2010

Hemispheric Differences in Semantic Priming Examined Across Handedness Groups

Andrea M. Coppens
University of Windsor

Hemispheric Differences in Semantic Priming Examined Across Handedness Groups

by

Andrea M. Coppens

A Thesis

Submitted to the Faculty of Graduate Studies

through the Department of Psychology

in Partial Fulfillment of the Requirements for

the Degree of Master of Arts at the

University of Windsor

Windsor, Ontario, Canada

2010

Hemispheric differences in semantic priming examined across handedness groups

by

Andrea M. Coppens

APPROVED BY:

____
Dr. P. Weir
Department of Kinesiology

____
Dr. L. Buchanan
Department of Psychology

____
Dr. C. Abeare, Advisor
Department of Psychology

____
Dr. D. Jackson, Chair of Defense
Department of Psychology

September 17, 2010

Author's Declaration of Originality

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

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

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

Abstract

The present study investigates hemispheric differences in semantic priming across handedness groups. A lexical decision task was administered to 87 individuals, classified into handedness groups: consistent right-handers; consistent left-handers; and inconsistent-handers. Participants were presented with strongly-associated and nonassociated category members in a visual half-field semantic priming task. The hypothesis was that the dominant hemisphere would have an advantage for strongly-associated category members, and the nondominant hemisphere would have an advantage for nonassociated category members. This effect was expected to be determined by handedness, such that consistent right-handers have left-hemisphere language dominance, while consistent left-handers have right-hemisphere dominance, and inconsistent-handers have no hemispheric dominance. Although the expected interaction was not found, effects of SOA, word association, and visual field were consistent with previous findings. When handedness was re-classified by stated handedness, there was an association between handedness and visual field. The implications of these findings are discussed.

Acknowledgments

I would like to take this opportunity to thank those who were involved in the process of completing this thesis. First, I wish to thank my thesis committee members: Dr. Weir, for your suggestions early on and encouragement during this process; Dr. Buchanan for sharing your expertise with me, and providing a glimpse into your wealth of knowledge.

I would especially like to thank Dr. Abeare, for your patience and creativity, from the moment the idea was first conceived through to the final phases of editing.

Thank you to my research assistant, Adan Khan, whose countless hours of work were invaluable in the completion of this project.

Finally, I would like to thank my family for their continued support and motivation throughout this entire endeavour.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

fMRI	Functional Magnetic Resonance Imaging
fTCD	Functional Transcranial Doppler Sonography
LH	Left Hemisphere
LVF	Left Visual Field
MNI	Montreal Neurological Institute Handedness Questionnaire
NAART	North American Adult Reading Test
RH	Right Hemisphere
RVF	Right Visual Field
SOA	Stimulus Onset Asynchrony

Introduction

Since the 19th century, when Marc Dax and Paul Broca first introduced the idea that speech may be localized to the left hemisphere, it has commonly been accepted that the brain is lateralized for left hemisphere language dominance. However, Broca also believed that language dominance was based on handedness, and that left-handers likely had right-hemispheric dominance for language (Goodglass & Quadfasel, 1954). The same year that Broca first published his findings on cerebral language dominance, Bouillaud proposed the idea of a link between handedness and speech. From this theory, researchers began examining language impairments in individuals with unilateral lesions, localized to one hemisphere or the other. In the late 1800s, Jackson and Ogle published case studies describing left-handers who had significant language impairment following right-hemisphere lesions. Researchers believed these findings suggested that individuals had a dominant hemisphere, which was linked to their handedness (see Goodglass & Quadfasel, 1954 for a review).

Despite the theorizing of the late 1800s, the idea of right-hemisphere language was not studied systematically until after World War II, when left-handed soldiers with unilateral right-hemisphere lesions were examined for the presence of language impairments. Hécaen, De Agnostini, & Monzon-Montes (1981) summarized these findings, and reported that left-handed individuals "do not have inverted dominance for language representation in the brain, but rather actually have different cortical organization" (p. 261). Therefore, cerebral language dominance in left-handers is not likely a mirror-image of that found in right-handers, as was originally speculated by Broca.

Following these findings, Gazzaniga and Sperry (1967) studied split-brain patients, and found that although language expression resided almost exclusively in the left hemisphere of the right-handed patients, language comprehension was present in both the left and right hemisphere. These findings led researchers to wonder to what extent language is present in either hemisphere, and why there may be differences in cerebral language dominance among individuals. The idea that cerebral language dominance may somehow be linked to handedness is an important piece of the puzzle.

Handedness

In attempting to understand individual differences in cerebral language dominance, researchers have examined the relationship between handedness and language lateralization, as handedness appears to be the individual difference measure most related to language lateralization (Bryden, 1987). Research shows that approximately 10% of the population is left-handed (Perelle & Erhman, 2005). Hunter and Brysbaert (2008) found that the left hemisphere is dominant for language in most people; specifically, 90% of individuals who self-report as right-handers and 70% of self-reported left-handers. Furthermore, Pujol et al. (1999) had previously shown that language does not lateralize to a single hemisphere in all individuals; they suggested that up to 96% of right-handers actually have language lateralized to the left hemisphere, while the other 4% have a bilateral language distribution among the two hemispheres. For left-handers, Pujol et al. (1999) found that 76% have left hemisphere language, 10% have right-hemisphere language, and 14% have bilateral language. These estimates are consistent with previous studies that have examined the prevalence of language dominance and handedness using the Wada procedure (Rasmussen & Milner, 1977), and, more recently, using functional transcranial Doppler sonography (fTCD; Knecht et al., 2000).

A significant proportion of individuals (4-10% of right-handers and 24-30% of left-handers), therefore, do not appear to have the expected left hemisphere dominance for language. These findings support the conclusions of Hécaen, De Agnostini, and Monzon-Montes (1981) that right- and left-handed brains are not always mirror-images of one another in terms of language dominance. Given this variability, it is important to take a closer look at factors that may account for the unexplained variance within traditional handedness groups.

In order to examine handedness, the contentious issue of handedness classification must be addressed. Annett (1998) stated that the reason handedness, and variables such as cerebral language dominance, remain uncertain is because researchers do not use one unified method of selecting and classifying handedness groups. Traditionally, individuals state their hand preference, based on the hand with which they write. This is the most basic method of classification, and the one most commonly used in research. However, many people prefer using different hands for different skilled tasks. Annett (1998) claimed that this is not simply due to social pressures imposed on those who are naturally left-handed, because there are many individuals who continue to write with their left hand, while using the right hand for other activities, such as throwing a ball or combing their hair.

Researchers have attempted to examine handedness in a more comprehensive way, to develop methods of classification that are better related to variables of interest, such as genetics and neurocognitive performance. Different handedness classification methods include the traditional right-handed vs. left-handed model, as well as methods of dividing handedness into two-, three-, and four-factor classification systems.

Christman (1995) developed a two-factor model that classifies individuals based on the degree of their handedness; that is, whether they are strong-handed (i.e., use one hand for all activities) or mixed-handed (i.e., use their non-dominant hand for at least one activity). Christman and colleagues typically use the Edinburgh Handedness Inventory (Oldfield, 1971) to make these discriminations. This methodology has yielded interesting findings, such as evidence of increased hemispheric interaction in individuals with mixed-handedness (Christman, Propper, & Brown, 2006). However, one of the primary concerns with this method of classification is that it groups strong right-handers together with strong left-handers, and there are likely differences between individuals who write with their right as opposed to their left hand, which are not being taken into account by this classification method. In fact, due to the relatively small proportion of strong left-handers in the population, the authors rarely consider them in their studies, focusing solely on mixed-handers and strong right-handers instead (Propper & Christman, 2004).

Peters and Murphy (1992) classified individuals into one of three handedness groups, based on their scores on the 60-item Waterloo Handedness Questionnaire (Steenhuis & Bryden, 1989) and a 14-item Edinburgh Handedness Inventory (Oldfield, 1971), both of which consist of questions about hand preference for a variety of common activities. The categories include: consistent right-handers (i.e., those who use their right hand for most activities); consistent left-handers (i.e., those who use their left hand for most activities); or inconsistent left-handers (i.e., those who write with their left hand, but do other activities, such as throwing a ball, with their right hand). The primary concern with this method of classification, however, is that inconsistent right-handers are not taken into account and, as Christman and colleagues have noted, there appear to be significant differences between consistent and inconsistent right-handers.

McManus, Porac, Bryden, & Boucher (1999) developed a four-factor model, which takes both degree and direction of handedness into account. Using Peters and Murphy's (1992) 3-factor model to divide individuals into consistent and inconsistent-handers, McManus and colleagues compared individuals' writing and throwing hands. They found that a minority of both right- and left-handers have crossed writing and throwing ability; approximately 29% of left-handers and slightly less than 2% of right-handers appear to be inconsistently-handed. This suggests that rather than having two or three handedness groups, there should be four: consistent right- and left-handers, and inconsistent right- and left-handers.

In order to examine cerebral language lateralization processes, visual half-field studies can be conducted. The visual half-field presentation relies on the fact that the brain is divided into two separate hemispheres and that the optic tracts are partially crossed. Information presented to one visual field is processed initially by the contralateral hemisphere before spreading to the rest of the brain (Lindell & Nicholls, 2003). Based on this knowledge, the assumption can be made that a stimulus presented to the Right Visual Field (RVF) is initially presented to the visual cortex of the left hemisphere (LH), and that Left Visual Field (LVF) presentation results in initial right hemisphere (RH) stimulation.

In accordance with this theory, recent fMRI research by Hunter and Brysbaert (2008) has demonstrated that participants with significant left-hemisphere language dominance (as evidenced in the scanner) respond faster and more accurately to words presented to their RVF; those with a significant right-hemisphere language dominance responded faster and more accurately to words presented to their LVF.

Kaploun and Abeare (2010) used the visual half-field method to test the four previously mentioned handedness classification schemes. They set out to determine which method best captured differences in language processing between the two cerebral hemispheres, based on the visual field of presentation. They examined the following models: the traditional right-handed vs. left-handed model; a two-factor model similar to that developed by Christman (1995); Peters and Murphy's (1992) three-factor model; and a four-factor model, similar to that of McManus and colleagues (1999).

Using the traditional handedness classification method, they found a trend for right-handers to respond faster to words presented to the RVF/LH than to the LVF/RH, although this difference was not significant. Left-handers, however, responded significantly faster to words presented to the LVF/RH than to the RVF/LH. This is an interesting finding, as it may suggest that right- and left-handers have opposite hemispheric dominance; right-handers appear to have the expected RVF/LH dominance for language, but left-handers may tend to be LVF/RH dominant.

When Kaploun and Abeare (2010) examined the two-factor model, in which strong-handers were compared with mixed-handers, they found no group differences, suggesting that hemispheric dominance for language is not necessarily based solely on the strength of handedness. However, in examining the three-factor model, comparing consistent left-handers, inconsistent left-handers, and consistent right-handers, they found that: consistent right-handers responded faster to words presented to the RVF/LH than to the LVF/RH; consistent left-handers responded faster to words presented in the LVF/RH than the RVF/LH; and inconsistent-handers showed no visual-field/hemisphere advantage. These findings demonstrate that consistent right-handers may have the expected RVF/LH advantage for language, while the consistent left-handers have the opposite hemispheric dominance (i.e., LVF/RH dominance for language). The inconsistent left-handers, however, appear to have a more bilateral representation, because they did not demonstrate a hemispheric advantage.

Finally, when examining the four-factor model comparing strong right-handers, weak right-handers, strong left-handers, and weak left-handers, Kaploun and Abeare found that: 1) strong right-handers responded faster to words presented to the RVF/LH than the LVF/RH; 2) strong left-handers had the opposite pattern of results, responding faster to words presented to the LVF/RH than the RVF/LH; and 3) weak right- and left-handers showed no advantage for either hemisphere. Overall, Kaploun and Abeare concluded that a three-factor model, such as that proposed by Peters and Murphy, was the best method of classifying handedness. Due to the fact that they found no difference between the weak right- and left-handers in the four-factor model, they suggested grouping them together. Therefore, they refer to the three groups as: consistent right-handers, consistent left-handers, and inconsistent-handers.

The terminology used by Kaploun and Abeare is similar to that used by Annett (1998), who stated that handedness can be considered on a continuum from strong left to strong right, and that individuals are likely consistent left-, consistent right-, or mixed-handers. This classification method is also in accordance with Propper and Christman's (2004) belief that "handedness should not be classified dichotomously, but should be classified trichotomously" (p. 708). Although they typically only examine two groups, Propper and Christman believe that there is a third classification; those who belong to the third group - whom Propper and Christman refer to as "strong left-handers" - only make up about 2-3% of the general population and therefore the researchers choose not to study them. Overall, research suggests that individual variations in handedness can be classified using a more specific method than the traditional left- vs. right-handed model.

Visual Half-Field Semantic Priming

Before the development of neuroimaging techniques, the most effective way to explore hemispheric differences in lateralization was to investigate clinical populations, such as split-brain patients, and to use the findings to make inferences about normal brain functioning. Due to the advances of modern technology, neuroimaging now provides an excellent means of examining both typical and abnormal brain functioning. As mentioned previously, fMRI studies have demonstrated clear differences in language processing between the two cerebral hemispheres (Hunter & Brysbaert, 2008; van Ettinger-Veenstra et al., 2010).

Although fMRI can demonstrate activity in specific brain regions, it is slow and insensitive to rapid changes in cognitive processing. Visual half-field tasks are used to examine hemispheric language dominance, by assuming that language stimuli are processed faster and more accurately when presented to the visual half-field that corresponds to the language-dominant hemisphere. The visual half-field task provides researchers with a non-invasive and cost-effective method for examining hemispheric lateralization in normal brains (Bourne, 2006), and can demonstrate minute differences in response time. The technique can be used on almost any population, therefore participants are easily acquired for studies, and each individual can provide information from both hemispheres (Chiarello, Liu, Shears, Quan, & Kacinik, 2003).

In order to examine hemispheric differences in semantic processing, visual half-field tasks can be used to present prime and target words to be followed by a lexical decision. The length of time taken to decide whether a string of letters combines to make up a real word (i.e., reaction time) can be used as a measure of cognitive processing. Another measure is the accuracy of the decision. Kinoshita and Mozer (2006) suggest that tasks involving reaction times appear to be the most popular way of examining the speed of cognitive processing. The theory is that "the longer the reaction time, the more complex the underlying processes required to produce the response" (Kinoshita & Mozer, 2006; p. 726). The reaction time for particular stimuli can be manipulated, by either increasing or decreasing the complexity of the cognitive processes involved. One method of decreasing the load on cognitive processing is to use words with high frequency; another is to use semantic priming.

Several models exist that describe semantic priming; the spreading activation theory of language processing is one model used to explain how semantic priming assists in word identification. Posner and Snyder (1975a) hypothesized that attention is divided into two processes: a fast, automatic spreading activation system; and a slow, conscious attention mechanism. They suggested that information is retrieved from long-term memory through one of these two attention processes. The automatic system is inhibitionless, free of strategy, and does not drain the resources of the conscious system, which has a limited capacity, is dependent on strategy, and draws from the resources of a limited central processing system (Posner & Snyder, 1975a).

Posner and Snyder (1975a) suggested that long-term memory is made up of *logogens*, which are units of memory that contain information about experienced events. Logogens for words that are semantically-related to one another are hypothesized to be located near each other, whereas unrelated logogens are located further apart. When a stimulus is presented, its logogen is automatically activated and it is believed to spread to related logogens quickly and automatically, without conscious awareness (Posner & Snyder, 1975a).

If a word is presented before the activation of a related logogen has completely dissipated, the activation of the most recent logogen will initially be greater than if the previous stimulus had been unrelated. This process is termed *semantic priming*; individuals are quicker to respond appropriately to a word (i.e., the target) if it is immediately preceded by a semantically-related word (i.e., the prime), than if it is preceded by an unrelated target word. Posner and Snyder's (1975a) theory can explain this process, since the logogen of the prime will automatically spread to the logogen of a related target, and the distance that attention must travel from the logogen of the prime to that of the related target is shorter than to that of the unrelated target. The spreading activation theory of priming is therefore based on the associative strength between two logogens.

One way of manipulating the spread of activation is by altering the amount of time between the onset of the prime and that of the target stimulus. Neely (1977) found that the stimulus onset asynchrony (SOA) has an effect on the processing of semantically-related words. When the target is presented soon after the prime (i.e., at short SOAs), automatic spreading activation is required; when the target is presented later (i.e., at long SOAs), the initial spreading activation begins to decay and individuals switch to using their limited-attention capacities. These minute differences in language processing can be analyzed even further by comparing the activation of the dominant and nondominant hemispheres.

Chiarello, Burgess, Richards, and Pollock (1990) found that the left hemisphere tends to organize lexical information based on logical conceptual relationships between words, whereas the right hemisphere tends to organize words based on associations between them. The left hemisphere also tends to quickly select the most likely response, with the closest related meaning of the word, and then inhibits all other responses; the right hemisphere tends to process information more slowly and diffusely, creating a variable list of possible responses, including distant semantic relations between words (Chiarello et al., 1990; Yochim, Kender, Abeare, Gustafson, & Whitman, 2005), multiple possible meanings of ambiguous words (Beeman & Chiarello, 1998; Burgess & Simpson, 1988; Faust & Lavidor, 2003), and metaphorical descriptions (Beeman & Chiarello, 1998).

When category exemplars are presented as the prime and target in visual half-field semantic priming tasks, there is facilitation for words that are members of the same category, over unrelated word pairs. Both strongly- and weakly-associated category members show this effect, although the strongly-associated category members are facilitated earliest (Neely, 1977). The strength of the initial prime determines the reaction time; when the prime is strongly-associated to the target, the reaction time will be faster than if the prime is weakly-associated to the target (Collins & Loftus, 1975). For example, categorical associates, such as “cat” and “dog” have the strongest association, because they belong to the same semantic category (i.e., animal) and are strongly associated. Noncategorical associates, on the other hand, such as “dog” and “bone”, have a weaker association, because they are associated, but are not members of the same semantic category. Nonassociated category members (e.g., “dog” and “zebra”), have an even weaker association, as they are members of the same semantic category, but are not commonly associated with one another (Chiarello, Richards, & Pollock, 1992).

The terminology and definitions used to identify different prime-target relationships varies in the literature. The most common method of determining association strength is to ask participants to generate a list of words associated with a given target. Researchers then ensure that none of the generated associates are included in the study of weakly-associated word pairs (Collins, 1999; Koivisto, 1997; McRae & Boisvert, 1998; Nelson, McEvoy, & Schreiber, 1998). Koivisto (1997) pointed out that it is difficult to determine the actual distance (strength of association) between primes and targets that are not identified as strongly-associated, and a lack of association cannot be assumed. However, researchers most frequently refer to category members with weak associations as *nonassociated category members*. Therefore, in the current study, the term nonassociated category member will refer to any category members that are not considered strongly-associated.

Research has shown that, in studies examining the typical brain, individuals respond faster and more accurately to strongly-associated category members (e.g., “dog” and “cat”) when the prime and target are presented to the RVF/LH; nonassociated category members (e.g., “cat” and “zebra”) are processed faster and more accurately when presented to the LVF/RH (Chiarello et al., 1992). However, Koivisto (1998) summarized a dozen studies examining this phenomenon, and found that the right-hemisphere advantage for nonassociated category members is only present when the SOA is considered to be long.

There are contrasting interpretations about why the right hemisphere has a priming advantage at longer SOAs. To account for the variations in the time-course of priming strongly- vs. non-associated category members in the right hemisphere, Chiarello and her colleagues (2003) developed a theoretical framework, which suggests that the right hemisphere is less efficient at processing language and is therefore a “noisier” system than the left. The framework hypothesizes that “excessive noise could increase the time required for the semantic system to settle into a stable pattern of activation…” (p. 730). Strongly-associated category members likely reduce the amount of strain put on the system, whereas nonassociated category members require more time for the system to find its pattern of activation, resulting in delayed priming in the right hemisphere. In order to further test this framework, the authors suggested that future research manipulate the degree of relatedness between primes and targets (Chiarello et al., 2003), which is one of the goals of the present study.

Another view suggests that word meanings are not activated in the right hemisphere; instead, the right hemisphere uses word meanings originally activated by the left hemisphere to conduct post-lexical semantic processes (Koivisto, 1998). To date, it appears that researchers have been unable to come to a consensus in explaining the phenomenon.

Regardless of the theory behind it, the findings suggest the importance of looking at the time-course of word meaning availability, in order to determine true hemispheric differences in language processing; this can be observed by manipulating the SOA. At shorter SOAs (i.e., between 165 and 450 ms), there is an early onset priming effect for the RVF/LH but not for the LVF/RH for nonassociated category members (Collins, 1999; Koivisto, 1997; Abernethy & Coney, 1996). However, at longer SOAs (i.e., greater than 500 ms), there is a LVF/RH priming effect for nonassociated category members (Collins, 1999; Koivisto, 1997), which is not seen in the RVF/LH (Koivisto, 1997). When examining strongly-associated category members, priming occurs in both hemispheres, at any SOA (Audet, Driessen, & Burgess, 1998), although the left hemisphere has a slight advantage in priming over the right, at very brief SOAs (e.g., 150 ms; Chiarello et al., 2003).

Language Lateralization and Handedness

Research on hemispheric differences in processing category members has been used as a measure of cerebral language dominance, however studies rarely take handedness into account; most research on hemispheric asymmetries exclusively examines right-handers (e.g., Abernethy & Coney, 1990; 1993; Chiarello & Richards, 1992; Chiarello, Richards, & Pollock, 1992). In fact, it is often recommended that researchers limit their investigations of lateralization processes to right-handers, so that the "typical" brain can be studied (Bourne, 2006). Although the majority of individuals do have left hemisphere language dominance, researchers have found a correlation between handedness and language lateralization (Gonzalez & Goodale, 2009). Differences among individuals in varying handedness groups may demonstrate further evidence of differences in cerebral language dominance.

Within their study on methods of classifying handedness, Kaploun and Abeare (2010) found that consistent right-handers showed the expected RVF/LH advantage for processing strongly-associated category members in a semantic priming visual half-field task. However, they found that consistent left-handers showed the opposite pattern; the LVF/RH presentation was most effective for processing strongly-associated category members. The inconsistent-handers did not show an advantage for either visual field. This finding may partially support the idea that right-handers and left-handers have opposite patterns of language lateralization, with the caveat that there is a group of inconsistently-handed individuals who have more bilateral representation, a finding that is consistent with more recent neuroimaging findings (Knecht et al., 2000).

In order to test this idea further, other aspects of semantic processing should be examined across handedness groups. For instance, research on hemispheric differences in semantic processing (in right-handers) has shown that the left hemisphere primarily activates strongly-associated words, whereas the right hemisphere has more non-specific pattern of semantic activation in which both high and low associates are activated in response to the presentation of a word. Thus, a more comprehensive examination of language lateralization in handedness groups should include the examination of the breadth of semantic processing in the hemispheres. If consistent left-handers truly have mirror-image language lateralization, then we would expect to find that they would have broad activation of both strongly-associated and nonassociated word pairs in the left hemisphere and more narrow activation of only strongly-associated word pairs in the right hemisphere.

Consistent with this idea, Chiarello and her colleagues (2003) discussed the need for future research to "… manipulate [the] degree of semantic similarity…" (p. 730); this is the main goal of the present study. Individuals, classified into one of three handedness groups (consistent right-handers, consistent left-handers, and inconsistent-handers), were presented with strongly-associated and nonassociated category members. The first hypothesis is that for strongly-associated category members, consistent right-handers will have a RVF/LH advantage, consistent left-handers will have a LVF/RH advantage, and inconsistent-handers will have no hemispheric advantage. The second hypothesis is that for nonassociated category members, the visual field advantages are expected to be opposite to those found using strongly-associated category members. Consistent right-handers are expected to have a LVF/RH advantage, consistent left-handers will have a RVF/LH advantage, and inconsistent-handers will have no hemispheric advantage. The advantages for the nonassociated category members, in the nondominant hemisphere, are only expected to occur at the longer SOA (i.e., 800 ms).

Method

Participants

Participants from the University of Windsor Psychology undergraduate participant pool were included in the study until 87 students (18 males and 69 females) met the selection criteria. Participants ranged in age from 18 to 44 years, with a mean age of 21 years. All were native English speakers with normal or corrected-to-normal vision. All participants were asked about a history of neurological impairment, to ensure that typical lateralization processes were investigated (Bourne, 2006).

To assess handedness, participants completed the Montreal Neurological Institute (MNI) Handedness Questionnaire (Crovitz & Zener, 1962). A median split was conducted on the scores of the 53 self-reported right-handers (median = 22) and the 34 self-reported left-handers (median = 69), to determine handedness group cutoffs. Consistent right-handers were considered those with MNI scores ≤ 22 (N = 33). Consistent left-handers were considered those with MNI scores ≥ 69 (N = 18). Inconsistent-handers were those whose MNI scores fell between 22 and 69 (N = 36). Preliminary analyses were conducted by dividing the MNI scores into three equal groups (N = 29), similar to Kaploun and Abeare's (2010) method of trichotomizing handedness. There were no differences in findings when individuals were grouped based on either method. Although using median splits to determine cutoffs leads to unequal group sizes, this method is likely more consistent with identifying actual handedness, than simply dividing the total number of participants into three equal groups, as the latter method may be largely influenced by the current unequal group sizes for left- vs. right-handers.

To determine reading ability, individuals were given the North American Adult Reading Test (NAART). The NAART is a modification of Blair and Spreen's (1989) National Adult Reading Test (NART), which involves reading a list of irregularly pronounced English words out loud.

Stimuli

The semantic priming task was a partial replication of Kaploun and Abeare's (2010) semantic priming task. In the present study, targets were all low frequency words; therefore, they are each encountered in written text less than 10 times per million words (Durda & Buchanan, 2006). The decision to use low frequency words was based on the knowledge that high frequency targets are identified faster than lower frequency targets, and tend not to show priming effects (see Paap et al., 1987 for a review). It was assumed that if strongly- and nonassociated category members were all made up of high frequency words, it would be difficult to see a difference in response times between the two groups. Therefore, low frequency words were used, due to the knowledge that they would have slower overall reaction times, and thus be more likely to show an effect of priming.

The stimuli for the semantic priming task consisted of 24 strongly-associated low frequency category members (i.e., semantically and categorically related word pairs with frequencies less than or equal to 10, such as "candy" and "mint"), and 24 nonassociated low frequency category members (i.e., semantically unrelated category members with frequencies below 10, such as "peach" and "banana"). Twenty-four (24) related high frequency word pair fillers were included (i.e., 12 strongly-associated and 12 nonassociated category members with frequencies greater than 10, such as "doctor" and "nurse"). Associations were derived from Nelson, McEvoy and Schreiber's (1998) free association norms.

Stimuli also consisted of 96 unrelated word pairs (i.e., 48 low frequency and 12 high frequency semantically and categorically unrelated word pairs, such as “crater” and “movie”), and 144 non-word pairs (i.e., 96 low frequency prime-nonword target and 48 high frequency prime-nonword target pairs). A total of 288 pairs (144 word trials and 144 non-word trials) were presented. The majority of words used were selected from previous studies: Chiarello and her colleagues (1990; 1992; 2003), Kaploun and Abeare (2010), Koivisto (1997), and McRae and Boisvert (1998). Additional words were selected from the noun pool developed by the University of Pennsylvania’s Computational Memory Lab (available at the internet address http:// memory.psych.upenn.edu/ files/ wordpools/ nounpool.txt).

The primes and targets were matched for word length, orthographic neighbourhood, and word frequency (Durda & Buchanan, 2006). The non-words were targets in half of the trials, and were always preceded by a real word prime, which did not occur in any of the real-word pairs as a prime or target. The nonwords were created using English words with one letter changed (while maintaining orthographic integrity), and were derived from a pool of non-words compiled by Hutchinson, Whitman, Abeare and Raiter (2003). Two different SOAs (150 ms and 800 ms) were used, as in Kaploun and Abeare (2010), to examine time-course differences in priming in the cerebral hemispheres.

Apparatus

The semantic priming task was conducted on a Dell computer, using DirectRT software, which presented the visual half-field stimuli. Chin rests kept the participants’ eyes fixed at a distance of 50 cm from the screen, such that the inner edge of the stimuli fell at an angle of three (3°) visual degrees, based on Bourne’s (2006) recommendation of

2.5-3º. Participants responded to the lexical decision task by pressing one of two keys on a keyboard (the 'up' arrow for yes, and the 'down' arrow for no).

Design and Procedure

Each participant first completed the MNI Handedness Questionnaire (Crovitz & Zener, 1962), and then the NAART (Blair & Spreen, 1989). They were randomly assigned to an SOA group; either 150 ms or 800 ms. The word pairs were presented in random order, with a 50% chance of the target being a non-word on every trial. In the experimental design there were four levels of visual half-field presentation: RVF prime-RVF target; RVF prime-LVF target; LVF prime-RVF target; LVF prime-LVF target. In examining the effects of visual field presentation, only the unilateral visual field presentations (RVF prime-RVF target and LVF prime-LVF target) were analyzed so that only the initial hemispheric processing was assessed, as opposed to the effects of interhemispheric transfer on semantic processing abilities (see Hutchinson et al., 2003 for a review). Each individual was therefore presented with half of the critical pairs in a unilateral RVF/LH presentation, and half of the pairs in a unilateral LVF/RH presentation; individuals were randomly assigned to the presentation, such that each participant saw 50% of the critical items in each visual field/hemisphere. Participants were instructed to decide whether the second stimulus they saw was a real word, by pressing the designated "yes" or "no" keys, as quickly and accurately as possible, using the index and middle finger of their dominant hand.

The trials began with a flickering red "+" on the computer screen, so that the participants paid attention to the centre of the screen. Bourne (2006) recommends presenting stimuli for no more than 180 ms, to ensure that the presentation is unilateral. The prime was therefore randomly presented to either the right or left visual field for 100 ms, and immediately followed by a mask, which was a series of "XXXXX" shown across the screen. Then (after the designated SOA), the target was randomly presented to either the right or left visual field for 180 ms, and the participant made the word/non-word judgment using the keyboard. Participants responded with their dominant hand. Pressing the "up" arrow key on the keyboard indicated that the participant believed it was a real word, and the "down" arrow was designated for non-words. These keys are located above one another on the keyboard and were separate from other keys, thus making it easier for individuals to press either key without accidentally hitting any others. Reaction time and response accuracy were recorded.

Statistical Analysis

A chi-square analysis was run to assess for disproportionate gender representation between the three handedness groups. In order to assess for potential gender effects, two mixed factorial ANOVAs were conducted, with visual field of presentation and word association as the within-subjects variables, and gender as the between-subjects variable. For the first ANOVA, reaction time was the dependent variable, and then the same ANOVA was conducted with accuracy as the dependent variable. Gender was not expected to have an effect on reaction time or accuracy, and was therefore anticipated to be removed from further analyses.

To evaluate the hypotheses, 4 mixed factorial ANOVAs were conducted with visual field of presentation and word association as the within-subjects variables, and handedness and SOA condition as the between-subjects variables.

Hypothesis 1: For strongly-associated category members, consistent right-handers were expected to have a left-hemisphere advantage, consistent left-handers were expected to have a right-hemisphere advantage, and inconsistent-handers were not expected to have a hemispheric advantage. There was no expected effect of SOA.

To evaluate hypothesis 1, the ANOVA was conducted with reaction time as the dependent variable, and the same ANOVA was then conducted with accuracy as the dependent variable.

Hypothesis 2: For non-associated category members, consistent right-handers were expected to have a right-hemisphere advantage, consistent left-handers were expected to have a left-hemisphere advantage, and inconsistent-handers were not expected to have a hemispheric advantage. The effects were only expected to be seen at the 800 ms SOA condition.

To evaluate hypothesis 2, the same ANOVA was conducted first with reaction time, and then again with accuracy, as the dependent variables.

To clean the data, prior to conducting analyses, all data sets with overall accuracy less than or equal to .70 were removed. Only correct responses were included in the analysis; reaction times greater than or equal to 1500 ms were considered incorrect responses and were removed. Once these conditions were met, there were no outliers in the sample. An alpha level of .05 was used for all analyses, such that a p less than .05 was considered significant. A series of *a priori* linear contrasts were conducted in combination with the Bonferroni t-test, in order to test the hypotheses.

Following the original analysis, further exploratory analyses were conducted. To determine whether or not there was an effect of visual field or SOA for unrelated word pairs, a univariate ANOVA was conducted with unrelated word pairs as the within-subjects variable, SOA condition as the between-subjects variable, and reaction time as the dependent variable.

For analyses in which handedness classification was manipulated, the previous mixed factorial ANOVA was conducted using handedness as a between-subjects variable with either 3 levels (consistent right-, consistent left-, and inconsistent-handers), 2 levels (right-handers, and left-handers), or a single level (right-handers).

Results

The Chi-square analysis revealed no effect of gender between the different handedness groups [$\chi^2(2, 87) = 1.05$, $p = .59$], although the analysis cannot be interpreted reliably, due to the fact that one of the cells had a count of fewer than 5 individuals.

A 2 (gender) x 2 (visual field) by 2 (word association) mixed factorial ANOVA was conducted to determine whether there was a main effect of gender. There was no effect of gender for reaction time [$F(1, 85) < 1$, $p = .82$] or for accuracy [$F(1,85) < 1$, $p = .56$]. There were also no interactions with gender, thus providing further support for removing gender as a variable in subsequent analyses.

Two 2 (visual field) by 2 (SOA) by 2 (word association) by 3 (handedness) mixed factorial ANOVAs were conducted. For reaction time, there was a main effect of word association [$F(1, 81) = 7.87$, $p = .0060$], such that strongly-associated category members were responded to faster [$M = 621.85$, $SE = 12.56$] than nonassociated category members [$M = 641.22$, $SE = 12.70$]. There was also a main effect of SOA for reaction time [$F(1, 81) = 6.65$, $p = .012$], such that the responses in the 150 ms SOA were faster [$M = 600.22$, $SE = 17.22$], on average, than in the 800 ms SOA condition [$M = 662.858$, $SE = 17.15$]. There was no main effect of visual field [$F(1, 81) < 1$, $p = .59$], or handedness [$F(2, 82) < 1$, $p = .89$].

An interaction was found for reaction time of visual field by SOA [$F(1, 81) = 4.38$, $p = .040$] (see Figure 1). In the 150 ms SOA condition, responses to the RVF/LH

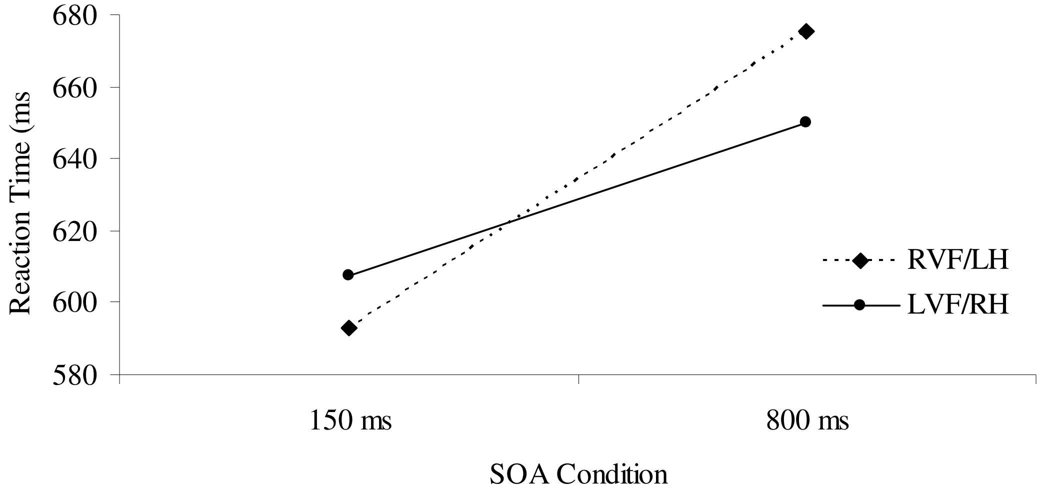

Figure 1. Interaction of Stimulus Onset Asynchrony (SOA) by visual field of presentation for reaction time (ms).

presentations were faster [*M* = 592.73, *SE* = 19.88] than to the LVF/RH presentations [*M* = 607.70, *SE* = 17.06]. In the 800 ms SOA condition, responses to the LVF/RH presentations were faster [*M* = 650.13, *SE* = 16.99] than to the RVF/LH [*M* = 675.58, *SE* = 19.81]. There were no other interactions for gender, visual field, word association, or SOA for reaction time; reaction times for all conditions can be found in Table 1.

There was an effect of word association, on accuracy [$F(1, 81) = 17.30$, $p = .000$], such that responses to strongly-associated category members were more accurate [*M* = .88, *SE* = .010] than to nonassociated category members [*M* = .83, *SE* = .012]. There was also a main effect of SOA on accuracy [$F(1, 81) = 7.51$, $p = .008$], such that responses in the 150 ms SOA condition were more accurate [*M* = .88, *SE* = .013] than in the 800 ms SOA condition [*M* = .83, *SE* = .013]. There was no effect of visual field [$F(1, 81) < 1$, $p = .96$] or handedness [$F(2, 82) < 1$, $p = .65$]. There were no other interactions for gender, visual field, word association, or SOA on accuracy; accuracy for each condition can be found in Table 2.

Following the original analyses, further exploratory tests were conducted, in order to find other possible trends in the results. In an attempt to further examine the effect of SOA for the reaction time of related word pairs, a univariate ANOVA was conducted for the reaction time of the unrelated word pairs presented in the contralateral visual field condition. There was no effect of SOA, [$F(1, 84) = 1.60$, $p = .21$].

Due to the fact that there was no effect of handedness in the previous analyses, handedness classification was manipulated in order to conduct further analyses. When only self-reported right-handers were considered (as is common for semantic priming studies), the results were similar to those found with the three handedness groups, with a main effect of word association and SOA, as well as an interaction between visual field

Table 1

Reaction Time (ms) for Lexical Decision Tasks by Handedness Group, Prime-Target Association, Stimulus Onset Asynchrony (SOA), and Visual Field of Presentation

		150 SOA				800 SOA			
		SA		NA		SA		NA	
		RVF/LH	LVF/RH	RVF/LH	LVF/RH	RVF/LH	LVF/RH	RVF/LH	LVF/RH
Consistent Right-handers	M	560.95	616.21	590.78	635.03	672.67	664.08	695.18	652.63
	(SE)	(27.39)	(24.91)	(29.88)	(24.41)	(36.24)	(32.95)	(39.53)	(32.29)
Inconsistent-handers	M	553.77	543.07	576.26	579.91	685.59	639.90	715.08	699.93
	(SE)	(31.38)	(28.54)	(34.23)	(27.96)	(28.07)	(25.53)	(30.62)	(25.01)
Consistent Left-handers	M	632.1	618.59	642.54	653.37	651.52	623.8	633.47	620.45
	(SE)	(44.38)	(40.36)	(48.41)	(39.54)	(39.70)	(36.10)	(43.3)	(35.37)

SA: Strongly-Associated Category Members; NA: Nonassociated Category Members; RVF/LH: Right Visual Field/Left Hemisphere Presentation; LVF/RH: Left Visual Field/Right Hemsiphere Presentation.

Table 2

Accuracy (%) for Lexical Decision Tasks by Handedness Group, Prime-Target Association, Stimulus Onset Asynchrony (SOA), and Visual Field of Presentation

		150 SOA				800 SOA			
		SA		NA		SA		NA	
		RVF/LH	LVF/RH	RVF/LH	LVF/RH	RVF/LH	LVF/RH	RVF/LH	LVF/RH
Consistent Right-handers	M (SE)	.90 (.026)	.90 (.025)	.82 (.029)	.82 (.031)	.84 (.034)	.88 (.034)	.86 (.038)	.79 (.041)
Inconsistent-handers	M (SE)	.95 (.029)	.92 (.029)	.85 (.033)	.86 (.036)	.83 (.026)	.83 (.026)	.78 (.030)	.78 (.032)
Consistent Left-handers	M (SE)	.87 (.041)	.92 (.041)	.88 (.047)	.91 (.050)	.90 (.037)	.88 (.037)	.80 (.042)	.82 (.045)

SA: Strongly-Associated Category Members; NA: Nonassociated Category Members; RVF/LH: Right Visual Field/Left Hemisphere Presentation; LVF/RH: Left Visual Field/Right Hemsiphere Presentation.

and SOA for reaction time. When handedness was divided into two groups, based on the self-reported handedness of the individual, there was no main effect of handedness, [$F(1, 83) < 1$, $p = .65$], however, there was a non-significant association between stated hand and visual field, [$F(1, 83) = 3.35$, $p = .071$], such that for self-reported right-handers, words presented to the RVF/LH were responded to faster [$M = 622.92$, $SE = 17.0$] than those presented to the LVF/RH [$M = 633.44$, $SE = 14.88$]; for self-reported left-handers, words presented to the LVF/RH were responded to faster [$M = 627.28$, $SE = 18.55$] than those presented to the RVF/LH [$M = 650.84$, $SE = 21.19$].

Discussion

The purpose of the present study was to examine the hemispheric differences in processing strongly-associated vs. nonassociated category members, examined across three handedness groups, in a visual half-field semantic priming paradigm with a lexical decision task. The hypothesis was that consistent right-handers would have a RVF/LH advantage for processing strongly-associated category members, regardless of the SOA, and a LVF/RH advantage for nonassociated category members at the 800 ms SOA. Consistent left-handers were expected to show the opposite effect, such that they would have a LVF/RH advantage for processing strongly-associated category members, regardless of the SOA, and a RVF/LH advantage for nonassociated category members at the 800 ms SOA. Inconsistent-handers were not expected to show an advantage in either hemisphere for the two types of category members, as previous research has demonstrated a more bilateral language representation in these individuals.

Although the expected four-way interaction (handedness by word association by visual field by SOA) was not found, some of the trends seen in the results lend support to findings from previous semantic priming research. In particular, the research on this subject has taken into account either manipulations of word association, visual field, or SOA; none of the known studies takes all three factors into account in one experiment. Therefore, although handedness did not play a significant role in the present study, the findings add to past research (which generally does not take handedness into account), by examining the effects of word association, visual field and SOA in a single design.

Previous studies on semantic priming have demonstrated that response time and accuracy of lexical decision tasks generally show an effect of word association between the prime and the target. In studies comparing strongly- and nonassociated category members (e.g., Chiarello et al., 1990), the strongly-associated pairs are responded to faster and more accurately than their nonassociated counterparts; this finding was demonstrated in the present study as well. Posner and Snyder's (1975a) theory of spreading activation can be used to explain the effect of word association, as it is based on the idea that words are connected to one another in a semantic network with linear, descriptive links. When a prime is activated, associated words will also be activated through those links. The theory of spreading activation relates priming to associations between words. Neely (1977) explained that the stronger the association between a prime and target, the more automatic the spread of activation, and therefore the shorter the response time.

There was an effect of SOA in the present study, such that targets presented at the 150 ms SOA were responded to faster and more accurately than those presented at the 800 ms SOA. Collins and Loftus (1975) suggested that the activation of primes decreases over time. Studies manipulating SOA have used a wide range of times considered to be *short*, *moderate*, or *long* SOAs; these labels are arbitrarily given to different times, based on an estimation of the different levels of priming activation. For example, Burgess and

Simpson (1988) used 35 ms as the *short* SOA and 750 ms as the *long;* whereas Neely (1977) manipulated SOAs ranging from 250 to 2000 ms. The present study used 150 and 800 ms as a measure of *short* and *long* SOA, respectively. The effect of SOA demonstrated in the present study suggests that somewhere between 150 and 800 ms after the prime is presented, activation begins to dissipate, and over time, there is less of an effect of association between the prime and target. As activation decreases, response times to the target words increase, and accuracy decreases.

When the reaction times of the low frequency unrelated word pairs were analyzed by SOA, there was no effect of SOA. Because these words were presented solely in a contralateral condition (i.e., the prime and target were presented to opposite hemispheres), there are differences in the way the brain processes these words, as compared to the category members, which were presented unilaterally (i.e., both the prime and target were presented to the same visual field/hemisphere). However, it is interesting to note that there is an effect of SOA for category members (regardless of the association between words), although there is no effect of SOA for unrelated words. Unrelated words are presumably uninfluenced by priming effects, as the spread of activation following the prime will not give an advantage to processing the target word. Therefore response times to the targets would not be influenced by the length of time between the prime and the presentation of the unrelated target.

An interaction was found between visual field and SOA in the present study for related prime-target pairs; the left hemisphere had an advantage for lexical decisions at the shorter SOA (i.e., 150 ms), and the right hemisphere had an advantage at the longer SOA (i.e., 800 ms). Despite the evidence that the left hemisphere is dominant for language processing in the majority of individuals, there is also evidence for the right hemisphere's involvement in language processes (e.g., Gazzaniga & Sperry, 1967). Chiarello and Richards (1992) explained that activation spreads in a much less constrained manner in the right hemisphere than it does in the left; therefore activation is maintained longer in the right hemisphere. Yochim et al. (2005) support this theory, by suggesting that although the left and right hemispheres have similar spreading activation, it occurs over different lengths of time. The interaction between visual field and SOA, in the present study is consistent with these findings.

Despite the prediction that there would be an interaction between word association, SOA, and visual field, this finding was not demonstrated in the present study. The most common studies of visual half-field semantic priming tasks looking at SOA, visual field, and/or word association are those conducted by Chiarello and her colleagues; however, the researchers have never taken all three factors into account. Chiarello et al. (1990) demonstrated an interaction between visual field and word association for words with three different types of associations. Chiarello and Richards (1992) also examined an association between visual field and word association, for strongly- and nonassociated category members. Chiarello et al. (1992) examined the association between visual field and word association for related and neutral word pairs. Chiarello et al. 2003 examined visual field by a range of SOAs, for strongly-associated category members only.

The studies conducted by Chiarello and her colleagues were all similar to the present study; however, the fact that the interaction with word association was not replicated, when all three factors were taken into account, suggests that there may be some fundamental differences between the designs. One of the greatest variations in the present study was the use of low frequency words. In the studies conducted by Chiarello and her colleagues, the frequencies ranged from 0.18 to 1429.09 words per million, with average frequencies ranging from 64.85 – 69.59 words per million. In the present study, however, the target words ranged in frequency from 0.19 to 10.67, with an average frequency of 4.79 words per million. The lack of interaction between word association, SOA, and visual field, in the present study, may be due to differences in the priming effects of low frequency words as opposed to high frequency words.

The Role of Handedness

In the original analyses conducted in the present study, handedness did not have an effect on the reaction time or accuracy of responses. Therefore, further analyses were conducted in which handedness classification was re-assessed to look for possible trends. Using the original classification (i.e., consistent right-, consistent left-, and inconsistent-handers), there was a trend in which consistent right-handers tended to have faster reaction times in the RVF/LH than in the LVF/RH, whereas consistent left-handers tended to have faster reaction times in the LVF/RH than in the RVF/LH, however these differences were not significant. This trend is consistent with previous research (Kaploun & Abeare, 2010) suggesting that consistent right-handers have left hemisphere dominance for language, whereas, consistent left-handers have the opposite hemispheric dominance, such that their right hemispheres tend to be dominant for language.

This research (Kaploun & Abeare, 2010) also suggested that inconsistent-handers do not have a dominant hemisphere; however, the present study was unable to replicate this pattern of results. In fact, a trend toward a right hemisphere advantage was demonstrated for inconsistent-handers, such that their response times were somewhat faster for the LVF/RH than the RVF/LH. This discrepancy may be due to a difference in the way the handedness groups were identified. As mentioned previously, Kaploun and Abeare (2010) divided individuals into three equal groups based on their MNI scores, whereas the present study used a median split of the MNI scores for the right- and left-handers to determine the handedness group cutoffs. The method used in the present study resulted in more self-reported left-handers having been placed in the inconsistent-handedness group than if the former method were used. With more self-reported left-handers in the inconsistent-handedness group, there might also have been a greater number of individuals with a tendency toward right-hemisphere dominance, thus resulting in the trend demonstrated in the present findings.

When handedness was re-classified, self-reported right-handers were initially considered separate from the left-handers, as is common for most research on semantic priming (Bourne, 2006). The results of this analysis demonstrated the same effects as those seen in the original analysis. This is a possible indication that different handedness classifications do not play a role in hemispheric dominance for language, or, at the very least, may not be related to semantic priming of category members.

However, when handedness was classified into one of two groups, based solely on the stated handedness of the individual, an association between visual field of word presentation and handedness was demonstrated. Right-handers tended to be faster at responding to words presented to the RVF/LH than the LVF/RH, and left-handers tended to show the opposite pattern of results (although there was no significant interaction). One could argue that rather than being an association between handedness and visual field, this may be the confounding effect of response hand and visual field of presentation, as individuals responded with their dominant hand (i.e., self-reported left-handers always responded with their left hands). To assess this possibility, future research should control for response hand. However, due to the extensive research suggesting a link between handedness and hemispheric dominance, it is likely that this trend (demonstrated both with right- vs. left-handers, as well as consistent right- vs. consistent left-handers) is evidence of the link between handedness and dominant visual field/hemisphere.

The fact that handedness was not a significant factor in the present study suggests that the classification methods for determining handedness may need to be reassessed. The importance of understanding language lateralization and hemispheric differences between individuals from different handedness groups has been demonstrated more frequently in recent research (e.g., Pujol et al., 1999; Knect et al., 2000, etc.). For example, it is important to consider the cerebral organization of individuals in different handedness groups when examining the effects of acquired brain injuries localized to one hemisphere. Therefore, despite inconsistent findings in the present study, further research should be conducted in order to determine whether or not there is an interaction between handedness and hemispheric dominance for semantic priming.

Methodological Considerations

Future research examining semantic priming in different handedness groups should take into consideration some of the methodological concerns that were encountered in the present study. One drawback in the design of the present study is that low frequency unrelated word pairs were not presented in a unilateral condition to either the LVF/RH or the RVF/LH. The current results cannot demonstrate true priming effects; without the ability to compare the response times of the unrelated word pairs to those of the matched category members, it is not possible to make determinations about the effects of *priming* in either hemisphere. Instead, inferences were made about the advantages or disadvantages of responding to word pairs, based on the degree of their association.

Another important consideration would be to ensure that there is a large sample size, as there are many factors involved in this type of study that will decrease sample size, and therefore reduce power in the analyses. For example, in the present study, after removing the results of those individuals who did not meet the inclusionary criteria of the study, dividing individuals into one of three handedness groups, and randomly assigning individuals to SOA conditions, the sample sizes for each condition were very small; for example, there were only eight (8) consistent left-handers in the 150 ms SOA condition.

Another reason for removing subjects from analyses was the exceptionally high overall error rates. Out of the original 198 individuals assessed, only 87 sets of data were valid. The study was initially set up such that target words were presented to individuals for 150 ms before disappearing, and individuals were asked to press either the “Y” or the “H” key to respond. While running the study, several errors were noted due to accidental key presses, causing the program to either freeze or record incorrect responses. Therefore, preliminary analyses were conducted on the data from the first 93 individuals. The results indicated that the average accuracy rate was 68%, and that 61 out of 93 individuals (65%) had accuracy rates less than or equal to 70%. The data from the original 93 participants was removed, and a few methodological changes were made in an attempt to decrease the error rates; the response keys were changed and the target word presentation was increased to 180 ms (as recommended by Bourne, 2006).

Following the methodological adjustments, further analyses demonstrated an improvement in accuracy; the average accuracy rate increased to 84%, therefore these individuals were the ones used in the final analysis (and the original 93 sets of data were discarded). Despite the increase in overall accuracy, 8% of the individuals included in the final analysis had accuracy rates less than 70%. This appears to be an especially high error rate, given the basic nature of the task.

The varying levels of reading ability in the present sample may be a possible explanation for the current findings, given that the participants in this study had an average score of only 27 out of 61 words correct on the North American Adult Reading Test (NAART; Blair & Spreen, 1989). The NAART involves reading a list of irregularly pronounced English words out loud, and therefore relies solely on semantic (as opposed to phonological/orthographical) processing to correctly identify the words. When the standard scoring procedure was used, 13 individuals out of the 94 assessed (14%) did not have at least a 6^{th} grade reading ability. A negative correlation was found between error rates and NAART scores for individuals in the present study [$r(92) = -.56$, $p = .000$]; as accuracy on the NAART decreased, error rates on the lexical decision task increased.

Conclusions

In this experiment, semantic priming in different cerebral hemispheres was examined in individuals divided into one of three handedness groups. The present study manipulated the degree of association between prime-target category members, the visual field/hemisphere of presentation, and the SOA. Prior to this study, no known research has taken all of these variables into account in one study of hemispheric lateralization of language.

Despite being unable to produce the expected interaction of all four variables, several findings were significant. An effect of word association was found, such that strongly-associated category members were responded to faster than nonassociated category members; an effect of SOA was found, such that words presented at the 150 ms SOA were responded to faster than words presented at the 800 ms SOA. There was also an interaction for visual field of presentation by SOA, such that at the shorter SOA, words were responded to faster when presented to the RVF/LH than the LVF/RH, and at the longer SOA, the effect was opposite.

Several trends were also demonstrated that were consistent with previous research of visual half-field semantic priming. For example, when handedness was split into two groups, based on stated handedness of the individual, a trend was demonstrated between visual field of presentation and handedness, such that right-handers tended to respond faster to words presented to the RVF/LH, and left-handers tended to show the opposite hemispheric advantage.

One cannot assume that there is no interaction between handedness, word association, visual field of presentation and SOA, based solely on the findings of the present study. Further research must be conducted such that the aforementioned methodological concerns are controlled for, by including unrelated word pairs to be compared to the strongly-associated and nonassociated category members. Both high and low frequency words could also be used to control for possible inflation of error rates. Response hand could be also be randomly assigned, to avoid confounding between the response hand and the related visual field/hemisphere of word presentation.

The goals of future research will be to: 1) attempt to replicate previous findings regarding strongly-associated category members with both high and low frequency words; and 2) attempt to answer the questions raised by the present study regarding nonassociated category members, using both high and low frequency words. Once these methodological concerns are controlled for, the picture should become clearer about how strongly- and nonassociated category members are processed in the dominant and nondominant hemispheres of individuals in different handedness groups.

References

Abernethy, M., & Coney, J. (1990). Semantic and phonemic priming in the cerebral hemispheres. *Neuropsychologia, 28*(9), 933-945.

Abernethy, M., & Coney, J. (1993). Associative priming in the hemispheres as a function of SOA. *Neuropsychologia, 31*(12), 1397-1409.

Abernethy, M., & Coney, J. (1996). Semantic category priming in the left cerebral hemisphere. *Neuropsychologia, 34*, 339-350.

Annett, M. (1998). Handedness and cerebral dominance: The right shift theory. *Journal of Neuropsychiatry 10*(4), 459-469.

Audet, C., Driessen, N., & Burgess, C. (1998). Evaluating semantic neighborhood effects in categorical and locative priming in the cerebral hemispheres. *Brain and Cognition, 37*, 67-69.

Beeman, M. J., & Chiarello, C. (1998). Complementary right- and left-hemisphere language comprehension. *Current Perspectives in Psychological Science, 7*(1), 2-8.

Blair, J. R., & Spreen, O. (1989). Predicting premorbid IQ: A review of the National Adult Reading Test. *The Clinical Neuropsychologist, 3*, 129-136.

Bourne, V. (2006). The divided visual field paradigm: Methodological considerations. *Laterality, 11*(4), 373-393.

Bryden, M. P. (1987). Handedness and cerebral organization: Data from clinical and Normal populations. In D. Ottoson (Ed.), *Duality and Unity of the Brain.* Houndmills, U.K.: Macmillan. 55-70.

Burgess, C., & Simpson, G. B. (1988). Cerebral hemispheric mechanisms in the retrieval of ambiguous word meanings, *Brain and Language, 33*(1), 86-103.

Chiarello, C., Burgess, C., Richards, L., & Pollock, A. (1990). Semantic and associative priming in the cerebral hemispheres: Some words do, some words don't… sometimes, some places. *Brain and Language, 38*(1), 75-104.

Chiarello, C., Liu, S., Shears, C., Quan, N., & Kacinik, N. (2003). Priming of strong semantic relations in the left and right visual fields: A time-course investigation. *Neuropsychologia, 41*(6), 721-732.

Chiarello, C., & Richards, L. (1992). Another look at categorical priming in the cerebral hemispheres. *Neuropsychologia, 30*(4), 381-392.

Chiarello, C., Richards, L., & Pollock, A. (1992). Semantic additivity and semantic inhibition: Dissociable processes in the cerebral hemispheres? *Brain and Language, 42*(1), 52-76.

Christman, S. D. (1995). Independence versus integration of right and left hemisphere processing: Effects of handedness. In F. L. Kitterle, (Ed.), *Hemispheric communication: Mechanisms and models* (pp. 231-253). Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Christman, S. D., Propper, R. E., & Brown, T. J. (2006). Increased interhemispheric interaction is associated with earlier offset of childhood amnesia. *Neuropsychology, 20*(3), 336-345.

Collins, M. (1999). Differences in semantic category priming in the left and right cerebral hemispheres under automatic and controlled processing conditions. *Neuropsychologia, 37*, 1071-1085.

Collins, M., & Loftus, E. (1975). A spreading-activation theory of semantic processing. *Psychological Review, 82*(6), 407-428.

Crovitz, H. F., & Zener, K. (1962). A group-test for assessing hand- and eye-dominance.

The American Journal of Psychology, 75(2), 271-276.

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

Faust, M., & Lavidor, M. (2003). Semantically convergent and semantically divergent priming in the cerebral hemispheres: Lexical decision and semantic judgment. *Cognitive Brain Research, 17*, 585-597.

Gazzaniga, M. S., & Sperry R. W. (1967). Language after section of the cerebral commissures. *Brain: A Journal of Neurology, 90*(1), 131-148.

Goodglass, H. & Quadfasel, F. A. (1954). Langauge laterality in left-handed aphasics. *Brain: A Journal of Neurology, 77*(4), 521-548.

Gonzalez, C. L. R., & Goodale, M. A. (2009). Hand preference for precision grasping predicts language lateralization. *Neuropsychologia, 47*, 3182-3189.

Hécaen, H., De Agnostini, M., & Monzon-Montes, A. (1981). Cerebral organization in left handers. *Brain and Language, 12,* 261-284.

Hunter, Z. R., & Brysbaert, M. (2008). Visual half-field experiments are a good measure of cerebral language dominance if used properly: Evidence from fMRI. *Neuropsychologia, 46*(1), 316-325.

Hutchinson, A., Whitman, R. D., Abeare, C., & Raiter, J. (2003). The unification of mind: Integration of hemispheric semantic processing. *Brain and Language, 87*, 361-368.

Kaploun, K. A., & Abeare, C. A. (2010). Degree vs. direction: A comparison of four handedness classification schemes through the investigation of lateralized semantic priming. *Laterality: Asymmetries in Body, Brain and Cognition, 15*(5), 481-500.

Kinoshita, S., & Mozer, M. C. (2006). How lexical decision is affected by recent experience: Symmetric versus asymmetric frequency-blocking effects. *Memory & Cognition, 34*(3), 726-742.

Knecht, S., Dräger, B., Deppe, B., Bobe, L., Lohmann, H., Flöel, A., Ringelstein, E.-B., & Henningsen, H. (2000). Handedness and hemispheric language dominance in healthy humans. *Brain, 123,* 2512-2518.

Koivisto, M. (1997). Time course of semantic activation in the cerebral hemispheres. *Neuropsychologia, 35*(4), 497-504.

Koivisto, M. (1998). Categorical priming in the cerebral hemispheres: Automatic in the left hemisphere, postlexical in the right hemisphere? *Neuropsychologia, 36*(7), 661-668.

Lindell, A. K., & Nicholls, M. E. R. (2003). Cortical representation of the fovea: Implications for visual half-field research. *Cortex Forum, 39*(1), 111-117.

McManus, I. C., Porac, C., Bryden, M. P., & Boucher, R. (1999). Eye-dominance, writing hand, and throwing hand. *Laterality, 4*(2), 173-192.

McRae, K., & Boisvert, S. (1998). Automatic semantic similarity priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24*(3), 558-572.

Neely, J. H. (1977). Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. *Journal of Experimental Psychology:General, 106*(3), 226-254.

Nelson, D. L., McEvoy, C. L., & Schreiber, T. A. (1998). The University of South Florida word association, rhyme, and word fragment norms. http://www.usf.edu/FreeAssociation/.

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

Paap, K. R.,McDonald, J. E., Schvaneveldt, R. W., Noel, R. W., & Coltheart, M. (1987). Frequency and pronounceability in visually presented naming and lexical decision tasks. *In Attention and Performance 12: The Psychology of Reading*. Hillsdale, N.J.: Lawrence Erlbaum Associates, Inc.

Perelle, I. B., & Ehrman, L. (2005). On the other hand. *Behavior Genetics, 35*(3), 343-350.

Peters, M., & Murphy, K. (1992). Cluster analysis reveals at least three, and possibly five distinct handedness groups. *Neuropsychologia, 30*(4), 373-380.

Plaut, D. C. (1997). Structure and function in the lexical system: Insights from distributed models of word reading and lexical decision. *Language and Cognitive Processes, 12*(5/6), 1-19.

Posner, M. I., & Snyder, C. R. R. (1975a). Attention and cognitive control. In R. L. Solso, (Ed.), *Information Processing and Cognition: The Loyola Symposium*. Hillsdale, N. J.: Erlbaum.

Propper, R. E., & Christman, S. D. (2004). Mixed- versus strong right-handedness is associated with biases towards “remember” versus “know” judgements in recognition memory: Role of interhemispheric interaction. *Memory, 12*(6), 707-714.

Pujol, J., Deus, J., Losilla, J. M., & Capdevila, A. (1999). Cerebral lateralization of language in normal left-handed people studied by functional MRI. *Neurology, 52*, 1038-1043.

Rasmussen, T., & Milner, B. (1977). The role of early left-brain injury in determining lateralization of cerebral speech functions, *Annals of the New York Academy of\ Sciences, 299,* 355-369.

Steenhuis, R. E., & Bryden, M. P. (1989). Different dimensions of hand preference that relate to skilled and unskilled activities. *Cortex, 25*, 289-304.

Yochim, B., Kender, R., Abeare, C., Gustafson, A., & Whitman, R. D. (2005). Semantic activation within and across the cerebral hemispheres: What's left isn't right. *Laterality:Asymmetries of Body, Brain, and Cognition, 10*(2), 131-148.

van Ettinger-Veenstra, H. M., Ragnehed, M., Hällgren, M., Karlsson, T., Landtblom, A. M., Lundberg, P., & Engström, M. (2010). Right-hemispheric brain activation correlates to language performance. *Neuroimage, 49,* 3481-3488.

Vita Auctoris

Andrea M. Coppens was born in Hamilton, Ontario, in 1985. She moved to Windsor in 1997, and subsequently graduated from St. Thomas of Villanova Secondary School in 2003. From there she went on to obtain a B.Sc. Honours degree in Psychology from the University of Western Ontario in 2007. She plans to graduate with an M.A. in Clinical Neuropsychology in October 2010.