his or her knowledge of the world to predict what should happen next. The punchline, however, is surprising in that it violates this expectancy… the subject reinterprets the punchline by figuring out how it might fit with the beginning of the joke…the success of a joke rests on the 'goodness of fit' between the punchline and what has come before, once the initial incongruity has been appreciated". (Brownell & Gardner, 1988, p.22).

more likely to choose non-sequitur endings than controls, indicating an overall understanding that a joke must contain an element of surprise, but not a specific enough level of comprehension to choose an ending that made sense to the particular context. The authors concluded that the RH is responsible for integrating content across all parts of a narrative. Because narratives require more attention than single sentences, it may have been too difficult to integrate all of the possible inferences in the joke stems.

Using Brownell, Michel, Powelson and Gardner (1983)'s stimuli, Shammi and Stuss (1999) found similar results when they tested participants with RH frontal lobe lesions. Like before, Shammi and Stuss' participants chose the surprise ending, and were unable to correctly identify the most congruent choice. Additionally, participants in this study were reported to display limited physical and emotional reaction to humour (i.e., smiling and laughter). Performance was correlated with measures of working memory, suggesting that verbal humour is associated with verbal abstraction ability and mental shifting. The emergence of more recent research investigating verbal humour processing has lent support to the notion that the RH specifically carries linguistic sub-functions.

Verbal Humour as a Specific Form of Language Processing

Recent literature has recognized that semantic processing is integral in the understanding of humour. Vaid, Hull, Heredia, Gerkens and Martinez (2003) carried out an experiment to ascertain when, in the time course of processing, the meaning of a joke is obtained. Through a lexical decision task, they tracked the initial and intended meanings by using targets that were related to the first activated sense or the second sense at three points along the presentation of the joke (i.e., (a) initial, (b) intermediary, and (c) immediately following the punchline). For example, following

Doctor calls patients and says, "The good news is you have 24 hours to live." (a)

Patient sobs, "Then what's the bad news?" (b)

Doctor says, "I forgot to call you yesterday!" (c),

related words reflecting first and second senses and nonwords were presented at the aforementioned time points. Priming effects for the first sense were present at the initial (a) and intermediary (b) time points. Priming for the second sense was present at the intermediary (b) and punchline (c) points. A second experiment investigated which target was primed following a prolonged delay after joke presentation. For *I went the extra mile, but my boss found me and brought me back,* targets related only to second meaning (i.e., *distance*) were primed. Targets related to first meaning (i.e., *excel*) did not show a strong priming effect after the 4500 ms delay. Results of this experiment demonstrate that the processing of humour requires a shift in semantics that favours the joke intent over time.

Other recent research has investigated the particular role the RH plays in joke comprehension. Goel and Dolan (2001) used fMRI to pinpoint the right medial ventral prefrontal cortex in humour appreciation. In an evoked related potential (ERP) study, Coulson and Lovett (2004) presented neurologically intact participants with sentences whose last word was altered so that it was either a joke or a straight sentence. For example, "*A device for finding furniture in the dark is a* ..." the joke ending was *shin* and the straight ending was *candle*. For right-handers (whose language is localized primarily the LH), jokes elicited positive activation over RH sites 500-900 ms after presentation and sustained negative activation over lateral LH sites. In left-handed participants (whose language is thought to be more bilateral[3]), jokes also elicited much broader RH activation 500-900 ms after stimulus presentation. The LH activation was absent from left-hander's results. The authors suggest that the processing of jokes must be rooted in a lateralized process.

Coulson followed with a study designed to further delve into the asymmetric aspects of verbal joke processing. Coulson and Williams (2005) performed a DVF ERP study that presented target words that were either semantically related or unrelated to jokes and nonjokes. Comprehension questions followed each target to measure understanding. Sample stimuli included: *The last time a guy in a mask took all my money, I was in* SURGERY (joke)/SHOCK (nonjoke). The comprehension question for the joke condition was: *I had been mugged* (no). The comprehension question for the nonjoke condition was: *I had been mugged* (yes). Results showed that priming occurred for LH targets related to jokes more than for nonjokes. RH presentation of targets related to jokes and nonjokes resulted in equal priming. These results support the previously-mentioned findings for single-word and non-joke sentence studies that demonstrate the RH's involvement as a broad activator and the LH's role as a specifier.

Coulson and Severens (2007) continued the investigation of RH contributions to joke processing by studying puns. Until then, no other known study had examined the lateralization of joke processing by using puns. The study of puns in language lateralization connects many of the aforementioned fields of study (i.e., automatic and controlled processing, discourse study, figurative language processing, and ambiguity resolution). In particular, sentence-primed ambiguity resolution takes place within a pun

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[3] For example, 22-27% of left-handers have symmetrical or RH lateralization of language versus 4-6% in right-handers (Knect, Dräger, Deppe, Bode, Lohmann, Flöel, et al., 2000; Pujol, Deus, Losilla & Capdevila, 1999; Szflarski, Binder, Possing, McKiernan, Ward & Hammeke, 2002).

context such that both meanings of an ambiguous word must be accessed and inferences made in order to understand the joke.

Coulson and Severens (2007) presented puns to participants in the auditory modality followed by visually-presented probes in a DVF paradigm and measured ERPs. Probes were created that were highly or moderately related to each meaning of the ambiguous words, by using Kucera and Francis (1967) word frequency norms. Probes were also matched for average word length. When probes were presented immediately following the end of each pun (i.e., 0 ms ISI), both meanings were activated in the LH. For the RH, the highly related meaning elicited activation, whereas the moderate associate did not. However, when probes were presented 500 ms after the pun, both meanings were activated bilaterally. These results suggest that puns likely force the LH to remain activated for a meaning it might typically suppress. That is, in order to understand the joke, the LH remained activated for both meanings of the ambiguous referent, which it had to maintain for comprehension. Later into processing, RH activation was noted. Consistent with previous lateralization literature, the RH was expected to remain activated for all meanings of the ambiguous word through even later stages of processing.

Coulson and Severens (2007)'s study was groundbreaking in that it was truly the next logical step in this evolutionary line of research. As outlined in the current review, what is known about the lateralization of language functioning started with early lesion studies, then moved to experimental study of word relationships and ambiguity resolution, then progressed to the processing of discourse and figurative language, and now incorporates the technology available to image these processes in special populations and within the neurologically intact. Coulson and Severens' recent study is exciting because it provides a convergence of technology (ERP), behavioural methods (ambiguity resolution), is driven by theory (e.g., Coltheart, 1987), and is supported by clinical observation (e.g., Shammi and Stuss, 1999).

Towards a Neuropsychological Model of Pun Processing

As knowledge unfolds about the process of ambiguity resolution, it would be helpful to compare research findings to a model. There are several models of ambiguity resolution that can be summarized as being driven by either context-dependent or context-independent processes. Regarding the former, selective access theories are based on the assumption that a single contextually appropriate meaning is appropriate for a given situation so is selected and drawn from memory (Simpson, 1994). Regarding the latter, ordered access models operate such that the most common meaning of an ambiguous word is the first to be retrieved. If this meaning is inappropriate, it is discarded and the next most common associate is activated (Hogaboam and Perfetti, 1975). Alternately, an exhaustive model is rooted in the notion that all meanings are accessed, and all but one are discarded, depending on what is appropriate for comprehension within a particular context (Onifer & Swinney, 1981).

In order to investigate lexical access in ambiguity resolution, most studies use methodologically controlled primes. For example, Faust and Lavidor (2003) used single words grouped together so that they either converged on one meaning (e.g., *association, society* → *club*) or were discordant across both meanings (e.g., *music, kidney* → *organ*).

Neither of these conditions mimics ambiguity resolution in vivo (where pragmatic discourse is typically neither so neatly constrained nor so divergent).

In contrast, Titone (1998) presented contexts that mimic ambiguity in parlance by constraining one meaning over another (e.g., for *Because the crime was so awful, it was a very bad sentence*, meaning is constrained to the subordinate [*jail*] rather than the dominant [*word*]). These sentences were primed bilaterally for the dominant and subordinate meanings. For sentences that reflected no bias *(e.g., It was a very bad sentence.),* priming was found for the dominant meaning in both hemispheres. For sentences that biased towards the peripheral aspects of the subordinate meaning (e.g., *Being swayed by public opinion, it was a very bad sentence*), the LH showed priming for the dominant meaning and the RH showed priming for the subordinate meaning (revealing its own sensitivity to context). Together, these results are consistent with a context-dependent model of processing in which lexical access is sensitive to bias.

The rationale for using puns in the current series of experiments was to provide the opportunity to investigate processing in a subset of language that purposefully encourages the activation of two separate meanings simultaneously. Because a model for pun processing does not currently exist, a working model will be outlined here, and evaluated against the outcome of a series of four experiments. The model has a basis in the Right Hemisphere Hypothesis and assumes hemispheric asymmetry of lexical access. It is expected that given the option between two semantically appropriate meanings, the LH will select the most common first (i.e., ordered access). However, because a second meaning is also appropriate, the LH will also show later priming for the subordinate associate. Because two means will always be appropriate to activate, the LH is forced to remain activated (i.e., suppression is prevented or halted), because the processing of both of the meanings within a pun context ensures the understanding of the joke. Consistent with the Right Hemisphere Hypothesis, the RH is also expected to demonstrate priming for both associates, however, the RH is expected to favour no option over another. Pragmatically, the RH will prime for both meanings, but is expected to have slower response times for both related conditions. However, once disambiguation is required (i.e. a change in context requires the subordinate meaning of the word to be activated as well), the LH will likely become reactivated. Particularly, puns likely force the LH to remain activated for a meaning that might otherwise be suppressed. That is, in order to understand the joke and resolve the conflict of meaning, the LH must remain activated for both meanings of the ambiguous referent. Thus, according to this model, participants who are exposed to puns will show priming for both meanings in a central lexical decision, with the response times for dominant meanings being faster (ordered access). Results of a DVF study are expected to demonstrate ordered access for the LH (i.e., both are primed and the dominant is faster), and broad activation for both meanings in the RH.

Grand Summary and Rationale

Cognitive researchers have investigated how the RH is specifically involved in word processing by testing the Right Hemisphere Hypothesis, a theory of language functioning compiled from the observations of individuals whose LH damage is so extensive that their language abilities are presumed to originate from only RH contributions. Evidence of asymmetric language processing has been collected from studies that manipulate depth of relationship, time course, and ambiguity resolution.

Simultaneously, researchers in the field of clinical neuropsychology had observed how individuals with RH damage lose the ability to understand humour, and concluded that patients' deficits arose from functions subsumed by frontal processes. New research has started to bridge these two lines of study by investigating the linguistic contributions to verbal humour processing.

The current series of experiments explored how ambiguous words were resolved in humourous contexts, while controlling for psycholinguistic variables that may drive semantics. Puns were presented to individuals with intact neurological systems using lexical decision and relatedness experiments. In the first experiment, ambiguous words were presented in a single-word lexical decision study to confirm the presence of priming for dominant and subordinate meanings. In the second experiment, puns were presented as primes in a lexical decision task where dominant and subordinate relations to ambiguous words acted as targets that were presented centrally. This task was included to determine whether the general effect of sentence priming existed using puns as primes, and to ascertain whether the dominant or subordinate relationship was more efficiently primed. The third experiment was a DVF study in which puns were presented as primes and dominant and subordinate targets were presented to either visual field. The results of this experiment were compared to the results of the study that presented targets centrally, as both were comprised of the same stimuli. In the fourth and final experiment, puns and the dominant and subordinate relatives of their ambiguous referent were presented in a forced-choice relatedness task in order to determine the primary meaning participants processed from puns (and whether the meaning chosen was associated with faster processing). As a collection, these four experiments were designed to blend ambiguous word research protocol with humourous contexts in order to unearth more about RH contributions to joke and language comprehension in a population of non-disordered readers. The results of this study will add to the small, but growing body of literature that is currently investigating hemispheric contributions to joke comprehension. Furthermore, because only one other study has used puns as stimuli in this pursuit to date, current results contribute towards the little that is known of asymmetrical language processing using puns.

My contribution to this nascent body of literature is threefold. Firstly, I was interested in keeping the modality of presentation and response within the visual domain to constrain resolution within reading. I wanted to use a measure of lexical co-occurrence that was based on text reading, so wanted to ensure that modalities of stimuli presentation was also in the visual modality.

Secondly, authors of the previous pun study (Coulson & Severens, 2007) considered ambiguity resolution in terms of the presence or absence of bias contained in the pun (i.e., highly related to one meaning or another). In order to develop their stimulus set, they asked independent raters to read each pun and rate potential probes for level of relatedness. Because ambiguity is typically resolved using context and frequency, my novel contribution was to approach the understanding of ambiguity resolution from a meaning frequency basis (i.e., dominance). I assigned dominance from a source that rates the level of relatedness from a model of lexical co-occurrence, rather than relying on human interpretation (which may have inadvertently included some aspect of successful identification and reinterpretation of the pun). Dominance was defined by the values generated from a model of meaning frequency to provide a strong psycholinguistic basis for understanding lateralization findings.

Finally, considering study results in light of what is known about neuropsychological findings (i.e., loss of humour appreciation in individuals with RH lesions) an investigation of puns was intended to contribute towards the Right Hemisphere Hypothesis. By studying individuals without neurological change, results are more generalizable as a natural consequence of language functioning, rather than as an artifact of injury.

Chapter 2: Experiment Series

Participants:

Participants for all studies were students from the University of Windsor. Those who were eligible, received course credit in exchange for their participation. All individuals who were able to complete the experiment participated[4], however, only data from those who met inclusion criteria were used in the analyses. Inclusion criteria consisted of right-handed native English speakers who self-reported being neurologically intact (i.e., no history of: stroke, traumatic brain injury, tumor, epilepsy, etc.).

Demographic information was collected from each participant including age, gender, number of years of formal education, and whether English was their first and primary language (see Appendix A).

Handedness was collected as a continuous variable, using The Edinburgh Inventory (Oldfield, 1971; see Appendix B). Data from individuals who identified

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[4] The rationale for this decision was to allow psychology undergraduate students the experience of participating in research as well as allow equal opportunity to earn course credit.

themselves with left-handed tendencies (i.e., individuals scoring below the 5th decile) were excluded from the divided visual field analyses because language laterality has been shown to be more atypical in left-handed individuals (e.g., 22-27% symmetrical or right lateralization versus 4-6% in right-handers) (Knect, Dräger, Deppe, Bode, Lohmann, Flöel, et al., 2000; Pujol, Deus, Losilla & Capdevila, 1999; Szflarski, Binder, Possing, McKiernan, Ward & Hammeke, 2002).

A measure of reading fluency on which to gauge facility with language was also included. Participants were asked to read a passage aloud as quickly and as accurately as they could for one minute. Total number of words read, substitution errors, omission errors, addition errors, and episodes of fluency failure were recorded, as outlined by Rasinski (2004). The passage chosen was the first few paragraphs of "Alice's Adventures in Wonderland" by Lewis Carroll (1865) (see Appendix C). This particular passage was chosen for its reading level (Grade 8.56; SearchLIT, 2009), sentence structure, and because the text was in the public domain. Data from participants whose reading fluency scores were lower than 3 standard deviations were excluded from analyses.

Materials:

Stimuli for all experiments were created using puns retrieved from www.punoftheday.com, a website in which members of the public submit puns they have created. Puns are rated by site users and are organized into categories regarding subject-matter. Puns for the current study were chosen based on subject-matter (i.e., regarding neutral topics like academia, careers, and animals), and contained only one ambiguous reference (i.e., puns like *The Buddhist refused pain-killers during the root canal because* *he wanted to transcend dental medication* were excluded because they had more than one ambiguous referent). Puns were also selected based on the type of wordplay used. Specifically, puns that used homographs as the ambiguous referent were chosen as experimental stimuli (e.g., *A box filled to the brim with jelly jars is jam packed*). Puns that used homophones with incongruent spellings were excluded from the experimental list (e.g., *A cardboard belt would be a waist (waste) of paper*). Overall, more than two hundred puns matching these inclusion criteria were selected from the website.

Homographs for each of the puns were then identified (e.g., for *A psychiatrist on a hike fell into a depression*, DEPRESSION was identified as the homograph). Two synonyms representing both meanings of each pun's homograph that suited the context of the joke, and were not otherwise repeated within the pun were chosen (e.g., for DEPRESSION, *sadness* and *hole* were chosen). Puns that duplicated homographs were excluded. Of the remaining puns, similarity distances between each homograph and its two synonyms were then drawn from Durda and Buchanan's (2008) Windsor improved norms of distance and similarity of representations of semantics (WINDSORS) model. WINDSORS provides values to represent semantic characteristics of words by analyzing the number of times a pairs of words occur near one another in text[5]. For example, the

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[5] WINDSORS is a model of semantic representation that relies on lexical co-occurrence (Durda and Buchanan, 2008). Semantic representations are derived by performing a statistical analysis of word use, gathered from a large corpus of written English. A small window is passed over each word in the corpus and the number of times that a pair of words occur together in each window is counted and stored in a large matrix. As word frequency has a strong effect on these counts, with higher frequency words appearing together more often than low frequency words, a statistical technique was used to reduce the effects of word frequency (see Damerau, 1993). The representations constructed by the WINDSORS method have been shown to capture some general characteristics of human semantic memory. The representations are sensitive to the differences in associative and semantic similarity and accurately reproduced the results of several behavioural experiments (e.g., Chiarello, Burgess, Richards, and Pollock, 1990; Ferrand and New, 2004; McNamara and Altarriba, 1988). The representations have also been shown to contain categorical information, revealed by multi-dimensional scaling. In addition, an artificial neural network was trained to map from the representation of a concept produced by WINDSORS to a list of features possessed by that concept (McRae, Cree, Seidenberg, and McNorgan, 2005). The resulting network accurately identified

relationship between DEPRESSION-*sadness* and DEPRESSION-*hole* was calculated to be 0.217 and 0.077, respectively. Generally, pairs with low similarity have low values (i.e., -0.2 to 0.2) and pairs with high similarity have higher values (i.e., 0.5 to 1.0). Regarding the creation of the current experimental stimuli, pairs with a low similarity values were labeled as *subordinate*, and pairs with higher similarity values were labeled as *dominant*.

Thus, each pun was associated with two word pairs: the ambiguous referent and its lexical co-occurrence dominant match, and the ambiguous referent and its lexical co-occurrence subordinate match. Dominant similarity pairs ranged from 0 to 0.78 (M=0.33, SD=0.19) and subordinate pairs ranged from 0 to 0.51 (M=0.12, SD=0.11).

Word length, number of syllables, orthographic frequency (per million words of text), and number of orthographic neighbours (total number of entries in the dictionary that are exactly one letter different, by substitution only, from the homograph), were collected for each homograph, its dominant synonym, and its subordinate synonym using Wordmine2 (Durda & Buchanan, 2006). Wordmine2 is a database that provides phonological and orthographic correlates of words based on a scan of over 300 million words of English text and factors out the influence of frequency. In order to create the current experimental list that was matched across values for length, number of syllables, orthographic frequency, and orthographic neighbours, many of the original puns had to be excluded. Controlling for the phonological and orthographic variables, there were a total of 96 experimental pun stimuli (see Appendix D for a complete list of experimental and control stimuli).

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features for all concepts on which it was trained and was able to generalize this ability to novel concepts, correctly identifying a high proportion of features for concepts on which the network had not been trained.

Means of each variable were compared to ensure that there was no significant difference between each group on orthographic and phonological variables. The experimental conditions did not differ on word length, syllable count, word frequency, or orthographic neighbourhood. Means of each variable were compared to ensure that there was no significant difference between each group. Groups were matched for word length, and number of syllables. With respect to word frequency, there was no difference when compared to word type [$F(3, 376)=.69, p=.56$]. Regarding orthographic neighbourhood, there was no difference when compared to word type [$F(3, 376)=1.59, p=.19$]. Tukey's post hoc analyses revealed no significant relationships. Table 1 lists all variables.

Due to the difficulty of securing so many homograph-only puns, a small number of sentences that used homophones with incongruent spellings were included in the control list for central and divided visual field experiments (e.g., *One hat told another to stay put while it went on* *<u>ahead</u>* *(a head)*). Average sentence length was 9.8 words (*SD*=2.4 words) for the experimental puns, and 9.7 words (*SD*=2.1 words) for the control puns. Puns ranged from 4 to 12 words in length.

Stimuli that looked like words, but had no meaning in the English language, were created to match ambiguous, dominant, and subordinate words for use in all lexical decision experiments. These *nonword* stimuli were matched by "word" length, number of syllables, and contained consonant and vowel blends that were pronounceable but were not pseudohomophones[6] (see Appendix E for a complete list of single word and nonword stimuli).

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[6]Sears, Siakaluk, Chow & Buchanan (2008) report that the use of pseudohomophones (i.e., nonwords by orthography which activate the phonology of real words, e.g., *brane*) increases reaction time to nonwords and influences participants to engage in more extensive orthographic processing. A greater focus on orthographic processing produces larger word frequency and neighbourhood size effects.

General Procedure:

All experiments were conducted in a private testing room within the Psychology Department at the University of Windsor. The experiments were presented on an IBM compatible Pentium 4 CPU 2.40 GHz with 504MB of RAM. Each was outfitted with a 19" flat screen Dell monitor, Microsoft Windows XP, and Direct RT Research Software (Empirisoft, 2006), a program that has the ability to vary time of display of stimuli down to the millisecond. Direct RT also measures reaction time of participants' responses to the millisecond.

Participants were initially provided a consent form (see Appendix F) that had been approved by the Research Ethics Board (REB) at the University of Windsor, then were given instruction about how to complete the task (see below), and finally performed practice trials (under the supervision and feedback from the experimenter) before completing the task on their own. Participants were assigned to each experimental condition randomly.

Experiment 1: Lexical Decision for Homographs and Related Words

The first study had two main goals: (1) to evaluate whether the experimental word pairs would produce semantic priming and (2) to examine whether the WINDSORS (Durda & Buchanan, 2008) categorization of the strength of the semantic relationships maps onto the priming behaviour described in the literature.

Method

In this continuous primed lexical decision experiment, participants were asked to decide whether a letter string that appeared in the centre of the screen in ALL CAPS was a real English word, or a nonword. If it was a real word, they were instructed to press the "?" key. If it was a nonword, they were instructed to press the "Z" key. Each letter string appeared on the screen until the participant responded[7]. The target homographs were preceded by their dominant or subordinate associate or by an unrelated word, such that participants were exposed to 32 pairs from each category. These primes were treated the same as the targets and participants had to make lexical decisions for these items as well. All stimuli were presented in upper case white font on a black screen for the length of time required for participants to respond. Lists were counterbalanced so that the dominant, subordinate or unrelated matches preceded each ambiguous word across three conditions. An equal number of nonword-nonword, word-nonword, and nonword-word pairs were also presented, in order to constrain responding within a lexical decision task and to prevent expectancy effects. Items used in the latter categories were not from the experimental conditions. Within each list, stimuli were presented in random order across participants. Lexical decision times and accuracy were recorded.

Results

A total of 46 participants completed the experiment. Data from six participants were excluded because they did not meet inclusion criteria (not native speakers of English). Additionally, another participant had indicated a suspicion of having Attention Deficit Hyperactivity Disorder (ADHD), but had not been formally diagnosed. As the majority of this participant's reaction times were also more than 3 SD from the mean, her

[7]This type of task is a continuous lexical decision task because a lexical decision was required for all stimuli presented. This method of delivery was chosen over the standard lexical decision task (in which only targets require a response) because it has been shown to be sensitive to even the most subtle semantic relationships (McNamara & Altarriba, 1988). Specifically, participants involved in standard lexical decision may adopt a strategy of comparing the strength of relatedness between two words that are paired temporally to assist in their word/nonword decisions, essentially blinding them to more subtle semantic relationships because of their tendency to engage in post retrieval checking (Balota & Lorch, 1986),

data was excluded. Therefore, data from a total of 39 participants was analysed. There were 25.6% men and 74.4% women. Average age of participants was 22.3 years (SD=4.5 years). Participants responded to target stimuli with 97.7% accuracy. Error trials were removed from analysis. Any reaction times greater than 3 SD from the mean (in this case, any reaction time greater than 2100 ms) were removed from the data set. This resulted in the removal of less than 0.5% all reaction time data.

An analysis was undertaken to ascertain whether there was any effect of counterbalancing lists of stimuli presented to participants. No interaction of list and relatedness was observed [$F(4,72)=1.90$. $p=.12$], and this factor was therefore excluded from the analysis. Participants produced shorter reaction times for targets preceded by primes [$F(1,38)=9.43$, $p<.01$]) as listed in Table 2 and as depicted in Figure 1. Comparison by t-test with Bonferroni correction revealed a difference between Dominant and Unrelated primes that was significant for subjects [$t(38)= -3.07$, $p<.01$]. The difference between Dominant and Subordinate primes approached significance [$t(38)= -2.02$, $p=.05$]. The difference between Subordinate and Unrelated primes was not significant [$t(38)= -1.00$, $p=.32$]An items analysis also confirmed the influence of dominance on reaction time [$F(1,95)=5.082$, $p=.03$].

Discussion

This experiment was performed to ensure that the ambiguous words chosen in this series of experiments elicited priming effects similar to those described in other studies using ambiguous words. The items do produce semantic priming with shorter reaction times for targets preceded by a related word than for targets preceded by an unrelated word. The question of whether the WINDSORS values represent semantic distance in a psychologically meaningful way was also answered: The similarity variable produced the expected result with greater priming for dominant than subordinate pairs. These results are consistent with literature that demonstrates priming is strongest for more similar relatives (Atchley, Burgess, Audet & Arambel, 1996; Burgess & Simpson, 1998; Hogaboam & Perfetti, 1975; Simpson, 1994), and effectively show that values based on WINDSORS (Durda & Buchanan, 2008) were appropriately predictive of semantic relationships based on lexical co-occurrence.

More specifically, these findings show that the frequency with which the words are paired (i.e., dominance) moderates the semantic priming effect. This implies that the most common meaning is either more strongly or more quickly activated than the less frequent meaning. In more pragmatic terms, the results show that the stimulus set has the desired semantic properties. Subsequent experiments in this dissertation therefore use a subset of this stimulus set.

Experiment 2: Centralized Lexical Decision for Puns

A centralized lexical decision experiment was designed to test priming of both meanings following pun reading. The working hypothesis about wordplay resolution gives rise to the prediction that equal priming will be found for both dominant and subordinate meanings.

Method

Experimental puns were presented serially and centrally (i.e., each word appeared singly in the middle of the screen), at a rate of 500 ms per word. Sentences were followed by a fixation cross that appeared for 500 ms. Participants were instructed to decide whether the letter string that appeared next in ALL CAPS was a real English word, or a nonword. If it was a real word, they were instructed to press the "?" key. If it was a nonword, they were instructed to press the "Z" key. Each letter string appeared centrally for 150 ms, 500 ms after the presentation of the final word of the pun. Lexical decision times and accuracy were measured for 96 experimental puns that were followed by: 32 dominant relatives, 32 subordinate relatives, and 32 unrelated words. Lists were counterbalanced so that every experimental pun was followed by its assigned dominant, subordinate and unrelated word. The dominant targets of other puns acted as "unrelated words" because they were matched to different puns and were not repeated within a condition[8]. The list also included 96 control puns that were followed by the same nonwords from Experiment 1. All stimuli were presented in a random order.

In order to ensure that participants attended to the puns that preceded each lexical decision, they were given a relatedness task for one third of the experimental stimuli, incorporating rationale used by other researchers. For example, Titone (1998) followed all of the lexical decision trials in her study with either response accuracy feedback or a comprehension question. All participants responded with at least 70% accuracy to these follow-up questions, ensuring that accurate perception and meaningful processing had occurred. With respect to the current study, the motivation for following lexical decisions with a relatedness task was two-fold. Firstly, the appearance of the relatedness cue provided participants with feedback that their previous lexical decision was accurate. Secondly, a decision about the relatedness between a word and its preceding sentence implicitly probes for the understanding of the pun without adding separate

[8] The rationale for choosing dominant words to be in the unrelated trials was to further test the ordered access model, allowing direct comparison of reaction times from the dominant condition to the subordinate and unrelated contextual/prime conditions.

comprehension questions that would increase length of experiment time and fatigue participants. The relatedness task required participants to respond whether the word about which they had just made a lexical decision was related to the previous sentence. They were instructed to press the "?" key if it was related. If it was a not related, they were told to press the "Z" key. Reaction time for each relatedness decision was recorded. The relatedness task appeared following 16 dominant relatives, 16 subordinate relatives, and 32 unrelated words. Thus, unrelated words and related words were presented in an equal ratio (32 each).

Results

A total of 46 participants completed the experiment. Data for one were excluded because she did not meet inclusion criteria (i.e., a formal diagnosis of Attention Deficit Hyperactivity Disorder (ADHD)). Data from a second participant was excluded because most reaction times were greater than 3 SD from the mean. Therefore, data from a total of 44 participants was analysed. There were 19.0% men and 81.0% women. Average age of participants was 29.8 years (*SD*=8.4 years). Average level of educational attainment was 17.4 years (*SD*=3.1 years). Participants responded to target stimuli with 98.6% accuracy. Inaccurate data were removed from analysis. Any reaction times greater than 3 SD from the mean (in this case, any reaction time greater than 2500 ms) were removed from the data set. This resulted in the removal of 30 RTs (equaling 0.68% of all reaction time data). An analysis was carried out to ascertain whether any effect of list counterbalancing existed. As in the single word study, no interaction of list and relatedness was observed [$F(2,41)=1.02$, $p=.37$], therefore, this factor was excluded from the analysis.

An analysis of variance of reaction time revealed priming effects for subjects [$F(1,43)=13.53$, $p<.01$] and items [$F(2,282)=3.41$, $p=.03$]. Further comparison by t-test with Bonferroni correction revealed a difference between Dominant and Unrelated primes that was significant for subjects for the left hemisphere [$t(59)= 5.48$, $p<.01$]. The difference between Subordinate and Unrelated primes was also significant for subjects for the left hemisphere [$t(59)= -3.34$, $p<.01$]. No other comparisons within subject data were significant. With respect to accuracy data, analysis showed a main effect of accuracy for subjects [$F(1,43)=10.03$, $p<.01$], but not for items [$F(2,285)=1.13$, $p=.32$]. Results of analyses are displayed in Table 3 and depicted in Figure 2.

Data from the comprehension relatedness task for this experiment were also analysed. Participants responded with 92.0% accuracy. Inaccurate responses were removed. Any reaction times greater than 3 SD (i.e., more than 6000 ms) were also removed. A total of 13 data points were removed, which was 0.5% of all accurate data. Results show that response times for words that were related to puns (M=979.1 ms, SD=434.2 ms) were shorter than for unrelated words (M=1176.8, SD =537.9) [$t(87)= -3.83$, $p<.01$], as illustrated in Figure 3. Additionally, within the related trials, there was a faster response time associated with dominant items (915 ms versus 987 ms for subordinate cases). This trend, along with the high accuracy rate, suggests that the relatedness task tracked participants' attention and comprehension of the pun primes.

Discussion

As expected, results of the pun-primed lexical decision task revealed an effect of dominance, with targets representing the dominant meaning being more efficiently primed by the puns than their unrelated counterparts. Moreover, the subordinate condition did produce some priming as evidenced by its advantage over the unrelated condition. These results confirm that, when exposed to puns, participants were able to access both meanings. Furthermore, greatest priming for the dominant condition is consistent with the order access model (Hogaboam & Perfetti, 1975), in which the most common meaning of an ambiguous word is accessed first and therefore most quickly. According to this model, retrieval for alternate meanings takes more time, as demonstrated by relatively weaker priming for the subordinate meaning than for the dominant meaning[9].

Although accuracy analysis revealed a main effect in the subject analysis, accuracy rates for all conditions were greater than 95%, indicating response rates well above chance. The relatively lower accuracy rate in the unrelated condition may be a direct consequence of the incongruous pairing of an unrelated word to pun prime, which likely reflects the presence of postretrieval relatedness checking (as alluded to earlier) described by Balota & Lorch (1986).

The clear demonstration of priming following pun reading is thus far consistent with the working model of pun processing, which supposes simultaneous activation of ambiguity. However, given researchers' account of deficits in verbal humour following RH injury (Brown, Paul, Symington & Dietrich, 2005; Brownell & Potter, 1988; Shammi & Stuss, 1999) and the potential link to Coltheart's (1987) Right Hemisphere Hypothesis, the question of whether there are specific hemispheric contributions for the observed priming remained. Considering many reports of asymmetric processing of ambiguous word meaning that show specific activation in the LH and broader activation in the RH

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[9] Although Duffy, Morris & Rayner (1988)'s model of re-ordered access (which is based on frequency and context) essentially replaces Hogaboam & Perfetti's 1975 model, I chose to conceptualize the behavioural results in the latter's frequency-only model because my experimental groups were based only on frequency.

(Beeman, 1994; Burgess & Simpson, 1998; Chiarello, Maxfield & Kahan, 1995; Faust & Lavidor, 2003; Simpson, 1994; Titone, 1998), and Coltheart's (1987) Right Hemisphere Hypothesis of semantic language functions, strong priming effects for both meanings in the LH and weak priming effects were expected in the RH. Although literature describes a suppression effect in the LH for other stimuli, it should not be found for pun processing because activation for both meanings must occur for a pun to be correctly processed.

Experiment 3: Divided Visual Field Lexical Decision for Puns

A divided visual field experiment ascertained the relative contribution of meaning dominance as an effect of lateralization in the processing of meaning from puns.

Method

Experimental puns were presented serially and centrally (i.e., each word appeared singly in the middle of the screen), at a rate of 500 ms per word. Sentences were followed by a fixation cross that appeared for 500 ms. Participants were instructed to decide whether the letter string that appeared next in ALL CAPS was a real English word, or a nonword. If it was a real word, they were told to press the "?" key. If it was a nonword, they were instructed to press the "Z" key. Each letter string appeared between 2.5° and 10.5° of either side of participants' central vision (Bourne, 2006). Visual angle was calculated using the formula:

$$\tan(\theta) = (|b-a| \div d)$$

where $\theta = 2.5°$ or $10.5°$, d is the distance from the fixation point to the eye and b-a is the distance from the fixation cross to the start or end of each word (Kaiser, 2009) (see Figure 4). In order to support participants keeping their gaze fixated centrally, a chin rest

(Richmond Products) was placed 45 cm from the monitor. Words were programmed to appear within 1.96 cm and no more than 8.34 cm away from the centre fixation cross. All words in all lists were individually measured to confirm proper placement from the centre of the screen. In this way, targets were presented consistently to participants' peripheral vision for 150 ms, 500 ms after the presentation of the prime. The distance between chin rests and monitors were recalibrated at the beginning of each session of data collection.

As in the centralized study, lexical decision, accuracy, and reaction times were measured for the 32 dominant relatives, 32 subordinate relatives, and 32 unrelated words that followed 96 experimental puns and for the 96 nonwords that followed 96 control puns. Lists were counterbalanced so that every experimental pun was followed by its assigned dominant, subordinate, and unrelated word and that these words were presented equally to the right and left visual fields. Unrelated words were chosen from the associates of other puns and were matched incongruously so that no target was repeated in a condition. The nonwords were also presented in either visual field. All stimuli were presented in a random order. A relatedness task followed one third of the experimental stimuli, as described in Experiment 2.

Results

A total of 70 participants completed the experiment. Data from 10 were excluded because they did not meet inclusion criteria (seven were not native speakers of English, and one had a traumatic brain injury where loss of consciousness exceeded 6 hours). Data from two participants were excluded because most of their reaction times were greater than 3 SD from the mean. Therefore, data from a total of 60 participants was analysed. There were 20.4% men and 79.6% women. Average age of participants was 28.6 years

(*SD*=9.0 years). Average level of education was 16.5 years (*SD*=2.5 years). Participants responded to target stimuli with 84.2% accuracy. Inaccurate data was removed from analysis. Any reaction times that were greater than 3 SD from the mean (in this case, any reaction time exceeding 4200 ms) were removed from the data set. A total of 26 RTs were removed in this way (equaling 0.51% of all accurate data).

An analysis was undertaken to ascertain whether there were any effects of counterbalancing list. No interaction of list and any other variable was observed (i.e., List x Dominance [$F(10,108)=1.64, p=.13$], or List x Hemisphere [$F(5,54)=1.86, p=.12$]). There was also no interaction of List x Dominance x Hemisphere [$F(10,108)=1.51$, $p=.15$]. Thus, it was appropriate to collapse data across lists for the analyses described below.

Means for each condition are displayed in Table 4 and illustrated in Figure 5. A two-way analysis of variance (ANOVA) was conducted for reaction time across subjects (F1) and items (F2) with Hemisphere (LH or RH) and Dominance (dominant, subordinate, or unrelated). Analyses revealed a significant main effect of Dominance for participants [$F1\ (2,58)=9.04, p<.01$] and an effect that approached significance for items [$F2\ (2,285)=2.73, p=.06$], favouring the dominance of relationship seen in the centralized experiment. There was also a main effect of Hemisphere for participants [$F1(1,59)=23.21, p<.01$] and items [$F2(1,285)=23.52, p<.01$], where the LH showed a priming advantage across all conditions. The interaction between Dominance x Hemisphere approached significance in participants [$F1(2,58)=2.78, p=.06$] and items [$F2(2,285)=2.33, p=.09$]. Further comparison by t-test with Bonferroni correction revealed a difference between Dominant and Unrelated primes that was significant

[$t(38) = -3.07$, $p < .01$] for participants. The difference between Dominant and Subordinate primes approached significance [$t(38) = -2.02$, $p = .05$].

Regarding accuracy data, analyses revealed a significant main effect of hemisphere for subjects [$F1$ $(1,59) = 45.11$, $p < .01$] and items [$F2$ $(1,284) = 37.73$, $p < .01$], expectedly favouring the higher accuracy rates in the (LH) language hemisphere. Dominance was also significant for subjects [$F1$ $(1,59) = 16.19$, $p < .01$], but not for items [$F2$ $(2,284) = 2.00$ $p = .14$], such that the unrelated trials had lowest accuracy. Subjects analysis revealed an interaction between dominance and hemisphere [$F1$ $(1,59) = 6.04$, $p = .02$]. No other relationships were significant.

Data from the relatedness task for this experiment were also analysed. Participants responded with 93.6% accuracy. Inaccurate responses were removed. Any reaction times that were greater than 3 SD (i.e., more than 6000 ms) were removed. This resulted in the removal of 14 data points, which totaled 0.45% of all accurate data. Response times for words that were related to puns ($M = 937.3$ ms, $SD = 335.4$ ms) were shorter than for unrelated words ($M = 1387.9$, $SD = 480.4$) [$t(117) = -11.28$, $p < .01$], as illustrated in Figure 6. As with the previous experiment, the high accuracy rate, relatively shorter reaction times for relatedness decisions made for dominant relatives, and the overall facilitation displayed for related pairs appeared to be useful in tracking participants' attention and comprehension of the pun primes.

Discussion

As with the centralized study, priming occurred in the DVF conditions because the reaction times for unrelated targets were slower than for related targets. The most notable finding for this study is the observation that the pattern of priming for the LH reflected the pattern garnered from the centralized study (i.e., dominant relatives were most quickly processed). As before, this finding lends support to an ordered access model of processing that outlines that the most common meaning will be activated first.

An equally important finding is the demonstration that there was little priming in the RH for both dominant and subordinate conditions. These results are consistent with the Right Hemisphere Hypothesis such that coarse coding revealed no relative advantage of dominance in processing either meaning of a homograph in pun contexts.

When the results for LH and RH were collapsed, the pattern of priming reflects that seen for the centralized study. The consistency of results likely means that frequency of dominance of the relationship is associated with the processing of meaning in puns. Investigating the relative contribution by either hemisphere suggests that ambiguity may be resolved through the concerted effort by two separate processes. It appears that process is driven by specific activation from the LH (by way of ordered access based on frequency) (Hogaboam & Perfetti, 1975), and is supported by broad activation of the RH. In this case, it appears that the RH may be the base of pun processing because this is where alternate meanings are made ready for access.

There are four possible reasons for the lack of a stronger interaction between all of the variables in the DVF task. Firstly, because the pattern of priming observed for the RH was (expectedly) weak, statistical results may be a result of the RH's subtle differentiation in priming across conditions. Secondly, it is possible that both meanings were not accessed at the 500 ms ISI used in this experiment. According to the ordered access model, the most common relationship would be primed first, so that more time would allow greater access to alternate meanings. Thirdly, participants showed sensitivity to the dominance of the stimuli in their accuracy of reporting. Although this sensitivity was in expected directions by hemisphere (i.e., poorer RH accuracy), it was not regarding dominance (i.e., the poorer accuracy for least related/frequent pairings was followed by poorer accuracy for dominant items). Although some targets were longer in length (increasing their chances for misperception in the left visual field), these particular items were not exclusively associated with longer RTs. Fourthly and finally, there may have been a selection bias in the original choice of dominant and subordinate referents, appropriate to each pun's context. More specifically, because words that represented two acceptable meanings were assigned membership in dominant and subordinate categories based on values generated from WINDSORS (Durda & Buchanan, 2008), it may be possible that the use of another word to reflect the dominant or subordinate meaning may have resulted in a stronger effect with respect to the sense intended within each pun. This hypothesis may be used advantageously to test the model that dominance in language plays a role, by purposefully manipulating the word used to represent the same dominant and subordinate meanings, and seeing whether priming continues to be a function of lexical co-occurrence.

Experiment 4: Relatedness Study

Given the possibility of ambiguity resolution based on dominance of meaning, it was important that the processes involved in meaning resolution also be considered directly. This was examined in an experiment in which puns and their relative targets were presented to participants who were asked to decide which of two words was most related to the meaning of the ambiguous word embedded in the pun.

Method

Experimental puns were presented wholly and centrally with the homograph typed in ALL CAPS (e.g., *Dermatologists are often RASH*). Participants were instructed to read each sentence and press the SPACE BAR when they were finished. Sentences were followed by the dominant (e.g., *skin*) and subordinate (e.g., *rude*) relatives of each homograph presented on the left and right side of the screen. Participants were asked to choose the word that was "most related to the meaning" of the homograph in the previously presented sentence. If they believed the word on the right side of the screen was most related, they were told to press the "?" key. If it was the word on the left side of the screen, they were instructed to press the "Z" key. To minimize the influence of side of presentation, lists were counterbalanced so that words that appeared on the left side in one list appeared on the right in the other list. Stimuli were presented in random order across participants. Words stayed on the screen until the participant responded. Word choice and reaction time were recorded.

Results

A total of 60 participants completed the experiment. Data from four participants were excluded because they did not meet inclusion criteria (i.e., not native speakers of English). Data from three more participants were excluded because all of their reaction times were more than 3 SD from the mean overall. Therefore, data from 53 participants was analysed. There were 32.1% men and 67.9% women. Average age of participants was 22.3 years (SD=5.5 years). Any reaction times greater than 3 SD from the mean (in this case, any reaction time greater than 12 seconds) were removed from the data set. This resulted in the removal of 21 data points (totaling 0.4% of all accurate data).

In this forced choice relatedness task comparing the 96 ambiguous words embedded in puns to participants' endorsement of the more strongly related associate, there was an effect of level of dominance [$F(1,52)=11.10$, $p<.01$]. However, the direction of this finding was not congruent with results of the previous studies. Rather, participants had shorter reaction times when they chose subordinate relatives (54% endorsement, M = 1697.1 ms, SD=1086.7 ms), compared to dominant relatives (46% endorsement, M=1784.5 ms, SD = 1178.0 ms).

Discussion

In general, results show an almost equitable preference for choice of the word with the most related meaning, supporting the intuitive notion that either meaning is appropriate to endorse (or process) for a pun. However, contrary to what would be expected from Hogaboam & Perfetti's (1975) ordered access model, participants showed some facilitation when they chose subordinate relatives. According to this ordered access model, the most common meaning (i.e., the most dominant meaning) is retrieved regardless of context. If the most common meaning is inconsistent with the contextual meaning, then it is discarded and another meaning is chosen. However, there is no need to discard a meaning for a pun, as either interpretation is appropriate. Thus, if ordered access based purely on frequency was occurring, then when given the opportunity to resolve on dominance and still maintain some meaning, participants should have continued to use dominance to drive their choices. Therefore, the facilitation for subordinate meanings amongst almost equitable endorsement must indicate the contribution of some other process[10].

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[10] Results may also be more fitting with Duffy, Morris & Rayner (1988)'s model of re-ordered access, which is based on both frequency and context. In order to test whether this may be more applicable, further

The clinical literature and the accounts of individuals with RH injury, provides hints about what that process might be. Brownell, Michel, Powelson, and Gardner (1983) found that individuals with RH injury were unable to choose joke endings that contained an element of surprise in a meaningful context. More specifically regarding pun resolution, the meaningful links that must be drawn are between two usually very independent concepts. Reconciling two disparate ideas in a cogent manner requires the ability to think abstractly. Individuals with RH injury have documented difficulty with drawing inferences and thinking metaphorically (Brownell, Michel, Powelson, & Gardner, 1983; Pimental & Kingsbury, 1989). Studying the processing of puns as a subset of their investigation into humour appreciation, Brown, Paul, Symington and Dietrich (2005) found that patients with agenesis of the corpus callosum were able to generate appropriate alternate meanings to puns, but they did not recognize the surprise/incongruence interacting between relative meanings. Brown and colleagues suggested that because they could not recognize the incongruence, the reinterpretation necessary for a humourous gist could not occur. Consequently, these patients did not find the puns funny. Therefore, reading of puns requires access to both meanings simultaneously, and the awareness that these also interact to create a humourous incongruity.

Vaid, Hull, Heredia, Gerkens and Martinez (2003) outlined the resolution of jokes to be one in which context is taken into consideration initially, and then reinterpreted, given a newfound sense of incongruity. Extending Vaid and colleagues' theory to puns, the placement of the ambiguous word at the end of a pun adheres to this joke structure,

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analysis would need to reveal whether participants showed a facilitation of responding to puns that were biased in the subordinate direction, evincing what these authors dub a "subordinate bias effect".

and aids in the aforementioned resolution process, as the majority of the preceding words bias the reader to one meaning, but then force the reader to consider another, once the ambiguous word is revealed. The process outlined in this hypothesis reconciles the current study's findings of stronger priming for dominant meanings in the lexical decision tasks with the facilitation for processing subordinate meanings in the forced choice task. Given the hypothesized requirement for incongruity to be experienced, the more efficient processing of the subordinate meaning (in the face of almost equitable categories of endorsement) is therefore not surprising because this is the meaning that causes the reader to consider incongruity and then reinterpret relative meanings to incorporate a new intent for the sentence.

Consistent with this theory, greater priming in the LH for the most common meaning increases likelihood that incongruity is more likely to be perceived during the introduction of the "surprise" (i.e., less common subordinate) shift in meaning (Brownell, Michel, Powelson, & Gardner, 1983). Understanding that lexical access for puns appears to be ordered favouring dominance, then the introduction of subordinate referents would bring about a noticeable change in context, necessitating a shift in meaning. Because the first meaning cannot be discarded, a process of reinterpretation to reconcile these two disparate meanings takes place. According to the work of Beeman and Chiarello (1998) and Beeman, Brown and Gernsbacher (2000), the RH must then be employed to draw related information between these two concepts, and the LH works to bridge the gap in understanding. Because the LH is required to conclude the incongruity, it does not show suppression.

Summarizing these findings, almost equitable endorsement of each meaning in a forced choice task revealed facilitation for deciding that the subordinate meaning was more related to the homograph in the pun. Dual priming of both meanings was observed in lexical decision tasks that showed an advantage for processing the dominant meaning. Reconciling these findings requires links to linguistic and humour models, which suggest that individuals who are exposed to puns should first be observed to produce priming effects for both meanings, next be able to recognize the incongruity that they are both activated in the same sentence, and finally reinterpret the situation using more abstract processing (which is also believed to be driven by asymmetrical processes). Current findings certainly lend support to this process. One possible test of this system would involve a lexical decision study that provided more time for the recognition of incongruity and reinterpretation stages to take place. Another future study might involve an eye tracking task that monitors gaze fixation on disambiguating portions of the sentence first for dominant meanings, then for subordinate ones. The former study is currently underway.

Chapter 3:

General Discussion

A series of four experiments provides additional details about how ambiguous words are resolved. The single word lexical decision study confirmed that the ambiguous words chosen for this study were primed by their most strongly related associate (i.e., dominant). This outcome reflects the findings of numerous studies in the literature that show priming based on most common relationship (Atchley, Burgess, Audet & Arambel, 1996; Burgess & Simpson, 1998; Chiarello, 1998; Chiarello, Maxfield & Kahan, 1995; Faust & Lavidor, 2003; Hogaboam & Perfetti, 1975).

Grounding findings in an ordered model of lexical access (e.g., Hogaboam & Perfetti, 1975) assisted in understanding the potential mechanisms underlying the priming effects seen in the two lexical decision experiments. The centralized experiment showed priming for both meanings of the homograph, with faster responses for the dominant meaning.

Likewise, the DVF lexical decision experiment also showed priming in both hemispheres, with a pronounced pattern of priming demonstrated by the LH. Fitting with the preceding findings, the LH was hypothesized to be involved in ordered lexical access, beginning with the most common meaning, and moderated by the relative role of the meaning within the pun. The RH activated both meanings without strong distinction, which is consistent with literature that shows that the RH is involved in broad activation of semantics, including for the resolution of ambiguous words (Atchley, Burgess, Audet & Arambel, 1996; Burgess & Simpson, 1998; Chiarello, Maxfield & Kahan, 1995; Faust & Lavidor, 2003).

Confirmation of Asymmetry in Processing

In general, the outcome of the current study supports the literature regarding asymmetry in the processing of semantics, with LH and RH activity priming in a seemingly complementary way (i.e., LH-stronger/RH-broader pattern found in the literature). Researchers who conduct DVF experiments have also shown that the RH has a specialized role throughout the course of processing. In time course studies, the RH tends to activate for broadly-related words and stays activated along the time course much longer than does the LH (Atchley, Burgess, Audet & Arambel, 1996; Beeman, Bowden & Gernsbacher, 2000; Burgess & Simpson, 1998; Faust & Lavidor, 2003). Like the results of the current study demonstrate, the LH has been observed by others to be more selective in its activation (Atchley, Burgess & Kenney, 1999; Faust & Babkoff, 1997; Faust & Lavidor, 2003; Titone, 1998), however, unlike in other studies, the LH did not appear to produce suppression at 500 ms in this study. This departure from the traditional finding likely reflects the special requirement of puns to keep both meanings active for full comprehension.

Finally, the forced-choice task results suggest that pun resolution requires more than just lexical access. The participants' choice for most related associate did not favour dominance and even more interestingly, there was facilitation evident in reaction times for the subordinate associate choices relative to the dominant choices. The facilitation for the subordinate choice was in keeping with the logic behind verbal humour: a dual resolution over time where one meaning is initially understood, and then a rapid reinterpretation of the second meaning ensures comprehension (Brownell & Gardner, 1988; Vaid, Hull, Heredia, Gerkens & Martinez, 2003). The facilitation for the subordinate meaning was inferred to reflect this nuance in comprehension.

The Role of Time

A 500 ms ISI was employed in the current DVF experiment. As this was the ISI used in the centralized experiment, it was no surprise that aggregating the reaction times for the right visual field with the left visual field would result in the same pattern of priming for both experiments. When considered in light of the literature that investigates the time course of processing, the results of the 500 ms ISI reflect the literature. That is, at 500ms, both hemispheres showed priming (Audet, Driesen and Burgess (1998), Coney, 2002; Chiarello, Burgess, Richards and Pollock, 1990; Chiarello, Liu, Shears, Quan and Kacinkik, 2003; Koivisto, 1997), with the pattern of LH priming being more pronounced than for the RH. According to the literature, asymmetry in processing is a function of time. A smaller ISI, like 250 ms, would allow participants less time to access the alternate meaning of the ambiguous words within each context, which would likely result in activation for the LH for the dominant meaning only (i.e., an ordered access of the most common meaning is activated initially). It is expected that there would be even weaker (or no) priming in the RH at this rate of presentation, compared to that found after 500 ms, which would be consistent with results found for other stimuli (i.e., Chiarello, Liu, Shears, Quan and Kacinik, 2003; Koivisto, 1997; Nakagawa, 1991), suggesting that RH activation does not come online as quickly as the LH.

A longer time lag would allow the lexicon an opportunity to (1) recognize that the subordinate meaning should also be activated, and (2) synthesize both meanings into a new interpretation. Given that participants showed a facilitation effect for subordinate meanings in the relatedness study, more time to access each of the homograph's meanings may result in more disparate hemispheric specialization, such that the RH would continue to prime all types of relationship. The LH is expected to continue to prime both meanings, but could shift activation to prime the subordinate meaning more favourably if allowed more time. That is to say, the LH is not expected to suppress meaning over time, as both meanings would need to stay activated to understand the pun.

Having initially primed the most dominant meaning, more time would allow access to another interpretation, which possibly results in the "aha!" feeling that most people experience when resolving ambiguity in a pun. Given the average reaction time for the relatedness study was approximately 1500 ms, a time lag of 1500 ms for another DVF experiment may allow enough time to reflect more controlled processing of word resolution in puns. An experiment using both 250 and 1500 ms is currently underway to test these hypotheses.

Support for The Right Hemisphere Hypothesis

Regarding the Right Hemisphere Hypothesis, results imply a division of labour between hemispheres that consist of broad RH activation (i.e., both relationships), and specific processing in the LH (i.e., facilitation of dominant relatives). In the neurologically intact, specializing of processing ensures that the broad activation of the RH will feed the selective mechanism of the LH, particularly in the context of a pun when reinterpretation (and therefore, need for alternative meanings) is probable. As predicted from the outset of the study, the asymmetric manner in which words are processed is an integral part to understanding any piece of written language. However, as previously outlined (Brownell & Gardner, 1988; Hirst, 1988; Vaid, Hull, Heredia, Gerkens & Martinez, 2003), humour processing requires the initial access to one meaning, then reinterpretation of an alternate meaning while still maintaining activation of the first meaning. That is to say, it appears that the LH acts as the "executive", choosing (and then adding/re-choosing) meaning to ensure understanding and draw conclusions, and the RH is the "warehouse" that opens every time semantic knowledge is required, or possibilities and predictions must be entertained (Beeman, Bowden & Gernsbacher, 2000; Beeman & Chiarello, 1998).

A future study that incorporated methods to suggest localization (i.e., neuroimaging, ERP, and lesion studies) could be paired with the current stimuli in an effort to elicit some convergence and provide insight into an anatomical model of language functioning. Together with Shammi and Stuss' (1999) lesion study and Goel and Dolan's (2001) fMRI study that related the right medial ventral prefrontal cortex to the processing of humour, these findings may contribute to the notion that language is mediated more by frontal functions than previously assumed (as suggested by Westbury and Buchanan, 2006). Localization in the frontal lobes especially makes sense, given the requirement for abstract thought to reinterpret the incongruity recognized within puns (Brownell & Gardner, 1988; Vaid et al., 2003).

Towards a Neuropsychological Model of Lexical Access in Pun Processing

Altogether, the results of the current series of experiments demonstrates that puns induce priming for dominant and subordinate meanings for LH and RH differently. With respect to the processing of meaning from puns, the current investigation offers the possibility that the LH might never suppress a first meaning, because the first and second meanings are together relevant to drawing conclusions to reconcile understanding. Because of the paucity of pun studies in the literature, and because puns are a unique language phenomena intuitively requiring simultaneous activation, there are no known established models of processing. However, some convergence in findings is beginning to emerge. Coulson & Severens (2007), who derived their metric of dominance from independent ratings, also found bilateral priming for both meanings at 500 ms ISI. Additionally, Coulson and Severens found LH priming for both meanings, and RH activation for only the dominant contextual meaning at 0 ms. These findings are congruent with the model of pun priming outlined herein.

Clinical Implications

With respect to how the current research fits with clinical findings, the implication that pun processing requires bilateral inputs means that individuals with unilateral lesions should demonstrate deficits in their comprehension. According to the model described, difficulty appreciating puns may come from problems at many steps along the process (i.e., access to alternate meanings, ability to maintain a meaning that might otherwise be suppressed, recognizing that there is an incongruity, creating predictive inferences about the relationship between seemingly disparate meanings, and then drawing a conclusion that ties the meanings together). A step-wise model can be used to identify where individuals who have difficulty with humour appreciation are operating. For example, Brown, Paul, Symington and Dietrich (2005) found that patients who have agenesis of the corpus callosum (and subsequently had no access to the RH) showed reduced understanding of narrative jokes, and were unable to fully appreciate puns. Particularly, Brown and colleagues suspected that although participants were able to select alternative meanings to the pun sentences, they lacked recognition for the incongruity that often drives the simultaneous resolution of pun meaning (likely because the RH is involved in inference-making). The authors conclusions imply either that the processing of puns requires steps that become more complex (i.e., the more basic task of accessing several meanings is possible, but their integration is too complicated), or that there may be separate neuroanatomical correlates responsible for each step that are generally located within each hemisphere, but are actually separate and not affected from one type of injury to another.

Consistent with the support already shown for the Right Hemisphere Hypothesis, I predict that individuals with LH lesions that result in deep dyslexia would not be able to select meaning from the many options activated. This hypothesis has yet to be tested, but if true, would appear to overlap what is seen in the clinic regarding our understanding of humour processing (e.g., Brownell, Michel, Powelson & Gardner, 1983; Cheang & Pell, 2005; Heath & Blonder, 2005; Shammi & Stuss, 1999), and may help to distinguish differences in processing joke-related information from pun-related information (Coulson & Severens, 2007).

Situating the current findings in a broader context, lesion study within neuropsychology inspires two types of research avenues: (1) informing normal functioning, based on deficits that occur after lesions are sustained, and (2) applying what is learned from both normal and injured functioning to improve skill and quality of life in patient populations. With respect to the latter, loss of the ability to appreciate the nuances of verbal humour has potentially far-reaching implications. For example, sense of humour has been correlated with coping ability (Martin, 2007; Rim, 1988), where the ability to handle the changes after a brain injury and having flexibility in thinking may increase an individual's ability to persevere with the efforts required toward recovery and adaptation (Anson & Ponsford, 2006; Ch'ng, French & McLean, 2008).

The involvement of humour in coping has larger psychosocial implications. For example, although individuals who sustain LH injury have historically been excluded from quality of life research (because of methodological limitations requiring them to provide verbal responses), recent progress has been made to capture their experience so that appropriate treatment and therapy avenues may be pursued for this population (Bose, McHugh, Schollenberger and Buchanan, 2009). In a similar vein, although individuals who sustain RH damage are more likely to retain the ability to express themselves verbally, evidence exists that suggests that their ability to appreciate/recognize the nuances in language, and therefore function pragmatically in social and occupational settings, are compromised (Brownell, Pincus, Blum, Rehak & Winner, 1997; Kaplan, Brownell, Jacobs & Gardner, 1990; Pimental & Kingsbury, 1989; Sabbagh, 1999). Greater understanding of more nuanced language processing may be used to serve this population through appropriate rehabilitation strategies. A future study that incorporated the resolution of puns with measures of inference-making and metrics of social and emotional functioning within a sample group of individuals with RH lesions may identify their particular difficulties (e.g., the possibility that individuals have access to alternate meanings, but not use them because they are not recognized as incongruous).

Contribution to Humour Literature

With the exception of Coulson and Severens (2007), few known studies have formally investigated the role of language in processing puns. The current series of studies documented dominance of relationship and hemispheric specialization to be fundamental psycholinguistic factors in processing puns. Given the preference for subordinate meanings in the relatedness study, future studies may consider the relative roles that controlled and automatic processing contribute. Using eye tracking technology in concert with lexical decision and relatedness tasks (while accounting for psycholinguistic variables like those provided by Wordmine2 and WINDSORS) would inform the attentional and linguistic foundations underlying implicit and explicit processing of puns.

Conclusions

Results of this series of experiments suggest a working model of pun processing in neurologically intact individuals, apply a lexical co-occurrence model to ambiguity resolution, and contribute to the body of literature supporting the Right Hemisphere Hypothesis of language processing. Interpretation of results as lending more concrete support for the existence of RH language processing encourages future research bridging cognitive neuropsychology and humour processing domains.

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Table 1. Psycholinguistic properties of the stimulus set.

Ambiguous Word	Frequency	LogFreq	OrthNeigh	Dominant	Frequency	LogFreq	OrthNeigh	Similarity	Subordinate	Frequency	LogFreq	OrthNeigh	Similarity
ALARMING	6.513	0.814	0	WARNING	42.920	1.633	6	0.243	FRIGHTENING	5.676	0.754	1	0.223
APPEAL	67.997	1.832	0	CASE	388.265	2.589	14	0.449	CHARISMA	0.893	-0.049	0	0.126
APPENDIX	15.759	1.198	1	INDEX	36.508	1.562	0	0.24	SPLEEN	1.692	0.228	0	0.204
ARMS	184.802	2.267	7	MOB	12.955	1.112	17	0.099	RAISE	49.489	1.695	0	0.063
ATTRACTIVE	34.977	1.544	0	ALLURING	2.939	0.468	1	0.424	FORCE	165.958	2.220	3	0.154
BALL	64.471	1.809	18	BAT	10.539	1.023	23	0.391	FUN	48.451	1.685	14	0.090
BAR	64.217	1.808	16	DRINK	93.495	1.971	4	0.423	COURT	196.666	2.294	1	0.150
BLUFF	8.421	0.925	1	LIE	88.129	1.945	12	0.118	MOUNTAIN	75.361	1.877	1	0.042
BOARD	118.856	2.075	3	COMMITTEE	100.486	2.002	1	0.330	LUMBER	4.866	0.687	6	0.034
BONE	25.906	1.413	16	SKULL	14.165	1.151	3	0.538	PRACTICE	106.469	2.027	1	0.014
BREAKTHROUGH	2.808	0.448	0	DISCOVERY	39.354	1.595	1	0.297	CHASM	3.645	0.562	2	0.178
CALIBER	4.985	0.698	0	SIZE	102.686	2.012	4	0.077	STATUS	47.707	1.679	2	0.000
CALVES	5.673	0.754	5	THIGHS	9.202	0.964	0	0.284	HORSE	158.291	2.199	8	0.281
CHEMISTRY	12.589	1.100	0	PHYSICS	11.749	1.070	1	0.604	ROMANCE	22.377	1.350	0	0.098
CLASS	165.850	2.220	8	DESK	45.627	1.659	2	0.010	STYLE	87.109	1.940	4	0.000
CLICK	13.937	1.144	8	SHUTTER	2.569	0.410	4	0.115	FIT	81.138	1.909	16	0.019
COMEBACK	2.024	0.306	0	POPULAR	74.394	1.872	0	0.008	RETURN	223.988	2.350	0	0.007
COMPOSED	30.843	1.489	2	TUNE	17.776	1.250	8	0.070	CALM	53.007	1.724	5	0.042
CONNECTIONS	12.705	1.104	1	CIRCUIT	16.648	1.221	0	0.261	COLLEAGUE	9.049	0.957	0	0.008
COOKED	14.124	1.150	10	BAKED	7.585	0.880	13	0.290	FALS_E	53.671	1.730	1	0.014
COUNT	72.736	1.862	3	ADD	67.694	1.831	8	0.027	RELY	16.566	1.219	0	0.160
CROAK	1.550	0.190	4	DIE	117.078	2.068	16	0.267	SING	45.784	1.661	13	0.207
CULTURE	56.491	1.752	1	SNOB	2.058	0.313	6	0.116	BACTERIA	6.154	0.789	0	0.149
DEGREES	33.644	1.527	1	TEMPERATURE	27.893	1.445	0	0.519	DIPLOMAS	0.907	-0.042	1	0.363
DEPRESSION	17.048	1.232	1	SADNESS	12.327	1.091	2	0.217	HOLE	56.678	1.753	15	0.077
DEPTH	29.790	1.474	1	DIVE	5.576	0.746	12	0.278	DETAIL	45.680	1.660	3	0.213
DOUGH	3.581	0.554	6	BREAD	59.079	1.771	6	0.377	MONEY	402.714	2.605	2	0.037
DRAINING	2.715	0.434	2	TIRING	2.487	0.396	9	0.095	PIPE	40.149	1.604	7	0.000
DRAW	72.108	1.858	6	GUN	50.684	1.705	16	0.125	PORTRAIT	22.922	1.360	0	0.115
DRAWING	88.353	1.946	1	SKETCH	14.038	1.147	0	0.557	SUCKING	8.253	0.917	9	0.044
DRILL	8.727	0.941	6	HAMMER	14.075	1.148	3	0.436	ROUTINE	27.351	1.437	1	0.206
ELEMENT	45.896	1.662	1	COMFORT	53.996	1.732	1	0.084	MOLECULE	3.925	0.594	0	0.046
FABRICATION	1.341	0.127	0	MANUFACTURE	13.164	1.119	0	0.348	FIB	0.665	-0.177	15	0.202
FATHOM	3.402	0.532	0	UNDERSTAND	231.329	2.364	0	0.281	DEEP	177.819	2.250	9	0.138
FAULTS	12.133	1.084	2	MISTAKES	14.000	1.146	1	0.474	CRACKS	5.482	0.739	5	0.219

FIELD	144.952	2.161	3	SOIL	49.705	1.696	7	0.078	PASSION	59.523	1.775	0	0.000
FLUSH	13.646	1.135	5	POKER	4.855	0.686	5	0.492	TOILET	12.040	1.081	2	0.348
FOOL	59.826	1.777	10	CLOWN	3.996	0.602	3	0.216	SHAME	44.776	1.651	7	0.206
FUNNY	37.852	1.578	7	HUMOUR	24.494	1.389	2	0.419	WEIRD	13.127	1.118	1	0.369
GRADE	16.951	1.229	7	SUCCEED	25.398	1.405	0	0.254	SLOPE	26.305	1.420	3	0.156
HEAT	66.772	1.825	11	MELT	7.536	0.877	10	0.455	RACE	105.117	2.022	15	0.024
HIGHLIGHT	5.258	0.721	0	YELLOW	80.231	1.904	3	0.102	PINNACLE	2.483	0.395	1	0.09
HOT	116.709	2.067	19	WARM	91.251	1.960	11	0.460	EXCITING	22.530	1.353	1	0.081
INFLATION	18.317	1.263	0	ECONOMY	49.586	1.695	0	0.570	PRESSURE	68.232	1.834	0	0.084
INTEGRAL	6.289	0.799	0	DERIVE	23.785	1.376	1	0.284	SIGNIFICANT	66.047	1.820	0	0.040
INTEREST	228.656	2.359	0	IDEAL	46.639	1.669	1	0.024	PERCENT	14.852	1.172	0	0.000
JAM	8.589	0.934	14	STRAWBERRY	3.309	0.520	0	0.531	STUFFED	9.131	0.961	3	0.012
LAME	7.346	0.866	19	PATHETIC	13.183	1.120	0	0.523	SORE	17.675	1.247	16	0.069
LEAKED	2.984	0.475	7	DRIP	3.391	0.530	3	0.139	SHARED	34.499	1.538	13	0.070
MEMORY	99.205	1.997	0	CHIP	11.110	1.046	10	0.554	REMEMBER	212.870	2.328	0	0.188
MIND	475.468	2.677	13	SOUL	164.379	2.216	4	0.530	BRAIN	72.258	1.859	6	0.427
MINUTES	173.980	2.240	3	SECONDS	34.305	1.535	0	0.614	NOTES	62.914	1.799	7	0.043
MUGGING	0.370	-0.432	7	ROBBERY	8.238	0.916	3	0.502	CUP	82.897	1.919	10	0.056
NUTS	10.034	1.001	11	ALMOND	3.335	0.523	0	0.441	CRAZY	23.243	1.366	1	0.212
PANTS	8.559	0.932	11	SLACKS	0.799	-0.097	7	0.761	BREATHE	16.600	1.220	3	0.033
PLOT	20.693	1.316	6	STORY	214.834	2.332	4	0.335	ACRE	10.427	1.018	3	0.196
POINT	350.843	2.545	3	IDEA	226.710	2.355	2	0.409	SHARP	71.529	1.854	4	0.139
POSITION	204.061	2.310	1	JOB	124.741	2.096	16	0.523	POSE	9.482	0.977	13	0.000
POSITIVE	52.611	1.721	0	OPTIMISTIC	6.834	0.835	0	0.318	INTEGER	10.822	1.034	0	0.191
POUND	40.056	1.603	7	KILOGRAM	0.310	-0.509	0	0.552	KENNEL	2.188	0.340	3	0.089
PROBLEMS	124.192	2.094	0	ISSUES	58.321	1.766	1	0.624	SOLUTION	41.034	1.613	0	0.383
PRODUCE	96.703	1.985	1	PERFORM	29.132	1.464	0	0.140	VEGETABLE	11.722	1.069	0	0.154
PROOF	44.500	1.648	0	EVIDENCE	140.407	2.147	0	0.617	WHISKY	13.231	1.122	1	0.032
PUNCH	11.932	1.077	5	GLASS	111.043	2.045	3	0.138	JOKE	28.852	1.460	6	0.158
PUPILS	40.179	1.604	0	STUDENTS	78.815	1.897	0	0.637	EYE	161.174	2.207	8	0.210
RASH	7.166	0.855	12	SKIN	71.746	1.856	8	0.408	RUDE	23.079	1.363	7	0.022
RECOVERED	30.424	1.483	0	FABRIC	14.351	1.157	0	0.024	HEALTHY	29.308	1.467	1	0.000
REFINED	12.339	1.091	5	PURE	60.950	1.785	11	0.281	CLASSY	0.825	-0.083	1	0.066
RELIEF	64.057	1.807	3	STATUE	16.555	1.219	1	0.000	FINISH	38.424	1.585	0	0.000
RETRAINING	0.451	-0.346	0	EMPLOYMENT	54.609	1.737	0	0.155	ENGINEERS	14.534	1.162	0	0.009
REVOLTING	2.580	0.412	1	DISGUSTING	6.715	0.827	0	0.510	WATTS	2.883	0.460	4	0.417

RING	76.754	1.885	11	DIAMOND	18.635	1.270	0	0.211	SOUND	182.311	2.261	7	0.079
ROOTS	25.715	1.410	14	GROW	69.192	1.840	7	0.401	HERITAGE	10.826	1.034	0	0.298
RUN	217.994	2.338	16	CHALLENGE	36.657	1.564	0	0.079	TEAR	23.198	1.365	17	0.047
SCHOOLS	78.946	1.897	0	EDUCATION	146.005	2.164	0	0.643	SWIM	14.990	1.176	6	0.07
SCOOP	2.304	0.363	5	NEWS	129.282	2.112	9	0.162	CONE	4.832	0.684	22	0.081
SENTENCE	46.953	1.672	0	PENALTY	16.779	1.225	1	0.589	PHRASE	30.215	1.480	0	0.505
SHORTS	6.961	0.843	7	UNDERWEAR	3.876	0.588	0	0.782	MOVIE	10.023	1.001	0	0.207
SHRINK	7.237	0.860	4	DISAPPEAR	15.248	1.183	0	0.284	THERAPY	9.654	0.985	0	0.229
SLASH	1.976	0.296	8	CUT	182.745	2.262	16	0.514	PUNCTUATION	10.273	1.012	0	0.149
SPELL	29.256	1.466	5	MEANING	89.219	1.950	3	0.121	MESSAGE	73.826	1.868	1	0.044
SPLINTER	1.441	0.159	1	REBEL	12.645	1.102	2	0.361	SLIVER	0.915	-0.039	3	0.172
SPOT	77.755	1.891	8	PUPPY	5.008	0.700	4	0.328	STAIN	7.738	0.889	6	0.065
SPREAD	76.317	1.883	0	PRESERVE	18.011	1.256	0	0.009	BLANKET	14.281	1.155	1	0.084
SQUARES	7.999	0.903	3	TRIANGLES	2.054	0.313	0	0.451	NERDS	2.907	0.463	3	0.055
STIRRING	13.631	1.135	2	SPOON	8.447	0.927	5	0.479	INSPIRING	6.229	0.794	0	0.097
SUITS	13.844	1.141	6	CLOTHING	25.043	1.399	1	0.372	CASES	130.911	2.117	15	0.056
TANGENTS	0.153	-0.815	0	GEOMETRY	3.988	0.601	0	0.275	STORIES	58.336	1.766	1	0.154
THIRST	11.091	1.045	0	HUNGER	21.152	1.325	2	0.497	LIQUID	19.135	1.282	0	0.007
TIE	27.400	1.438	15	MATCH	64.075	1.807	8	0.124	CLOTHING	25.043	1.399	1	0.111
TRACK	50.348	1.702	6	DIRECT	85.474	1.932	1	0.208	TRAIN	90.160	1.955	6	0.169
TURNS	39.253	1.594	7	FLIPS	0.269	-0.570	7	0.398	DEED	19.662	1.294	15	0.009
TYPE	139.022	2.143	5	STAMP	14.180	1.152	4	0.116	GENRE	3.988	0.601	1	0.067
UMBRELLA	10.681	1.029	0	CORPORATION	18.665	1.271	0	0.271	RAIN	82.079	1.914	13	0.247
VENT	6.898	0.839	12	HEATING	10.098	1.004	7	0.401	COMPLAIN	14.852	1.172	0	0.126
WORK	792.611	2.899	9	FAIL	42.561	1.629	15	0.141	GYM	3.092	0.490	3	0.019
Mean	**59.105**	**1.313**	**4.854**	**Mean**	**49.045**	**1.344**	**4.188**	**0.326**	**Mean**	**47.319**	**1.321**	**4.229**	**0.121**
SD	**106.572**	**0.700**	**5.185**	**SD**	**62.874**	**0.626**	**5.151**	**0.193**	**SD**	**63.429**	**0.620**	**5.271**	**0.110**

Table 2.

Reaction time data for Experiment 1 as a function of frequency of pairing between prime and target.

	Homograph Target		
Prime Type	Mean (SD)	% Accurate	Priming
Dominant	654.0 (94.8)	98.6	25 ms
Subordinate	669.0 (109.5)	98.5	10 ms
Unrelated	678.8 (106.3)	98.3	

Table 3

Reaction time data for Experiment 2 as a function of frequency of pairing between homographs in pun primes and their related targets.

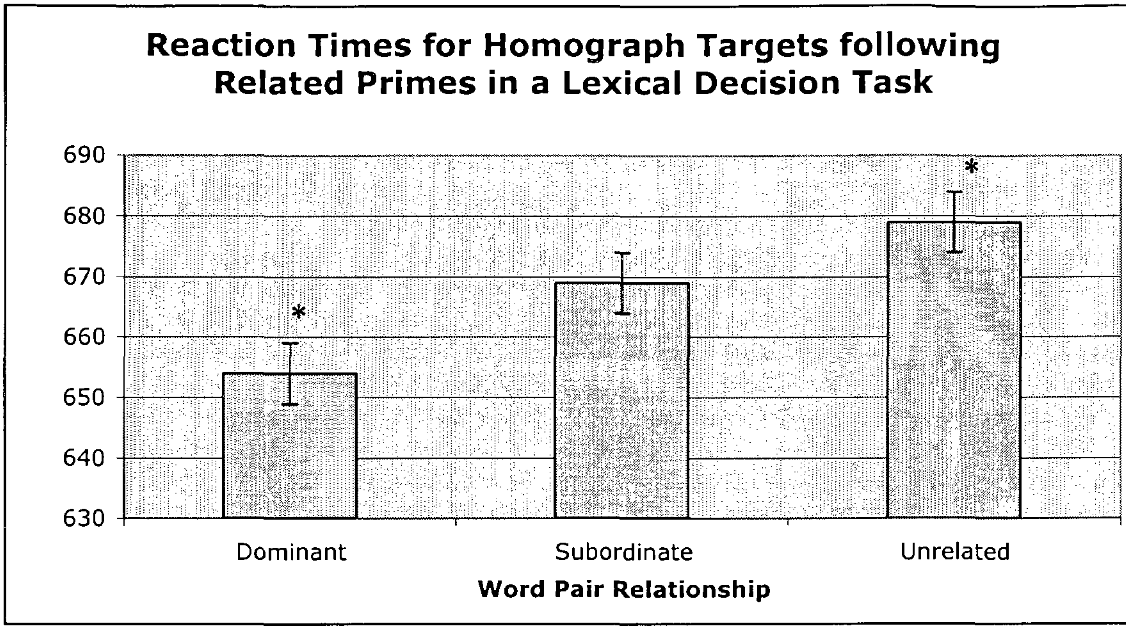
Target Type	Mean (SD)	% Accurate	Priming
Dominant	596.6 (146.3)	98.3	40 ms
Subordinate	610.2 (141.1)	97.3	22 ms
Unrelated	637.2 (154.8)	97.0	

Table 4

Reaction time data for Experiment 3 as a function of frequency of pairing between homographs in pun primes and their related targets in a DVF study.

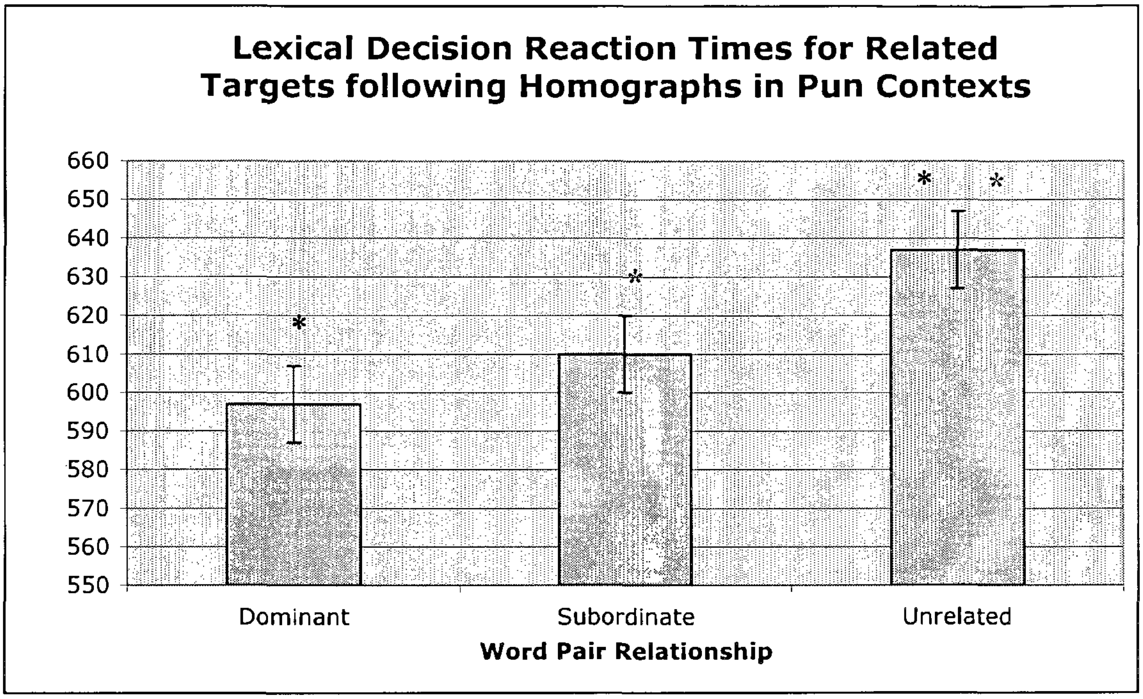
RVF (LH) Target Type	Mean (SD)	% Accurate	Priming
Dominant	875.3 (246.6)	85.7	122 ms
Subordinate	909.1 (263.2)	82.4	88 ms
Unrelated	996.6 (295.8)	73.7	

LVF (RH) Target Type	Mean (SD)	% Accurate	Priming
Dominant	1017.8 (281.0)	72.0	41 ms
Subordinate	1026.1 (326.3)	76.3	32 ms
Unrelated	1058.2 (310.1)	62.6	



* Planned t-test and Bonferroni corrections revealed this comparison to be significant.

Figure 1. Priming is depicted in Experiment 1 participants' faster identification of homograph targets following dominant, subordinate, and unrelated primes, reflecting similarity values obtained from WINDSORS (Durda and Buchanan, 2008).



* Planned t-test and Bonferroni corrections revealed this comparison to be significant.

Figure 2. Priming is depicted in Experiment 2 participants' faster identification of related targets following homographs embedded in pun contexts, reflecting similarity values obtained from WINDSORS (Durda and Buchanan, 2008).

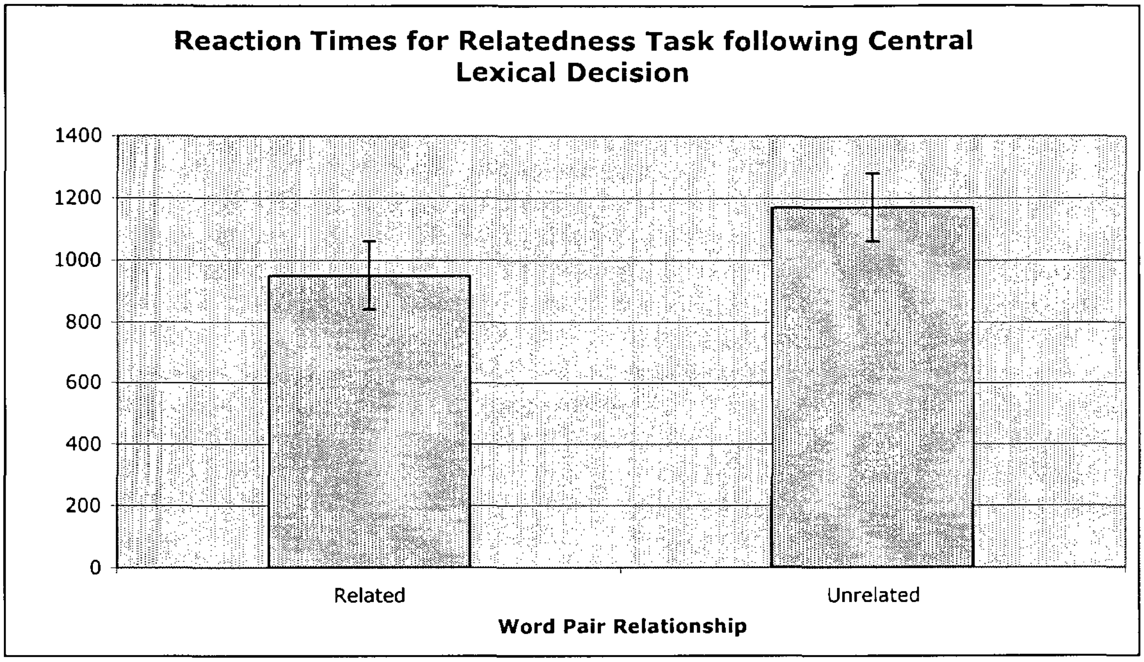


Figure 3. Response times for words that were related to puns were shorter than for unrelated words. This trend, along with the high accuracy rate, suggests sufficient attention and comprehension of the pun primes.

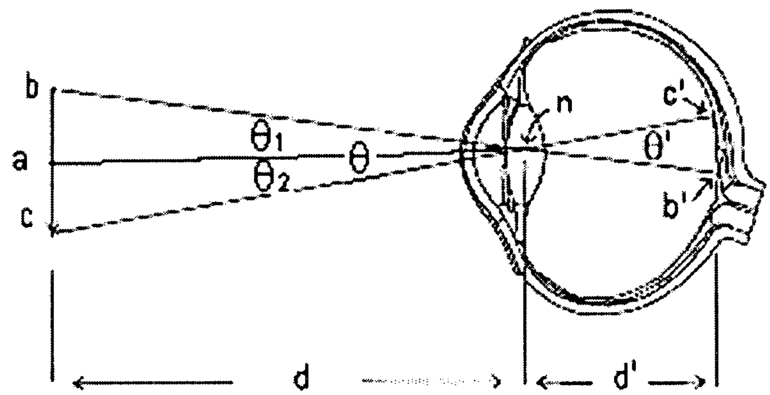


Figure 4. The calculation of visual angle (θ) is dependent on the distance of the stimuli from the eye (d), the distance from the fixation point (a) to the outermost part of the stimuli (Kaiser, 2009).

* Planned t-test and Bonferroni corrections revealed this comparison to be significant.

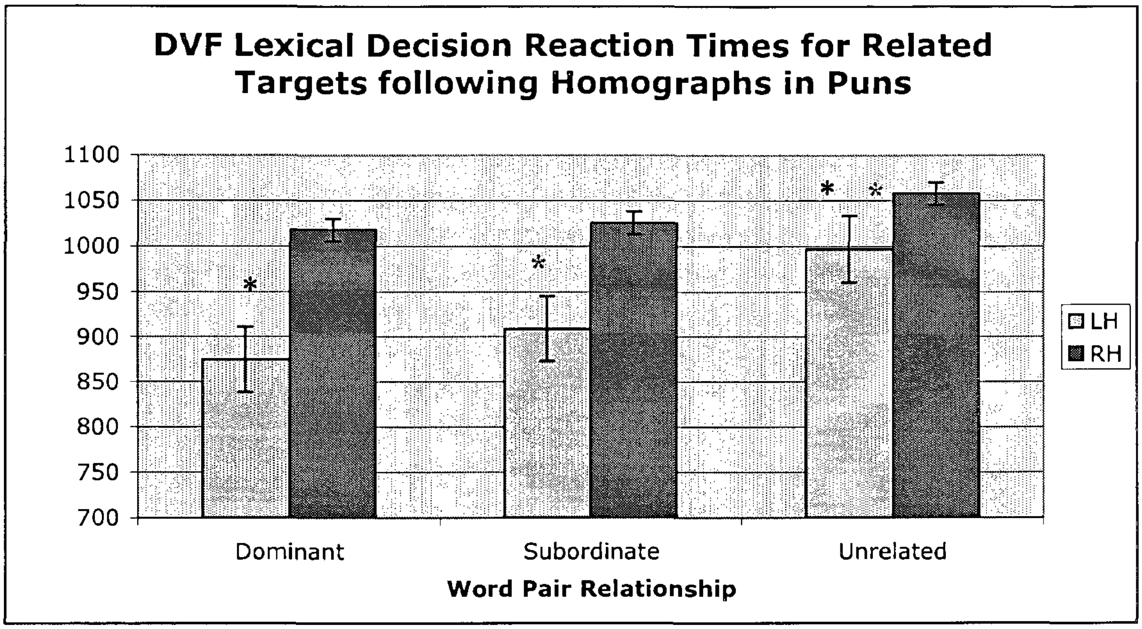


Figure 5. Stronger LH than RH priming is depicted in Experiment 3 participants' faster identification of related targets following homographs embedded in pun contexts in a divided visual field study.

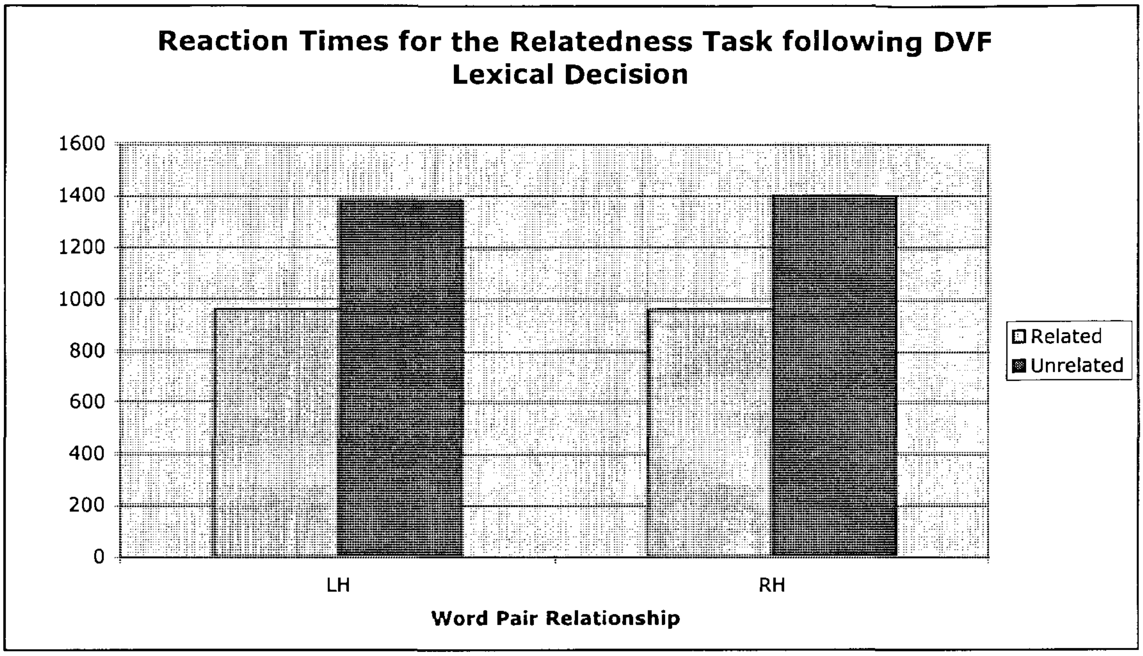


Figure 6. Response times for words that were related to puns were shorter than for unrelated words in the DVF experiment. This trend, along with the high accuracy rate, indicates sufficient attention and comprehension of the pun primes.

Appendix A: Demographic Data

Participant ID # ______ # Yrs Education: Gr. 12/13 + College ____ + Uni____ = ____

Gender: M F Age______________ Date of Birth: ____________________

Please answer each of the following questions:

What is your native language? ________________________________

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

Do you have a learning disability? Y N

If yes, does this learning disability affect any of the following:

Reading? Y N **Writing?** Y N **Math?** Y N

Do you have dyslexia? Y N

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

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

If yes, did this therapy focus only on a single speech sound, such as a lisp or difficulty producing "r"? Y N

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

Do you have ADD/ADHD? Y N

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

Are you color blind? Y N

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

Which hand do you use to hold the scissors when you cut paper? Right Left Both

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

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

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

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

Have you ever been diagnosed with a neurological condition, such as MS, Parkinson's, or tumor?
Y N

Appendix B: Handedness Inventory (Oldfield, 1971)

Please indicate your preferences in the use of hands in the following activities *by putting + in the appropriate column*. Where the preference is so strong that you would never try to use the other hand unless absolutely forced to, *put* + +. If in any case you are really indifferent *put + in both columns*. Some of the activities require both hands. In these cases the part of the task, or object, for which hand preference is wanted is indicated in brackets.

Please try to answer all the questions, and only leave a blank if you have no experience at all of the object or task.

		LEFT	RIGHT
1	Writing		
2	Drawing		
3	Throwing		
4	Scissors		
5	Toothbrush		
6	Knife (without fork)		
7	Spoon		
8	Broom (upper hand)		
9	Striking Match (match)		
10	Opening box (lid)		
i	Which foot do you prefer to kick with?		
ii	Which eye do you use when using only one?		

L.Q. ____________ Leave these spaces blank DECILE ____________

MARCH 1970

Appendix C: Reading Fluency Passage (Carroll, 1865)

Alice was beginning to get very tired of sitting by her sister on the bank, and of having nothing to do. Once or twice she had peeped into the book her sister was reading, but it had no pictures or conversations in it, "and what is the use of a book," thought Alice, "without pictures or conversations?"

So she was considering in her own mind (as well as she could, for the day made her feel very sleepy and stupid), whether the pleasure of making a daisy-chain would be worth the trouble of getting up and picking the daisies, when suddenly a White Rabbit with pink eyes ran close by her.

There was nothing so very remarkable in that, nor did Alice think it so very much out of the way to hear the Rabbit say to itself, "Oh dear! Oh dear! I shall be too late!" But when the Rabbit actually took a watch out of its waistcoat-pocket and looked at it and then hurried on, Alice started to her feet, for it flashed across her mind that she had never before seen a rabbit with either a waistcoat-pocket, or a watch to take out of it, and, burning with curiosity, she ran across the field after it and was just in time to see it pop down a large rabbit-hole, under the hedge. In another moment, down went Alice after it!

The rabbit-hole went straight on like a tunnel for some way and then dipped suddenly down, so suddenly that Alice had not a moment to think about stopping herself before she found herself falling down what seemed to be a very deep well.

Either the well was very deep, or she fell very slowly, for she had plenty of time, as she went down, to look about her. First, she tried to make out what she was coming to, but it was too dark to see anything; then she looked at the sides of the well and noticed that they were filled with cupboards and book-shelves; here and there she saw maps and pictures hung upon pegs. She took down a jar from one of the shelves as she passed. It was labeled "ORANGE MARMALADE," but, to her great disappointment, it was empty; she did not like to drop the jar, so managed to put it into one of the cupboards as she fell past it.

Down, down, down! Would the fall never come to an end? There was nothing else to do, so Alice soon began talking to herself. "Dinah'll miss me very much to-night, I should think!" (Dinah was the cat.) "I hope they'll remember her saucer of milk at tea-time. Dinah, my dear, I wish you were down here with me!" Alice felt that she was dozing off, when suddenly, thump! thump! down she came upon a heap of sticks and dry leaves, and the fall was over.

Appendix D: Experimental Puns

Becoming a yoga instructor offers the possibility of a unique teaching position.
I could have been an electrical engineer but I had no connections.
If you are what you eat, I'm staying away from the nuts.
Finding area is an integral part of calculus.
At the time, installing an air-conditioning unit wasn't such a hot idea.
Stealing someone's coffee is called 'mugging'.
When attorneys dress for fun cases, they have leisure suits.
Sometimes a pencil sharpener is needed to make a good point.
I could have been a geologist but I disliked finding faults.
Every so often, railroad conductors have to go for retraining.
The story about missing land was nonsense because it had no plot.
Acrobats are always doing good turns.
A box full to the brim with jelly jars is jam packed.
Her exam was on the skeleton, so she decided to bone up.
Math teachers have lots of problems.
To many girls, the word 'marriage' has a nice ring to it.
A radical segment of woodworkers broke off to form a splinter group.
Food for bad dogs is bought by the pound.
The cook's speech was very stirring.
My advanced geometry class is full of squares.
Long films about boxing never sell because people prefer boxer shorts.
In the air duct installers union they have much opportunity to vent.
When tires are up, it's due to inflation.
This beverage says it's non-alcoholic, but I want to see the proof.
Lawyers must like alcohol because they're always being called to the bar.
Weather forecasters have to have lots of degrees.
Dermatologists are often rash.
My dog's gone because I spilled spot remover on him.
With a keyboard or a knife, be careful with your back slash.
The leech was an artist because he was good at drawing blood.
A restaurant accoutant has to make sure the books aren't cooked.
Meetings are where we spend hours and take minutes.
There was once a cross-eyed teacher who couldn't control his pupils.
Gravity is studied a lot because it's a very attractive field.
A marathon on a scorching day ended in a dead heat.
Lumber companies have many board meetings.
Those who play team sports usually have a ball.
A student limped into class with a lame excuse.
People who make motor oil are very refined.
He studied water purification and had a great thirst for knowledge.
The old carpenter knew the drill.
The math teacher bored his students because he went off on tangents.
Wintertime, Rover wears his coat summertime Rover wears his coats and pants.
The science teachers broke up because they had no chemistry
Old lawyers never die, they just lose their appeal.
When fish are in schools they sometimes take debate.
The man opened a bakery using his father's dough.
Old programmers never die, they just lose their memory.

The teacher asked a question and the students were up in arms.
Some people find fire drills quite alarming.
He said he'd jump off the cliff, but it was a bluff.
Those who experiment with thin ice will achieve a breakthrough.
After the human cannonball retired, no replacement was the right caliber.
During branding, cowboys have sore calves.
Old teachers never die, they just lose their class.
I could have been a photographer but things didn't click.
A man who used to sell boomerangs is trying for a comeback.
Noteworthy musicians are very composed.
Trust your calculator, because it's something to count on.
Biologists immortalized frogs by removing their vocal cords so they can't croak.
People who like yogurt have culture.
A river dredging project was to undergo an in depth audit.
I could have been a plumber, but the work is too draining.
The cowboy artist was a fast draw.
He was studying chemistry but now felt out of his element.
I could have been a farmer but it wasn't my field.
For plumbers, a flush beats a full house.
I knew a self-taught comedian who made a fool of himself.
A circus lion won't eat clowns because they taste funny.
I could have been a mountaineer but I couldn't make the grade.
Two banks with different rates have a conflict of interest.
News of a coming flood was leaked.
A psychiatrist on a hike fell into a depression.
The progressive neurosurgeon had an open mind.
Some mathematicians are on the negative side while others are quite positive.
I got fired from the grocery store because I couldn't produce.
Thirsty comedians can be seen waiting in the punch line.
The man who fell into an upholstery machine is fully recovered.
When ancient wall sculptors were done, it was a relief.
My rechargeable batteries are revolting.
A gardener who moved back to his home town rediscovered his roots.
Nylons give women a run for their money.
A reporter was at the ice cream store getting the scoop.
To some, marriage is a word, to others, a sentence.
I could have been a psychiatrist but the thought made me shrink.
If you forget alphabet soup on the stove it could spell disaster.
Spilling jelly on my mattress meant sleeping with a bed spread.
Two silk worms had a race and ended up in a tie.
Monorail enthusiasts have a one track mind.
I could have been a printer but I wasn't the type.
The weather bureau is an umbrella organization.
I wanted to exercise last night but it didn't work out.
When the captain's ship ran aground he couldn't fathom why.
The promises of some tailors are pure fabrication.
Students who accent textbooks with markers add a highlight to their day.
That anatomy book is not good because it has no appendix.

Appendix D (continued): Control Puns

Teachers who take class attendance are absent-minded.
A mailman has many problems to address.
Astronauts work in a nice atmosphere.
The string went to the dance and had a ball.
The untruthful deli clerk was full of baloney.
The duck said to the bartender, 'put it on my bill.'
On the surface of things whales are always blowing it.
I could have been a librarian but they were fully booked.
Old bankers never die, they just pass the buck.
The inventor of a hay baling machine made a bundle.
A math professor in an unheated room is cold and calculating.
The play on fishing had quite a cast.
The two guys caught drinking battery acid will soon be charged.
The best place for a mathematician is behind a counter.
A ham walked out of the hospital and said I'm cured.
For a long time, black holes were a dark secret.
Income tax time is when you test your powers of deduction.
Graduates receiving their doctorates often get the third degree.
Everyone in the town had low IQ's so the population was dense.
Old skiers never die, they just go downhill.
A flat rate is the monthly rent for an apartment.
Everyone's fuming over the high cost of gas.
Some commands given by a Army are specific, others are General.
Those who throw dirt are sure to lose ground.
Wrestlers don't like to be put on hold.
Those who like fishing can really get hooked.
When the big fish got caught, the jig was up.
Making fun of a tree is a knock on wood.
Lumberjacks have to keep problem logs.
A blood-sucking arachnid from the moon would be a luna tick.
I could have been a magician but it didn't materialize.
The unveiling of the statue was a monumental occasion.
Every calendar's days are numbered.
Two mathematicians arguing about even numbers were at odds.
The kind of tree that grows on hands is a palm.
Musical mechanics always sing in parts.
Selling coffee has it's perks.
The triangle told the circle that it was pointless.
The Olympic swimming program has a large talent pool.
Lions always take great pride in their families.
When the TV repairman got married the reception was excellent.
'Change the channel' she said remotely.
The colour of the sun in the early morning is rose.
An archaeologist's career ended in ruins.
If you give some managers an inch, they think they're rulers.
Prison walls are never built to scale.
You shouldn't interrupt a judge in the middle of a sentence.
Small people are in short supply.

I know a lingerie buyer who gave his wife the slip.
A horse is a very stable animal.
Telescope owners are starry eyed.
He installs car ignitions because he's a real self starter.
Drinking wet cement could make you stoned.
He bent over to pick up a sieve and strained himself.
Sports are refereed by people of many stripes.
Taxidermists really know their stuff.
Skipping school to bungee jump will get you suspended.
The frustrated cannibal threw up his hands.
When fleas disappear they might be back in a tick.
Driving on so many turnpikes was taking its toll.
A hippo's opinion carries a lot of weight.
I could have been a statistician but I didn't have the figure.
I could have been an actor but my father created a scene.
I was arrested for stealing adhesive tape, but the charges didn't stick.
Those who get up at sunrise have many ideas dawn on them.
Have an optometrist run for president they are people with good vision.
Be true to your teeth, or they will be false to you.
When the artist failed to draw cubes, he had a mental block.
I could have been a billiard player but nobody gave a break.
I got fired from the computer shop because I didn't have drive.
I could have been a nuclear scientist but I didn't have energy.
I could have been a gravel merchant but I didn't have grit.
He auditioned as a trumpet player but he blew it.
While training at Coca Cola, he was given a pop quiz.
I was once a tap dancer until I fell in the sink.
I hear the Sylvester Stallone Film Festival started off rocky.
I could have been a sprinter but was on the wrong track.
Being too big for your britches gets you exposed in the end.
Leaving a banana on a plane will make a fruit fly.
The optician fell into the lens machine and made himself a spectacle.
Spelunkers tried holding onto the treasure's location until they finally caved.
Talk to a fish by dropping it a line.
To find the marionnette I wanted, I had to pull some strings.
The man who survived pepper spray is now a seasoned veteran.
I used to work at casinos, but was offered a better deal.
Their home is beside a cliff because they live on the edge.
A lumberjack good with chainsaws was promoted to branch manager.
I was busy until my candle-lighting gigs began to taper off.
The room's curtains were drawn, but the other furniture was real.
Although the earth rotates, scientists always put their own spin on it.
The crab in financial difficulty was starting to feel the pinch.
Flies always fear the swat team.
Music store owners prefer you pick out a drum then beat it.
Our baseball victory cake was terrible because we lacked a good batter.
Vets always charge retriever owners a lab fee.
Many folks didn't give a hoot about the spotted owl.

Appendix E: Complete List of Stimuli

Ambiguous Word	Nonword	Unrelated	Dominant	Nonword1	Subordinate	Nonword2
ALARMING	AMUPPING	PROPOSAL	WARNING	WIRASED	FRIGHTENING	FLARNOGMINT
APPEAL	FOLDEV	STAPLE	CASE	CADE	CHARISMA	CHAKEOUG
APPENDIX	AMMUTEND	ROTATION	INDEX	IGOLS	SPLEEN	SLARNE
ARMS	ARVS	MINE	MOB	MEB	RAISE	RILNS
ATTRACTIVE	ATTRICTOAF	ATMOSPHERE	ALLURING	ANKERSTY	FORCE	FULSH
BALL	BEAL	BUCK	BAT	BYM	FUN	FEP
BAR	YAD	BIT	DRINK	DEXED	COURT	COOGS
BLUFF	BLUNC	BLOCK	LIE	LOY	MOUNTAIN	MOUXTAIM
BOARD	BRENK	DATES	COMMITTEE	CHARTRUGY	LUMBER	LARTER
BONE	ROOS	FLAT	SKULL	SMEIN	PRACTICE	PHRANGER
BREAKTHROUGH	BLOGTHOORNE	BREASTSTROKE	DISCOVERY	DETEGMOUS	CHASM	CHORY
CALIBER	CYLOPHER	WAITED	SIZE	SLIZ	STATUS	STENDA
CALVES	CLURTS	COURTS	THIGHS	THEEKS	HORSE	HORMZ
CHEMISTRY	CHEMILEE	AFTERMATH	PHYSICS	PREJONG	ROMANCE	SAQUOTS
CLASS	CRUSS	CASTS	DESK	DORP	STYLE	SPYAL
CLICK	CLUSK	STAGE	SHUTTER	SHRUVEY	FIT	FUP
COMEBACK	COANBUKE	DOWNHILL	POPULAR	PREBEO	RETURN	RAPIRB
COMPOSED	CULTREEP	GROUNDED	TUNE	TENX	CALM	CLOM
CONNECTIONS	CREMULOUSLY	UNDERMINES	CIRCUIT	CORTUBE	COLLEAGUE	CROGGOONE
COOKED	CRASED	STEADY	BAKED	BOLKS	FALS_E	FIRSH
COUNT	COLCS	DUCKS	ADD	ARP	RELY	RIKA
CROAK	CRATH	CURED	DIE	DIV	SING	SELT
CULTURE	CULSPIR	CLOGGED	SNOB	SALP	BACTERIA	BURMIDIA
DEGREES	PARISTS	FIGURES	TEMPERATURE	TIBRAPHOSES	DIPLOMAS	DORTINAL
DEPRESSION	DISPLOPPEL	MOONLIGHTS	SADNESS	SUDNART	HOLE	HYLF
DEPTH	DRETH	DENSE	DIVE	DIRD	DETAIL	DEQUAT
DOUGH	GILED	JOINT	BREAD	BONTH	MONEY	AWALE
DRAINING	DRILKING	NUMBERED	TIRING	TUVERY	PIPE	PISK
DRAW	DOAF	DEAL	GUN	GUG	PORTRAIT	PLOURKET
DRAWING	DREBLIS	EXHAUST	SKETCH	SCHEAD	SUCKING	SNOPPET
DRILL	DROTE	DRIVE	HAMMER	MONORZ	ROUTINE	RELEAPE
ELEMENT	ELEGRAT	GENERAL	COMFORT	COMBITH	MOLECULE	MORAMBEE
FABRICATION	DIXATRATION	VEGETABLES	MANUFACTURE	MORBENIPHONE	FIB	LEZ
FATHOM	FEEPER	MAROON	UNDERSTAND	UNKERSTINT	DEEP	DOPH
FAULTS	FEBBED	RIGHTS	MISTAKES	MISGOLDE	CRACKS	CRARTS
FIELD	FOISE	FUMES	SOIL	SRYA	PASSION	PROISET
FLUSH	FLUPS	HOOKS	POKER	PLEPY	TOILET	TOOZET
FOOL	FOYS	FAIR	CLOWN	CLOSP	SHAME	SHEEM
FUNNY	FOCEY	FILED	HUMOUR	HAMFIK	WEIRD	WRALT
GRADE	GLUPE	GRAIN	SUCCEED	SUCHITS	SLOPE	SMURB
HEAT	HEAB	GRIT	MELT	MEEB	RACE	REAN
HIGHLIGHT	HANPLYCKS	UPSTAGED	YELLOW	YERDER	PINNACLE	PADRUCLE
HOT	HIG	FLY	WARM	WEND	EXCITING	FERVINCY
INFLATION	INFOOTZIN	DEVELOPED	ECONOMY	ERAMENY	PRESSURE	PHRANGLE
INTEGRAL	INFORDER	CALCULATE	DERIVE	DEFROY	SIGNIFICANT	GALLIVACTED
INTEREST	INGARESK	IMMERSED	IDEAL	ITOKX	PERCENT	PLEBINT
JAM	JIT	JIG	STRAWBERRY	SALTONATE	STUFFED	SPREAKS

LAME	LEAL	LOGS	PATHETIC	PERILOUD	SORE	SONE
LEAKED	LAUMED	RIFLES	DRIP	DUTE	SHARED	SHARVS
MEMORY	MALICA	PENALTY	CHIP	CHAL	REMEMBER	SCUNPERI
MIND	MEBB	FOOL	SOUL	SREG	BRAIN	BREME
MINUTES	MANKRUT	FLYERS	SECONDS	SAGNITZ	NOTES	NOLKS
MUGGING	MOTTING	MEASURE	ROBBERY	RASUALS	CUP	CAZ
NUTS	NUST	COLD	ALMOND	AKKEZE	CRAZY	COOMY
PANTS	FANDS	PARTS	SLACKS	SOUNKS	BREATHE	BROUGHS
PLOT	BROM	PALM	STORY	SPOWL	ACRE	ADEX
POINT	PLEEP	PECKS	IDEA	IXAL	SHARP	SCALK
POSITION	PLURIOUS	RELATIVE	JOB	JIK	POSE	PESS
POSITIVE	PUXITAVE	SKELETON	OPTIMISTIC	OPTAVASTAC	INTEGER	IRGUET
POUND	PRUSS	PINCH	KILOGRAM	KLEMAGRY	KENNEL	RONTER
PROBLEMS	POLLSTUK	BALANCES	ISSUES	CREZERS	SOLUTION	SONOFRAK
PRODUCE	PREZYTE	PEANUTS	PERFORM	PLUNCEY	VEGETABLE	VULDIOXX
PROOF	PRAFF	PRIDE	EVIDENCE	PREBEOM	WHISKY	WHAZER
PUNCH	PURNE	POOLS	GLASS	GWILP	JOKE	JORN
PUPILS	PUCAYZ	PRUNED	STUDENTS	STOCKZER	EYE	EWK
RASH	RASK	ROCK	SKIN	SQUI	RUDE	RELD
RECOVERED	RECABERED	REPOSSESS	FABRIC	FIZNIL	HEALTHY	HUNKSED
REFINED	REFRUCE	SERVING	PURE	PRED	CLASSY	CLUFFY
RELIEF	RALUFF	REMOTE	STATUE	STYPOP	FINISH	FURVIT
RETRAINING	REPHOOMING	DEDUCTIONS	EMPLOYMENT	EXLERRGENT	ENGINEERS	ERMOFIES
REVOLTING	REFRICTED	SUSPENDED	DISGUSTING	DILPANNIST	WATTS	WAZZE
RING	ROOG	ROSE	DIAMOND	DROINET	SOUND	SOYNE
ROOTS	RALDS	ROUND	GROW	GUME	HERITAGE	HECLAREY
RUN	RUL	TIP	CHALLENGE	CHOOPINNZ	TEAR	TERZ
SCHOOLS	SCHOMES	VOLUMES	EDUCATION	EROPATION	SWIM	STIT
SCOOP	MROOP	LINES	NEWS	NOSP	CONE	CLYS
SENTENCE	SEADUNCE	SEASONED	PENALTY	PLUDIOX	PHRASE	PHREPH
SHORTS	SHYMES	STRIKE	UNDERWEAR	UNTOUCLAD	MOVIE	TONIP
SHRINK	SHOLTS	STONED	DISAPPEAR	DEBORNATE	THERAPY	TUROLIV
SLASH	SLENT	STOLE	CUT	CAJ	PUNCTUATION	ORUCTATIONS
SPELL	SPETT	SHOOT	MEANING	MERTIVE	MESSAGE	MORREEZ
SPLINTER	SPLAUNTY	SUBJECTS	REBEL	REUGG	SLIVER	SLOFFY
SPOT	SILP	SLIP	PUPPY	PODBRI	STAIN	STUNE
SPREAD	SPRPS	BRANCH	PRESERVE	PAWSTING	BLANKET	BLONZET
SQUARES	SQUEADS	STRINGS	TRIANGLES	TILEEKETS	NERDS	FRUDE
STIRRING	STERPING	SHOULDER	SPOON	SNOPS	INSPIRING	INEXTIKET
SUITS	SULLS	STUFF	CLOTHING	CLARPEST	CASES	CRATEZ
TANGENTS	TUNOSHED	WITHDRAW	GEOMETRY	GAMOLOMY	STORIES	STOOMIE
THIRST	THECKS	TRUNKS	HUNGER	HAVEER	LIQUID	LALMEY
TIE	TIJ	TOP	MATCH	MOACH	CLOTHING	CRUNTING
TRACK	TREAK	CHOPS	DIRECT	DARVEC	TRAIN	TRALC
TURNS	TUNCH	TICKS	FLIPS	FLORT	DEED	DARG
TYPE	TYLC	TOLL	STAMP	STAWT	GENRE	GREPU
UMBRELLA	UMWELTKA	BENEFITS	CORPORATION	CLUMAPATING	RAIN	ROWN
VENT	VARP	SWAT	HEATING	VOOTING	COMPLAIN	COMBANED
WORK	WOBB	WAVE	FAIL	FORP	GYM	GYX

Appendix F: Consent Form

UNIVERSITY OF
WINDSOR

CONSENT TO PARTICIPATE IN RESEARCH

Title of Study: **Word resolution in lexical decision and relatedness tasks.**

You are asked to participate in a doctoral dissertation research study conducted by ***Tara McHugh under the supervision of Dr. Lori Buchanan***, from the ***Psychology Department*** at the University of Windsor. **The results of this study will contribute towards a doctoral dissertation project for Tara McHugh.**

If you have any questions or concerns about the research, please feel to contact ***Tara McHugh or Dr. Lori Buchanan at (519) 253-3000 ext 2240.***

PURPOSE OF THE STUDY

This study is designed to investigate how people process information from words.

PROCEDURES

If you volunteer to participate in this study, we would ask you to do the following things:
You will be asked to make decisions as to whether a letter string on a computer screen is a real word or whether it is a nonword, or whether it is related to a sentence or unrelated. You will be asked to enter your responses into the computer using keys that are designated to indicate your decisions. You will be asked to make your decisions as quickly and accurately as possible. You will be given the opportunity to do a number of practice trials until you feel comfortable with your task. The entire experiment should take about 45 minutes. You will be provided with a more detailed set of instructions by the experimenter. This study will take place in room 62 in Chrysler Hall South.

POTENTIAL RISKS AND DISCOMFORTS

There are no foreseeable risks associated with this study.

POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

Your participation in this study will help us learn more about how people process information about words and about methods we can use to investigate linguistic processing in laboratory settings. In general, this information will help us learn more about language functioning. Other than experience with how research is conducted, you will likely have few direct benefits in exchange for your participation.

PAYMENT FOR PARTICIPATION

Participants may be eligible for bonus points in Psychology courses which permit bonus points.

CONFIDENTIALITY
Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. In order to ensure confidentiality, no personal information will be in anyway connected with the data you provide.

PARTICIPATION AND WITHDRAWAL
You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you don't want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

FEEDBACK OF THE RESULTS OF THIS STUDY TO THE SUBJECTS
At the conclusion of this project, if you wish to receive research findings, they will be sent to you via email or telephone (depending on which contact information you provide to the investigators).

SUBSEQUENT USE OF DATA
This data will be used in subsequent studies.

RIGHTS OF RESEARCH SUBJECTS
You may withdraw your consent at any time and discontinue participation without penalty. If you have questions regarding your rights as a research subject, contact: Research Ethics Coordinator, University of Windsor, Windsor, Ontario N9B 3P4; telephone: 519-253-3000, ext. 3916; e-mail: lbunn@uwindsor.ca.

SIGNATURE OF RESEARCH SUBJECT/LEGAL REPRESENTATIVE
I understand the information provided for the study **Word resolution in lexical decision and relatedness tasks** as described herein. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

____
Name of Subject

______________________________________ ____________________
Signature of Subject Date

SIGNATURE OF INVESTIGATOR
These are the terms under which I will conduct research.

______________________________________ ____________________
Signature of Investigator Date

Vita Auctoris

Name:	Tara S. McHugh
Place of Birth:	Chatham, Ontario
Year of Birth:	1974
Education:	Saint John High School, Saint John, NB International Baccalaureate Diploma
	Queen's University, Kingston, ON 1992-1996 Hons. B.Sc. Psychology
	University of New Brunswick, Fredericton, NB 1997-1998 B. Ed.
	University of New Brunswick, Saint John, NB 1999-2002 M.A. Psychology
	University of Windsor, Windsor, ON 2002-2009 Ph.D. Clinical Neuropsychology