DISSERTATION

EXTENDING LOCAL-GLOBAL PROCESSING TO THE SEMANTIC DOMAIN: THE ROLE OF STIMULUS CONTEXT

Submitted by

Gwen L. Schmidt

Department of Psychology

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Colorado State University

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ProQuest Information and Learning Company
300 North Zeeb Road
P.O. Box 1346
Ann Arbor, MI 48106-1346

COLORADO STATE UNIVERSITY

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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY GWENDOLYN L. SCHMIDT ENTITLED EXTENDING LOCAL-GLOBAL PROCESSING TO THE SEMANTIC DOMAIN: THE ROLE OF STIMULUS CONTEXT BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

Committee on Graduate Work

Patricia Davies

Patricia Davies

Janice Nerger

Janice Nerger

Benjamin Clegg

Benjamin Clegg

Advisor – Carol Seger

Department Head/Director

ABSTRACT OF DISSERTATION

EXTENDING LOCAL-GLOBAL PROCESSING TO THE SEMANTIC DOMAIN: THE ROLE OF STIMULUS CONTEXT

The current set of experiments tested the view that there are mechanisms common to visual and semantic processing, and they relate to general properties of the right and left hemispheres. Two properties of local-global visual processing were tested with semantic stimuli to determine if the properties apply to both the visual and semantic domains.

In Part 1 the property explored was that the visual local-global distinction between the left and right hemispheres is relative rather than absolute, based on the properties of the stimulus set (Robertson & Ivry, 2000). A divided visual field technique was used with sentence stems centrally presented and sentence endings laterally presented for initial processing in the contralateral hemisphere, allowing for examination of lateralized timing differences in processing. Unlike medium spatial frequency local-global visual stimuli, metaphors of medium familiarity did not show different patterns of lateralization depending on whether they were processed in the context of high versus low familiarity metaphors. Results indicated, however, that it is necessary to have a broad range of familiarity in a stimulus set in order to obtain a right hemisphere advantage for low familiar metaphors.

In Part 2, the property explored was that priming occurs based on the level of processing, local or global (the level repetition effect; Robertson, 1996). Metaphorical sentences and priming word pairs were presented centrally for ease of understanding or relatedness judgments, respectively. It was hypothesized that reaction time priming would occur based on the familiarity or association level of the preceding trial, as with visual stimuli. A strong effect of preceding trial was obtained, but it was based on following a high association trial, rather than following a trial at the same level of association, as is the case for visual stimuli. For the sentential stimuli, a delayed level repetition effect was obtained, showing faster processing of metaphors low in familiarity following several sequential low familiar trials.

Generally speaking, these experiments demonstrate that the processing of semantic stimuli is affected by the surrounding stimulus context; specifically levels of familiarity in the surrounding stimuli, in both the overall stimulus set, and the immediately preceding trials.

Gwen L. Schmidt
Department of Psychology
Colorado State University
Fort Collins, CO 80523
Summer 2006

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CHAPTER 1: INTRODUCTION

The goal of the work presented here is to explore parallels between cognitive and neural mechanisms of semantic processing and those found in the vision and audition literature. Several parallels have been identified among these domains. The coarse semantic coding model (Beeman, 1998) suggests that the left hemisphere activates and processes words that are closely related to each other (fine semantic coding) whereas the right hemisphere is involved in the processing of words distantly related (coarse semantic coding). A similar distinction between the left and right hemispheres has been noted with respect to spatial and auditory processing: the left hemisphere of the brain is involved in fine tuned, local processing (i.e. high spatial or auditory frequency), and the right hemisphere is involved in broad, global processing (i.e. low frequency) (Sergent, 1982; Ivry & Lebby, 1993; Ivry & Robertson, 1998). The aim of this project is to determine whether specific properties of local-global processing (Robertson, 1996; Robertson & Ivry, 2000) also apply to semantic processing or whether fundamentally different processes underlie semantic processing. If the local-global properties can be extended to the semantic domain, this would unify our understanding of hemispheric differences in function and cognitive processes, establishing that local-global elements of visual, auditory, and semantic processing are related to more general properties of the left and right hemispheres and of cognitive functioning. If these properties do not extend to the semantic domain, this suggests that semantic processing can best be explained by mechanisms specific to the language domain.

The properties of visual and auditory processing that will be compared to semantic processing both involve what will be called *stimulus context* in the work presented here. This term is used to distinguish the concept of context in the current work from context in its usual sense with semantic processing, the role of the meanings of surrounding words to comprehension and other processes. It encompasses two aspects of cognitive processing. The first is that which is normally thought of in terms of priming. What influence does an immediately preceding trial have on the processing of the current trial? The preceding trial could be thought of as a stimulus context, as various aspects of this trial might influence processing of the current trial. The second aspect of cognitive processing has to do with properties of a stimulus set that might influence processing of individual trials in that set. For example, with a stimulus set that is quite difficult to process, an easier trial might be processed at a different speed than it would in a stimulus set composed of all easy trials.

The role of stimulus context in semantic processing will be explored via two interesting properties of local-global processing. The first is that the local-global distinction between the left and right hemispheres is relative rather than absolute, i.e. based on the properties of the stimulus set (Robertson & Ivry, 2000). This property allows for the exploration of stimulus set context effects. The second is that priming occurs based on the level of processing (local or global) (Robertson, 1996). In other words, the immediately preceding stimulus context influences current processing.

Significance of the Project

By examining properties of semantic processing that can be connected to mechanisms in other modalities such as visual and auditory processing, the work presented here fills an important gap in our understanding of lateralized brain processing asymmetries. By extending mechanisms and theories from the visual and auditory domain to the semantic domain, it is possible to come to a better understanding of both general features of lateralized brain functioning as well as features of semantic processing in the two hemispheres. From a clinical standpoint, studying semantic processing and its underlying mechanisms is important, since semantic processing is compromised in prominent disorders such as Alzheimer's disease (Kim & Thompson, 2003; Tippett, Gendall, Farah, & Thompson-Schill, 2004) and schizophrenia (Goldberg et al., 1998; Elvevag et al., 2002). Furthermore, other disorders, such as autism spectrum disorders (MacKay & Shaw, 2004) and right hemisphere brain damage (Winner & Gardner, 1977) are associated with specific problems with metaphors and figurative language.

Right Hemisphere and Semantic Processing

Although language is principally lateralized to the left hemisphere, the right hemisphere has also been shown to be involved in diverse aspects of human language processing, including interpretation of ambiguity (Burgess & Simpson, 1988; Titone, 1998), humor (Brownell, Michel, Powelson, & Gardner, 1983; Coulson & Williams, 2005), indirect requests (Weylman, Brownell, Roman, & Gardner, 1989) and figurative language (Winner & Gardner, 1977; Brownell, Simpson, Bihrle, Potter, & Gardner, 1990). Metaphor is one specific type of figurative (nonliteral) language thought to involve the right hemisphere. A metaphor is both a linguistic and literary device as well as a form of symbolization, which, in either conceptualization, permits the efficient expression of ideas that would otherwise be awkward to explain (Glucksberg, 2001). For example to say *My job is a jail* is very efficient and conveys broad information about the *job* in question. To use only literal language would require a longer explanation.

Linguistic situations involving the right hemisphere (ambiguity, humor, indirect requests, figurative language, etc.) have in common the presence of more than one possible meaning. An explanation of the role of the right hemisphere in such linguistic situations has been provided by suggesting that the right and left hemispheres differentially process semantic information (e.g. Beeman's 1998 coarse coding model; Chiarello, 1998; see also Swinney et al., 2000). In a particular linguistic context, a word or phrase has many semantic features (definitive properties and associative information), some of which are more relevant in that context than others. According to these models, in the left hemisphere, semantic activation is selective, only activating very closely related semantic features, but doing so strongly, resulting in fine semantic coding within a small semantic field. The right hemisphere, on the other hand, weakly activates a broader set of semantic features to create coarse semantic coding within a larger, but less strong semantic field. Thus both the left hemisphere and right hemisphere engage in semantic processing, but they do so differently, according to these models.

Right hemisphere processing of unusual or unfamiliar word combinations has been supported by studies using a divided visual field method (Schmidt, DeBuse, & Seger, in press; Faust & Lavidor, 2003), event-related potentials (Abdullaev & Posner, 1997), and functional magnetic resonance imaging (fMRI) (Seger, Desmond, Glover, & Gabrieli, 2000). In a dual meaning situation, it is advantageous to activate and explore a broader range of semantic features in order to correctly assign meaning, which leads to recruitment of right hemisphere semantic processing.

A metaphor is likely to contain unusual or unfamiliar word combinations; also the metaphorical meaning of a word is usually more distantly related to other words in a sentence than its literal meaning. For example in the sentence *The camel is a desert taxi*, *taxi* is used in a metaphorical sense, and *camel* and *taxi* are not close semantic associates. On the other hand, literal language is more likely to contain ideas that are closely related semantically. For example in *The camel is a desert animal*, *camel* and *animal* are close semantic associates. Thus a right hemisphere involvement in metaphor processing can be predicted by the coarse coding model (Beeman, 1998), whereas literal sentences are more likely to predominantly recruit the left hemisphere. Figure 1 depicts a selective right hemisphere processing time advantage for metaphors based on work in our laboratory (Schmidt et al., in press; see also Bottini et al., 1994; Anaki, Faust, & Kravetz, 1998; Mashal, Faust & Hendler, 2005).

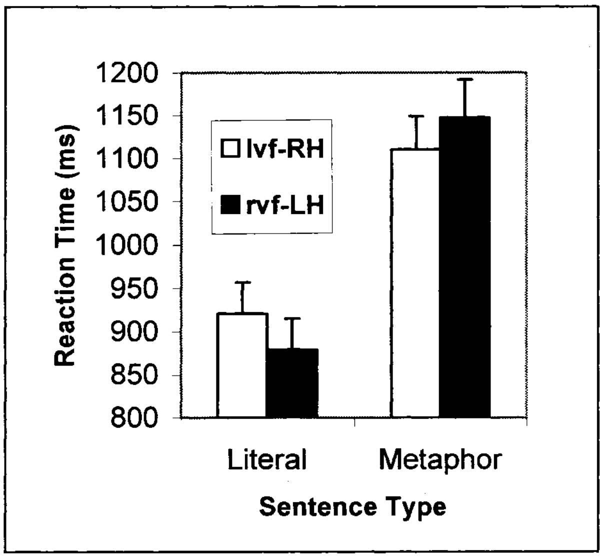

Figure 1: **Processing times for literal and metaphorical sentences in the cerebral hemispheres from Schmidt et al. (in press). Error bars reflect standard errors.**

Although the coarse coding model presented above, or variants of it, is the most widely cited, there are other theories which also attempt to elucidate the differences between left and right hemisphere processing and how they can explain the role of the right hemisphere in understanding humor, metaphor, indirect requests, etc. One complementary view of hemispheric asymmetries in semantic processing has to do with processing speed. According to this view, the left hemisphere not only strongly activates a small semantic field, but also does so quickly, and the activations decay more quickly. The right hemisphere, on the other hand, activates a larger semantic field which stays active longer, i.e. decays more slowly (Burgess & Simpson, 1988).

The graded salience hypothesis (Giora, 1997, 1999, 2003) is another related, but distinct theory that encompasses lateralized semantic processing differences. This hypothesis also characterizes the difference between right and left hemisphere semantic processing without referring to a literal– metaphor distinction. Earlier theories suggested that when processing any language, the literal meaning is activated first, and only if it is unsuccessful in providing meaning are metaphorical meanings considered (Grice, 1975). In contrast, the graded salience hypothesis asserts that it is the degree of salience rather than the degree of figurativeness that determines sentence-processing characteristics. The salient meanings of an utterance are determined by various factors such as how familiar or frequent a particular meaning is or which meaning is conventional. When processing linguistic stimuli with several salient meanings, all of them will be activated initially before one is selected as the correct meaning. Thus, when an utterance has both literal and metaphorical meanings that are salient, both are initially activated. When an utterance has only one salient meaning (whether literal or metaphorical), only that meaning will be accessed initially. This view has been extended by suggesting that only a few salient meanings are activated in the left hemisphere, but many nonsalient meanings are activated in the right hemisphere (Giora, 1997, 1999, 2003). This again implies that the right hemisphere tends to be more likely to be involved in the processing of metaphors, inferences, and so on, when these consist of less salient meanings of utterances.

Coulson and Williams (2005) suggest an attentional bias between the hemispheres, such that hemispheric differences in semantic representation might be related to differences in attention between the hemispheres. This is related to a similar bias reported in the visual processing literature: the right hemisphere shows superior ability to pay attention to the global aspects of stimuli (the big picture), while the left hemisphere is better at paying attention to local aspects of stimuli (the object features). They suggest that an attentional bias could influence the way information is encoded into memory, and thus how it is subsequently retrieved while inferences are being drawn during sentence comprehension. These inferences could include those drawn during joke and metaphor comprehension, as well as understanding of indirect requests.

Another proposed difference between the left and right hemispheres in terms of semantic processing was proposed by Federmeier and Kutas (1999) who suggest that the hemispheres use different strategies in processing contextual semantic information. Their electrophysiological studies suggest that the left hemisphere uses a predictive strategies for semantic activation, by activating semantic features associated with the current word being processed that are most likely to be needed down the line. The right hemisphere, on the other hand, uses an integrative strategy, whereby it compares semantic features of the current word and other words in the sentence. Coulson and Williams (2005) suggest that jokes require a more integrative strategy for comprehension, rather than a predictive strategy, explaining the facility of the right hemisphere in joke comprehension. The same explanation could be applied to metaphors and other types of language that show efficient right hemisphere processing. A predictive strategy would not work well for a metaphor, particularly an unfamiliar metaphor, since the ending of the metaphor is usually not very predictable, as in *That afternoon, the mood was vinegar*. However, an integrative strategy would be helpful, since it would allow for the semantic integration of the topic (*mood*) and vehicle (*vinegar*) of the metaphor. Thus this explanation would predict a right hemisphere advantage for metaphors, although it has not been tested with metaphors.

The semantic activation models described above suggest that bottom–up processes are important for metaphor comprehension. One possible scenario is that when processing a metaphor, such as *A camel is a desert taxi*, a wide range of meanings of the vehicle (*taxi*) are activated and maintained in the right hemisphere. This allows for the meaning of the entire sentence to emerge, as the relatively small semantic field connected with the topic (*camel*) in the left hemisphere and the larger semantic field of the vehicle in the right hemisphere are integrated and the meaning of the sentence is constructed (Coulson & Van Petten, 2002).

Two common models characterize metaphor comprehension as involving either analogical processes (*my job* shares certain properties with *a jail*; Gentner & Bowdle, 2001b), or class-inclusion processes (*my job* and *a jail* belong to a class of things that share certain properties; Glucksberg, 2001), in which the semantic relationship between the topic (*my job*) and vehicle (*a jail*) of the metaphor must be determined for metaphor comprehension to take place. These are both top–down processes, which provide an explanation for the meaning integration process. That the right hemisphere may be involved in these top–down processes is consistent with other views of right hemisphere processing which suggest it is involved in more holistic or pragmatic aspects of language (Burgess & Chiarello, 1996; Sabbagh, 1999; Kacinik & Chiarello, in press). It is not clear whether the right hemisphere is only involved in maintaining the active semantic field, or whether it is also involved in the subsequent integration that must take place for the full meaning of the sentence to emerge. For further discussion of top–down and bottom–up processes in metaphor comprehension, see Kacinik & Chiarello (in press).

Metaphor Familiarity

Much of the work on metaphor and the right hemisphere has tended to examine relatively familiar or conventional metaphors (e.g., Winner & Gardner, 1977; Brownell, Potter, & Michelow, 1984; Brownell et al., 1990; Tompkins, 1990). Despite this focus on familiar metaphors in the literature, metaphors can vary widely in familiarity. Some words are often used metaphorically, as *gold* in *His ideas were all gold.* Other words (or phrases) may be used in a metaphoric sense never (or rarely) heard before by the listener, as *bag of toffees* in *The close friends were a bag of toffees.* The coarse coding model (Beeman, 1998) entails that metaphoric meanings within familiar metaphors can, through repetition, become closely associated and thus be activated within a small semantic field in the left hemisphere. Thus, it is important to distinguish between more familiar and less familiar semantic relationships according to the coarse coding model. This view is supported by the results of a study of patients with brain damage which indicates that the right hemisphere could be involved in the processing of less familiar meanings of words

(Burgess & Cushman, 1990 cited in Beeman, 1998). Patients with left hemisphere damage showed an advantage for processing the less frequent meanings of target words whereas patients with right hemisphere damage tended to respond more slowly to the less frequent meanings. This suggests that the right hemisphere is more proficient at processing the less frequent meanings of words while the left hemisphere may process more frequent or salient meanings. This provides further evidence for the coarse coding model which suggests that it is closely related meanings that are processed in left hemisphere while more distant relationships are processed in the right hemisphere. It seems intuitive to suggest that less frequent meanings of words would be less closely related to one another. Thus, while sentence familiarly and semantic relatedness are not exactly the same thing, the former provides a good index of the latter (Schmidt et al., in press). In the experiments reported here, metaphor familiarity was used as an index of semantic relatedness.

The Link to Perceptual Processing: Local versus Global

The variation between left and right hemisphere semantic processing could be considered analogous to the local-global distinction seen in the vision and audition literature. Sergent (1982) reported a left hemisphere specialization for processing "local" visual information, and a right hemisphere specialization for "global" information. She tested left and right visual fields with hierarchical letters consisting of large letters made up of smaller letters, called Navon figures (see Figure 2). The large letters are considered low spatial frequency, while the small ones are high frequency (Shulman et al., 1986; Shulman & Wilson, 1987; but for alternate explanations of left-right processing asymmetries see Kosslyn, et al., 1992; Kosslyn, et al., 1994; Roth & Hellige, 1998;

Laeng, et al., 2003). Sergent found that the left hemisphere was faster at processing information with a high spatial frequency and the right hemisphere faster with low spatial frequency stimuli. This finding was corroborated by work with patients with brain damage. Patients with left hemisphere damage have more trouble remembering and reproducing the details of a hierarchical stimulus whereas patients with right hemisphere brain damage have trouble with the overall configuration (Delis et al., 1986). These findings are similar to the semantic model discussed earlier, based on a right hemisphere superior ability to pay attention to the global aspects of linguistic stimuli, and a left hemisphere superior ability to pay attention to local aspects of linguistic stimuli (Coulson & Williams, 2005).

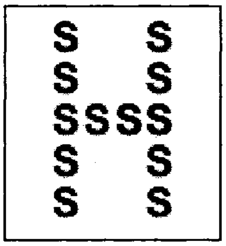

Figure 2: **Hierarchical stimulus. Adapted from Sergent, 1982.**

While the local-global lateralized differences have been well documented in the vision literature, there is also some indication that these differences may also extend to auditory stimuli. For example, a right hemisphere specialization for processing low frequency information has also been obtained with auditory stimuli. Ivry and Lebby (1993) found a right ear (left hemisphere) advantage for discriminating relatively higher frequency tones and a left ear (right hemisphere) advantage for discriminating relatively lower frequency tones. Similarly, in the temporal domain, it has been suggested that the left hemisphere is specialized for processing information that changes over high temporal frequencies; the right hemisphere, over low temporal frequencies. This view is based on lesions studies with left- and right- hemisphere damaged patients (Tallal, Miller & Fitch, 1993). Difficulties with interpreting the effects of prosody (intonation patterns) in right hemisphere damaged patients has also been attributed to the low frequency information inherent in prosody, processed most efficiently by the right hemisphere, and it is speculated that certain aspects of consonant perception recruit the right hemisphere due to their reliance on low frequencies (Ivry & Lebby, 1998). Similarly, Poeppel (2003) proposes a model of speech perception that incorporates lateralized differences in processing the temporal and frequency aspects of speech.

Researchers have speculated about the possibility that the local-global elements of visual and auditory processing are related to coarse and fine semantic processing, and by extension to more general properties of the left and right hemispheres. Beeman et al. (1994) suggest that since it appears that the hemispheres do not divide the task of processing based on modality, that perhaps the important division of labor between the hemispheres is based on mode of processing. He discusses this in terms of both spatial frequency differences (high spatial frequencies being processed more efficiently in the left hemisphere, and low spatial frequencies being processed more efficiently in the right hemisphere), and the larger receptive field sizes thought to characterize the right hemisphere and result in coarser visual coding (Kosslyn et al., 1989). Beeman et al. do not explain how larger receptive field sizes would result in coarser semantic processing, but a connection between visual and semantic coarse coding, and their connection to the right hemisphere, is implicit in his discussion. Robertson and Ivry (2000), in their review of their double filtering by frequency theory of visual and auditory processing, mention the existence of lateralized differences in semantic representations. They suggest that further work is needed to determine if there is a causal link between these patterns, or if the apparent parallels are simply due to inadvertent use of descriptive terms like coarse coding in both visual and semantic domains. Thus one of the main aims of this work is to explore a possible link between patterns found in visual and auditory processing on one hand, and semantic processing on the other hand.

Although it is possible that such widely disparate modes of processing simply do not have any neural processing mechanisms in common, theories in other areas of inquiry have also linked language and visual tasks under a central processing mechanism. For example, the autism literature links language and visual tasks that incorporate local-global elements by a proposed common mechanism, central coherence (Frith, 2003). In this view, people with autism spectrum disorders show a facility at processing at the local level rather than at the global level, a pattern of processing called weak central coherence. This pattern is suggested to cut across modalities, with relevant findings with both visual tasks such as block design and semantic tasks such as using context to determine the pronunciation of homographs. This could again relate to hemispheric differences, since local processing is thought to characterize the strengths of the left hemispheres; and global processing, the right hemisphere.

Beeman (1998) suggests that there are more functional connections in the right hemisphere than the left hemisphere, supporting the idea that left and right hemisphere processing are qualitatively different. He cites various neuroanatomical and neurophysiological studies supporting this notion. Gur et al. (1980) used a xenon inhalation method to examine the ratio of white matter to gray matter in the cerebral hemispheres. Participants inhaled xenon-133, and then perfusion of xenon from the brain was measured with sodium iodide crystal detectors placed on left and right homologues on the scalp. Since the perfusion rate of grey matter is about four times that of white matter, ratios can be calculated. Results indicated a higher ratio of white matter to gray matter in the right hemisphere than the left hemisphere, for eight areas distributed over the frontal, parietal, and temporal lobes. Two areas were exceptions: the posterior middle temporal area and a central parietal area. These investigators concluded that there was an overall larger ratio of grey to white matter in the left hemisphere and the converse in the right hemisphere. Since grey matter is composed of primarily of cell soma (and small amounts of unmyelinated axons), while white matter consists mainly of myelinated axons, more white matters suggests the existence of more functional connections in the right hemisphere. If this is so, it implies a fundamentally different processing style in the right hemisphere, which could account for many of the proficiencies attributed to it. For example, the right hemisphere proficiency in attending to the global aspect of visual stimuli would, arguably, require broader and more connections in order to put the "big picture" together. Similarly, having coarser or broader semantic connections might also require more functional connections in order to connect words or concepts that are less closely related.

A number of studies report on quantitative dendritic analyses of language areas and their right homologues. Scheibel et al. (1985) report (based on six right handed participants) that overall basilar dendritic length did not vary in the opercular area between left and right hemispheres. However, on the left, there were more higher-order (4, 5, and 6) dendrite branches, while on the right, there were more lower-order (1, 2, and 3) dendrite branches. Coulson and Williams (2005) interpret this finding as indicating that the right hemisphere has more dendritic branching in this area. Examination of brain tissue from 20 neurologically normal dextrals revealed that the left hemisphere had slightly higher scores for total dendritic length, mean dendritic length, and number of dendritic segments, although this asymmetry was not present in all participants (Jacobs, Schall, & Scheibel, 1993). On an individual participant whose language areas had been mapped via cortical stimulation mapping, there were more dendritic spines on right hemisphere neurons in classic language areas than there were in the same areas on the left; the opposite pattern was found in motor areas (Jacobs, Batal, Lynch, Ojemann, Ojemann, & Scheibel, 1993). This is consistent with other work which suggests that the language areas of the right and left hemispheres differ in terms of density of interneurons (Hustler & Gazzaniga, 1995).

These dendritic differences between the hemispheres extend the finding of greater white to grey matter ratios in the right hemispheres, since they imply a denser, more complex and extensive pattern of connectivity in the right hemisphere. A richer network of neural connections may facilitate the processing of the global features of a visual stimulus, since it would allow the integration of the local features into a coherent whole. The same thing could be said of coarse semantic processing, which would also require richer interconnections between concepts that are not closely related.

Semmes (1968) reported an unexpected finding with a large number of war veterans who had lateralized brain lesions, suggesting that damage to the right hemisphere produces more diffuse impairments. She found that sensory deficits in the right hand were directly related to lesions in the left sensory-motor areas, but sensorimotor deficits in the left hand were not as clearly related to lesions in the right sensory-motor areas. This finding extended to ipsilateral sensory functions, such that it was concluded that there was a lesser degree of concentration of sensory mechanisms in the right hemisphere than in the left hemisphere. Semmes suggested that this finding represents a general organizing principle of hemispheric differences, which could explain why the left hemisphere was more proficient at fine sensorimotor control (including speech) and predict that the right hemisphere would be better at tasks which require the integration of diverse elements, such as spatial tasks. This again has an obvious extension to the theory of coarse semantic coding. If the right hemisphere is organized in a more diffuse way, this could be why semantic information is maintained more coarsely there. Diffuse semantic representations would allow for less closely related words to be connected in the semantic system, in the same way that diffuse visual elements could be combined in perceiving the global aspects of a visual stimulus.

Consistent with these findings are the results from a study of somatosensory evoked potentials (Trotman & Hammond, 1989). Participants experienced mild taps on their index finger, and electrophysiological recordings were made from the posterior half of the contralateral hemisphere in a 10-20 system (Jasper, 1958). Two complexes (pairs of peaks), the N23-P29 complex and the N32-P42 complex, showed wider scalp distribution over the right hemisphere than the left hemisphere in normal participants. This finding of more diffuse evoked potentials in the right hemisphere is again consistent with the idea of a pattern of more diffuse representations in the right hemisphere than the left hemisphere. If this finding represents a general feature of the right hemisphere, it could be extended to semantic processing, and a more "diffuse," or coarse semantic system, as well as to global, low frequency visual and auditory processing.

Another piece of supportive evidence for this view of the right hemispheres comes from a power spectral analysis of electroencephalography (EEG) frequencies. EEG data were collected from 14 right handed men weekly over a period of several months. Coherence was measured between eight scalp locations (four lobes, two sides each) for five frequency bands (delta, theta, alpha, beta 1 and beta 2). Both inter-hemisphere and intra-hemisphere coherences were measured, with the finding that there was a greater EEG intra-hemisphere coherence over the right hemisphere than the left hemisphere (Tucker et al., 1986). This is again consistent with the idea that there is greater functional connectivity within the right hemisphere than the left hemisphere.

Converging evidence has now been presented regarding qualitative differences in left and right hemisphere processing, which points to an increase in connectivity in the right hemisphere which is broader and more diffuse, and more interconnected. These qualities of the right hemisphere are general, and thus could potentially be used to explain the right hemisphere's relative proficiency with global (low frequency) visual processing, low frequency auditory processing and coarse semantic processing. While some work has been done to find links between local and global aspects of visual and auditory processing, this extension has not yet been make to semantic processing. Thus one main purpose of the work presented here is explore possible associations between the local-global aspects of visual processing and the coarse and fine aspects of semantic processing, as they related to patterns found in lateralization of function. One way this can be done is by exploring whether properties of local-global visual processing also apply to semantic processing. One of these hypothesized properties is that the high – low frequency processing distinction between the left and right hemispheres is not absolute, but relative to the stimulus context, i.e., the stimulus set used. Part 1 explores whether this property also holds for semantic stimuli.

The properties of visual and auditory processing that could be extended to semantic processing discussed so far all involve lateralized differences in processing. However, if there really is a link between these disparate types of processing, there is no reason why they must only be linked in terms of brain lateralization. Attempts have been made to link non-lateralized properties of local-global processing in the vision literature to auditory processing, focusing on features that are not necessarily lateralized. The local-global vision literature suggests that the level of processing (local or global) is primed and thus facilitated when the previous trial is at the same level, termed the level repetition effect (Robertson, 1996). This pattern was explored by manipulation of two features of auditory stimuli: a frequency manipulation (high and low) and a temporal manipulation (fast and slow) using musical stimuli (Justus & List, 2004). The stimuli and task were designed to parallel the earlier local-global vision work with Navon figures (Sergent, 1982). Both features, frequency and time, showed evidence of a priming effect such that stimuli processed at the same level (of frequency or time) as the preceding trial were faster than those following a trial at a different level. It is the aim of Experiments 3 and 4 to take the hypothesized link from visual local-global processing characteristics, which has been extended to auditory processing, and extend it further to semantic processing.

Stimuli Selection

In the experiments in Part 1, stimuli are sentential metaphors, while in Part 2 they consist of sentential metaphors in Experiment 3 and prime-target word pairs in Experiment 4. Much previous work exploring the role of the right hemisphere in processing metaphors, both lesion studies (Brownell et al., 1990; see also Brownell et al., 1984; Tompkins, 1990) and divided visual field experiments (Anaki et al., 1998; Kacinik & Chiarello, in press) have focused on the processing of metaphorical relationships between single words. There has been very little examination of the role of the right hemisphere in processing sentential metaphors. There are, however, a number of reasons to examine metaphors in a natural sentence context. Processing a metaphorical semantic relationship in a sentence allows the listener to use context in the processing and understanding of the utterance and the relationships between the words. The right hemisphere is more sensitive than the left hemisphere to sentence contexts, especially those that emphasize peripheral semantic features. For example, Titone (1998) used a context-creating sentence to prime subordinate meanings of ambiguous words. In one condition, the priming sentence focused on a central semantic feature of the ambiguous word (*Showing her to be the legal owner, everyone remembered the* deed); in another condition, the priming sentence focused on a peripheral semantic feature of the ambiguous word (*Being printed on gold leaf, everyone remembered the* deed). She found that the right hemisphere was particularly sensitive to the peripheral semantic features (but see Faust, Kravetz, & Netzer, 2002 for an alternate view). Thus it is also important to study the role of the right hemisphere in metaphor processing with sentence level stimuli that provide a context, rather than word level stimuli, which do not provide a context. Furthermore, the processing of sentential metaphors is of interest since they are more similar to the natural language typically encountered by language users than word pairs. Most importantly, extending the field of inquiry to the sentence level allows us to investigate the processing of a range of metaphor familiarity, including unfamiliar metaphors, while investigations of word-level metaphor must use relatively familiar metaphors. This is because without a sentence, there is no context for meaning to be derived from, so word-level studies are limited to familiar metaphorical relationships that can be grasped without a context.

Based on previous findings of the author (Schmidt et al., in press), the right hemisphere is recruited by any course semantic relationship, or unfamiliar sentence, even those that are not metaphorical. Metaphorical, rather than literal sentences with coarse semantic relationships, were used in the current experiments, not for any profound theoretical reasons, but simply because metaphorical stimuli with the necessary characteristics had already been developed. Word pairs were used in the final experiment as a means of generalizing the findings with sentences. It was not possible to extend the experiments in Part 1 to word pairs, due to the difficulty of obtaining lateralized differences in priming with word pairs.

Method and Task Selection

All the tasks used in the experiments reported here used various lexical-semantic priming methods. Lexical-semantic priming traditionally has been used to examine two facets of semantic representation, that is, how existing semantic memory is accessed and how it is organized. The hypothesized existence of automatic spreading activation (Collins & Loftus, 1975) contributes to both of these questions. A typical paradigm involves the presentation of a prime word, and then very shortly after, the target; the participant must either decide if it is a word or not (lexical decision) or pronounce it (naming). When the prime and target are semantically related in some way, the response latencies and accuracy ratings are higher. By varying the nature of the relationship between the target and prime, it is possible to learn about how semantic information is stored and accessed. For example, much work has been done investigating whether knowledge structures are organized semantically/categorically (i.e., by shared semantic features: dog-goat) or associatively (cradle-baby), and dissociations between the two types of relationships have been found. (Hines et al., 1986; Chiarello et al., 1990; Beeman, 1998; Chiarello, 1998; Beeman, 1998). It is possible to examine the time course of meaning activation and lexical access even as a single word is being produced. More automatic, bottom-up meaning activation processes can be studied by using a low proportion of related primes and a short stimulus onset asynchrony (35-250 ms); more strategic, top-down processes are investigated by using a high proportion of related primes and a longer stimulus onset asynchrony (more than 500 ms).

Sentences are also used as primes, allowing examination of the role of sentential context in lexical activation. The paradigm is very similar to that of word pairs, with the same tasks and dependent measures, with the exception that the prime is a sentence or sentence stem (i.e. without the final word, which is the target). The current experiments mainly used sentential priming, and investigated the relationship between the stem of the sentence and the final word.

The lateralized aspects of semantic processing were explored using the divided visual field (DVF) technique in conjunction with sentential priming in Part 1. The DVF method was originally used to study commissurotomized patients and was implemented for use with study of normal participants in the 1970s. With this technique, stimuli are briefly presented to one side of the visual field. Word targets presented to the left visual field are initially processed by the right hemisphere (lvf-RH) whereas words presented to the right visual field are initially processed by the left hemisphere (rvf-LH). Only the initial processing is lateralized (both hemispheres are eventually involved due to passage of information across the corpus callosum), yet by looking at differences in response latencies for stimuli initially presented to each hemisphere it is still possible to make deductions about the involvement of each. A faster processing time for stimuli initially presented to the right hemisphere suggests there is an advantage to beginning processing in the right hemisphere; the same is true for the left hemisphere. This DVF technique is used for Experiments 1, 2 and 2B.

There are a number of advantages to using this technique to examine lateralized differences in semantic processing. In contrast to neurophysiological or neuroanatomical techniques such as event-related potentials (ERP) or functional magnetic resonance imaging (fMRI), it is inexpensive, and relatively simple to administer. It allows a focus on overall differences between the left and right hemispheres, without the need to consider specific areas of activation within the brain. This characteristic is a limitation as well, however. Focusing on overall differences between left and right hemisphere semantic processing may obscure important differences between how the hemispheres operate.

Part 2 of the current work essentially examined what could be called priming of priming, by testing how immediately previous priming trials would influence a current trial. Both sentence processing and word pair priming were used. This allowed for the examination of longer-term activation of the spreading activation network over several sets of trials, and of other effects that may take place over this time frame.

It is typical in divided visual field studies of semantic processing to employ a lexical decision task, where participants must decide if a letter string is a valid English word (e.g. Beeman et al., 1994; Faust & Kahana, 2002; Chiarello, Liu, Shears, Quan & Kacinik, 2003). Tasks were chosen that involved some sort of semantic judgment instead in order to ensure participants accessed the actual meaning of the words, rather than a lexical decision task that can merely require accessing their lexical representation. Tasks previously used by the author include those which required not only semantic comprehension, but a decision about the stimulus. One task was to say whether the last word "fit" the sentence in a yes/no judgment. Another task required participants to judge whether or not metaphors were "metaphorically plausible" and whether literal sentences were "literally plausible" (Schmidt et al., in press). The problem with these types of tasks is that any difference between response times in the left visual field and right visual field presentation conditions could therefore partly originate from differential ability to determine “fit” or “plausibility” of the sentences rather than from differences in sentence comprehension itself.[1]

Therefore, for the current experiments, tasks were chosen which would minimize additional decision making required in addition to comprehension. For Part 1 participants were asked to judge whether each sentence was meaningful or not meaningful, a more natural comprehension task. In Part 2, tasks were chosen that would require the participants to explicitly pay attention to the stimulus dimension being tested, which was the relatedness of the words – in a sentence for Experiment 3 and in a prime-target pair in Experiment 4. For the former, participants judged whether the sentence was easy or hard

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[1] Thanks for this perspective goes to an anonymous reviewer of an earlier version of Schmidt et al., in press.

to understand; for the latter, they judged whether the two words were closely related or if they were not as closely related. These tasks, while simpler than the ones described earlier, still do require a decision component, and behavioral differences between the two visual fields could be at least partly due to making this decision rather than from differences in sentence comprehension itself. Nevertheless there is evidence that lexical decision and semantic judgment tasks are sensitive to the same cognitive processes and that semantic judgment does not distort response latencies. Faust and Lavidor (2003) used both a lexical decision task and a more complex binary decision task requiring participants to decide if two words were semantically related. They found the same pattern of response latencies in both visual fields with both tasks.

Summary

The connection between the lateralized asymmetry properties of visual and auditory processing as compared to semantic processing has never been systematically explored. Thus the proposed project aims to fill an important gap in our understanding of lateralized brain processing asymmetries. This will be done by exploring two known properties of local-global processing, its relative (as opposed to absolute) nature with respect to lateralization, and priming based on level of processing (local or global). Exploring these properties allows for the examination of stimulus context effects at two levels. The former property leads to the investigation of overall or broad context effects of the semantic set based on levels of coarse or fine semantic processing. The latter property leads to the investigation of the immediately preceding context based on levels of coarse or fine semantic processing.

CHAPTER 2: PART 1 – DOUBLE FILTERING BY FREQUENCY

The double filtering by frequency theory suggests that the difference between high and low frequency preferences of the left and right hemispheres is not absolute, but relative. This view is supported by studies that find that stimuli of intermediate frequency, both visual (Kitterle et al., 1990) and auditory (Ivry & Lebby, 1993), are differentially lateralized depending on the context they are processed in. In the context of high frequency stimuli (preferentially processed in the left hemisphere), the right hemisphere is more sensitive to stimuli of intermediate frequency, whereas in the context of low frequency stimuli (preferentially processed in the right hemisphere), the left hemisphere is more sensitive to them. The explanation for this pattern is that visual and auditory stimuli are processed in two successive filtering steps. The first step involves attentional selection of the range of frequencies that is relevant for the task at hand. Both hemispheres perform this filtering step in the same manner. The second step entails a high-pass filter in the left hemisphere and a low-pass filter in the right hemisphere, as described in more detail below (Ivry & Robertson, 1998; Robertson & Ivry, 2000).

This double filtering mechanism has been proposed as a general principle of hemispheric specialization (Robertson & Ivry, 2000). However, it has not been empirically extended to other domains such as semantic processing. If it can be demonstrated that the fine-coarse semantic processing differences between the left and right hemispheres is relative rather than absolute, this will support the idea that the double filtering by frequency theory represents a general processing mechanism of the human brain. Alternatively, if this effect is not found, this suggests that the double filtering by frequency theory is not generalizable to semantic processing and may be specific to certain sensory domains.

Experiment 1

This experiment tested the hypothesis that the coarse versus fine distinction between right and left hemisphere semantic processing is not absolute but relative to the context as seen with visual and auditory stimuli (Robertson & Ivry, 2000). This was tested with sentence-level relationships.

The experimental design parallels that of work done in the visual modality. A typical visual experiment (Christman et al., 1991; Hellige, 1993; Robertson & Ivry, 2000) required participants to identify the spatial frequency of laterally presented stimuli ("thick bars" vs. "thin bars"). Two different stimulus sets were used – one with sinusoidal gratings of 1 and 3 cycles/deg, and one with 3 and 9 cycles/deg. They were laterally presented to the right or left visual field for initial processing in the contralateral hemisphere. Participants were college students, and they were simply required to indicate by button press which of the two stimuli in the set they saw each time. In both situations, the result was the same – the lower frequency of the stimulus set was processed faster in the right hemisphere and the higher frequency of the stimulus set was faster in the left hemisphere Thus the stimuli with 3 cycles/deg were processed more efficiently in a different hemisphere depending on the stimulus context. If the double filtering frequency explanation for these results can be applied to the semantic domain, lateralization of moderately related words should be different depending on whether they are processed in the context of closely or distantly related words.

Previous work has shown that unfamiliar metaphors (and in some cases, literal sentences) show a right hemisphere processing time advantage (Schmidt et al., in press). Metaphors are thought to embody course semantic relationships, since the metaphorical meaning of a word is usually more distantly related to other words in a sentence than its literal meaning, and thus shows a right hemisphere processing advantage (see Figure 1). Thus for the purposes of this experiment, low familiar metaphors were considered to represent distant semantic relationships, while high familiar metaphors were considered to represent close semantic relationships. Stimuli for this experiment consisted of high, medium, and low familiarity metaphors. A between-subjects design was utilized such that one group of participants only saw high and medium familiarity metaphors while another group only saw low and medium familiarity metaphors.

If the double filtering by frequency model of visual and auditory processing can be extended to the semantic domain, it would be expected that the medium level metaphors would show different priming patterns depending on the processing context, with preferential left hemisphere processing in the context of close semantic associations (high familiar metaphors) and preferential right hemisphere processing in the context of distant semantic associations (low familiar metaphors). The medium level metaphors would then show stronger right hemisphere priming in the context of highly related metaphors (which show stronger left hemisphere priming), but show stronger left hemisphere priming in the context of low related metaphors (which show stronger right hemisphere priming). It seems plausible that such a filtering mechanism might be common to both visual and semantic processing, since it is an attentional mechanism. It seems less likely that there would be completely separate types of attention that applied to these different domains.

If the double filtering by frequency model of visual and auditory processing does *not* extend to the semantic domain, then no difference would be obtained between the medium level metaphors in the two contexts. This would imply that semantic processes are not affected by context, or that alternate explanations of left-right processing asymmetries need to be considered. For example, Roth & Hellige (1998) suggest that the differences between local and global processing are the result of two visual processing pathways (the magnocellular and parvocellular) which originate at the retina and continue through the lateral geniculate nucleus to the lateral cortices. If the differences between global and local visual processing start at such a low level, it may not be plausible to extend them to semantic processing.

Method

Participants

Undergraduate psychology students (n = 101) from the Colorado State University psychology department participant pool earned course credit for participating in the experiment. The data from two participants were excluded from analysis; one responded more than three standard deviations slower than the group mean, and the other responded with a mean under 300 ms, and was clearly not complying with task instructions. The remaining 99 participants were right-handed, native English speakers who had normal or corrected-to-normal visual acuity, with all criteria determined by self report.

Stimuli

Metaphors were taken from a normed list, which rated metaphors on a seven-point scale along several dimensions, including familiarity (Katz et al., 1988). Nonliterary metaphors were chosen from this list which would work well with the divided visual field method; namely, those which had a short ending which could be presented laterally. Sentence endings varied in length from 3 to 15 characters (including spaces) with a mean length of 7.5 (*SD* = 3.0). The metaphors were all of the form *X is (*or *are) Y.* On the seven-point scale, the metaphors chosen had familiarity scores ranging from 1.52, the lowest familiarity rating (*Creativity is a toaster*) to 6.63, the highest familiarity rating (*Alcohol is a crutch*). These metaphors were divided by a three-way median split, resulting in three groups of 52 metaphors each: Low Familiar metaphors (ratings ranging from 1.52 to 2.79, *M* = 2.32, *SD* = .35), Medium Familiar metaphors (ratings ranging from 2.79 to 3.90, *M* = 3.31, *SD* = .33), and High Familiar metaphors (ratings ranging from 3.93 to 6.63, *M* = 4.67, *SD* = .63). One-way ANOVAs confirmed that the three groups did not differ significantly in sentence stem length or ending length, based on either number of characters or number of words, *p*s > .05). It should be noted that although the metaphors were labeled as ranging from very high to very low in familiarity, this is with respect to the range of metaphors used; the range itself does not include any highly familiar (lexicalized) metaphors. The Low, Medium, and High Familiarity groups of metaphors were considered to contain close, moderate, and distant semantic relationships respectively. See Table 1 for sample metaphors.

***Table 1.* Sample metaphorical sentences used in Experiment 1.**

Familiarity Level	Sentence Stem	Ending
high	Babies are	angels
high	The mind is a	sponge
high	Honey is a bear's	best friend
high	Alcohol is a	crutch
medium	Poems are the seeds of	culture
medium	Power is capitalism's	narcotic
medium	A shadow is a piece of	night
medium	Perfume is a	magic spell
low	The South African prime minister is	ivory steel
low	A bagpipe is a	newborn baby
low	A fisherman is a	spider
low	Rain clouds are	pregnant ghosts

Procedure

Participants signed an informed consent form and read experiment instructions on a PC computer screen. They were seated in a chair and placed their chin in a chin rest such that the distance from their eyes to the computer screen was approximately 71 cm. They performed judgments on 16 practice metaphors and then 104 experimental metaphors which were presented in the same random order for each participant. For each sentence participants saw a fixation symbol (+) in the middle of the screen for 1000 ms, the stem of the sentence until they pressed the space bar, the fixation symbol for another 300 ms, and finally the end of the sentence in the right or left visual field for 200 ms. The distance between the central fixation symbol and the innermost letter of this stimulus subtended approximately 2 degrees of horizontal visual angle. Presentation to the right or left was randomized for each participant. Participants used their personal judgment and experience to rate the metaphors as meaningful or not meaningful, pressing 1 for meaningful and 2 for not meaningful.

It is common practice in divided visual field experiments to display stimuli in lateralized visual fields for 180 ms or 200 ms at the most (e.g. Nicholls & Wood, 1998). This is because research has shown that saccadic eye movements with a divided visual field paradigm typically begin 180-200 ms poststimulus onset (Rayner, 1978). By keeping the presentation of the laterally presented stimulus to 200 ms, it is possible to be reasonably certain that participants are not moving their eyes towards the presented word and using both visual fields and thus both cerebral hemispheres for initial processing of the presented word. In addition, participants were instructed before the experiment began that they must be very careful to keep their eyes focused on the fixation point and not move their eyes to the left or right when reading the ends of the sentences. The practice blocks were used to help the participants learn what was expected. The experimenter observed participants' eyes with a mirror during the experiment and made a notation for each participant as to the estimated amount of eye movement that had taken place. All participants in Experiment 1 showed minimal eye movement.

Design

A between-subjects design was utilized such that approximately half (n = 48) the participants were assigned to the A (Low Context) group and only saw sentences of Low or Medium Familiarity and the other half (n = 51, High Context group B) were tested only on the Medium and High Familiarity sentences. There were two independent variables, Side (Left or Right) and Context (Medium in the context of High and Medium in the context of Low). The dependant variable was reaction time.

Results

Response Times

For the reaction time data, a 2x2 MANOVA was conducted on the Medium level of semantic relationships from the two groups of participants, with a between-subject factors of Context (Medium in the context of High and Medium in the context of Low) and a within-subject factor of Side (Left or Right). The purpose of this analysis was to test the main hypothesis: that Medium Familiarity metaphors would show different patterns of lateralization in the context of High versus Low Familiarity metaphors. MANOVAs were used throughout the experiments where possible to avoid the assumption of sphericity inherent in repeated measures experimental designs. The analysis revealed no significant effects or interactions ($ps > .05$). The lack of any effect of Context was surprising, since the overall reaction time differences between the two experiments is close to 100 ms, and there were close to 100 participants. The reason for this situation is probably the fact that there was still low power (= .18) to detect a difference due to very high standard deviations (approximately 400 ms). There was simply a high degree of variability between participants in terms of their response times. An additional analysis was conducted to circumvent this problem, by treating the sentences, rather than the participants, as the random variable. This $F2$ analysis thus used the same factors as in the first analysis, but they were both within-sentences, eliminating the high variability between subjects. This analysis resulted in a significant effect of Context, $F(1,51) = 23.8, p < .001$, but not of Side, and there was no interaction ($Fs < 1$).

Additional 2x2 MANOVAs were conducted for the A and B groups separately with factors of Side (Left or Right) and Familiarity [High and Medium (B) or Medium and Low (A).] The Low-Medium (A) group had no significant effects or interactions, *F*s < 1. The High-Medium group (B) analysis showed a significant effect of Side, $F(1,50) = 14.8, p > .001$, and a significant Side x Familiarity interaction, $F = 6.8, p = .01$), but no effect of Familiarity ($p > .05$). Paired samples *t* tests revealed that High Familiar metaphors (from participants in group B) were processed faster in the left hemisphere (right visual field) than the right, $t\ (51) = 2.7, p = .01$. The other three lateralized comparisons (group A Low Familiar, groups A and B Medium Familiar) showed no significant differences between left and right visual fields (*p*s > .05). See Figure 3.

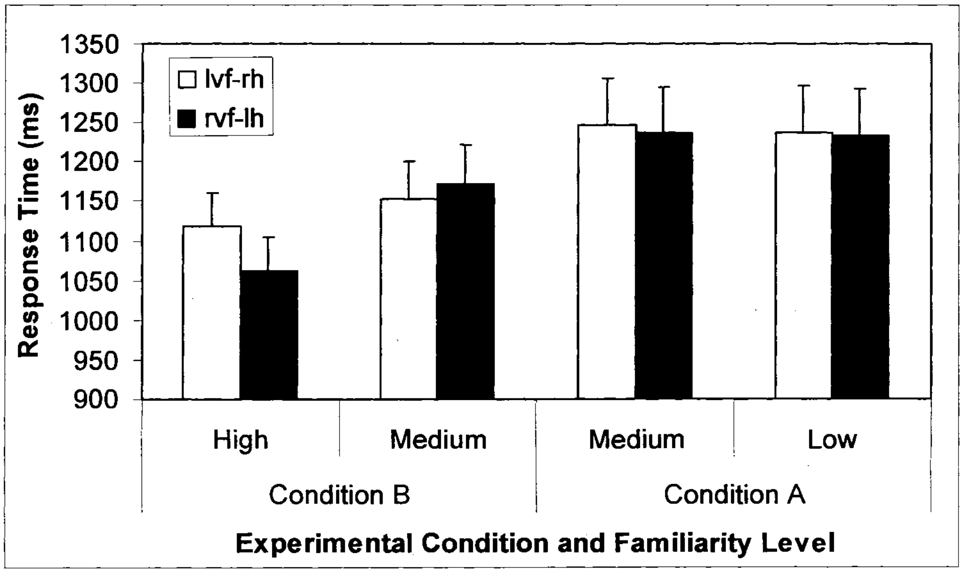

Figure 3. **Experiment 1 Response times to metaphors presented to two groups of participants. Group A viewed metaphors of Low or Medium Familiarity; group B viewed metaphors of High or Medium Familiarity. The Medium level metaphors were exactly the same stimuli for each group of participants. Error bars reflect standard errors.**

In order to determine if a different pattern of results exists when considering only responses to stimuli that were understood by the participants, the above three analyses were conducted again considering only positive responses ("sentence is meaningful"). Two participants from condition A were excluded from the analysis due to the existence of empty cells. The 2x2 MANOVA conducted on the Medium level of semantic relationships from the two groups of participants revealed a significant effect of Condition, $F(1,96) = 13.7, p < .001$, with no other significant effects or interactions ($ps > .05$). This is unlike the first analysis which had no significant effects or interactions. For the additional 2x2 MANOVAs, the Low-Medium (A) group again showed no significant effects or interactions, $ps > .05$. The High-Medium group (B) analysis showed a significant effect of Side, $F(1,50) = 4.5, p > .05$, as it did before, but an additional effect of Familiarity, $F = 27.7, p < .0001$); the Side x Familiarity interaction was no longer evident ($p > .05$). As before, paired samples t tests revealed that High Familiar metaphors (from participants in group B) were processed faster in the left hemisphere (right visual field) than the right, $t(50) = 3.3, p < .01$. The other three lateralized comparisons (group A Low Familiar, groups A and B Medium Familiar) showed no significant differences between left and right visual fields ($ps > .05$). See Figure 4.

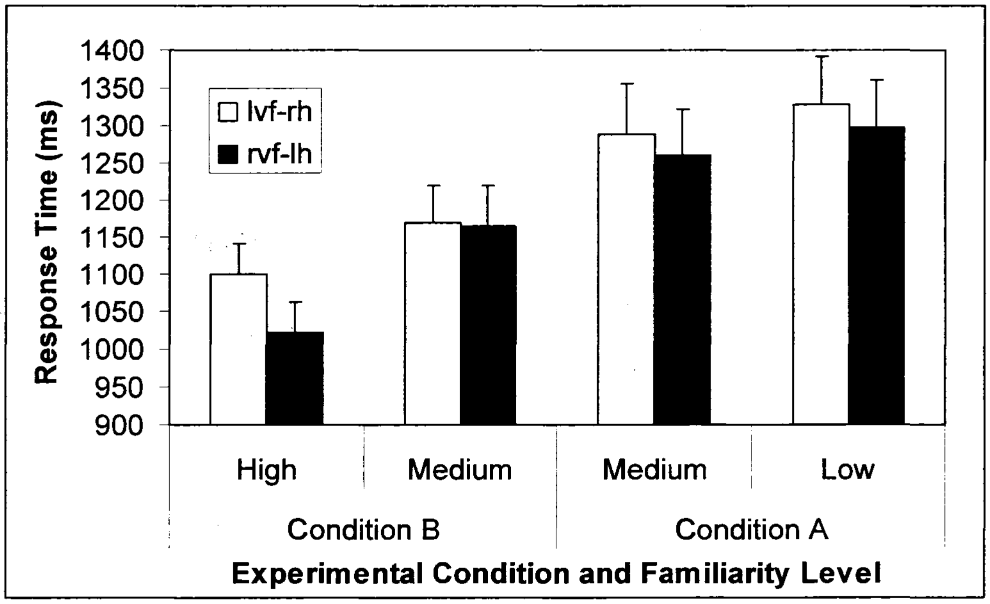

***Figure 4.* Experiment 1 response times based on positive responses. Group A viewed metaphors of Low or Medium Familiarity; group B viewed metaphors of High or Medium Familiarity. Error bars reflect standard errors.**

Responses

Overall rates of positive responses ("sentence is meaningful") are depicted in Figure 5. The mean rate of positive responses for Condition B ($M = 55\%$, $SD = 12\%$) was higher than that for Condition A ($M = 40\%$, $SD = 14\%$, $t(97) = 6.3$, $p < .001$). A 2x2 MANOVA was conducted on the Medium level of semantic relationships from the two groups of participants, with a between-subject factors of Context (Medium in the context of High and Medium in the context of Low) and a within-subject factor of Side (Left or Right) to determine if reaction time differences found between the two context conditions are also reflected in responses. This resulted in an effect of Side, $F(1, 97) = 16.5$, $p < .001$, but not of Context, and there was no interaction, Fs < 1. Thus it is clear that the context did not influence how well the sentences were understood. To confirm that this negative result was not due to high variability between subjects as in the reaction time analysis, an $F2$ analysis was conducted on these data as well with sentences as the random variable. This again resulted in an effect of Side, $F(1, 51) = 23.0$, $p < .001$, but not of Context, and there was no interaction, ps > .05.

A 2x2 MANOVA conducted on Condition B revealed significant effects of Familiarity level, $F(1,50) = 94.9$, $p < .001$, and Side, $F(1,50) = 22.8$, $p < .001$; the interaction was not significant, $F < 1$. A 2x2 MANOVA conducted on Condition A revealed significant effects of Familiarity level, $F(1,47) = 105.8$, $p < .001$, and Side, $F(1,47) = 4.9$, $p < .05$; the interaction was not significant, $p > .05$. The rvf-LH had a higher rate of positive responses than the lvf-RH for B-High Familiar, $t(50) = 3.3$, $p < .01$, B-Medium Familiar, $t(50) = 4.1$, $p < .001$, and A-Medium Familiar, $t(47) = 2.5$, $p < .05$, but not A-Low Familiar ($p > .05$).

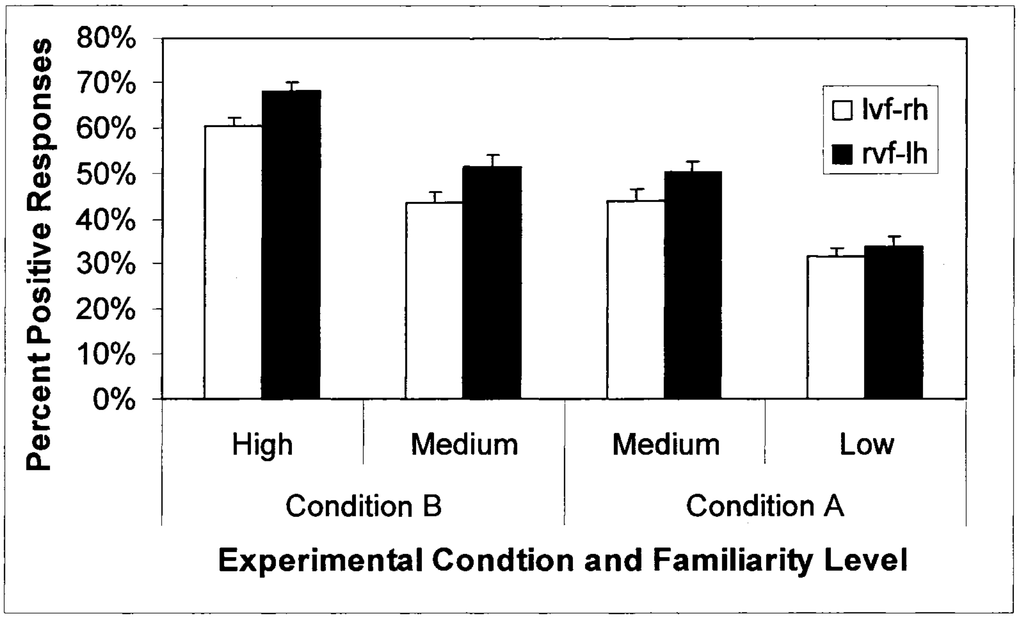

***Figure 5*. Mean percentage of positive responses ("sentence is meaningful") in Experiment 1. Group A viewed metaphors of Low or Medium Familiarity; group B viewed metaphors of High or Medium Familiarity. The Medium level metaphors were exactly the same stimuli for each group of participants. Error bars reflect standard errors.**

Discussion

The double filtering by frequency model predicts that the metaphors at the Medium level of familiarity will show different patterns of lateralization in different stimulus contexts: a right hemisphere processing time advantage in the stimulus context of High Familiar metaphors and a left hemisphere advantage in the stimulus context of Low Familiar metaphors.

The reaction time results do not clearly follow the predictions suggested by the double filtering by frequency model, since the Medium Familiarity metaphors show no lateralized processing time advantages in either context. The lack of a left hemisphere processing time advantage for the Medium Familiarity metaphors could be interpreted as a trend towards a facility in the right hemisphere for processing low familiar stimuli, but this is problematic for the double filtering by frequency theory since the same pattern existed for both conditions. The lateralized nature of the rate of positive responses ("sentence is meaningful") for each familiarity level indicates that most sentences were easier to understand when initially presented to the left hemisphere. This was true of all categories except the Low Familiar metaphors in Condition A. This pattern is consistent with the idea that the right hemisphere is better at comprehending less familiar metaphors (or rather, that the left hemisphere is worse), or perhaps that both hemispheres are equally poor at determining that something is meaningless. However, the pattern does not support the double filtering by frequency theory which would show different patterns for the Medium Familiarity metaphors in the two different contexts.

The results do, however, support lateralized differences in the processing of different levels of metaphor familiarity. Condition B showed an interaction between Familiarity and Side of processing, and individual *t*-tests confirmed that there was a clear left hemisphere processing time advantage for the High Familiar metaphors which did not exist for the Medium or Low Familiar metaphors. While this interaction disappeared when the analysis was limited to only positive responses, the lateralization patterns with a left hemisphere advantage for the High Familiar stimuli was upheld. Since the existence of a right visual field (left hemisphere) processing time advantage for various linguistic tasks has been well established in the literature (Nicholls & Wood, 1998), the lack of such a pattern for the Medium Familiarity metaphors in both conditions A and B is interesting, and supports the idea that the left hemisphere is more proficient at processing highly familiar stimuli than the right hemisphere, while the right hemisphere gains proficiency with less familiar stimuli such that both hemispheres are equally good at processing them.

What was surprising was the lack of a right hemisphere advantage even in the Low Familiarity condition of Condition A. The stimuli used were identical to those used in Schmidt et al. Experiment 3 (in press; see Figure 6) and thus should have shown a right hemisphere advantage for the Low Familiarity metaphors. One possible explanation concerns how the stimuli were divided up into conditions. A total of 156 metaphors rank-ordered by familiarity rating were used in each experiment. For the Schmidt et al. experiment, the four conditions of Very High, High, Low and Very Low were created by dividing the list into quartiles. For the current Experiment 1, there were only three levels. Thus in this case, the Low category of metaphors included all the Very Low as well as some of the Low from the Schmidt et al. experiment. A widening of the Low category to include metaphors that were not as extreme in their familiarity score could have obscured the right hemisphere processing time advantage for this category of metaphors.

To explore whether this could be the reason for the discrepancy, the data from Experiment 1 were reanalyzed by creating groups of stimuli that paralleled the quartiles

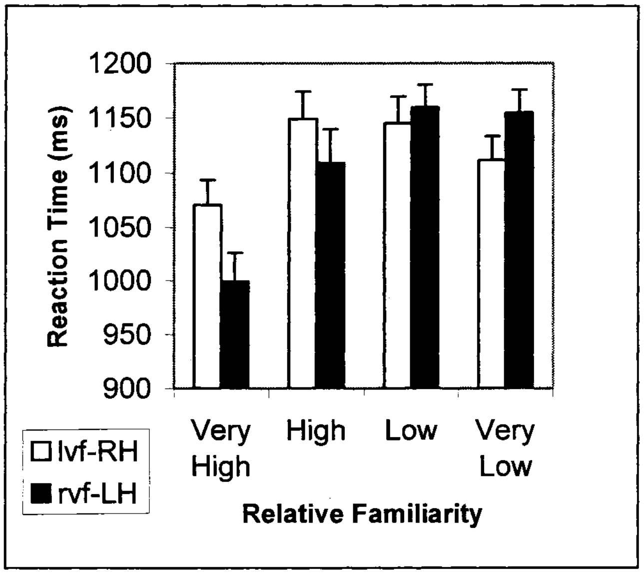

***Figure 6.* Processing times for four levels of metaphor familiarity in the right and left hemispheres (from Schmidt et al., in press). Error bars reflect standard errors.**

from Schmidt et al.(in press) Experiment 3, with about 40 metaphors in each group. The new High Familiarity and Low Familiarity groups were of exactly the same size and composition as those from Schmidt et al. Experiment 3. The new Medium Familiarity group was the same size as the other two groups, and was a combination of the High and Low groups from Schmidt et al. Experiment 3. The reanalysis based on these new groups resulted in the same pattern of findings as reported earlier, suggesting that stimuli group composition differences did not drive the differences.

Since the same list of stimuli was used, the data from the two experiments were combined visually for an informal comparison, as can be seen in Figure 7. Here the

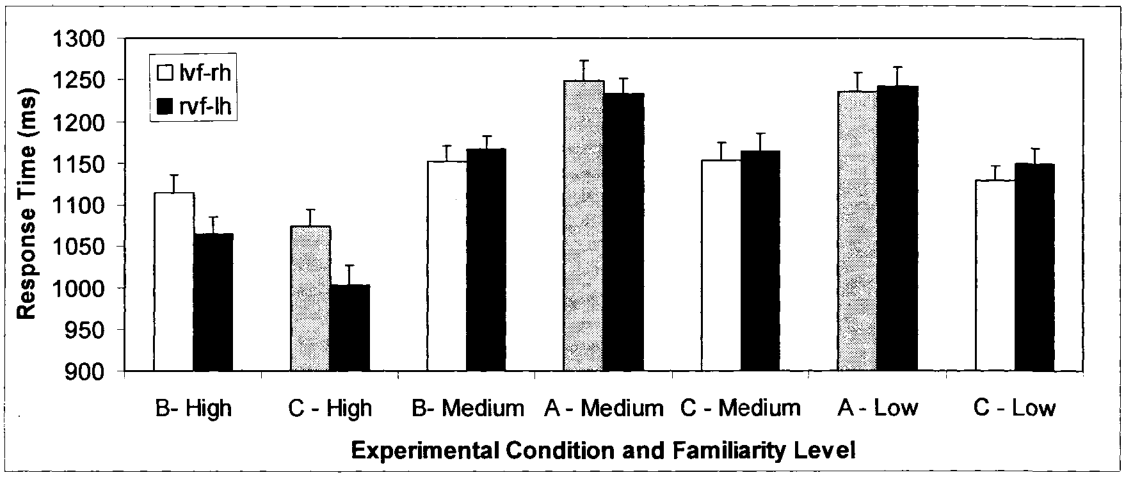

***Figure 7.* Experiment 1 results (Participant groups A and B) compared with Schmidt et al. (in press) (Participant group C). High, medium, and Low categories represent exactly the same stimuli between conditions and experiments. Results presented here are based on the *F2* analysis, with sentences as the random variable. Error bars reflect standard errors.**

stimuli groups match the groups in Experiment 1, such that the stimuli in each of the High, Medium and Low Familiarity groups are exactly the same between experiments (52 metaphors per group). Given that different numbers of participants were analyzed in each experiment (99 and 47 respectively), and that Experiment 1 was a between-subjects design while the Schmidt et al., (in press) experiment was not, statistical analyses were not conducted.

A number of points become clear after viewing the figure. The pattern of results for Condition B is very similar to those in the original experiment (Condition C in Figure 7). Both the response times and pattern of lateralization appear to be largely the same. However, Condition A shows a different pattern than the original experiment: response times are much slower and there is no right hemisphere processing time advantage for the Low Familiar metaphors. In contrast, Low Familiar metaphors from the original experiment (Condition C) still shows a right hemisphere advantage, even though this category has been broadened to include additional metaphors with higher familiarity scores as was done for this comparison.

This leads to the speculation that there may be something about the situation in Condition A that changes the participants' strategy, and perhaps obscures any real differences in reaction time between sides. Clearly the responses for Condition A are much slower than either in Condition B or the original experiment (Condition C). However, an examination of the nature of the responses, as seen in Figure 3, reveals that participants in both conditions found these metaphors easy to understand at about the same rate, and this was confirmed statistically. Thus the slower response latencies are more likely to be due to some other factor.

The Low Familiar metaphors were more difficult to understand, as indicated by the response latencies for this condition. It may be that since this is so, participants got into a pattern or rhythm of responding at a slower pace, creating a pacing effect. When participants are slow on one trial, they are more likely to be slow on the next trial.

However, this explanation could be questioned when looking at the results of the other experiments, where reaction time differences were found between conditions. It could be that somehow participants viewing only relatively unfamiliar metaphors (Medium and Low), come to expect to find the metaphors difficult to understand, and thus get into a pattern of responding more slowly. With a stimulus set including High Familiar metaphors (as in Condition B) or even with a wider range of familiarity (as in the original Schmidt et al., in press, experiment), participants may not automatically get into a slower pace of responding because of the inclusion of the High Familiar metaphors. It may be that a slower pace of responding in general will obscure any differences in lateralized response times, since responses in both hemispheres are subjected to a slower, more deliberate pace. This possibility will be explored in Experiment 2.

Another, related explanation for the differences between the current experiment and Schmidt et al., (in press) Experiment 3 is also possible. A right hemisphere advantage for unfamiliar metaphors may be dependent on the overall stimulus processing context. For example, a right hemisphere advantage may only be obtained for unfamiliar metaphors in a general context that incorporates a wide range of familiarity, including more familiar metaphors, as in the Schmidt et al. study. When all the metaphors in a general study context are very or somewhat unfamiliar, perhaps the contrast is diminished or lost. This appears to be the pattern obtained when both the current Experiment 1 and Experiment 3 of the Schmidt et al. study are considered together. This possibility will also be explored in Experiment 2.

The rate of positive responses ("sentence is meaningful") for each familiarity level is very similar to those in the original experiment (Schmidt et al., in press). Since each group of participants saw a different range of familiarity, the higher ratings for group B are to be expected. It could be argued that the Low Familiarity metaphors, which were only rated as meaningful 33% of the time, might not have been processed as metaphors at all, but treated as nonsense. However, this rate is similar to the 32% endorsement rate for the Very Low Familiar metaphors in Schmidt et al. (in press) Experiment 3, which was based on 40 of the 52 metaphors in the current Low Familiar group. For that study, it was argued that since approximately half of the overall corpus was judged as meaningful across conditions, the participants simply evenly divided their yes and no responses. If truly nonsensical sentences had been included, it is likely that more of these metaphors would have been rated as meaningful. The rate of positive responses was higher in the current experiment for Condition B than in A. This difference is driven by the differences between High Familiar metaphors in Condition B and Low Familiar metaphors in Condition B, since the positive response rate was the same between conditions for Medium Familiarity metaphors. Thus we cannot argue in this case that participants divided their responses evenly. However, the same general argument applies. Because there were two possible responses, ("yes" the sentence is meaningful, or "no" it is not) participants were likely to expect that some of the sentences in the corpus were not meaningful, although in actual fact they all did have a real meaning. This could have resulted in demand characteristics influencing the results. The lower rate of endorsement for the Low Familiar metaphors therefore certainly indicates that they were more difficult to understand, but not that they were not understood at all or treated as nonsense.

Experiment 2

The purpose of Experiment 2 was to investigate the reasons for the lack of right hemisphere advantage in Experiment 1 (black and white bars in Figure 6), despite the existence of one in a previous experiment with the same stimuli (grey bars in Figure 6; Schmidt et al., in press). Since the pattern hypothesized by the double filtering by frequency model is dependant on the existence of a right hemisphere processing time advantage for the Low Familiarity metaphors, Experiment 1 can neither confirm nor disconfirm the double filtering by frequency model for semantic stimuli. Thus, it would be instructive to determine an explanation for the slow responses in Condition A, and any lateralized differences in reaction time.

Experiment 2 thus tested the idea that a right hemisphere advantage for semantic processing requires not only distant semantic associations (as has already been established by Schmidt et al., in press) but also a broad stimulus context of both high and low familiarity sentences. This was done by having one group of participants processing all three groups of metaphors (High, Medium, and Low Familiarity), the With High Familiarity group, and another group process only Medium and Low Familiarity metaphors, the Without High Familiarity group. It also tested the idea that a pacing effect, such that participants get into a slower pace with more difficult stimuli, was the reason for the slow responses found in Experiment 1, Condition A.

It was predicted that the With High Familiarity group would show a right hemisphere processing time advantage for the Low Familiar metaphors but the Without High Familiarity group would not. This result would confirm the reason for the lack of right hemisphere processing time advantage for the Low Familiarity metaphors in

Experiment 1 and suggest that a right hemisphere advantage is only obtained in a general context of mixed familiarity. This would also allow for firmer conclusions to be drawn with respect to double filtering by frequency and semantic processing. It was also predicted that the response times for the Without High Familiarity group would be slower, due to a pacing effect.

Method

Participants

Undergraduate psychology students (n = 89) from the Colorado State University psychology department participant pool earned course credit for participating in the experiment. All participants were native English speakers who had normal or corrected-to-normal visual acuity by self report and were right handed. Right handed was defined as having a score at or above .50 on the Annett handedness scale where +1 represents completely right handed and -1 represents completely left handed (Annett, 1985). The mean handedness score was .87 (*SD* = .13).

Stimuli & Procedure

The same normed metaphors used in Experiment 1 and Schmidt et al. Experiment 3 were used, divided in the same Low, Medium, and High Familiarity groups of metaphors. The beginning of each metaphor was presented centrally; the last word(s) were presented laterally to the left or right visual field. For each sentence participants saw a fixation symbol (+) in the middle of the screen for 1000 ms, the stem of the sentence until they pressed the space bar, the fixation symbol for another 300 ms, and finally the end of the sentence in the right or left visual field for 200 ms, as in Experiment 1.

Participants again used their personal judgment and experience to rate the metaphors as meaningful or not meaningful, pressing 1 for meaningful and 2 for not meaningful.

As in Experiment 1, participants were instructed before the experiment began that they must be very careful to keep their eyes focused on the fixation point and not move their eyes to the left or right when reading the ends of the sentences, and the experimenter observed participants' eyes with a mirror during the experiment and made a notation for each participant as to the approximate amount of eye movement that had taken place. All participants in Experiment 2 again showed minimal eye movement.

One difference between Experiment 1 and Schmidt et al. (in press) Experiment 3 not previously mentioned is the length of presentation of the lateralized stimulus. Lateralized stimuli were presented for 250 ms in Schmidt et al. Experiment 3 but 200 ms in Experiment 1. Using a presentation time of 200 ms results in less eye movement issues (Rayner, 1978; Nicholls & Wood, 1998), and it was successfully used in Experiment 1, thus this presentation time was maintained for Experiment 2. It should be noted however, that results obtained could be attributed to these differences in stimuli presentation time.

Design

A between-subjects design was utilized similar to Experiment 1. The presence of high familiarity metaphors was manipulated. A With High familiarity group (n = 43, B) was tested on all three levels of metaphors (High, Medium and Low Familiarity, 156 total metaphors). A Without High familiarity group (n = 46, A) was tested only on the Medium and Low Familiarity sentences (for a total of 104 metaphors). By comparing the performance on the Low and Medium Familiar metaphors between the two conditions, it was possible to determine whether the presence of metaphors high in familiarity will influence the findings.

This design has the advantage that it directly replicates the conditions in Experiment 1 and Schmidt et al. (in press) Experiment 3. The disadvantage is that the two groups of subjects will be tested on differently sized lists, meaning that any differences that are found between the groups could be attributed to the differing list lengths. This difference is necessary in order to replicate as closely as possible the results of the previous two experiments. To address the potential confound, additional analyses will be conducted. The performance of the With High familiarity group will be analyzed based on all 156 sentences and also based only on the first 104 sentences (the same number of sentences completed by the Without High familiarity group). If the pattern of results is the same for the two analyses, this will imply that the length of the stimulus list was not a factor in the results.

Results

Response Times

For the reaction time data, a 2x2x2 MANOVA was conducted on the Low and Medium level of semantic relationships from the two groups of participants, with a between-subject factor of Context (With High familiarity and Without High familiarity) and within-subject factors of Side (Left or Right) and Familiarity (Medium and Low; the High Familiarity data was not considered for this analysis). The analysis revealed no significant effects or interactions (*p*s > .05).

Additional 2x2 MANOVAs were conducted for the A and B groups separately with factors of Side (Left or Right) and Familiarity (High, Medium and Low (B) or

Medium and Low (A)). The Without High (A) group had no significant effects or interactions, *p*s > .05. The With High group (B) analysis showed a significant effect of Familiarity, *F*(2,41) = 22.0, *p* > .001, with no other main effects or interactions, *F*s < 1. Post hoc comparisons conducted for the B analysis using paired sample *t*-tests revealed significant differences between High and Medium Familiarity, *t*(42) = 5.8, *p* > .001 and between High and Low Familiarity, *t*(42) = 6.5, *p* > .001. Paired samples *t* tests of lateralized comparisons (Left versus Right) showed no significant differences (*p*s > .05). See Figure 8.

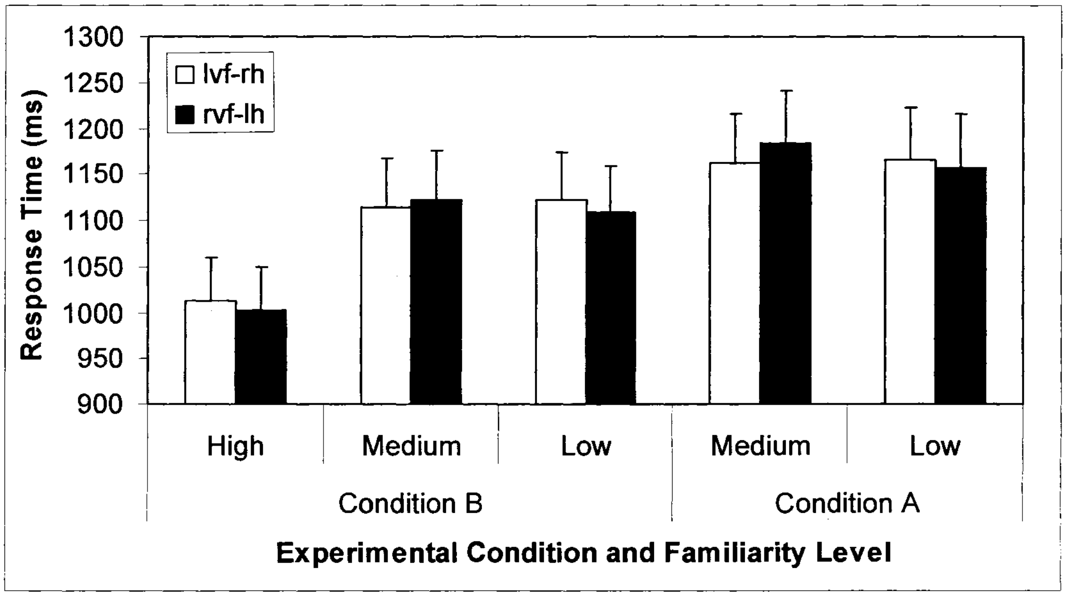

***Figure 8.* Experiment 2 results. RT to metaphors presented to two groups of participants. Group A viewed metaphors of low or medium familiarity; group B viewed metaphors of high, medium or low familiarity. Error bars reflect standard errors.**

In order to determine whether the difference in length between the A (104 metaphors) and B (156 metaphors) conditions had an influence on the results, the analyses were conducted again using only the first 104 metaphors processed for each participant in the B condition. The data in the A condition remained the same. The pattern of results between these two sets of analyses were very similar, with the only divergence being a significant difference between Medium and Low Familiarity metaphors in Condition B, $t(42) = 2.2, p < .05$ in the second analysis that was not evident in the first analysis. See Figure 9. To compare the results for Condition B with the full 156 metaphors to the results with only the first 104 metaphors, the data were subjected to a 2x2x2 MANOVA with the factors of Number of Trials (104 or 156), Side (Left or Right) and Familiarity (High, Medium and Low). There was no effect of Number of Trials ($F < 1$), suggesting that the increased number of trials in Condition B did not alter the results, although it is not possible to be certain with a null result.

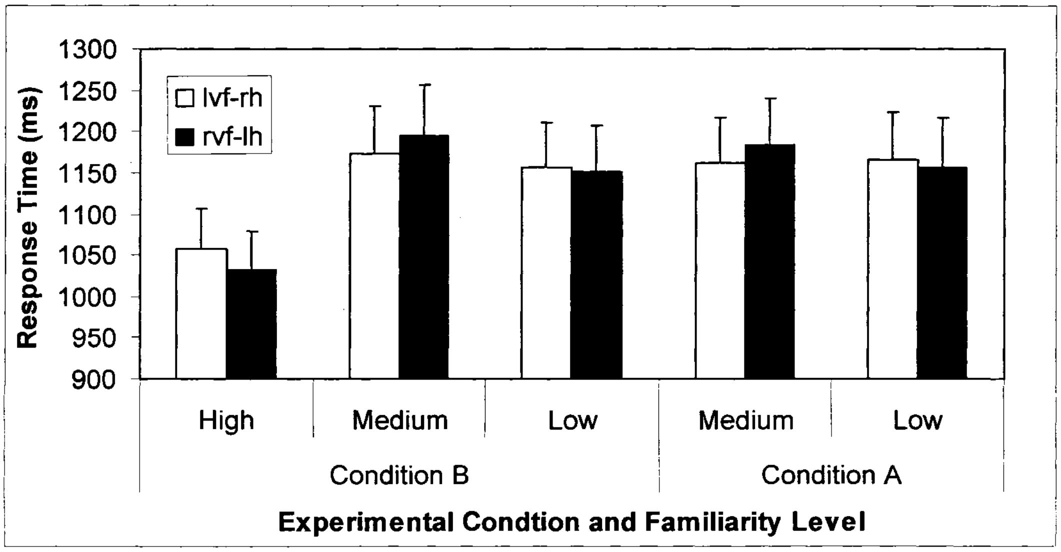

***Figure 9.* Experiment 2 results based on the first 104 metaphors. Response times to metaphors presented to two groups of participants. Group A viewed metaphors of low or medium familiarity; group B viewed metaphors of high, medium or low familiarity. Error bars reflect standard errors.**

In order to determine if a different pattern of results exists when only considering responses to stimuli that were understood by the participants, the analyses were conducted again based only on positive responses ("sentence is meaningful"). Two participants from condition B were excluded from the analysis due to the existence of empty cells. In addition, participants who had one or more cells that were 2.5 standard deviations above the mean were also excluded, resulting in the elimination of an additional 3 participants. This was necessary due to the existence of cells which were based on only a few positive responses, most of which were considerably slower than the participant's other responses. The 2x2x2 MANOVA again revealed no significant effects or interactions (*p*s > .05). The Without High (A) group analysis again showed no significant effects or interactions, *p*s > .05. The With High group (B) analysis again revealed a significant effect of Familiarity, $F(2,37) = 16.2, p < .0001$, with no other main effects or interactions, *F*s < 1. Paired samples *t* tests of lateralized comparisons (Left versus Right) showed no significant differences (*p*s > .05). See Figure 10.

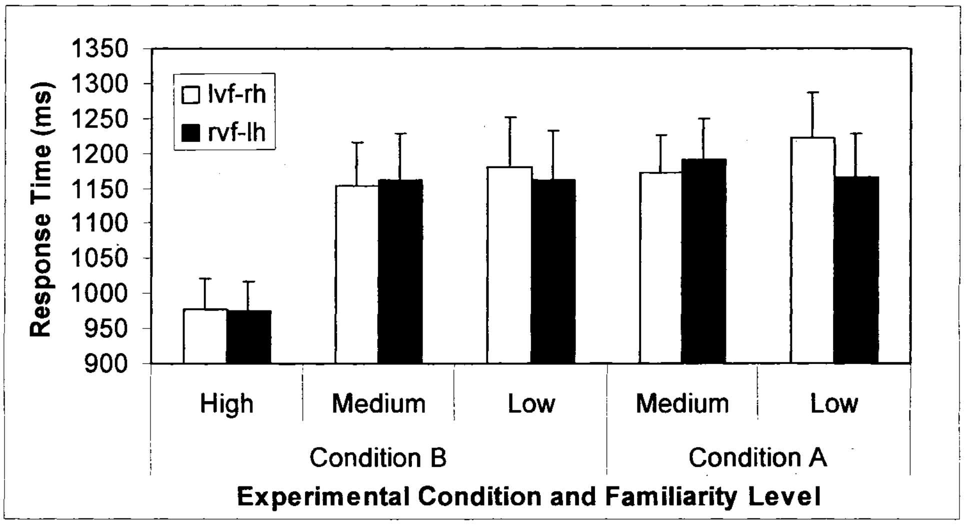

***Figure 10.* Experiment 2 response times based on positive responses. Group A viewed metaphors of low or medium familiarity; group B viewed metaphors of high, medium or low familiarity. Error bars reflect standard errors.**

Responses

Overall rate of positive responses ("sentence is meaningful") are depicted in Figure 11. The mean rate of positive responses for Condition B ($M = 47\%$, $SD = 12\%$)

was higher than that for Condition A (M = = 41%, SD = 13%, $t(87) = 2.2$, $p < .05$). A 2x3 MANOVA conducted on Condition B revealed a significant effect of Familiarity level, $F(2,41) = 114.4$, $p < .001$, and the effect of Side approached significance, $F(1,42) = 3.7$, $p = .06$; the interaction was not significant, $F < 1$. A 2x2 MANOVA conducted on Condition A revealed significant effects of Familiarity level, $F(1,45) = 65.6$, $p < .001$, and Side, $F(1,45) = 65.6$, $p < .01$; the interaction was not significant, $F < 1$. The rvf-LH had a higher rate of positive responses than the lvf-RH for A-Medium Familiar, $t(45) = 2.4$, $p < .05$, and A-Low Familiar, $t(45) = 2.1$, $p < .05$. In Condition B, this pattern was exhibited as a trend in B-High Familiar, $t(42) = 1.7$, $p = .09$, B-Medium Familiar, $t(42) = 1.8$, $p = .08$, but not B-Low Familiar ($p = .61$).

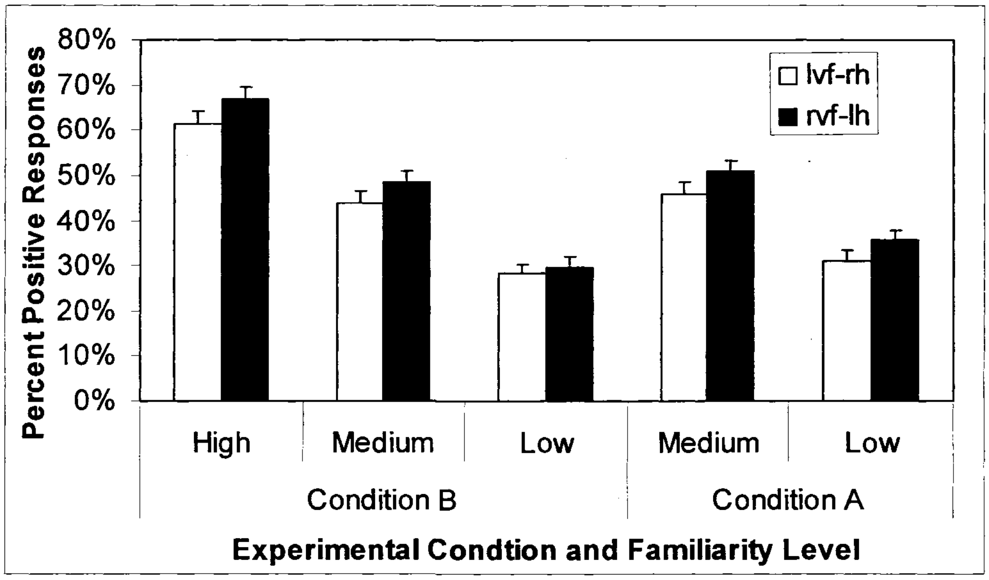

Figure 11. **Mean percentage of positive responses ("sentence is meaningful") in Experiment 2. Error bars reflect standard errors.**

Discussion

For this experiment, it was predicted that a broad stimulus context including a wide range of familiarity (With High condition) would result in a left hemisphere advantage for the High Familiarity metaphors and a right hemisphere advantage for the Low Familiarity metaphors, while a more restricted range of familiarity including only Medium and Low Familiarity metaphors (Without High condition) would not result in lateralized differences in processing. It was also predicted that there would be overall slower responses in the latter condition due to a pacing effect.

Overall, the results are not consistent with these predictions; the patterns of lateralization are very similar between the conditions. Actually, one could better say that the *lack* of lateralized differences is similar between conditions, since there were not even trends towards lateralization in any of the five individual conditions (for Condition A Low, $p = .27$, for the other four conditions, ps > .54). This was true in the additional analyses investigating alternate selections of the data, although the analysis considering only positive responses did have a significant Familiarity x Side interaction, but in a direction opposite to what was hypothesized. It is striking that the left hemisphere processing time advantage that existed for the High Familiarity metaphors in Experiment 1 is not significant in Experiment 2, and does not even display a trend towards a left hemisphere advantage (the difference of 9 ms is in the correct direction with the rvf-LH being faster, but $p = .59$; numbers are similar for the first 104 trial analysis). This left hemisphere advantage for High Familiarity metaphors also existed in Schmidt et al., (in press) Experiment 1 for exactly the same stimuli. This lack of a left hemisphere processing time advantage is surprising given the previous findings and the robust finding of right visual field (left hemisphere) processing time advantages found in the literature for linguistic stimuli (Nicholls & Wood, 1998).

The rates of positive responses ("sentence is meaningful") for each familiarity level also are not consistent with the predictions. The patterns are again very similar to those in the original experiment (Schmidt et al., in press) and Experiment 1, and the same conclusions can be drawn. The lateralized nature of the responses indicates that most sentences were easier to understand when initially presented to the left hemisphere, except for the Low Familiar metaphors in Condition A. This pattern is again consistent with the idea that the right hemisphere is better at comprehending low familiar metaphors (or rather, that the left hemisphere is worse). The pattern does not, however, reflect an effect of stimulus context as hypothesized.

It is not possible to draw firm conclusions from these findings without an adequate explanation for the patterns found here, especially the lack of a left hemisphere advantage for the High Familiarity metaphors. Certainly high levels of variability (with standard deviations ranging from 304 to 398 ms), and a subsequent lack of power (observed power for the interaction was .05) are an important part of the explanation.

Another possibility is that the use of a lateralized stimuli presentation time of 200 ms made processing somehow more difficult overall. Thus the left hemisphere did not perform as efficiently, causing its performance to slow down to a time similar to the right hemisphere. However, this explanation seems unlikely considering that a 200 ms stimulus presentation time was used in Experiment 1 where a left hemisphere advantage was obtained for the High Familiar metaphors. However, there is also no right hemisphere advantage for the Low Familiar metaphors, as was found in Schmidt et al., (in press) Experiment 3. The latter experiment had both a left hemisphere advantage for High Familiar metaphors and a right hemisphere advantage for Low Familiar metaphors.

The only difference between that experiment and the current experiment (Condition B) is the 200 vs. 250 ms presentation time for the lateralized stimuli. All other details, including other timings and stimuli, were exactly the same. This suggests that the differences in lateralized presentation time may be part of the explanation for the pattern of results in Experiment 2.

Experiment 2B

Since the difference in lateralized presentation time is the only difference between these two experimental situations, Experiment 2 was conducted again with a 250 ms lateralized stimuli presentation time, in order to determine whether this factor was the result of the puzzling differences. It was predicted that this change would result in the pattern hypothesized for Experiment 2.

Method

Participants and Procedure

Undergraduate psychology students (n = 75) from the Colorado State University psychology department participant pool earned course credit for participating in the experiment. All participants were native English speakers who had normal or corrected-to-normal visual acuity by self report and were right handed. Right handed was defined as having a score at or above .50 on the Annett handedness scale where +1 represents completely right handed and -1 represents completely left handed (Annett, 1985). The mean handedness score was .91 (*SD* = .12).

All other details of this experiment were identical to Experiment 2, except that the presentation of the lateralized sentence endings was extended to 250 ms. Lateralized eye movement increased in this experiment compared to previous experiments due to the longer presentation time. Thus as in previous experiments, the experimenter observed participants' eyes with a mirror during the experiment and made a notation for each participant as to the approximate number of trials in which eye movement that had taken place. This information was used to exclude participants who shifted their eyes from the center fixation symbol (+) on more than approximately 50% of trials. This number was chosen after an informal examination of previous data (Schmidt et al., in press), which revealed that the data of participants who shifted their eyes less than 50% followed the same pattern as the participants who demonstrated minimal eye shifting. As a result, the data from two participants were excluded from analysis, leaving a total of 73 participants.

Results

Response Times

For the reaction time data, a 2x2x2 MANOVA was conducted on the Low and Medium level of semantic relationships from the two groups of participants, with a between-subject factor of Context (With High familiarity and Without High familiarity) and within-subject factors of Side (Left or Right) and Familiarity (Medium and Low; the High Familiarity data was not considered for this analysis). The analysis revealed no significant effects or interactions (*p*s > .05), although the Context x Familiarity interaction approached significance, $F(1,71) = 3.3, p = .07$.

Additional two-way MANOVAs were conducted for the A and B groups separately with factors of Side (Left or Right) and Familiarity (High, Medium and Low (B) or Medium and Low (A)). The Without High (A) analysis revealed significant effects of Side, $F(1,37) = 4.5, p < .05$ and Familiarity, $F(1,37) = 5.0, p < .05$, but no interaction, $F < 1$. The With High group (B) analysis showed a significant effect of Familiarity,

$F(2,33) = 6.4, p > .01$, with no other main effects or interactions, *ps* > .05. Post hoc comparisons conducted for the B analysis using paired sample *t*-tests revealed significant differences in response latencies for High and Medium Familiarity metaphors, $t(34) = 3.6, p = .001$ and between High and Low Familiarity, $t(34) = 3.2, p > .01$.

Paired samples *t*-tests of lateralized comparisons (Left versus Right) showed no significant differences (*ps* > .05), although the left hemisphere advantage for High Familiar metaphors in Condition B approached significance, $t(34) = 1.98, p = .06$. The lateralized difference for Condition B, Low did showed a difference of 20 ms in the expected direction, but it was not significant, $p = .60$. See Figure 12.

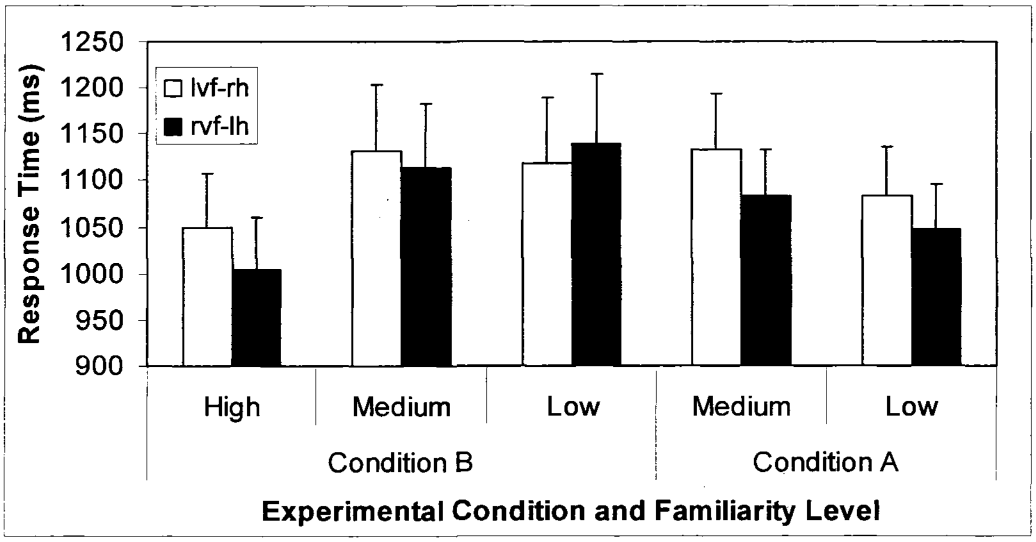

***Figure 12.* Experiment 2B results. RT to metaphors presented to two groups of participants. Group A viewed metaphors of low or medium familiarity; group B viewed metaphors of high, medium or low familiarity. The only change from Experiment 2 was that the lateralized stimulus presentation time was increased to 250 ms. Error bars reflect standard errors.**

To compare the results for Condition B with the full 156 metaphors to the results with only the first 104 metaphors, the data were subjected to a 2x2x2 MANOVA with the factors of Number of Trials (104 or 156), Side (Left or Right) and Familiarity (High, Medium and Low) as before. There was again no effect of Number of Trials ($F < 1$), indicating that the increased number of trials in Condition B did not alter the results.

The patterns in these results, while not statistically significant, do appear to show some trends in the expected directions. The lack of statistically significant results is again likely due to high variability and low power. Thus additional analyses were again conducted to further explore the data, by treating the sentences, rather than the participants, as the random variable. These $F2$ analyses made it possible to treat the factors of Context and Side as within-sentence variables, but the factor of Familiarity became a between-sentence variable. For the three-way analysis, this resulted in effects of Context, $F(1,102) = 5.5, p > .05$, a marginal effect of Side, $F(1,102) = 3.3, p = .07$, and trends towards interactions between Context and Familiarity, $F(1,102) = 2.4, p = .12$, and between Side and Familiarity, $F(1,102) = 2.1, p = .15$. Group A ($M = 1088$) was faster than Group B ($M = 1123$ ms) on the combination of Medium and Low Familiarity metaphors.

For the Without High context group (A), this resulted in a significant effect of Side, $F(1,102) = 5.5, p > .05$, and a marginal effect of Familiarity, $F(1,102) = 3.2, p = .08$, but no interaction, $F < 1$. For the With High context group (B), there was an effect of Familiarity, $F(1,102) = 6.8, p = .001$, but no effect of Side ($p = .44$) and no interaction, $F = 1.3, p = .29$. An additional 2x2 MANOVA was conducted on only the Low Familiarity level with between-sentence factors of Side and Context. This resulted in an effect of Context, $F(1, 102) = 8.1, p < .01$, but not of Side, $F < 1$, and the interaction approached significance, $F(1,102) = 2.7, p = .11$.

In order to determine if a different pattern of results exists when considering responses to stimuli that were understood by the participants, the analyses were conducted again based only on positive responses ("sentence is meaningful"). One participant from each condition was excluded from the analysis due to the existence of empty cells. In addition, participants who had one or more cells that were 2.5 standard deviations above the mean were also excluded, resulting in the elimination of an additional 5 participants. Again, this was necessary due to the existence of cells which were based on only a few positive responses, most of which were considerably slower than the participant's other responses. The 2x2x2 MANOVA revealed an effect of Familiarity, $F(1,64) = 5.9, p < .05$, which did not exist in the original analysis. There were no other significant effects or interactions (*p*s > .05). The Without High (A) analysis again revealed significant effects of Side, $F(1,35) = 4.5, p < .05$, and Familiarity, $F(1,35) = 5.2, p < .05$ and there was again no interaction, $F < 1$. The With High group (B) analysis showed a significant effect of Familiarity, $F(2,28) = 17.8, p < .001$, with no other

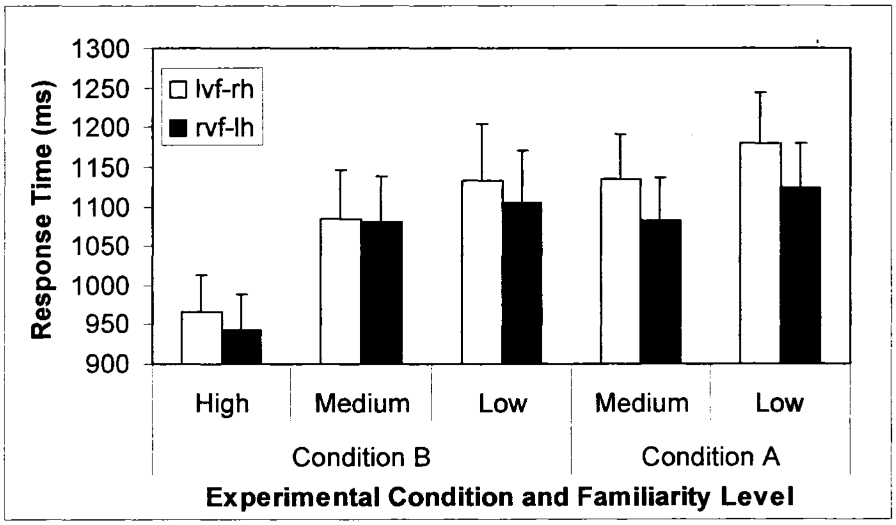

***Figure 13.* Experiment 2B response times based on positive responses. Group A viewed metaphors of low or medium familiarity; group B viewed metaphors of high, medium or low familiarity. Error bars reflect standard errors.**

main effects or interactions, *ps* > .05, as before. Paired samples *t* tests revealed that Medium Familiar metaphors (from participants in group A) were processed faster in the left hemisphere (right visual field) than the right, *t* (35) = 2.04, *p* > .05. The other three lateralized comparisons (group A Low Familiar, group B High, Medium, and Low Familiar) showed no significant differences between left and right visual fields (*ps* > .05). See Figure 13.

Responses

Overall rates of positive responses ("sentence is meaningful") are depicted in Figure 14. The mean rate of positive responses for Condition B (*M* = 45%, *SD* = 13%) was not significantly different than that for Condition A (*M* = 41%, *SD* = 13%, *p* = .24). It appeared that, unlike the previous experiments, Condition A found the Medium Familiarity metaphors more comprehensible than the B condition. A MANOVA

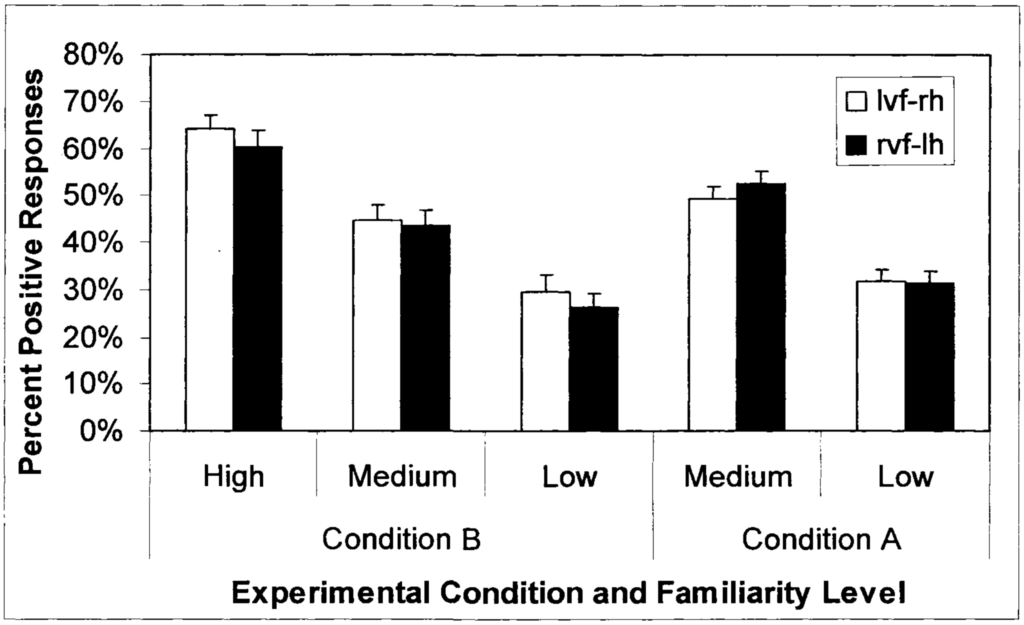

***Figure 14.* Mean percentage of positive responses ("sentence is meaningful") in Experiment 2B. Error bars reflect standard errors.**

conducted on just the Medium Familiar metaphors with factors of Side (Left or Right) and Context (A or B) confirmed this with a strong trend, $F(1,71) = 3.8$, $p = .06$.

A 2x3 MANOVA conducted on Condition B revealed a significant effect of familiarity level, $F(2,33) = 51.7$, $p < .001$, but not of Side, and the interaction was not significant, *F*s < 1. A 2x2 MANOVA conducted on Condition A revealed a significant effect of familiarity level, $F(1,37) = 126.2$, $p < .001$, but not of Side, and the interaction was not significant, *ps* > .05. There were no differences in responses between the rvf-LH and the lvf-RH for any of the individual conditions (*ps* > .17).

Discussion

For this experiment, it was predicted that a change to a lateralized stimulus presentation time of 250 ms would result in the pattern hypothesized for Experiment 2: a broad stimulus context including a wide range of familiarity (With High condition) would result in a left hemisphere advantage for the High Familiarity metaphors and a right hemisphere advantage for the Low Familiarity metaphors, while a more restricted range of familiarity including only Medium and Low Familiarity metaphors (Without High condition) would not result in lateralized differences in processing between familiarity conditions. It was also predicted that there would be overall slower responses in the latter condition due to a pacing effect.

There is some indication that such a pattern exists, although the differences are not all significant. In Condition B, there was a strong trend towards a left hemisphere processing time advantage for the High Familiar metaphors, and the left hemisphere advantage disappeared for the Medium and Low Familiar metaphors. However, for Condition A, with only Low and Medium Familiarity metaphors, there was a significant effect of Side, in both *F*1 and *F*2 analyses, with an overall left hemisphere processing time advantage. This was demonstrated by a trend towards a left hemisphere advantage for the Low ($p = .11$) and Medium ($p = .14$) Familiar metaphors in Condition A. Thus, as hypothesized, we do have two different patterns of lateralization depending on whether the stimulus context included High Familiarity metaphors or not. This pattern is also supported by the existence of a marginal interaction between Context and Side for the Low Familiarity metaphors, such that there is a trend towards a right hemisphere advantage in the B condition, but a left hemisphere advantage in the A condition.

These findings point to the idea that the stimulus context is important in obtaining a range of lateralized differences within a stimulus set. This provides an explanation for the findings of Experiment 1. The lack of any lateralized differences between the Medium and Low Familiarity metaphors in Condition A of Experiment 1 appears to be due to a lack of metaphors high in familiarity within the stimulus set. The suggestion that when all the metaphors in a general study context are very or somewhat unfamiliar, perhaps the contrast in lateralization between conditions is diminished or lost, is supported. For example, a right hemisphere advantage (or the lack of a left hemisphere advantage) may only be obtained for unfamiliar metaphors in a general context that incorporates a wide range of familiarity, including more familiar metaphors. The finding of an effect of Side in the current A condition is actually quite interesting and supports the idea that it is a stimulus set with a range of familiarity including highly familiar stimuli which results in variable lateralization between high and low familiar metaphors.

The current findings in Experiment 2B also confirm that high familiar metaphors typically result in a left hemisphere processing time advantage. This is contrary to the findings of Experiment 2.

Part 1 General Discussion

Contrasting with Experiments 1 and 2, where the responses showed at least a trend towards more positive ("the sentence is meaningful") responses for the left hemisphere, there were no lateralized differences in the responses of Experiment 2B. Since the only factor that differed between Experiment2 and Experiment 2B was the change to a lateralized presentation time of 250 ms, and since Experiment 1 also had a lateralized presentation time of 200 ms it could be that this change to a presentation time of 250 ms is somehow driving the results. Thus one aspect of the response data that is consistent across studies is the lack of lateralized response differences with a 250 ms lateralized stimulus presentation time, as found in the current experiment as well as Schmidt et al. (in press) Experiment 3. Lateralized differences in response times only occurs when the lateralized stimulus presentation time was 200 ms. The responses in both Experiments 1 and 2 both showed higher levels of positive responses for the left hemisphere, and both those experiments had a 200 ms lateralized presentation time. It could be that the longer presentation time resulted in more of the lateralized stimuli being processed in a controlled fashion, rather than automatically. This is supported by the fact that participants in Experiment 2 were not able to consciously process as many of the lateralized stimuli. At the end of the experiment, they were asked to give a rough estimate of the percentage of lateralized words that they were able to see. In Experiment 2, participants reported on average being able to see 55% (*SD* = 21%, range 8-100%) of the lateralized stimuli while those in Experiment 2B reported being able to see 65% (*SD* = 21%, range 10-100%) of the lateralized stimuli. This difference was significant, $t(159) = 3.2, p < .01$. (This information was not collected for Experiment 1.) This suggests that Experiments 1 and 2 involved more unconscious processing than did Experiment 2B.

It should be noted this is not subliminal or unconscious priming as typically conceptualized. Unconscious priming is generally conceived of as unconscious processing of the *prime*, which nonetheless results in faster lexical decision or naming (for a review, see Neely, 1991). In the present circumstance, processing of the prime (i.e. sentence stem) was fully conscious, and it was the *target* that was perhaps in many cases unconsciously processed. One can only speculate how this would affect processing times for the current tasks. The fact that the task (meaningfulness judgment) was less automatic than a lexical decision task or naming task is also relevant. The fact remains that participants often made a judgment about whether a sentence was meaningful or not even when they claimed they were not able to read the final word of the sentence, and the pattern of responses indicates that these judgments were not random.

It is not clear why more automatic processing of the target (sentence ending) is more likely to result in a lateralized difference in responses. The left hemisphere is considered to be most proficient at post-lexical access meaning integration. The left hemisphere very quickly activates meanings, selects the one needed based on semantic context, and then actively inhibits meanings not required in the current context. The right hemisphere more slowly activates a broader range of meanings, which gradually decay if they are not subsequently needed (Chiarello, 1991). However, the current pattern of results suggests that the left hemisphere is better at subliminal priming and automatic processing than the right hemisphere. Clearly more work is needed to systematically explore the roles of the left and right hemispheres in unconscious processing.

There are other differences between the current experiment and Experiments 1 and 2 which may be attributable to the longer lateralized presentation time and resulting reduction of unconscious processing. It is interesting that Condition A is now faster than Condition B, whereas in Experiments 1 and 2 it was the opposite pattern, with Condition B being faster than Condition A. An informal comparison of Experiments 2 and 2B reveals that the response latencies for Condition B were similar between the two experiments, but the overall response latencies for Condition A were approximately 150 ms faster in Experiment 2B than in Experiment 2. It could be that the longer exposure to the lateralized word endings allowed for more controlled processing to take place, and less unconscious processing, which provided more of an advantage for the less familiar, more difficult stimulus set in Condition A. Furthermore, in the current experiment, the participants in Condition A rate the Medium Familiarity metaphors as more comprehensible than participants in Condition B. This pattern did not exist in Experiments 1 and 2. Again, it is possible that the longer exposure to the sentence ending allowed for more conscious processing to take place, which provided more of an advantage in an overall stimulus context that did not include any highly familiar metaphors.

There are various reasons why it may be difficult to consistently obtain a right hemisphere processing time advantage for low familiar metaphors. First of all, it should be noted that even though such an effect was not obtained in any of the above three experiments, they all did show an elimination of a left hemisphere processing time advantage. It may be that this is the most likely result with more difficult stimuli such as unfamiliar metaphors. Secondly, it should be noted that the extent of variability in the findings is very high. Standard deviations were typically around 400 ms in the individual conditions, so a large number of participants is needed to obtain adequate power. In looking at individual data, even when a significant lateralized effect is obtained, close to half of the participants show lateralization patterns opposite to the main effect. It may be that more participants are needed to obtain clear results. For results that were not statistically significant, the observed power was typically low, often below .15.

One possible reason for such variability in lateralization is referred to as characteristic arousal asymmetry. It has been reported that, independent of a left hemisphere specialization for language, each person has a tendency to have one side of the brain more active or aroused than the other side. This idea was first suggested by Levy, Heller, Banich and Burton (1983). Subsequent work provided further support, showing that participants' asymmetry scores on various tasks, including left hemisphere language tasks and right hemisphere face processing tasks, are correlated (Levine, Banich & Kim, 1987). Thus characteristic arousal asymmetry is thought to be stable within individual participants, but variable between participants (Levine, 1995). This could account for the high level of variability in the current experiments and the lack of significant findings.

The current results may appear to leave us in the unfortunate position of being unable to draw any definitive conclusions about the connection between the lateralization of semantic processing and visual processing with respect to the double filtering by frequency theory. This theory, extended to semantic stimuli, predicts that *if* a left hemisphere advantage is obtained for High Familiar metaphors, and *if* a right hemisphere advantage is obtained for Low Familiar metaphors, *then* metaphors of Medium Familiarity should show different lateralization depending on whether they are processed in conjunction with High or Low Familiarity metaphors. Since the right hemisphere processing time advantage for Low Familiar metaphors was not obtained with the current results, and this finding is a prerequisite for the applicability of the theory, it is not possible to conclude either way regarding whether the double filtering by frequency theory can be applied to semantic stimuli.

However, important patterns have been uncovered with respect to semantic processing itself, which may be possible to explain with a slightly revised double filtering by frequency theory (see the *General Discussion*). The trends in the current results are consistent with the idea that the stimulus context is important in obtaining a range of lateralized differences within a stimulus set. In other words, it appears that a right hemisphere advantage may only be obtained in low familiarity stimuli when there is a range of familiarity within the stimulus set, but not when there are only relatively low familiar stimuli included in the experiment. This finding is important in its own right, and helps to explain the lack of significant findings in Experiment 1. Thus the lack of lateralized differences between the Medium and Low Familiar metaphors in Condition A of Experiment 1 appears to be due to a lack of high familiarity metaphors within the stimulus set.

CHAPTER 3: PART 2 – LEVEL REPETITION EFFECT

The findings in Part 1 are consistent with the concept that overall broad processing context influences how lateralization of semantic processes takes place. With a context that includes only moderately familiar or unfamiliar metaphors, a right hemisphere processing time advantage is attenuated resulting in roughly equal processing times in the right and left hemispheres. The role of the right hemisphere is thus diminished in such a situation. The question now becomes, how do more immediate stimulus context changes influence the pattern of lateralization?

The local-global vision literature suggests that the level of processing (local or global) is primed and thus facilitated when the previous trial is at the same level, termed the level repetition effect (Robertson, 1996). Applying this paradigm to the semantic domain allows for the investigation of the role of the immediately preceding context on semantic processes. Thus Part 2 of the dissertation explores the level repetition effect with semantic stimuli.

The level repetition effect is explained in terms of a computational processing model that adjusts attentional weights to the different levels of processing (local and global). If this priming phenomenon also exists with semantic stimuli, it might be explained in terms of similar attentional mechanisms. There has been no systematic exploration of attention to different levels of semantic relatedness (i.e. close vs. distant). However it is possible that a selective attention model may also apply to different levels of semantic relatedness based on related work exploring attention and semantic processing. The discovery of a priming effect based on the level of semantic relatedness would add to what is known about the role of attention in semantic processes.

The role of attention in semantic processes may involve selective attention to various aspects of the semantic situation. For example, Balota et al. (2001) suggest that attention is focused on different semantic levels depending on the task. If the task is naming, attention will be focused on the orthography-to-phonology pathway, whereas if it is to make a semantic relatedness judgment, attention will be focused on meaning level representations. Allport (1989) also discusses the role of attention in Stroop-like tasks involving dividing attention between pictures and superimposed words. For example, Allport cites Glaser and Düngelhoff (1984) who found that the performance of participants is dependant on the task used. Participants were presented with pictures that had superimposed words that were either congruent or incongruent with the picture. In a semantic categorization task, there was more interference when categorization was based on words, and the pictures were incongruous, than when categorization was based on pictures, and the words were in congruous. The opposite was true for naming tasks: there was more interference when naming was based on the picture, and the word was incongruous, than when naming was based on the word, and the picture was incongruous. Thus the visual information was more crucial for the categorization task, but the lexical information was more important for the naming task. This finding is compatible with the view that attention divides itself between different aspects of a stimulus, the visual and lexical information in this case. Thus it seems plausible that attention would also be selectively paid to coarse or fine semantic networks depending on the context.

If it can be demonstrated that the close versus distant semantic processing levels produce priming effects similar to those in the visual domain, this will support the idea that the level repetition effect represents a general processing mechanism of the human brain. The explanation of this effect in terms of a computational processing model that adjusts attentional weights to the different levels of processing (global and local) would also apply and it can be surmised that attention to the level of semantic relatedness (coarse or fine) is an important part of semantic processing. On the other hand, if this type of priming is not found, this suggests that the level repetition effect is not generalizable to semantic processing.

Experiment 3

Experiments 3 and 4 tested the hypothesis that priming occurs based on the level of semantic relatedness (close or distant) as seen with the level repetition effect with visual stimuli (Robertson, 1996). This was tested with both sentence- (Experiment 3) and word- (Experiment 4) level relationships.

The sentences used in the current experiment were again metaphors that varied in terms of familiarity. As previously discussed, unfamiliar metaphors are thought to embody more coarse semantic relationships than familiar metaphors (Schmidt et al., in press), thus are a sentence-level type of linguistic stimuli that can be divided into closely and distantly related groups of stimuli analogous to global and local types of visual stimuli. These can be used to explore the level repetition effect with respect to semantic processing.

Stimuli consisted of metaphors that were at two levels of semantic relatedness: either very familiar or very unfamiliar, and were presented in a pseudo random order. It was predicted that trials preceded by the same semantic level of relatedness will be processed faster than those at a different level. This would support the notion that the semantic attentional system is capable of directing attention based on the level of semantic relatedness.

Method

Participants

Thirty (15 male, 15 female) undergraduate psychology students from the Colorado State University psychology department participant pool participated in this experiment. They were native English speakers who had normal or corrected-to-normal visual acuity by self report, and a mean age of 19.1 years (range 18-23).

Stimuli and Design

A total of 124 normed metaphors from various sources, rated for familiarity on a seven-point scale (Schmidt et al., in press), were used. Familiar metaphors were considered to contain relatively fine semantic relationships while unfamiliar metaphors contain more distant semantic relationships, as Schmidt et al. (in press) maintain. Two groups of metaphors were selected by rank-ordering a list of 178 metaphors based on their familiarity score, and then selecting the top 62 metaphors and the bottom 62 metaphors for the Low and High Familiarity groups respectively. This resulted in Low Familiar ($M = 3.1$, range 1.93 - 3.83) and High Familiar ($M = 5.5$, range 4.87 - 6.40) groups of metaphors. All metaphors were 4 to 9 words in length and of the form *An X is a Y,* to eliminate any priming due to syntactic structure. There were no differences in sentence length between the experimental conditions based on number of words or number of characters (ps > .05). Response latencies and responses in each trial were compared based on the semantic level in the preceding trial. One condition consisted of trials where the semantic level (Low or High) was the Same in the previous trial; the second condition consisted of trials where the semantic level was Different.

Sentences were presented in a pseudo random order so that repetitions of Same or Different priming conditions were not repeated more than four times in a row, and so that there would be roughly equal numbers of Same and Different trials. Same and Different trials were further divided according to whether they were the first repetition of that priming type (i.e., its second sequential occurrence) or the second or third repetition (the third and fourth in a repeated sequence). There were 68 sentences in the former group and 55 in the latter group. Thus if there were four Same trials in a row, that represented the repetition of four High or four Low trials. If there were four Different trials in a row, that represented an alternating back and forth of High and Low trials. See Table 2 for a sample sequence.

Table 2. **Sample metaphorical sentences used in Experiment 3. The Preceding Level column reflects a reconceptualization of the Level Repetition factor for a further analysis discussed in the Results and Discussion section.**

Metaphors (in order presented)	**Familiarity Level**	**Level Repetition**	**Repetition Number**	**Preceding Level**
The lawyer they've hired is a shark.	high	n/a	n/a	n/a
The bachelor living upstairs is a pig.	high	same	1	high
The newlywed's heart was a lovebird's egg.	low	different	1	high
The account James landed was a homerun.	high	different	2/3	low
That scientist's brain is a computer.	high	same	1	high
Angie's stepmother's heart is ice.	high	same	2/3	high
The saleswoman's smile was sunshine.	high	same	2/3	high
The radio DJ's voice was gravel.	low	different	1	high
This afternoon the mood was vinegar.	low	same	1	low
That actress is a peacock.	low	same	2/3	low

Procedure

Participants signed an informed consent form and read experiment instructions on a PC computer screen. They were seated at a comfortable viewing distance from a 15 inch computer monitor. They performed judgments on 6 practice metaphors and then 124 experimental metaphors. For each sentence participants saw a fixation symbol (+) in the middle of the screen for 400 ms, then the sentence, also presented centrally, until they responded. Participants judged whether the sentence was easy or hard to understand by pressing 1 or 2 on the numeric keypad of the computer keyboard. The 400 ms inter-trial interval was selected based on the desire to tap into automatic attentional mechanisms rather than the more controlled processing that takes place at longer intervals (Chiarello, 1991).

Results and Discussion

Response Times

For the reaction time data, a 2x2 MANOVA was conducted with the factors of Level Repetition (Same or Different) and Familiarity (High or Low). This resulted in a significant effect of Familiarity, $F(1,29) = 80.5, p < .001$ and a Level Repetition x Familiarity interaction, $F(1,29) = 12.6, p = .001$, as seen in Figure 15. For the factor of Familiarity, The High Familiarity condition ($M = 2142$ ms) showed a faster response time than the Low Familiarly condition ($M = 2613$ ms), as would be expected given that Low Familiar metaphors are more difficult to understand. The interaction will be discussed further below.

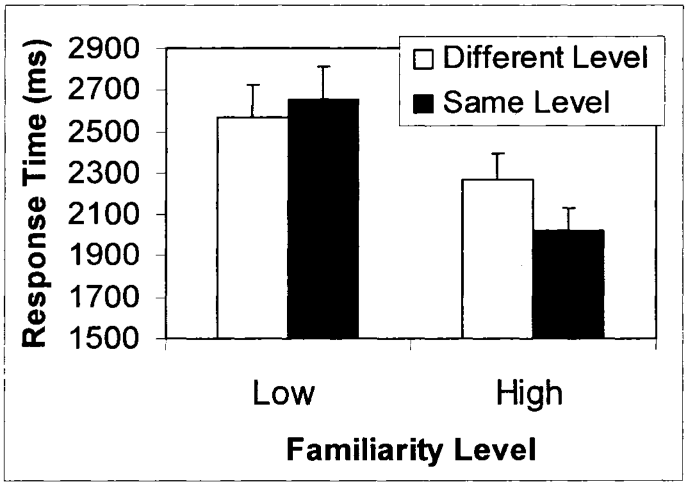

***Figure 15.* Experiment 3 results. Response times to High and Low Familiar metaphors when preceded by the Same or Different level of familiarity. Error bars reflect standard errors.**

Contrary to what was hypothesized, there was no effect of Level Repetition. In order to further explore patterns of responding over several trials, the additional factor of Repetition Number was added to the analysis. A 2x2x2 MANOVA was conducted with the factors of Level Repetition (Same or Different), Familiarity (High or Low), and Repetition Number (First or Second/Third). Significant effects and interactions are depicted in Figure 16 and Table 3.

This analysis contributed further findings: a significant effect of Repetition Number and interactions of Repetition Number amount with Level Repetition and with Familiarity. The effect of Repetition Number was such that the Second/Third repetition (M = 2331 ms) of either the Same Level Repetition or the Different Level Repetition was faster than the First repetition (M = 2419 ms) of these Level Repetitions. This effect is primarily driven by the Same Level Repetition, since the interaction between Level Repetition and Repetition Number was significant. Paired sample t-tests indicate that at the First repetition, there is no reaction time difference between the Same (M = 2386 ms)

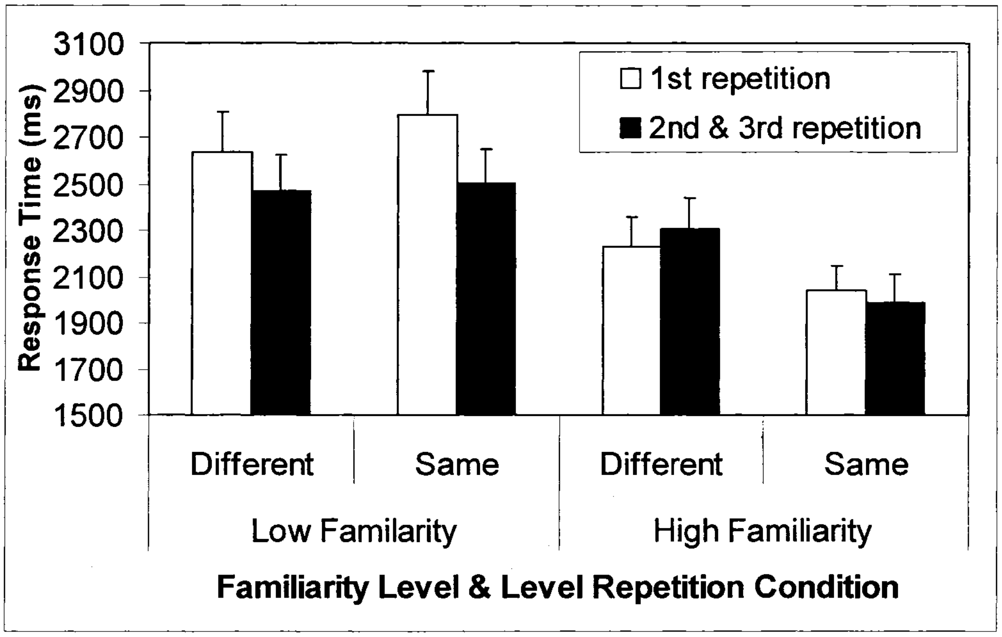

Figure 16. **Experiment 3 results. Response times to High and Low Familiar metaphors when preceded by the *same* or *different* level of familiarity based on Repetition Number. Error bars reflect standard errors.**

Table 3. **Reaction time data showing significant results from Experiment 3 based on a 2x2x2 MANOVA with Level Repetition of Same or Different.**

Effect	**Wilks' λ**	***F***	**DF**	**Sig.**	**Partial η^2**
Familiarity	0.27	78.7	1,29	0.000	0.73
Repetition Number	0.55	23.4	1,29	0.000	0.45
Level Repetition x Familiarity	0.68	13.7	1,29	0.001	0.32
Level Repetition x Repetition Number	0.82	6.2	1,29	0.019	0.18
Familiarity x Repetition Number	0.66	14.7	1,29	0.001	0.34

and Different ($M = 2453$ ms; $p > .05$) conditions. However at the Second/Third repetition, the Same condition ($M = 2277$ ms) is significantly faster than the Different condition ($M = 2382$ ms; $t(29) = 2.3, p < .05$). Having a sequence of three or four Different trials in a row (i.e. switching back and forth between High and Low Familiarity) results in *small* decreases in processing times over the sequence. However, having a sequence of three or four Same trials in a row (i.e. four High trials in a row or four Low trials in a row) results in *larger* decreases in processing times over the sequence. A paired samples *t*-test revealed that the difference in processing times between the First ($M = 2797$ ms) and Second/Third ($M = 2606$) repetition of a Low Familiarity level is significantly different, $t(29) = 3.9, p < .001$.

This pattern is also supported by the interaction between Repetition Number and Familiarity Level. There was no difference between processing times at the First ($M =$ 2123 ms) and Second/Third ($M = 2166$ ms; $p > .05$) repetitions for the High Familiarity level, but for the Low Familiarity level, there was faster processing for the Second/Third repetition ($M = 2490$ ms) than there was for the First repetition ($M = 2714$ ms; $t(29) =$ $4.4, p < .001$). Thus there was facilitation of processing after two or three Low trials in a row. Consequently, based on the two interactions discussed above, the Second/Third repetition results in faster processing for Low Familiarity trials in the Same condition – Low Familiarity trials that follow two or three preceding Low Familiarity trials. This suggests that there is a "delayed" level repetition effect that only manifests itself at the third or fourth repetition of a level. Thus the level repetition effect may simply be delayed to the third or fourth occurrence of a level.

The Level Repetition x Familiarity interaction indicates that following a High Familiarity trial, having the Same level results in faster processing, but having the Same level following a Low Familiarity trial results in slower processing. In other words, it appears that following a High Familiar trial induces a facilitory effect on processing speed. To further explore this observation, the Level Repetition variable was reconceptualized based on whether the preceding level was a High or Low level of familiarity, rather than whether it was the Same or Different level of familiarity, resulting in a Preceding Level priming type variable. This conceptualization of the preceding level variable eliminates the existence of an interaction in the results. A 2x2 MANOVA was then conducted with the factors of Preceding Level (After High or After Low) and Familiarity (High or Low). This resulted in significant effects of Familiarity, $F(1,29) = 80.5, p < .001$, as before, and Preceding Level, $F(1,29) = 12.6, p = .001$. Figure 17 depicts the data from this conceptualization, both with and without the Repetition Number factor. While this MANOVA does not provide any additional statistical analysis than the original MANOVA, but simply renames each effect and interaction, it is included to provide additional clarity and understanding of the pattern of data.

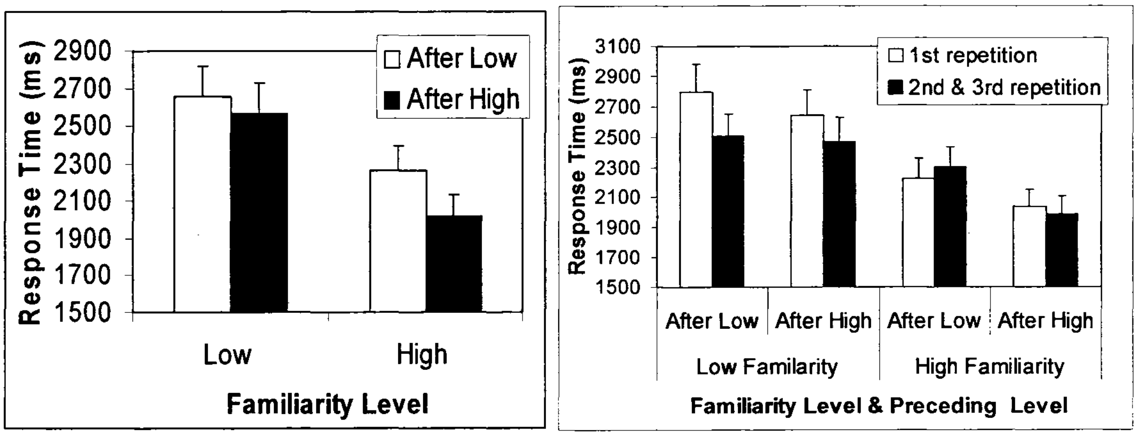

Figure 17. **Experiment 3 Response times based on the reconceptualized Preceding Level variable, collapsed across Repetition Number (on the left) and including the Repetition Number variable (on the right). Error bars reflect standard errors.**

The After High condition (*M* = 2295 ms) showed a faster response time than the After Low condition (*M* = 2462 ms). This finding suggests that, unlike the visual information explored in the local-global literature (Robertson, 1996), semantic information does not show faster processing when following a trial of similar level of familiarity. Rather, there seems to be a context effect based on following a trial of high familiarity.

Responses

Overall rates of positive responses ("sentence is easy to understand") are depicted in Figure 18. Response data were subjected to a 2x2x2 MANOVA with factors of Level Repetition (Same or Different), Familiarity (High or Low) and Repetition Number (First or Second/Third). This resulted in all possible effects and interactions being significant, with details outlined in Table 4 and depicted in Figure 18. The High Familiarity condition ($M = 92\%$) showed a higher rate of positive responses than the Low Familiarly condition ($M = 55\%$), as would be expected given that Low Familiar metaphors are more difficult to understand.

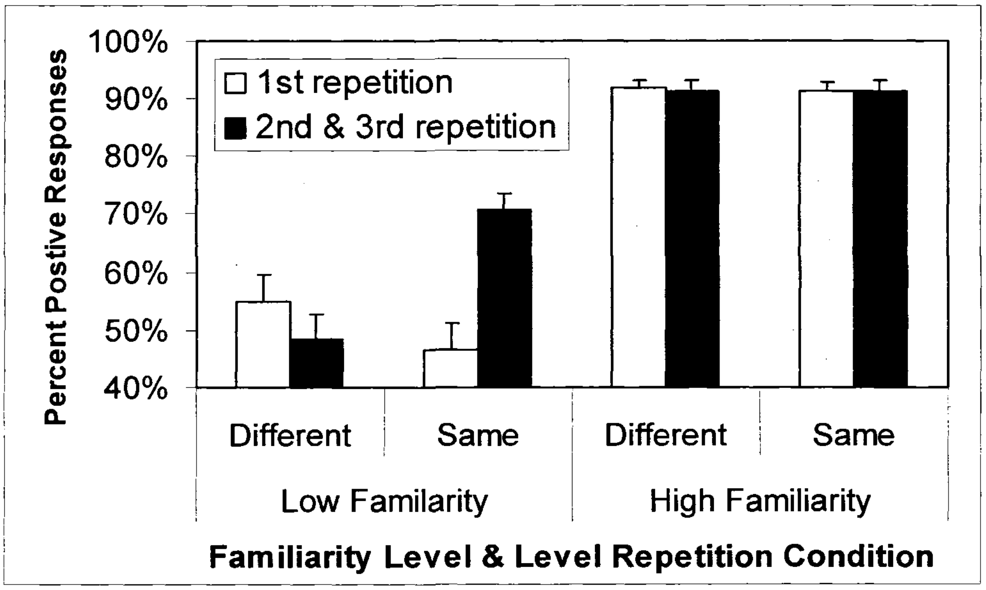

***Figure 18.* Rates of positive responses ("sentence is easy to understand") from Experiment 3. Error bars reflect standard errors.**

In this experiment, participants judged how easy the metaphorical sentences were to understand, thus making a metacognitive judgment about their own understanding of the sentences. Thus any differences in their responses reflect the underlying ease which they perceived themselves having in understanding the stimuli. Although the effect was

Table 4. **Response data results from Experiment 3 based on a 2x2x2 MANOVA with Level Repetition of Same or Different.**

Effect	**Wilks' λ**	***F***	**DF**	**Sig.**	**Partial η^2**
Level Repetition (Same or Different)	0.84	5.5	1, 29	0.026	0.16
Familiarity	0.19	121.4	1, 29	0.000	0.81
Repetition Number	0.78	8.3	1, 29	0.007	0.22
Level Repetition x Familiarity	0.84	5.7	1, 29	0.024	0.16
Level Repetition x Repetition Number	0.50	29.5	1, 29	0.000	0.50
Familiarity x Repetition Number	0.68	13.9	1, 29	0.001	0.32
Level Repetition x Familiarity x Repetition Number	0.35	53.5	1, 29	0.000	0.65

not large (partial $\eta^2 = .16$) participants indicated a higher level of understanding following a trial at the Same level of familiarity (*M* = 75%) than at a Different familiarity level (*M* = 72%), as depicted in Figure 19. Perceived understanding increased over a series of Same or Different trials, with the Second/Third repetition (*M* = 76%) showing a higher rate of positive responses than the First repetition (*M* = 71%). This finding is consistent with the level repetition effect in the local-global vision literature. However, since the measure involves a metacognitive judgment rather than response time, which is not metacognitive, a direct comparison is not possible.

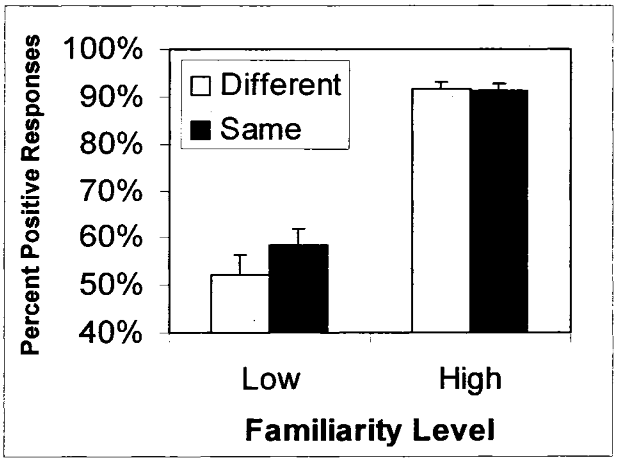

Figure 19. **Rates of positive responses ("sentence is easy to understand") from Experiment 3, collapsed across the Repetition Type variable. Error bars reflect standard errors.**

A visual examination of the patterns of the three-way interaction in Figure 18 suggests the possibility that the responses for High Familiarity metaphors are at ceiling, resulting in no effects or interactions. Thus the three-way interaction essentially consists of a Level Repetition x Repetition Number interaction that exists only for the Low Familiarity trials, and not the High Familiarity trials. This observation is borne out statistically. MANOVAs performed with these two factors on the High and Low Familiarity data sets separately resulted in main effects of Level Repetition, $F(1,29) = 7.0, p = .01$, Repetition Number, $F(1,29) = 14.6, p < .001$, and an interaction for the Low Familiarity data, $F(1,29) = 46.5, p < .001$, but no effects or interactions for the High Familiarity data (Fs < 1). Thus for the Low Familiar metaphors, the facilitative effect of the Second/Third repetition as compared to the First repetition exists for the Same condition, but the opposite pattern is found for the Different condition.

In other words, in the Different condition, having a sequence of two High Familiarity trials before the Low Familiarity trial results in a higher rate of reported understanding ($M = 55\%$) than having a Low then a High Familiarity trial before the Low Familiar trial ($M = 48\%$; $t(29) = -2.4, p < .05$, paired sample t-test). But in the Same condition, having a sequence of two Low Familiarity trials before the measured Low Familiarity trial results in a higher rate of reported understanding ($M = 71\%$) than having a High, then a Low Familiarity trial before the Low Familiar trial ($M = 47\%$; $t = 6.7, p < .001$, paired sample t-test). These finding suggest that there is a cost to switching back and forth between High and Low Familiarity trials, but that having three or four Low Familiar trials in a row results in higher understanding on the last two trials.

As with the response time data, the Level Repetition variable was reconceptualized based on whether the preceding level was a High or Low level of familiarity, rather than whether it was the Same or Different level of familiarity. 2x2x2 MANOVA was conducted comparing response latencies with the factors of Preceding Level priming type (After High or After Low), Familiarity (High or Low), and Repetition Number (First or Second/Third). Additional significant effects and interactions based on the reconceptualization are depicted in Table 5. However, the reader is reminded that these do not add any statistical information to the previous analysis, but simply reorder the data in order to provide a fuller picture of the patterns.

Table 5. **Additional response data results from Experiment 3 based on a 2x2x2 MANOVA with Preceding Levels of High or Low. Findings for Familiarity and Repetition Number factors and their interaction are, of course the same as in the previous analysis.**

Effect	**Wilks' λ**	***F***	**DF**	**Sig.**	**Partial η^2**
Preceding Level (High or Low)	0.84	5.7	1, 29	0.024	0.16
Preceding Level x Familiarity	0.84	5.5	1, 29	0.026	0.16
Preceding Level x Repetition Number	0.35	53.5	1, 29	0.000	0.65
Preceding Level x Familiarity x Repetition Number	0.50	29.5	1, 29	0.000	0.50

With this reconceptualization, trials following a Low Familiarity trial (*M* = 75%) showed a higher rate of reported ease of understanding than those following a High Familiarity trial (*M* = 72%). This seems counterintuitive at first glance, and is not in concordance with the reaction time data for the same comparison, which shows faster responding after High Familiar than after Low Familiar. However, this finding is plausible when one considers that some of the sentences in the Low Familiarity condition are so obscure they would make any following sentence look comprehensible in comparison. After an easy or familiar sentence, anything will seem hard and vice versa.

This pattern could be called a contrast effect, and further analyses support this interpretation.

Visual inspection of the data broken down by Familiarity Level and Preceding Level (After High/After Low) as depicted in Figure 20 suggests that this finding may be caused by a high level of understanding for a Low trial following a Low trial. This is again consistent with the contrast effect described above. These data were collapsed across the Repetition Number variable, since this variable only makes sense in the context of the original Level Repetition variable which had levels of Same or Different. The new Preceding Level (High/Low) variable has no meaning in conjunction with the Repetition Number variable, since the later is tied to sequences of Same or Different trials, information which is no longer available in this new reconceptualization.

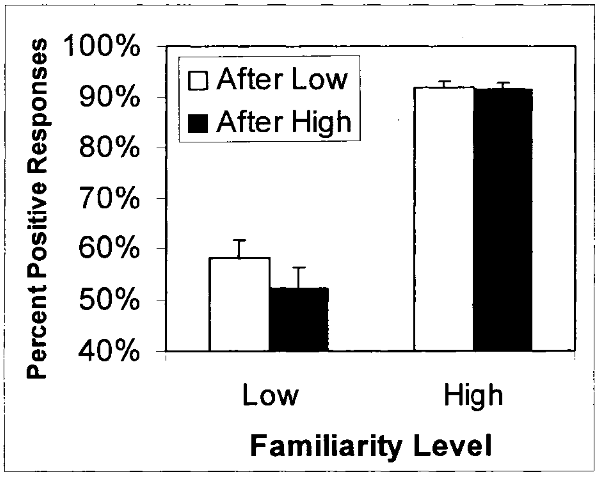

Figure 20. **Rates of positive responses ("sentence is easy to understand") from Experiment 3 based on the reconceptualized Preceding Level variable, and collapsed across Repetition Number. Error bars reflect standard errors.**

A 2x2 MANOVA carried out on these data confirms the visual observation described above, showing a trend toward an interaction between Familiarity Level and the reconceptualized Preceding Level (High/Low), $F(1,29) = 4.0, p = .06$. This finding is consistent with the 3 way interaction in the original response data analysis. Thus it is the case that there is not a facilitory effect of following a Low Familiar trial in general, but rather this general finding is caused by the especially strong effect of a Low trial following a Low trial. This again is consistent with the notion of a level repetition effect such that a Low Familiar metaphor is easier to understand when immediately following another Low Familiar metaphor.

Experiment 3 Discussion and Summary

Both the reaction time data and the response data converge on the idea that there is some influence of a preceding level of familiarity on the current processing of a metaphorical sentence. However, this influence is not parallel to the level repetition effect found in the visual local-global literature, since there was no evidence of faster sentence processing following a trial at the same level of familiarity, as is found in the local-global literature. Rather, there was evidence for a facilitory context effect, with lower response times for both High and Low Familiar metaphors following a trial of high familiarity. Further examination of the data revealed that there was a reaction time facilitation of processing after two or three sequential trials that were the same (either High or Low). A "level repetition effect" may simply be delayed to the third or fourth repetition of a level while the facilitory context effects of following a High Familiar trial appear on the second repetition.

Participant responses indicated that their perceived understanding increased over a series of Same trials. This finding is consistent with the level repetition effect in the local-global vision literature, since it began with the first repeat of a familiarity level, and thus shows better understanding of a metaphor when it follows a metaphor at the same level of familiarity. The context effect found with the reaction time data seemed to show an opposite effect with the response time data, with better understanding of a sentence following a Low Familiar trial than a High Familiar trial. This can be explained by a contrast effect, whereby any trial following a Low Familiar trial seems easier to understand in contrast.

The common finding across reaction time and response data is the facilitation that occurred with several sequential Low Familiar trials, in terms of faster responding and better understanding. While this is similar to the level repetition effect in the vision local-global literature, it also differs in several respects. There was a reaction time facilitation following a High Familiar trial, but not a single repetition of a Low Familiar trial as with the level repetition effect. These results are not consistent with an attentional explanation, since the effect was not the same for High Familiarity trials.

One possibility is that a spreading activation explanation better explains the results. Determining the meaning of a sentence may in part depend on finding a semantic link between the words in the sentence. Finding this link may depend on a spreading activation mechanism. For example, to understand the metaphor *A camel is a desert taxi*, it is necessary to find a semantic link between *camel* and *taxi* (they can both be means of transportation). This link may be found by finding an overlap in the spreading activation network of the two words. Closely related words (in more familiar stimuli) are likely to require less spreading activation in order for understanding to take place than more than less closely related words (in less familiar stimuli). It thus may take more time for spreading activation networks to become activated and find a semantic overlap for the latter. Thus less familiar sentences may also take longer to return to baseline, and result in interference for the next trial.

Experiment 4: Word Pairs

If a spreading activation explanation can be applied to the results in Experiment 3, this would suggest that a similar pattern should also occur in a simpler context where only word pairs are used. Priming with word pairs is the traditional method for exploring the nature of the spreading activation network (Neely, 1991). Thus the purpose of Experiment 4 is to determine if the patterns found with sentence level stimuli in Experiment 3 can be generalized to word-level stimuli. Pairs of words that were closely or distantly related (based on word association norms (Nelson et al., 1998), were presented in a prime-target paradigm; participants indicated whether they thought the words were closely related or not. It was predicted that trials preceded by the same level of semantic association will be processed faster than those at a different level. This would support the notion that the semantic attentional system is capable of directing attention based on the level of semantic relatedness.

Method

Participants, Stimuli and Design

Participants from Experiment 3 also participated in Experiment 4, which was completed immediately before Experiment 3 for all participants. Stimuli were prime-target word pairs based on association norms (Nelson et al., 1998) with Low (forward association strength $M = .014$, $SD = .001$, range .010 to .018) or High (forward association strength $M = .48$, $SD = .13$, range .30 to .85) levels of semantic association. Target words for each group did not differ in terms of word frequency or concreteness (*p*s

> .05). Each participant saw the same 120 prime words, however the assignment of a Low or High Association strength target was counterbalanced among participants such that for each prime word (*cigar*) half the participants saw the Low Association target (*pipe*) and half saw the High Association target (*smoke*). See Table 6 for sample stimuli. Response latencies in each trial were compared based on the semantic association level of the preceding trial. One condition consisted of trials where the semantic level (Low or High) was the same in the preceding trial; the second condition consisted of trials where the semantic level was different.

***Table 6*. Sample stimuli used in Experiment 4.**

Counterbalancing List A				**Counterbalancing List B**			
Prime	**Target**	**Assoc Level**	**Level Repetition**	**Prime**	**Target**	**Assoc Level**	**Level Repetition**
acre	**land**	**high**	n/a	abdomen	stomach	high	n/a
joke	laugh	high	same	adult	child	high	same
satin	sheen	low	different	**acre**	**property**	**low**	different
liberty	freedom	high	different	days	nights	high	different
feather	bird	high	same	ballot	vote	high	same
walk	run	high	same	**cigar**	**smoke**	**high**	same
majority	minority	high	same	**coral**	**reef**	**high**	same
genuine	good	low	different	actor	male	low	different
cigar	**pipe**	**low**	same	bake	food	low	same
coral	**spring**	**low**	same	ballet	girl	low	same

Procedure

Participants signed an informed consent form and read experiment instructions on a PC computer screen. They were seated at a comfortable viewing distance from a computer monitor. They performed judgments on 6 practice word pairs and then 120 experimental word pairs. For each word pair, participants viewed a fixation cross for 400 ms, the prime for 150 ms, the fixation for 150 ms and then the target for 150 ms, all centrally presented. They were then prompted to respond by pressing 1 if they thought the two words were closely related and 2 if they were not as closely related. This task ensured that the participants were actually engaging with the semantic content of the words. However, this is not a metacognitive task as in Experiment 3. The inter-trial interval of 400 ms was deliberately chosen to be the same as that in Experiment 3.

Results and Discussion

Response Times

For the reaction time data, a 2x2 MANOVA was conducted with the factors of Level Repetition (Same or Different) and Association (High or Low). This resulted in a significant effect of Association, $F(1,29) = 31.8, p < .001$ and a Level Repetition x Association interaction, $F(1,29) = 9.2, p < .01$, as seen in Figure 21. For the factor of Association, the High Association condition (877 ms) showed a faster response time than the Low Association condition (1035 ms); this seems plausible since it is likely to take less time to process word pairs that are more closely related. The interaction will be discussed further below.

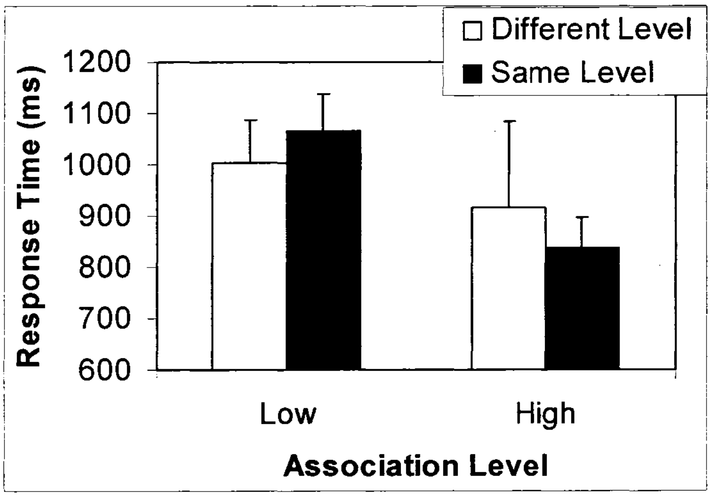

***Figure 21.* Experiment 4 results. Response times to High and Low Association word pairs when preceded by the Same or Different level of association. Error bars reflect standard errors.**

Again, contrary to what was hypothesized, there was no effect of Level Repetition. In order to further explore patterns of responding over several trials, the additional factor of Repetition Number was added to the analysis. A 2x2x2 MANOVA was conducted with the factors of Level Repetition (Same or Different), Association Level (High or Low), and Repetition Number (First or Second/Third). This resulted in a significant effect of Association Level, $F(1,29) = 28.6, p < .001$,and a significant Association Level x Level Repetition interaction, $F(1,29) = 8.6, p < .01$. The Association Level x Repetition Number interaction approached significance, $F(1,29) = 3.2, p = .09$. See Figure 22.

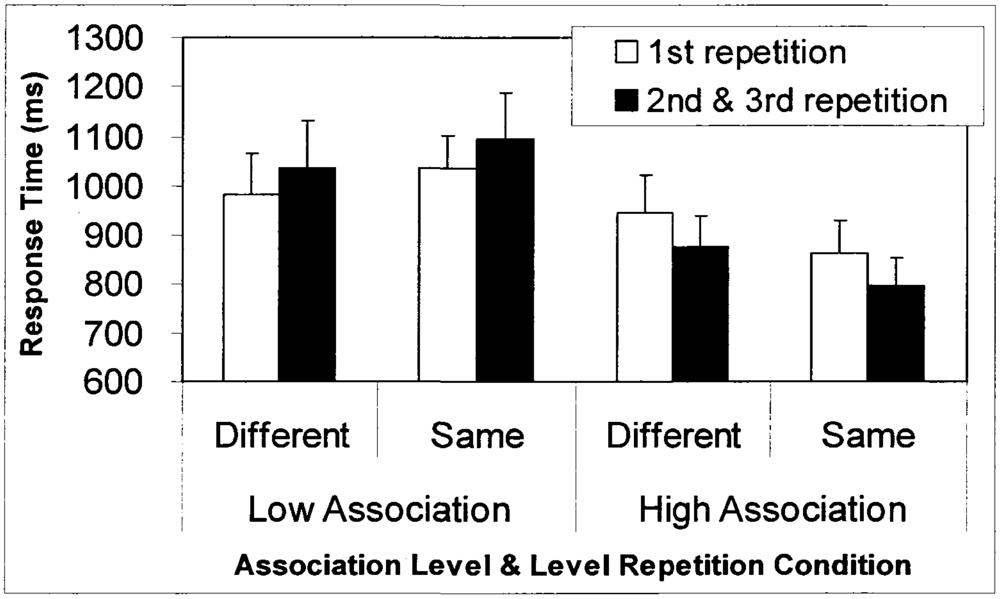

Figure 22. **Experiment 4 results. Response times to High and Low association word pairs when preceded by the Same or Different level of association. Error bars reflect standard errors.**

The Level Repetition variable was reconceptualized based on whether the preceding level was a High or Low level of Association, rather than whether it was the Same or Different level of association. A 2x2x2 MANOVA was conducted comparing response latencies with the factors of Preceding Semantic Level priming type (High or

Low), Association (High or Low), and Repetition Number (First or Second/Third). This resulted in a main effect of Preceding Level, $F(1,29) = 8.6, p < .01$. The After High condition (921 ms) showed a faster response time than the After Low condition (991 ms).

These results parallel those of Experiment 3. Again, the predicted "level repetition" effect was not found with the reaction time data: trials were not faster when following a trial of the same association level than a trial of a different association level. Rather, an interaction was observed such that both High and Low Association trials following a High Association trial were faster than respective High and Low Association trials following a Low Association trial. In other words, when the Level Repetition variable was reconceptualized based on whether a trial followed a High or Low Association trial (rather than the Same or a Different level of association), there was a significant facilitation effect based on following a High Association trial. This finding again suggests that, unlike the visual information explored in the local-global literature (e.g., Robertson, 1996), semantic information does not show faster processing when following a trial of similar level of association. Rather, there seems to be some sort of context effect based on following a High Association trial.

There are some differences between these results and those of Experiment 3. A visual inspection of the figures suggests that in the current experiment, repetition makes people slower for Low Association words whereas in Experiment 3, participants were faster after repetition of Low Familiar metaphors. This is demonstrated statistically as a trend, with a Level Repetition x Repetition Number MANOVA on the Low Familiarity data only revealing a marginal effect of Repetition Number, $F(1,29) = 2.2, p = .15$. Thus in Experiment 3 there was a difference with faster responding with repetition of Low familiarity sentences, while there was no statistical difference in response latencies in Experiment 4 across repetitions of Low association word pairs, and even a trend towards slower responding.

Responses

Overall rates of positive responses ("words are closely related") are depicted in Figure 23. Response data were subjected to a 2x2x2 MANOVA with factors of Level Repetition (Same or Different), Association Level (High or Low) and Repetition Number (First or Second/Third). This resulted in a significant effect of Association Level, $F(1,29) = 88.7, p < .001$, and a significant Level Repetition x Association Level x Repetition Number interaction, $F(1,29) = 5.0, p < .05$. The Level Repetition x Association Level interaction approached significance, $F(1,29) = 4.1, p = .05$. The High Association Level condition (81%) showed a higher rate of positive responses than the Low Association Level condition (53%), indicating that the judgments of the participants in the current study were similar to those participating in the association norm experiments, as would be expected.

The Level Repetition variable was again reconceptualized based on whether the preceding level was a High or Low level of Association, rather than whether it was the Same or Different level of Association. A 2x2x2 MANOVA was conducted comparing response latencies with the factors of Preceding Semantic Level priming type (High or Low), Association Level (High or Low), and Repetition Number (First or Second/Third). This resulted in trend towards a main effect of Preceding Level, $F(1,29) = 4.1, p = .05$ and a significant Preceding Level x Repetition Number interaction, $F(1,29) = 5.0, p < .05$. The After High condition (68.3%) showed a higher rate of positive responses than the After Low condition (65.5%). This suggests that once participants see one word pair as being closely related, they tend think the next pair is close also. This could be called a similarity effect, and is the opposite pattern to the contrast effect found in Experiment 3.

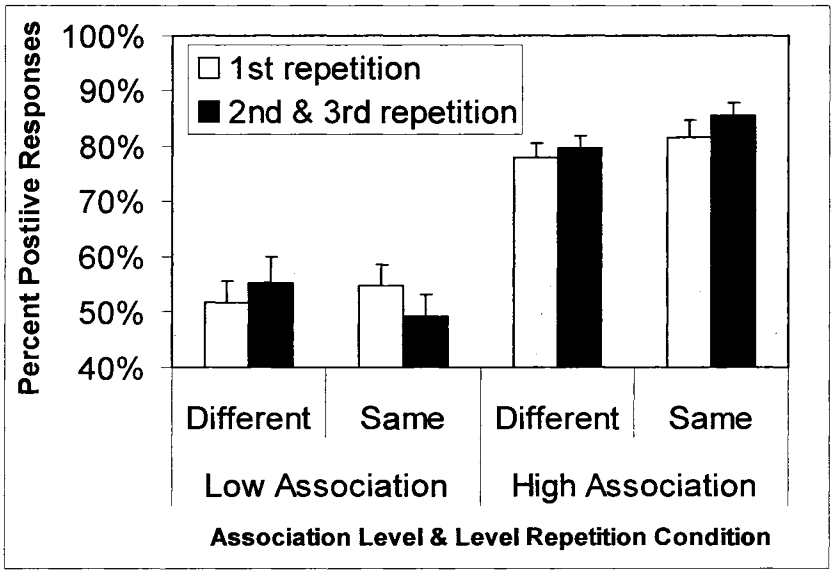

***Figure 23.* Rates of positive responses to word pairs ("words are closely related") from Experiment 4, separated by Association Level. Error bars reflect standard errors.**

The three-way interaction in the initial analysis was indicative of three 2-way interactions that existed only on one of two levels. First, the Level Repetition x Repetition Number interaction appears upon visual inspection of Figure 23 to occur only for the Low Association trials. MANOVAs performed with these two factors on the High and Low Association data sets separately revealed a trend towards an interaction for the Low Association data, $F(1,29) = 3.5, p = .07$, but no interaction for the High Association data ($F < 1$). Thus for the Low Association word pairs, higher perceived word pair relatedness for the Second/Third repetition as compared to the First repetition exists for the Different condition, but the opposite pattern is found for the Same condition. In other words, participants rated the third or fourth sequential Low Association trial as being less related that the second sequential Low Association trial. This is the opposite interaction for the Low Association trials of that which was found for the sentences in Experiment 3.

Separate MANOVAs for First and Second/Third Repetitions revealed that the interaction between Level Repetition and Association level, which is also significant on its own in the main analysis, existed only for the Second/Third repetition, $F(1, 29) = 10.3, p < .01$, but not the First repetition ($F < 1$), as seen in Figure 24. This way of representing the three-way interaction again highlights the fact that for Low Association word pairs, participants were more likely to indicate that they were not as related after two or more repetitions of Low Association word pairs. This pattern was not true for the first repetition of an association level or for subsequent repetitions of a High Association level. This suggests that after participants see several pairs in a row that seem unrelated, everything seems unrelated. Again, this is a similarity effect rather than a contrast effect as was seen in Experiment 3.

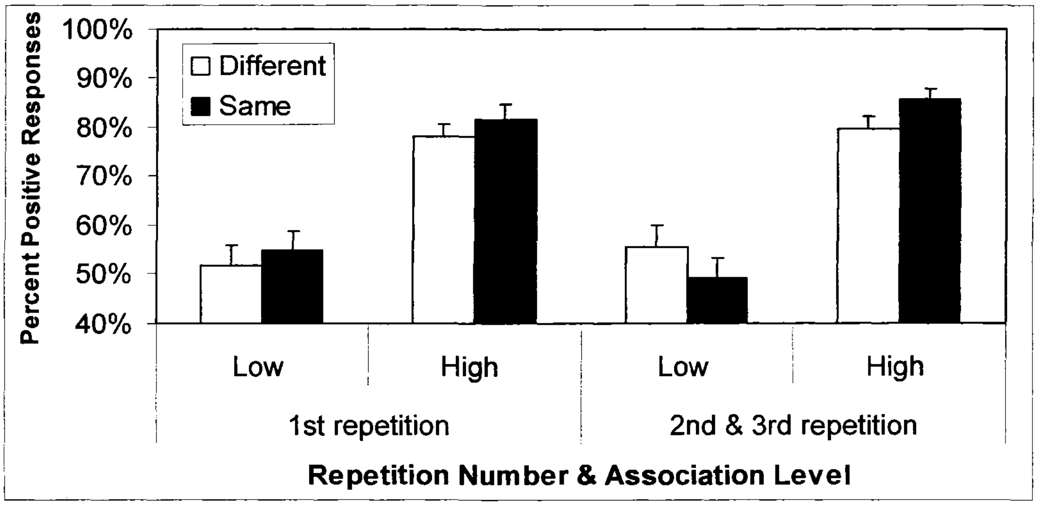

***Figure 24.* Rates of positive responses to word pairs ("words are closely related") from Experiment 4, separated by Repetition Number.**

A third set of MANOVAs for the Different and Same conditions revealed that the interaction between Repetition Number and Association type existed only for the Same condition, *F*(1.29) = 6.0, *p* > .05, but not the Different condition (*F* < 1), as seen in Figure 25. This again confirmed that pattern of higher relatedness ratings for the Second/Third repetition, except for the Low Association condition with the Second/Third Same condition, such that repeated levels of Low Association resulted in a lower relatedness score.

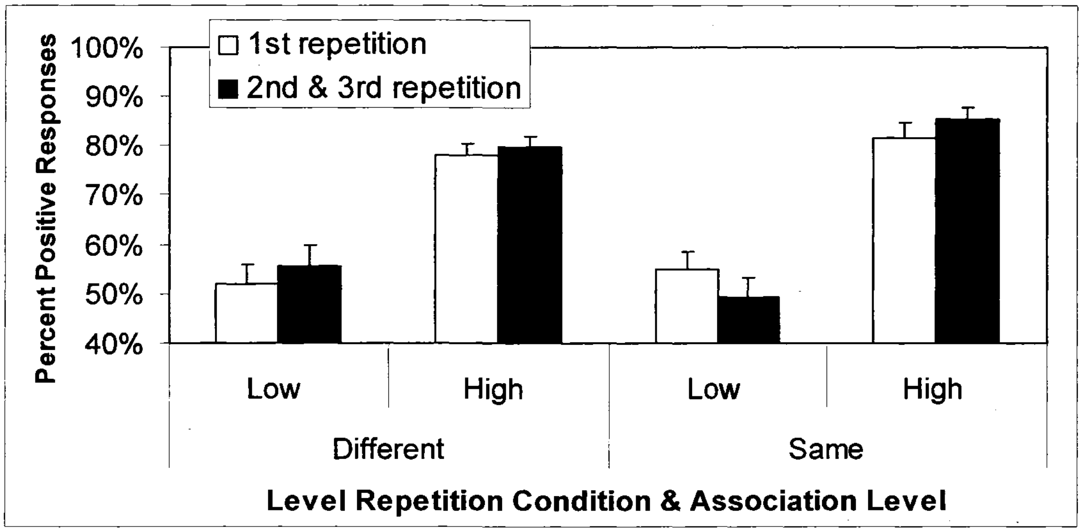

***Figure 25.* Rates of positive responses to word pairs ("words are closely related") from Experiment 4, separated by Level Repetition variable. Error bars reflect standard errors.**

Experiment 4 Discussion and Summary

The reaction time results display a similar pattern as was found with words in Experiment 3, providing clear evidence that the patterns can be generalized to word pair priming. This is a striking parallel, given that the two tasks are so different, and suggests that some underlying function must underlie both tasks. What interpretation can then be applied to explain these results? The level repetition effect could potentially be operating with the High Familiarity/Association trials with both the metaphor and the word pair experiments, but this pattern certainly does not extend to the Low Familiarity/Association trials. Rather than resorting to a level repetition explanation of the results and attempting to link these results to the level repetition effect in visual local-global processing, it may be more parsimonious to conceptualize these findings in terms of the type of preceding trial as was done in Experiment 3 with the sentences, where trials following a familiar trial were faster than those following an unfamiliar trial. Again what we then have is not priming based on a Level Repetition, but a facilitation effect based on following a High Familiarity trial, and this is the clearest and strongest effect seen in the current experiment.

Unlike the reaction time data, findings for responses did not converge between the two experiments. Both Experiments 3 and 4 resulted in an interaction between Level Repetition and Association level for the Low Association word pairs, but it was in opposite directions. In Experiment 4, there were more word pairs reported to be closely related after the Second/Third repetition as compared to the First repetition in the Different condition, but the opposite pattern was found for the Same condition. Thus Low Association word pairs were judged to be not as related after several sequential Low Association trials. This reflects a similarity effect in the current experiment, which is essentially the opposite of the contrast effect in Experiment 3 with the metaphors.

Another difference in the response data between the two experiments is the pattern of responses from the perspective of the reconceptualized Preceding Level variable with levels of After High and After Low (rather than Same or Different). With the word pairs, (unlike the sentence level data in Experiment 3), there was a higher reported rate of closely related word pairs in the High Association category with an After High trial. In other words, a High trial following a High trial was judged easier to understand than following a Low trial. Figure 26 shows this pattern, which can be compared with the Experiment 3 data in Figure 20. Here it can be seen that in Experiment 3 there was a facilitation After High in the Low condition rather than in the High condition as in Experiment 4.

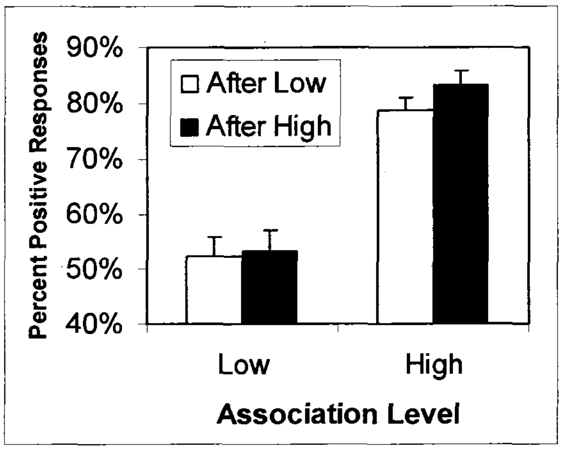

Figure 26. **Rates of positive responses ("words are closely related") from Experiment 4 based on the Preceding Level variable, and collapsed across Repetition Number. Error bars reflect standard errors.**

The reason for this finding and the difference between the experiments may have to do with the type of task involved. For the sentences, making a metacognitive judgment about whether the sentence was easy or difficult to understand may have resulted in more understanding after several Same trials. However, the current task only involved judging whether the words were closely related or not, but not making a judgment about the ease of understanding. While such a judgment could be implicit in the task, it is more likely that it simply involves a judgment about the stimuli themselves rather than a self-referential judgment.

Thus in the Different condition, after switching back and forth between High and Low Association word pairs a few times, the participants were more likely to judge a word pair as being closely related when it was not. But in the Same condition, participants were more likely to judge a word pair as being less closely related after there had been several Low Association word pairs in a row.

Part 2 General Discussion

The reaction time findings of Experiments 3 and 4 suggest that, unlike the visual data explored in the local-global literature (Robertson, 1996), semantic data does not show faster processing when immediately following a trial of similar level of familiarity or association. This rules out an attention-based explanation for the priming effects found here. With the local-global level repetition effect, it is hypothesized that attention to the different hierarchical levels (local or global) accounts for the effect. This clearly could not be the case for the different familiarity/association levels in the current situations, since the effect was only seen following High Familiarity and High Association trials. This provides converging support for the idea that semantic processing is faster following a trial with more closely related words, whether they are in a sentence context or simply a pair of words.

One possible explanation for the results in Part 2 is a simple pacing effect. When participants are fast on one trial, they may be more likely to be fast on the next trial, and vice versa. Thus being faster following a High Association trial and slower following Low Association trial would have a very simple explanation. This explanation is consistent with the findings in Part 1, where participants who saw a range of metaphors that were only low or medium in familiarity were slower on the Medium Familiar metaphors than participants who saw a wider range of familiarity. If this explanation can account for the results in Part 2, then it would not be necessary to rely on a semantic processing explanation, and the models and theories discussed here would be superfluous. However, this explanation is not sufficient to fully explain the pattern of results in the current set of experiments. For example, in Experiment 3, participants were significantly faster on the second/third repetition of a Low Familiarity trial than on the first repetition. This cannot be explained by a simple pacing effect, since it cannot provide an explanation for increased efficiency over a series of Low Familiar sentences. A more powerful model will be covered in the *General Discussion.*

CHAPTER 4: GENERAL DISCUSSION

The current set of experiments tested the view that there are mechanisms common to visual processing and semantic processing, and these mechanisms relate to general properties of the right and left hemispheres. Two properties of local-global visual processing were tested with semantic stimuli to determine if the properties would apply to both the visual and semantic domains.

In Part 1 the property explored was that the local-global distinction between the left and right hemispheres is relative rather than absolute, based on the properties of the stimulus set (Robertson & Ivry, 2000). It was not possible to confirm the same pattern of relative differences between left and right hemisphere processing with semantic stimuli. Metaphors of medium familiarity did not show different patterns of lateralization, depending on whether they were processed in the stimulus context of high versus low familiarity metaphors. However, additional properties of right hemisphere language comprehension were revealed. Results indicated that it is necessary to have a broad range of familiarity in a stimulus set in order to obtain a right hemisphere advantage for low familiar metaphors.

In Part 2, the property explored was that priming occurs based on the level of processing (local or global; Robertson, 1996). In other words, the immediately preceding stimulus context influences current processing. A strong effect of preceding trial was obtained, but it was based on following a High Association trial, rather than following a trial at the same level of association. For the sentential stimuli, a delayed level repetition effect was obtained, showing faster processing of Low Familiar metaphors following several sequential Low Familiar trials.

There are two possible interpretations of the findings presented here. The first is to conclude that there may yet be a connection between local-global visual processing and fine-coarse semantic processing, but it was not possible to demonstrate that it exists with the current experiments. In other words, the current null results are not definitive. This could be due to inherent difficulties in working with semantic stimuli, for example controlling for word frequency effects. The second possibility is that there actually is no connection between local-global visual processing and fine-coarse semantic processing. In this case, any similarities that were detected between the two modalities would reflect only surface similarities, but not shared mechanisms that could describe overall differences in left vs. right hemisphere function. These two interpretations will be systematically explored in what follows.

Yes, there is a Connection, but it is Hard to Find

Although the current set of experiments did not find the hypothesized link between visual and semantic processing, it could still be that there is some sort of underlying neural mechanism common to the two domains which is difficult to find. The functionalist view of cognition suggests that sometimes processes can be the same on an algorithmic level yet differ in implementation. If so, there are interesting similarities between visual and semantic processing even if not all the details are the same.

Whatever connection there may be between visual and semantic processing, the current experiments demonstrate that it would be very difficult to find. One possible reason for the failure to find a level repetition effect/double filtering by frequency effect in these experiments may have to do with the many inherent differences between the visual tasks in the local-global literature and the semantic tasks used here. Many of these are inherent to the tasks, and cannot be changed. Hemispheric asymmetries are explored using the divided visual field technique in both the visual and semantic domains. However, that is where the similarity ends. In the visual domain, various tasks have been tried with varying degrees of success. It appears that a task that simply requires participants to detect various spatial frequencies does not result in the required hemisphere by frequency interaction, whereas an identification task does (e.g. identify "thick bars" vs. "thin bars"). Increased computational complexity appears to be what is required (discussed in Christman et al., 1991). In the semantic domain, priming is typically used to investigate the variables of interest. Both lexical decision and naming have been used with priming, and have resulted in hemispheric asymmetries. Occasionally, a semantic judgment task has also been successfully employed (Faust & Lavidor, 2003). The challenge is how to decide which of these tasks is most similar to the visual tasks, so that they could be considered equivalent.

An attempt was made to use tasks in the current experiments that were analogous to those used in the local-global vision literature. For example, in local-global visual tasks (such as Sergent, 1982) and in the one example of relative local-global processing in the audition literature (Ivry and Lebby, 1993), the tasks involved active engagement of the stimulus dimension under investigation.[2] For the visual task, this involved paying attention to whether information was at the local or global level (i.e. the spatial

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[2] Thanks for this idea goes to an anonymous reviewer of an NRSA fellowship proposal submitted based on these experiments.

frequency). For the auditory task, it again involved paying attention to the frequencies of the tones. Thus in the current experiments, participations were required to pay attention to the semantic relatedness of the stimuli in order to do the task. For Experiments 1, 2 and 2B, they were required to make a judgment about whether the sentence had meaning. This required that they attend to the semantic relationships in the stimuli. In Experiments 3 and 4, participants were required to make a judgment about whether a sentence was easy or hard to understand, or how closely related two words were. Both these tasks required participants to actively engage the semantic content of the words involved and thus actually pay attention to the stimulus dimension being tested. This was familiarity in Experiment 3 and semantic association in Experiment 4.

However, another aspect of the current tasks is not analogous with those in the local-global vision literature. It was also the case that that the visual tasks involved stimuli that incorporated both high and low spatial/auditory frequency within the same stimulus, and the task involved disregarding the information at one level and paying attention to the other level. For the current experiments, it was not possible to incorporate both high and low association words or semantic relationships into one stimulus in quite the same way. Rather, each trial was either at a high or low level of semantic association. Thus in this sense there is a difference between the local-global visual stimuli and the semantic stimuli used here.

For the first set of experiments (Experiments 1, 2 and 2B), it is possible that paying attention to one level of a stimulus incorporating multiple frequencies is crucial to obtaining the double filtering by frequency relative patterns seen in the vision literature. It is plausible, for example, that directing attention towards the dimension that determines the global/local status of the stimulus is the first step in the double-filtering model.[3] However, it could be argued that this characteristic of the visual task is not crucial to the double filtering by frequency relative pattern of processing. The one study that extended this work to the auditory domain did not include both frequency levels into the same stimulus. Ivry and Lebby's (1993) study, while incorporating different pitch frequencies, did not include them in the same stimulus, but only in the same stimulus set. They also found patterns that supported the double filtering by frequency model. Therefore it seems reasonable to conclude that this aspect of the local-global stimuli is not crucial to the relative nature of processing as predicted by the double filtering by frequency model.

The level repetition effect experiments have also been applied to auditory stimuli. Justus and List (2005) used stimuli that carefully replicated the patterns found with local-global hierarchical stimuli. They used patterns of tones that included both high and low frequencies (both pitch and temporal) within the same stimulus, and obtained results that were consistent with the double filtering by frequency model. Thus for the level repetition effect experiments (3 and 4), one could argue that it is important for the two levels (in this case of semantic relatedness) to be integrated into the same stimulus, as is the case with the visual stimuli and auditory. The visual studies testing the level repetition effect used the same Navon figures as in the double filtering by frequency experiments, which incorporate both local and global aspects into the same stimuli (Robertson, 1996). Thus the crucial question is whether the attentional model used to explain the level repetition effect is still valid even without the different levels being incorporated into the same stimulus, as in Experiments 3 and 4. Although each trial in the

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[3] Thanks for this idea goes to an anonymous reviewer of an NRSA fellowship proposal submitted based on these experiments.

experiments was designated as having a high or low level of semantic association, there was still a combination of different semantic association levels incorporated into the stimuli, at least the sentential stimuli in Experiment 3. It could be argued that a low familiarity metaphor, with a distant semantic relationship between the topic and the vehicle, likely also contained some words more closely related. The low familiarity metaphor *After falling my bruise was a plum* contains a distant relationship between the topic (*bruise*) and vehicle (*plum*) but also a closer semantic relationship between other words in the sentence (*falling* and *bruise*). The converse however is not true – most high familiar metaphors do not contain any distant semantic relationships. Therefore it may be that an attentional mechanism may not be the explanation for the level repetition effect effects found in Experiment 3. This seems plausible, especially since the effects did not appear in the first repetition of a level, but only in later repetitions.

Another reason for making this argument is the lack of any level repetition effect in the word pair priming data of Experiment 4. Only the facilitation effect following a High Association trial existed with both words and sentences. The delayed level repetition effect found in Experiment 3 with sentences did not extend to Experiment 4 with word pairs.

One way around the problems presented here would be to use a different approach to investigate the existence of visual properties in the semantic domain. For example one could conduct an experiment that would directly test the idea of successive filtering stages as proposed by the double filtering by frequency model. If successive filtering stages are used by the semantic system, we could make the following predictions. At a short stimulus onset asynchrony (SOA), when the first attentional filtering stage is applied, both the right and left hemispheres should filter in the same way based on context. This should result in identical priming results. Then at a longer stimulus onset asynchrony, the left hemisphere should subsequently filter out lower frequencies and the right hemispheres, higher frequencies. This should result in relative differences between the cerebral hemispheres (a hemisphere by relatedness interaction). The difficulty would be to determine which SOAs should be used for the long and short conditions. Many similar experiments have already been conducted with semantic stimuli which indicate that the pattern proposed here would likely not be obtained. The left and right hemispheres are differentially affected by context (Chiarello, 1991), and appear to have different time-courses of meaning activation (Beeman, 1998). It is not clear what the time course would be of the two successive filtering stages, so it is possible that by using different SOAs than have been used in past experiments the filtering stages could be established. However this very fact underlines how difficult it would be to show a connection, since the double filtering by frequency does not specify when the two stages take place. Perhaps if these times are established for visual stimuli, they could then be tested with semantic stimuli.

If the double filtering by frequency and level repetition effect patterns had been found in the current experiments with semantic stimuli, this would have shown that double filtering by frequency happens for both modalities, similar to the approach that was taken to extend the local-global visual patterns to the auditory modality in Ivry and Lebby, 1993 and Justus and List, 2005. However, it may happen for different reasons and due to different neural instantiations. Perhaps an experiment that would best test the connection between the visual and semantic domains is one that could potentially disprove, rather than confirm the extension by directly comparing processing in the two domains. This would require an experimental paradigm that incorporated both semantic and visual stimuli.

This potential approach presents some challenges in terms of controlling across conditions. The visual and semantic realms are so inherently different that it is difficult to know how to equate them. For example, in a typical well-controlled semantic priming experiment, stimuli are equated in terms of word frequency, length, orthographic neighborhood, length of exposure, stimulus onset asynchrony, and so on, and only one aspect of the stimuli is systematically varied (the independent variable). Second, the standard practice of equating length of exposure might have different effects on the different types of stimuli. It might be necessary to expose participants to stimuli for different lengths of time for each type of stimuli. Certainly with linguistic stimuli, a difference of a few hundred milliseconds can give dramatically different results (e.g. Burgess & Simpson, 1988; Chiarello, 1991). With visual stimuli, the timing is equally important. One could also consider attempting to equate the tasks used in the two domains. Since an identification task is known to be successful with the visual task, perhaps it could also be employed for the semantic task. For example, rather than using priming, the prime and target could be presented simultaneously. Participants could be required to identify in some way whether the stimuli showed a "close relationship" or a "distant relationship." This seems at least somewhat equivalent to identifying "thick bars" vs. "thin bars."

Determining close versus fine semantic relationships in word pairs is not an exact science as it is with visual stimuli. Even to create a minimum number of semantic levels would present a challenge. In order to equate the visual tasks with a semantic task, it would be necessary to have at least three levels of semantic relatedness. No semantic experiments have ever explored processing of more than two levels of semantic relatedness, except possibly the metaphor familiarity study from our lab (Schmidt et al., in press). However it would be necessary to use word pairs rather than sentences, especially with the task proposed previously. How can degrees of semantic relatedness be quantified? Which types of word pairs will result in right hemisphere processing advantages? These questions pose additional challenges that must be dealt with in further experiments that explore the relationship between visual and semantic processing.

No, there is no Connection, and any Similarities are Merely Surface Similarities

The second possible explanation for the results presented here is that there is no connection between visual and semantic processing as hypothesized. Previously observed similarities between visual, auditory, and semantic processing, such as a propensity for processing high frequencies and close semantic relationships in the left hemisphere and low frequencies and distant semantic relationships in the left hemisphere, are simply surface similarities, with no common underlying mechanisms. The fact that the current experiments did not find any new exact parallels between visual and semantic processing properties could suggest that there may be no mechanisms in common between the semantic modality and the perceptual modalities of vision and audition. The similarities which were found were not "identical" to the patterns seen in the vision literature. For example, a level repetition effect with metaphors was found, but it only manifested itself after at least two repetitions. It may be that the same mechanism cannot be responsible for the "level repetition effect" in the local-global vision literature, and the effect found in the current Experiment 3. The same concept applies to the similarity in laterality differences that have already been noted. In the visual domain, the right hemisphere does better with the global aspects of stimuli while the left hemisphere does better with the local aspects of stimuli, and the same thing applies to close and distant semantic relationships and the left and right hemispheres, respectively. Perhaps this is just a coincidence which does not have any neural underpinnings.

Even if one concluded that there is no connection between patterns in visual processing and semantic processing, the results reported here present a comprehensive picture of the role of stimulus context in semantic processing and how these effects are lateralized. The results from Part 1 are consistent with the idea that efficiency in processing semantic stimuli is partly determined by the broad stimulus context. Lateralized processing time patterns for a particular sentence will depend on the overall corpus of sentences being processed. The right hemisphere appears to be recruited when there is a wide range of familiarity, including fairly familiar sentences, but not when there are only unfamiliar sentences. Part 2 demonstrated that the immediately preceding stimulus context appears to play a role in the processing times for a stimulus. Thus the major contribution these experiments make is to suggest that the processing of semantic stimuli is affected by the surrounding stimulus context. This stimulus context specifically refers to levels of familiarity in the surrounding stimuli, both the overall stimulus set, and the immediately preceding trials.

Theoretical Explanations of the Results

The current findings entail that stimulus context has an effect on semantic processing, both broadly in terms of the stimulus set (Part 1), and more narrowly, in terms of the immediately preceding trials (Part 2). The findings in Parts 1 and 2 cannot easily be explained by a single model or mechanism, since they involve very different aspects of stimulus context. In what follows, models are described that can account for the pattern of findings in each part of the findings separately.

The results of Part 1 are consistent with a revised double filtering by frequency model. According to this new model, the first attentional filter is set differently depending on the characteristics of the stimulus set. Given a stimulus set with a wide range of familiarity the filter must be set broadly, in order to capture the whole range. Then, with the neural system focused attentionally on a wide range of familiarity, the second step of lateralized filters are set, with a high-pass filter in the left hemisphere and a low-pass filter in the right hemisphere, as in the original double filtering by frequency model. This results in the lateralized differences seen in Condition B in the experiments in Experiment 2B.

However, with a stimulus set that has a more narrow range of familiarity, the first attentional filter is set narrowly. With a narrower range of attention set, the right hemisphere is minimally recruited, leaving the left hemisphere to carry the majority of the processing burden. This results in a similar lateralized pattern of processing across all stimuli in the set, with faster left hemisphere processing, as seen in Condition A of Experiment 2B. Thus, according to this model, the second filtering step is not needed when the stimulus set has a narrow range of familiarity, since only the left hemisphere is primarily recruited. This view is consistent with findings in the neuroimaging literature, which suggest that the right hemisphere is only recruited in language processing tasks that are more difficult or require more processing resources (Just, Carpenter, Keller, Eddy, & Thulborn, 1996).

Since faster processing was found following both familiar metaphorical sentences and pairs of words with high associations in Part 2, a spreading activation explanation of the findings is supported. With a metaphor that is relatively familiar, there is more likely to be close semantic relationships between the topic and vehicle of the metaphor and established network connections in a spreading activation view of their relationship. For example, with the metaphor *All babies are angels*, *babies* and *angels* may have an established connection in a semantic network. This would be less likely for a less familiar metaphor such as *The camel is a desert taxi.* According to the conceptual integration theory of sentence comprehension (Coulson & Van Petten, 2002), understanding a novel utterance such as an unfamiliar metaphor requires the linking of two separate semantic domains, as seen in Figure 27. This requires a broad semantic activation for both *camel* and *taxi*. The small circles in the diagram represent a small semantic network which might be automatically activated once the focus word (*camel* or *taxi*) has been heard or

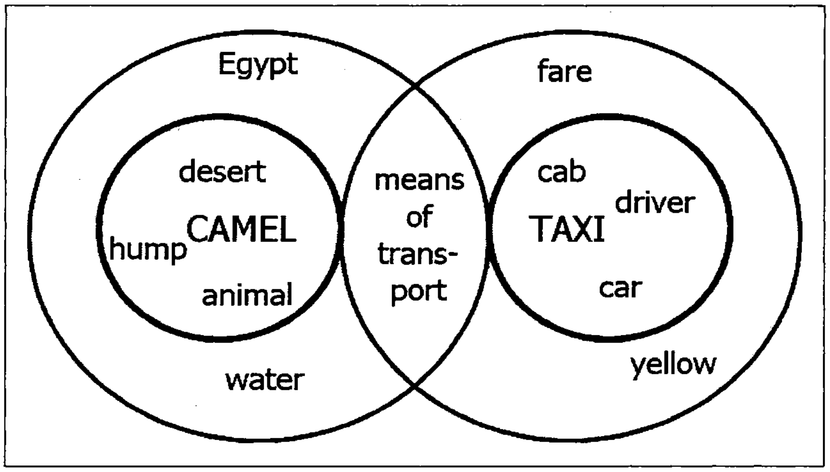

***Figure 27.* Conceptual integration as a means of comprehending the meaning of a metaphor. See the text for explanation.**

read. However the further activation of the larger circle, or broader semantic network, would be required in order for understanding of the sentence to take place. This broader activation provides the needed overlap between the two semantic concepts to understand the metaphor.

Consequently, understanding this metaphor for the first time would require the forging of new semantic connections in a spreading activation network. Thus with the High Familiarity trials, less of the semantic network needs to be activated before the task is completed. However for Low Familiarity trials, more of the spreading activation network must be activated before the task can be completed. This network then, being more activated, would take longer to return to baseline. Thus a trial following such a Low Association trial would not be as efficiently processed since it is not starting at baseline. This theory predicts that there is interference caused by processing Low Association trials, rather than facilitation by processing High Association trials, consistent with the results of Experiment 3.

This model also could be applied to the priming task in Experiment 4. We could assume that in order to determine how closely two words are related, spreading activation must occur for each word until a link is found, similar to the conceptual integration required for sentences. Then the degree of relationship between the words could be determined by how far apart they are in the network, or by how long it took to find the connection. This model thus predicts slowed processing following Low Association trials in a manner analogous to that for sentences. Since more of the spreading activation network must be activated before the task can be completed it would take longer to return to baseline. Thus a trial following such a Low Association trial would not be as efficiently processed since it is not starting at baseline.

While this model needs to be tested, it seems plausible based on similar models in the priming literature. For example, the postaccess relatedness checking model of priming (Neely, 1991; Chiarello, Richards & Pollack, 1992) gives an explanation for why responses are faster in a lexical decision task when the target is a word than when it is a nonword. When the target is a word, and it is related to the prime, a relationship can be found in the spreading activation network. If this relationship is found, that confirms that the target must be a word, and a response can be made. However, with a nonword, no semantic relationship can be found, therefore the target is less likely to be a word. Participants use this information and thus are able to give faster *yes* (this is a word) responses. To determine that a high association pair of words is related requires less activation of the semantic network, than to determine the same thing for a low association trial.

This spreading activation explanation is particularly appealing since it is supported by two very different experiments, both of which could be said to include a variable that embodies close versus distant semantic associations in different ways. This explanation would require further experimentation in order to be established. For example, one way to test this idea would be to vary the inter-trial interval. If this effect is eliminated with a longer inter-trial interval, the current explanation would be supported, as it could be assumed that the longer inter-trial interval allowed the spreading activation network to return to baseline.

REFERENCES

Abdullaev, Y. G., & Posner, M. I. (1997). Time course of activating brain areas in generating verbal associations. *Psychological Science, 8*, 56-59.

Allport, A. (1989). Visual attention. In M. I. Posner (Ed.), *Foundations of cognitive science*. Cambridge, MA: MIT Press.

Anaki, D., Faust, M., & Kravetz, S. (1998). Cerebral hemispheric asymmetries in processing lexical metaphors. *Neuropsychologia, 36,* 353-362.

Annett, M. (1985). *Left, right, hand and brain: The right shift theory.* Hillsdale, NJ: Lawrence Erlbaum.

Balota, D. A., Cortese, M. J., & Wenke, D. (2001). Ambiguity resolution as a function of reading skill, age, dementia, and schizophrenia: The role of attentional control. In D. S. Gorfein (Ed.), *On the consequences of meaning selection: perspectives on resolving lexical ambiguity* (pp. 87-102). Washington, DC: American Psychological Association.

Beeman, M. (1998). Coarse semantic coding and discourse comprehension. In M. Beeman & C. Chiarello (Eds.), *Right hemisphere language comprehension: Perspectives from cognitive neuroscience* (pp. 255-284). Mahwah, NJ: Erlbaum.

Beeman, M., Friedman, R. B., Grafman, J., Perez, E., Diamond, S., & Lindsay, M. B. (1994). Summation priming and coarse semantic coding in the right hemisphere. *Journal of Cognitive Neuroscience, 6,* 26-45.

Bottini, G., Corcoran, R., Sterzi, R., Paulesu, E., Schenone, P., Scarpa, P., et al. (1994). The role of the right hemisphere in the interpretation of figurative aspects of language: A positron emission tomography activation study. *Brain, 117,* 1241-1253.

Brownell, H. H., Michel, D., Powelson, J., & Gardner, H. (1983). Surprise but not coherence: Sensitivity to verbal humor in right-hemisphere patients. *Brain and Language, 18,* 20-27.

Brownell, H. H., Potter, H. H., & Michelow, D. (1984). Sensitivity to lexical denotation and connotation in brain-damaged patients: A double dissociation? *Brain and Language, 22,* 253-265.

Brownell, H. H., Simpson, T. L., Bihrle, A. M., Potter, H. H. & Gardner, H. (1990). Appreciation of metaphoric alternative word meanings by left and right brain-damaged patients. *Neuropsychologia, 28,* 375-383.

Burgess & Chiarello, (1996). Neurocognitive mechanisms underlying metaphor comprehension and other figurative language. *Metaphor and Symbolic Activity, 11*, 67-84.

Burgess, C. & Cushman, L. (1990, February). Right-hemisphere processing of subordinate word meanings: Evidence from brain-damaged patients. Paper presented to the International Neuropsychological Society, Orlando. FL. Cited in M. Beeman, (1998), Coarse semantic coding and discourse comprehension. In M. Beeman & C. Chiarello (Eds.), *Right hemisphere language comprehension: Perspectives from cognitive neuroscience* (pp. 255-284). Mahwah, NJ: Erlbaum.

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

Chiarello, C. (1991). Interpretation of word meanings by the cerebral hemispheres: One is not enough. In P. J. Schwanenflugel (Ed.), *The psychology of word meanings.* Hillsdale, NJ: Erlbaum.

Chiarello, C. (1998). On codes of meaning and the meaning of codes: Semantic access and retrieval within and between hemispheres. In M. Beeman & C. Chiarello (Eds.), *Right hemisphere language comprehension: Perspectives from cognitive neuroscience* (pp. 255-284). Mahwah, NJ: Erlbaum.

Chiarello, C., Burgess, C., Richards, L., & Pollak, A. (1990). Semantic & associative priming in the cerebral hemispheres: Some words do, some words don't ... sometimes, some places. *Brain and Language, 38,* 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*, 721-732.

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

Christman, S., Kitterle, F. L., & Hellige, J. (1991). Hemispheric asymmetry in the processing of absolute versus relative spatial frequency. *Brain & Cognition, 16,* 62-73.

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

Coulson, S. & Van Petten, C. (2002). Conceptual integration and metaphor: An event-related potential study. *Memory & Cognition, 30,* 958-968.

Coulson, S., & Williams, R. F. (2005). Hemispheric asymmetries and joke comprehension. *Neuropsychologia, 43,* 128–141.

Delis, D. C., Robertson, L. C., & Efron R. (1986). Hemispheric specialization for memory for visual hierarchical stimuli. *Neuropsychologia, 24*, 205-214.

Elvevag, B., Weickert, T., Wechsler, M., Coppola, R., Weinberger, D. R., & Goldberg, T. E. (2002). An investigation of the integrity of semantic boundaries in schizophrenia. *Schizophrenia Research, 53,* 187-198.

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.

Faust, M., & Kahana, A. (2002). Priming summation in the cerebral hemispheres: Evidence from semantically convergent and semantically divergent primes. *Neuropsychologia, 40,* 892-901.

Faust, M., Kravetz, S., & Netzer, E. (2002). Effects of sentential context on the processing of unambiguous words by the two cerebral hemispheres. *Brain & Language, 80,* 438-448.

Federmeier, K. D., & Kutas, M. (1999). Right words and left words: Electrophysiological evidence for hemispheric differences in meaning processing. *Cognitive Brain Research, 8,* 373-92.

Frith, U. (2003). *Autism: Explaining the Enigma. 2nd Edition.* Cambridge, MA: Blackwell.

Gentner, D., & Bowdle, B. F. (2001a). Convention, form and figurative language processing. *Metaphor and Symbol, 16,* 223-247.

Gentner, D., & Bowdle, B. F. (2001b). Metaphor is like analogy. In D. Gentner, K. J. Holyoak & B. N. Kikinov (Eds.) *The analogical mind.* MIT Press: Cambridge, MA.

Giora, R. (1997). Understanding figurative and literal language: The graded salience hypothesis. *Cognitive Linguistics, 8,* 183-206.

Giora, R. (1999). On the priority of salient meanings: Studies of literal and figurative language. *Journal of Pragmatics, 31*, 919-929.

Giora, R. (2003). On our Mind: Salience, Context and Figurative Language. New York: Oxford University Press.

Glaser, W. R., & Düngelhoff, F. J. (1984). The time course of picture-word interference. *Journal of Experimental Psychology: Human Perception and Performance, 10,* 640-654.

Glucksberg, S. (2001). *Understanding figurative language: From metaphors to idioms.* New York: Oxford University Press.

Glucksberg, S. (2003). The psycholinguistics of metaphor. *Trends in Cognitive Sciences, 7,* 92-96.

Goldberg, T. E., Aloia, M. S., Gourovitch, M. L., Missar, D., Pickar, D., & Weinberger, D. R. (1998). Cognitive substrates of thought disorder, I: The semantic system. *American Journal of Psychiatry, 155,* 1671-1676.

Grice, H. P. (1975). Logic and conversation. In P. Cole & J. L. Morgan (Eds.), *Syntax and Semantics: Vol. 3. Speech Acts* (pp. 41-58). New York: Academic Press.

Gur, R. C., Packer, I. K., Hungerbuhler, J. P., Reivich, M., Orbrist, W. D., Amarnek, W. S., & Sackeim, H. A. (1980). Differences in the distribution of gray and white matter in human cerebral hemispheres, *Science, 207,* 1226-1228.

Hellige, J. B. (1993). *Hemispheric asymmetry: What's right and what's left.* Cambridge, MA: Harvard University Press.

Hines, D., Czerwinski, M., Sawyer, P. K., & Dwyer, M. (1986). Automatic semantic priming: Effect of category exemplar level and word association level. *Journal of Experimental Psychology: Human Perception and Performance, 12,* 370-379.

Hustler, J. J., & Gazzaniga, M. S. (1995, March). Hemispheric differences in the density of parvalbumin-containing interneurons are found within language-associated regions of the human cerebral cortex. Poster presented and the 2nd annual meeting of the Cognitive Neuroscience Society, San Francisco. Cited in M. Beeman, (1998), Coarse semantic coding and discourse comprehension. In M. Beeman & C. Chiarello (Eds.), *Right hemisphere language comprehension: Perspectives from cognitive neuroscience* (pp. 255-284). Mahwah, NJ: Erlbaum.

Ivry, R. B., & Robertson, L. C. (1998). *The two sides of perception.* Cambridge, MA: MIT Press.

Ivry, R., & Lebby, P. (1993). Hemispheric differences in auditory perception are similar to those found in visual perception. *Psychological Science, 4,* 41-45.

Ivry, R., & Lebby, P. (1998). The neurology of consonant perception: Specialized module or distributed process? In *M.* Beeman & C. Chiarello (Eds.), *Right hemisphere language comprehension: Perspectives from cognitive neuroscience* (pp. 3-26). Mahwah, NJ: Erlbaum.

Jacobs, B., Batal, H. A., Lynch, B., Ojemann, G., Ojemann, L. M., Scheibel, A. B. (1993). Quantitative dendritic and spine analyses of speech cortices: A case study. *Brain and Language, 44*, 239-253.

Jacobs, B., Schall, M., & Scheibel, A. B. (1993). A quantitative dendritic analysis of Wernicke's area in humans. II. Gender, hemisphere, and environmental factors. *Journal of Comparative Neurology, 327*, 97-111.

Jasper, H.H. (1958). The ten twenty electrode system of the international federation. *EEG Journal, 10,* 371-375.

Just, M. A., Carpenter, P. A., Keller, T. A., Eddy, W. F., & Thulborn, K. R. (1996). Brain activation modulated by sentence comprehension. *Science, 274*, 114-6.

Justus, T., & List, A. (2005). Auditory attention to frequency and time: An analogy to visual local-global stimuli. *Cognition, 98*, 31-51.

Kacinik, N. A., & Chiarello, C. (in press). Understanding metaphors: Is the right hemisphere uniquely involved? *Brain & Language*, in press.

Katz, A. N., Paivio, A., Marschark, *M.* & Clark, J. *M.* (1988). Norms for 204 literary and 260 nonliterary metaphors on 10 psychological dimensions. *Metaphor and Symbolic Activity,* 3, 191-214.

Kim, M. & Thompson, C. K. (2003). Semantic anomaly judgment in individuals with probable Alzheimer's disease. *Aphasiology, 17,* 1103-1113.

Kitterle, F. L., Christman, S., & Hellige, J. B. (1990). Hemispheric differences are found in the identification, but not the detection, of low versus high spatial frequencies. *Perception & Psychophysics, 48,* 297-306.

Kosslyn, S. M., Anderson, A. K., Hillger, L. A., & Hamilton, S. E. (1994). Hemispheric differences in sizes of receptive fields or attentional biases? *Neuropsychology, 8,* 139-147.

Kosslyn, S. M., Chabris, C. E, Marsolek, C. J., & Koenig, O. (1992). Categorical versus coordinate spatial relations: Computational analyses and computer simulation. *Journal of Experimental Psychology: Human Perception and Performance, 18*, 562-577.

Kosslyn, S. M., Koenig, O., Barrett, A., Cave, C. B., Tang, J., & Gabrieli, J. D. (1989). Evidence for two types of spatial representations: Hemispheric specialization for categorical and coordinate relations. *Journal of Experimental Psychology: Human Perception and Performance, 15,* 723-35.

Laeng, B., Chabris, C. F., & Kosslyn, S. M. (2003). Asymmetries in encoding spatial relations. In K. Hugdahl & R. J. Davidson (Eds.), *The asymmetrical brain.* (pp. 303-339). Cambridge, MA: MIT Press.

Levine, S. (1995). Individual differences in characteristic arousal asymmetry: Implications for cognitive functioning. In F.L. Kitterle (Ed.). *Hemispheric communication: Mechanisms and models.* Hillsdale, NJ: Lawrence Erlbaum.

Levine, S., Banich, M. T., & Kim, H. (1987). Variations in arousal asymmetry: Implications for face processing. In D. Ottoson (Ed.), *Duality and unity of the brain: unified functioning and specialisation of the hemispheres: proceedings of an international symposium held at The Wenner-Gren Center, Stockholm, May 29-31, 1986.* New York: Plenum Press.

Levy, J., Heller, W., Banich, M. T., & Burton, L. A. (1983). Are variations among right-handed individuals in perceptual asymmetries cause by characteristic arousal differences between hemispheres? *Journal of Experimental Psychology: Human Perception and Performance, 9,* 329-359.

MacKay, G., & Shaw, A. (2004). A comparative study of figurative language in children with autistic spectrum disorders. *Child Language Teaching & Therapy, 20,* 13-32.

Mashal, N., Faust, M., & Hendler, T. (2005). Processing conventional vs. novel metaphors by the two cerebral hemispheres: Application of principle component analysis to fMRI data. *Neuropsychologia, 43,* 2084-2100.

Neely, J.H. (1991). Semantic priming effects in visual word recognition: A selective review of current findings and theories. In D. Besner & G. W. Humphreys (Eds.), *Basic processes in reading: Visual word recognition.* (pp. 264-336). Hillsdale, NJ, England: Lawrence Erlbaum.

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/.

Nicholls, M. E., & Wood, A. G. (1998). The contribution of attention to the right visual field advantage for word recognition. *Brain and Cognition, 38*, 339-357.

Poeppel, D. (2003). The analysis of speech in different temporal integration windows: Cerebral lateralization as 'asymmetric sampling in time.' *Speech Communication 41*, 245–255.

Rayner, K. (1978). Eye movement latencies for parafoveally presented words. *Bulletin of the Psychonomic Society, 11*, 13–16.

Robertson, L. C. (1996). Attentional persistence for features of hierarchical patterns. *Journal of Experimental Psychology: General,* 125, 227-249.

Robertson, L. C., & Ivry, R. (2000). Hemispheric asymmetries: Attention to visual and auditory primitives. *Current Directions in Psychological Science, 9*, 59-63.

Roth, E. C. & Hellige, J. B. (1998). Spatial processing and hemispheric asymmetry: Contributions of the transient/magnocellular visual system. *Journal of Cognitive Neuroscience*, *10*, 472-484.

Sabbagh, M. A. (1999). Communicative intentions and language: Evidence from right-hemisphere damage and autism. *Brain & Language, 70,* 29-69.

Scheibel, A., Paul, L. A., Fried, I., Forsythe, A. B., Tomiyasu, U., & Weschler, A. et al. (1985). Dendritic organization of the anterior speech area. *Experimental Neurology*, *87*, 133–142.

Schmidt, G. L., DeBuse, C. J., & Seger, C.A. (in press). Right hemisphere metaphor processing? Characterizing the lateralization of semantic processes. *Brain and Language.*

Seger, C. A., Desmond, J. E., Glover, G. H. & Gabrieli, J. D. E. (2000). Function magnetic resonance imaging evidence for right-hemisphere involvement in processing unusual semantic relationships. *Neuropsychology, 14,* 361-369.

Semmes, J. (1968). Hemispheric specialization: A possible clue to mechanism. *Neuropsychologia, 6*, 11-26.

Sergent, J. (1982). The cerebral balance of power: Confrontation or cooperation. *Journal of Experimental Psychology: Human Perception and Performance, 8,* 253-273.

Shulman, G. L. & Wilson, J. (1987). Spatial frequency and selective attention to local and global information. *Perception, 16*, 89-101.

Shulman, G. L., Sullivan, M. A., Gish, K., & Sakoda, W. (1986). The role of spatial-frequency channels in the perception of local and global structure. *Perception, 15*, 259 - 273.

Swinney, D., Prather, P., & Love, T. (2000). The time-course of lexical access and the role of context: Converging evidence from normal and aphasic processing. In Y. Grodzinsky, L. P. Shapiro, et al. (Eds.), *Language and the brain: Representation and processing. Foundations of neuropsychology series* (pp. 273-292). San Diego, CA: Academic Press.

Tallal, P., Miller, S., & Fitch, R. H. (1993). Neurobiological basis of speech: A case for the preeminence of temporal processing. *Annals of the New York Academy of Sciences, 682*, 27-47.

Thompson-Schill, S. L., Kurtz, K. J., & Gabrieli, J. D. E. (1998). Effects of semantic and associative relatedness on automatic priming. *Journal of Memory & Language, 38,* 440-458.

Tippett, L. J., Gendall, A., Farah, M. J., & Thompson-Schill, S. L. (2004). Selection ability in Alzheimer's disease: Investigation of a component of semantic processing. *Neuropsychology, 18,* 163-173.

Titone, D. (1998). Hemispheric differences in context sensitivity during lexical ambiguity resolution. *Brain and Language, 65*, 361-394.

Tompkins, C. A. (1990). Knowledge and strategies for processing lexical metaphor after right or left hemisphere brain damage. *Journal of Speech and Hearing Research, 33,* 307-316.

Trotman, S. C. A., & Hammond, G. R. (1989). Lateral asymmetry of the scalp distribution of somatosensory evoked potential amplitude. *Brain and Cognition, 10,* 132-147.

Tucker, D. M., Roth, D. L., & Bair, T. B. (1986). Functional connections among cortical regions: Topography of EEG coherence. *Electroencephalography and Clinical Neurophysiology, 63*, 242-250.

Weylman, S. T., Brownell, H. H., Roman, M., & Gardner, H. (1989). Appreciation of indirect requests by left- and right-brain-damaged patients: The effects of verbal context and conventionality of wording. *Brain and Language, 36*, 580-591.

Winner, E., & Gardner, H. (1977). The comprehension of metaphor in brain-damaged patients. *Brain, 100*, 717-729.