VERBAL CREATIVITY AND AMBIGUITY RESOLUTION IN THE CEREBRAL HEMISPHERES

LINZI GIBSON

B.S., COLORADO STATE UNIVERSITY, 2005

M.A. UNIVERSITY OF KANSAS, 2007

SUBMITTED TO THE GRADUATE DEGREE PROGRAM IN COGNITIVE PSYCHOLOGY AND THE GRADUATE FACULTY OF THE UNIVERSITY OF KANSAS IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

Dr. Ruth Ann Atchley
Chairperson

Committee members

Dr. Paul Atchley

Dr. Evangelia Chrysikou

Dr. Chris Ramey

Dr. Barbara Kerr

Date defended: July 24, 2013

THE DISSERTATION COMMITTEE FOR LINZI GIBSON CERTIFIES
THAT THIS IS THE APPROVED VERSION OF THE FOLLOWING DISSERTATION:

VERBAL CREATIVITY AND AMBIGUITY RESOLUTION IN THE CEREBRAL HEMISPHERES

Dr. Ruth Ann Atchley
Chairperson

Date defended: July 24, 2013

ABSTRACT

This study examined hemispheric differences in ambiguity resolution in subjects who vary on measures of creativity. Subjects were classified as either low, moderate, or high creative based on the results of convergent and divergent thinking tests as well as a personality inventory. Two experiments utilized a divided visual field (DVF) paradigm to study hemispheric processing of sentences containing an ambiguous word followed by a lateralized target word. In Experiment 1 the subjects were presented with sentences that bias the reader to either the dominant or subordinate meaning of the ambiguous word. In Experiment 2 the initial context of the sentence provided a bias towards either the subordinate or dominant meaning of the word. After the ambiguous word occurred, the end of the sentence switched the context to the alternative. The sentences were then be followed by a lateralized target word that was either related to the dominant meaning, subordinate meaning, or there was no relation to the target word. Participants performed a relatedness judgment to the sentence and the target word. A Stroop task was also utilized as a measure of cognitive control. The low creative participants performed worse on the DVF priming study as well as the Stroop task. These individuals seemed to rely on more automatic/bottom-up activation in both the Stroop and DVF priming tasks. Both the low and moderate creative participants had a preference for dominance in the DVF sentence priming tasks. The low creative group also had more difficulty resolving ambiguity than the high and moderate creative participants. When a biased sentence was presented, the high creative individuals activated the alternative meaning of the ambiguous word. This

seems to be evidence of a broad pattern of activation and may be a reflection of the role of the left hemisphere (LH) in the high creative group. The LH seems to be maintaining both representations of the ambiguous word. It may be that the high creative subjects do in fact show greater salience for both dominant and subordinate meanings in the LH.

TABLE OF CONTENTS

List of Tables

List of Figures

INTRODUCTION

Creativity and Ambiguity Resolution

Creativity is defined as "the ability to produce work that is both novel (i.e. original, unexpected) and appropriate (i.e. useful, adaptive concerning task constraints)" (Sternberg & Lubart, 1999, p.3). Creative cognition is a valuable construct to study as it has implications in the fields of art, music, science, and multiple other aspects of our everyday lives. When examining human innovation and creativity, several questions emerge. What are the conditions under which creative thought occurs? Why are some people more creative than others? What are the neuralcorrelates of creative thought?

Because creativity is such a heterogeneous construct, the intent of this paper is to focus on verbal creativity using theories of semantic access in the cerebral hemispheres. The overall goal of this dissertation project for the degree of Doctor of Philosophy in Cognitive Psychology is to demonstrate that hemispheric differences in semantic processing of ambiguous stimuli will evoke different patterns of performance in high-creative and low-creative individuals. Specifically, high-creative individuals will show greater ambiguity tolerance, which is the ability to maintain activation of multiple, conflicting, and/or distantly related concepts in the context of ambiguity (Tegano, 1990; Atchley, Keeney & Burgess, 1999). Additionally, this series of studies aims to explore the nature of the processing differences that lead to ambiguity tolerance in the two hemispheres between high and low creative individuals. The results of this study will illuminate the underlying processes, specifically differences in semantic access, that lead to creative cognition.

Measures of Creativity

Divergent thinking, the ability to generate multiple solutions to an open-ended problem, is often seen as an important ability that contributes to creativity (Guilford, 1950, 1967). Guilford (1950) made the distinction between convergent thinking (discovering the single best answer to a problem) and divergent thinking (a given problem might be tackled in different ways). The former is thought to be related to intelligence and the latter representing the free-associative style that is commonly linked to creative thinking (Grabner, Fink, & Neubauer, 2007; Molle, Marshall, Wolf, Fehm, & Born, 1999).

Some of the most commonly used tests of divergent thinking include: the Torrance Test of Creative Thinking (TTCT; Torrance, 1974), which includes both verbal and non-verbal subtests; the Remote Associates Test (RAT; Mednick, 1962) in which participants are presented with three words (e.g. tooth, potato, heart) and are asked to produce a solution word (e.g. sweet) that is related to all three words; and the Alternative Uses Test (AU; Guilford, 1967) in which participants name alternative uses for everyday objects (e.g. a brick). The dependent variables of tests of divergent thinking include ideation fluency (the number of ideas), flexibility (the number of categories of ideas), novelty (uniqueness or originality), and elaboration (the amount of detail in the response; Dietrich & Kanso, 2010). The vast majority of studies discussed in this paper employed one or more of these techniques in the study of divergent thinking, creativity and insight.

While most of the research presented here views creativity as an entirely cognitive process, other researchers have examined creativity through a model of

personality traits (Kerr & Gagliardi, 2003; Batey & Furnham, 2006). The five-factor model (FFM) has been a popular measure of personality for many years (Costa & McCrae, 1985). The FFM proposes five factors of personality including neuroticism (N), extraversion (E), openness to experience (O), agreeableness (A), and conscientiousness (C). The other major model of personality is Eysenck's Gigantic 3, which proposes three orthogonal dimensions of personality including extroversion versus introversion (E), emotional stability versus instability or neuroticism (N), and psychoticism versus impulse control (P; Eysenck & Eysenck, 1976; Eysenck, Eysenck, & Barrett, 1985). Various personality traits have been linked to creativity using these two models, though findings have been mixed. Because different personality measures have been used along with various conceptualizations of creativity, this short review of the literature will address factors of these two models of personality and how they relate to tests of divergent thinking.

The FFM component that has been most consistently linked to creativity is openness to experience (for reviews see Feist, 1998; Batey & Furnham, 2006). It has been suggested that openness is closely related to having a flexible cognitive style (McCrae, 1987), which may lend itself to divergent thinking. Feist (1998) suggested several reasons for the link between openness and creativity including a preference for open-ended problem solving, flexibility of thought, and an interest in more varied experiences. Batey and Furnham (2006) proposed that openness consists of two sub factors: an attitudinal openness to new experiences and a perceptual openness representing the inability to inhibit irrelevant information.

Reduced cognitive inhibition could be linked to activating distantly related associative connections, which may contribute to novel ideation and creative thought. Though some research has failed to find correlations between the TTCT (Strong, Nowakowska, Santosa, Wang, Kraemer et al., 2007) or the AU (Batey, Furnham, & Safiullina, 2010) and personality measures, many others have found openness to experience to be positively correlated to creative ability as measured by the TTCT and other divergent thinking measures (King, Walker and Broyles, 1996; King and Pope, 1999; McCrae, 1987; Furnham, Batey, Anand, & Manfield, 2008).

Extroversion has also been found by many to be correlated with tests of divergent thinking using both the FFM and the Gigantic 3 (King, et al., 1996; Martindale & Dailey, 1996; Aguilar-Alonso, 1996; Batey & Furnham, 2006). An explanation of this finding may lie in Eysenck's (1967) well-known theory that extroverted individuals are low in cortical arousal. Some studies of cortical arousal have shown creative people to exhibit less cortical arousal during tests of creativity (Martindale & Hines, 1975). A review of the literature on EEG studies of cortical arousal and divergent thinking can be found below, however they have produced mixed results. It has also been proposed that extroverted individuals may perform better at tests of divergent thinking because they provide an opportunity to take risks (Batey & Furnham, 2006).

There is, however, an alternative account of the relationship between extroversion and creativity that is possibly mediated by another personality trait - agreeableness. A review by Feist (1998) found negative correlations with extroversion and certain types of creativity. He proposed that individuals in the arts

and sciences may have more of an asocial or even anti-social orientation, as the creative process often requires solitude. Spending time alone during the creative process may be beneficial because the individual is secluded from social influence. Agreeableness is another FFM trait that consistently shows a negative correlation with creativity (Feist, 1998; King, Walker, & Broyles, 1996; Kerr & Gagliardi, 2003) as those who score low on this trait are much less likely to conform to social norms. Individuals who score high on agreeableness are more susceptible to social influence, while those who score low have a tendency toward independent thought and action (King, et al., 1996; Kerr & Gagliardi, 2003). Nonconformity and independent thought likely lead to the novel ideation characteristic of high creative individuals.

The final personality trait linked to divergent thinking is psychoticism. Some studies have shown a positive correlation between tests of divergent thinking and verbal creativity and the measure of psychoticism (Aguilar-Alonso, 1996; Merten & Fischer, 1999; Woody & Claridge, 1977) while others have not (Martindale & Dailey, 1996; Kline & Cooper, 1986; Rawlings, 1985). This correlation is quite interesting particularly with respect to individuals diagnosed with schizophrenia and schizotypal personality disorder. A typical characteristic of schizophrenia and schizotypal personality disorder is the loosening of associations. Tests of verbal creativity emphasize novelty and flexibility of thought, and those who score high on psychoticism tend to produce unusual or atypical responses on these measures. This trait has also been linked to reduced cognitive inhibition (Baruch, Hemsley, & Gray, 1988; Lubow, Ingberg-Sacha, Zalstein-Orda, & Gerwitz, 1992). This lack of

inhibition may result in defective filters for irrelevant stimuli (Batey and Furnham, 2006), which may increase the chance of making novel associations, a characteristic that has been proposed to reflect high creativity (Mednick, 1962). There seems to be a growing consensus that tests of divergent thinking, while informative, are not sufficient in assessing creativity (Batey & Furnham, 2006; Kerr & Gagliardi, 2003). Due to the multi-faceted nature of creativity, assessment of creativity would benefit from utilizing measures of both cognition (process) and personality (person).

Semantic Processing in the Cerebral Hemispheres

The left hemisphere (LH) has traditionally been thought of as the "language hemisphere" in the brain. However, the right hemisphere (RH) appears to have a unique role in lexical ambiguity resolution, particularly with respect to the processing of distantly related words and subordinate meanings of ambiguous words (Atchley, Burgess, & Keeney, 1999; Beeman, et al., 1994; Burgess & Simpson, 1988a; Coney & Evans, 2000; Faust, Bar-lev, & Chiarello, 2003; Faust, Ben-Artzi, & Harel, 2008; Faust & Chiarello, 1998; Faust & Lavidor, 2003; Hasbrooke & Chiarello, 1998; Michael, 2009; Titone, 1998; Titone & Salisbury, 2004). In fact, access to semantic information is not lost when the RH can no longer communicate with the LH (as in commissurotomy patients), therefore, the LH and RH seem to represent distinct and parallel semantic processing systems (Faust & Mashal, 2007). This proposition leads to the question of whether there are identical bilateral semantic representations, or are semantic representations different with respect to type and organization in the two hemispheres? There seems to be a growing consensus that meaning is represented in a highly distributed fashion across the cortex involving

multiple brain areas (Federmeier & Laszlo, 2009). I propose that asymmetries arise due to processing differences of each hemisphere, which is supported by the research that will be subsequently presented.

Three important theories emerge that can illuminate the study of semantic processing, verbal creativity and divergent thinking. These models help us to understand creative cognition through the study of semantic access in the two hemispheres. As such, the discussion begins with a hallmark study of the role of the right and left hemisphere in semantic processing of ambiguous words (Burgess & Simpson, 1988a), a common type of stimuli used in studies of semantic access, and continues with detailed descriptions of each of the relevant theories.

Semantic priming is defined as the improvement in speed or accuracy in response to a stimulus, such as a word or picture, when it is preceded by a semantically related stimulus (Neely, 1991; McNamara, 2005). Divided-Visual Field (DVF) semantic priming has been established as an effective method for examining semantic networks in the cerebral hemispheres. This method involves presenting a prime either centrally or to the left or right visual field, followed by a target presented to either the left or right visual field. Priming is defined as the facilitation (faster reaction time) to related word pairs when compared to unrelated word pairs. Research conducted by Burgess and Simpson (1988a) used a DVF technique to present their subjects with a single ambiguous prime word (e.g. BARK) and a lateralized target related to either the dominant (e.g. GROWL) or subordinate (e.g. TWIG) meaning of the prime word at either 35 ms or 750 ms stimulus onset asynchrony (SOA). In both the left and right hemispheres the dominant meaning

was activated quickly and priming for the dominant meaning was found at both the short and long SOA. However, priming for the subordinate meaning was only seen at the short SOA in the right visual field/left hemisphere (RVF/LH) and only at the long SOA in the left visual field/right hemisphere (LVF/RH). Burgess and Simpson proposed that the LH has a selection process in which the inappropriate (in most cases the subordinate) word meaning is inhibited (Burgess & Simpson, 1988a; Simpson & Burgess, 1985). This is thought to be a controlled, attention-driven process of meaning activation and active selection. In contrast, the RH showed priming for only the dominant meaning at the short SOA and priming for both meanings at the long SOA. While the RH is thought to be somewhat slower during the initial stage of semantic access, it maintains weaker activation of all possible meanings in order to reactivate a suppressed meaning or to revise an initial interpretation, and appears to be due to a more passive spreading activation.

The Coarse Semantic Coding Hypothesis

The coarse semantic coding hypothesis (Beeman, 1993; Beeman, et al., 1994; Beeman & Chiarello, 1998; Jung-Beeman, 2005) proposes that the LH engages in relatively fine semantic coding, in which it activates a small semantic network of closely related words, dominant representations of ambiguous words, and aspects of words that are closely related to local context. In contrast, the RH engages in relatively coarse semantic coding, in which it activates a large semantic network of both alternative meanings (e.g. both dominant and subordinate meanings of ambiguous words), and distantly related words. If a participant is presented with a word like BANK, which has a dominant representation related to *money* and a

subordinate representation related to *river*, the LH would rapidly select the dominant representation and possibly suppress peripheral semantic information (Burgess & Simpson, 1988a; Simpson & Burgess, 1985). The RH, conversely, would maintain activation of both representations as well as more distantly related semantic information related to the multiple meanings of the ambiguous word. Beeman proposed that fine semantic coding in the LH is extremely useful in selecting some information for online processing in a local context, while the activation of a larger semantic field in the RH could be useful in maintaining coherence or drawing inferences in a more global context. The ability of the RH to maintain activation of these representations may be more efficient than reactivating distantly related or subordinate meanings in the LH in the event of meaning misassignment during online comprehension (Atchley, et al., 1999).

Much of the evidence to support the coarse semantic coding theory comes from investigations of hemispheric asymmetries in processing of ambiguous words, insight and figurative language (discussed below). The use of semantically convergent versus semantically divergent primes for ambiguous words has provided support for the coarse coding theory (Faust, 2003; Faust & Kahana 2002). In this paradigm, multiple prime words are presented that are either both related to the dominant meaning of an ambiguous word (new, fresh-NOVEL; semantically convergent), both related to the subordinate meaning of an ambiguous word (story, book-NOVEL; semantically convergent), or one prime related to the dominant and one to the subordinate meaning (new, story-NOVEL; semantically divergent). The

LH benefited most from semantically convergent primes, while the RH benefited most from semantically divergent primes (Faust, 2003; Faust & Kahana, 2002).

While much of the literature has investigated ambiguity resolution using single-word priming studies, researchers have also examined this process in the presence of sentence context (Faust & Gernsbacher, 1996; Faust & Chiarello, 1998; Titone, 1998; Coney & Evans, 2000). One such study (Faust & Chiarello, 1998) presented sentences containing an ambiguous word, and the context of the sentence biased the reader to either the dominant or subordinate meaning. A lateralized target word was then presented that was related to the contextually appropriate, contextually inappropriate, or unrelated meaning of the ambiguous word.

Results demonstrated that the RH activates both meanings of the ambiguous word, suggesting that this hemisphere is not engaged in controlled meaning selection in the presence of context (Grindord, 2003; Faust & Chiarello, 1998). This is in accordance with the view that meaning activation in the RH is largely due to automatic spread of activation and this hemisphere uses only intra-lexical (word level) information during semantic processing. Conversely, the LH activated only the contextually appropriate meaning, i.e. following a dominant biased sentence context, only dominant meanings were activated, and following a subordinate biased sentence context, only subordinate meanings were activated. These results suggest that in the LH, both message level and intra-lexical level mechanisms can influence word recognition in the presence of sentence context. Interestingly, the LH did not show inhibition of the contextually inappropriate meanings, as would be expected according to the results of single word priming studies (Burgess &

Simpson, 1988a; Burgess & Simpson, 1988b; Simpson & Burgess, 1985). However, the SOA was quite long in this experiment (900 ms), which is likely the reason there was no inhibition found for the inappropriate meaning.

Not all evidence to supporting the coarse semantic coding theory comes from studies using ambiguous words. An investigation by Atchley, Burgess and Keeney (1999) used unambiguous words in a DVF lexical decision experiment and revealed support for the RHs role in maintaining activation of subordinate and distantly related information. In addition, the results supported a modification to the coarse semantic coding theory with respect to the LH's role in semantic access. This study used unambiguous prime words (LAMB) and target words that were related to the dominant (WOOL) or two categories of subordinate representation of the primes. The subordinate words were either compatible with the dominant representation (EARS), or they were related to an alternative subordinate representation (CHOPS). They were presented at both short (50 ms) and long (750 ms) SOAs. The coarse coding theory would predict that only the dominant meaning would be activated at the long SOA in the LH because this activation is driven solely by association strength. However, they found that at the long SOA the LH maintained activation of the dominant and dominant-compatible subordinate targets, but not the incompatible-subordinate targets. They proposed that unrelated representations of ambiguous words often have little feature overlap and therefore it may be beneficial to inhibit one meaning because maintaining activation of both incompatible representations could cause confusion during meaning selection. These results suggest that the LH makes a rapid selection of the dominant representation, which

includes both strongly and weakly associated information, and that the selection process is not solely contingent on association strength.

The Graded-Salience Hypothesis

Another important theory has been proposed with respect to semantic processing in the two hemispheres known at the graded salience hypothesis (Giora, 1997; 2002), which proposes that the degree of semantic salience determines differences in semantic processing between the two hemispheres. To be salient, the meaning of a word must be encoded into the mental lexicon, and the degree of salience is a function of its conventionality, familiarity, and frequency (Giora, 1997; 2002). Three key assumptions to this model are as follows (Giora, 199, p. 186):

1. The salient meaning of an utterance is always activated.
2. Novel interpretation of a salient meaning involves a sequential process, whereby the salient meaning is processed first, rejected as the intended message, and reinterpreted.
3. Novel interpretation must be more difficult to derive.

When examined in conjunction with the coarse coding hypothesis, research has shown that the LH seems to activate very salient/familiar relationships, while the RH activates less salient/less familiar relationships. The ability to maintain multiple features of a representation for both closely and distantly related information, is a key feature of many theories of creativity (Atchley, et al., 1999; Bogen & Bogen, 1969; Mednick, 1962).

An Associative Model of Creativity

Mednick (1962) proposed an associative model of creativity wherein the creative process is defined as "the forming of associative elements into new combinations which either meet specified requirements or are in some way useful." (p. 221). Individual differences in creativity were described in terms of differences in the gradient of an associative hierarchy. When presented with a word such as "table," the associate response(s) one makes is an indication of their associative hierarchy. If the individual makes one or two conventional responses, they are said to have a relatively steep associative hierarchy. However, if an individual who provides the conventional response also provides less probable responses, they are said to have a flat associative hierarchy.

Elements of Beeman's (1998) coarse coding theory, the graded salience hypothesis (Giora, 1997; 2002), and Mednick's associative model of creativity (1962) can be combined to form a new model of creativity through lateralized semantic processing. The LH seems to show activation of dominant (salient) associations (steep hierarchy), or what Beeman refers to as fine semantic coding. Conversely, the right hemisphere maintains activation of a broad network of distantly related (less salient) associations (flat hierarchy), or what Beeman refers to as coarse semantic coding.

Based on this new model, one might conclude that the RH could be characterized as the "creative" hemisphere for its ability to maintain activation of a broad network of distantly related associations. However, recent research seems to better support an interactive model of creative cognition in which both hemispheres contribute to creative processing (Atchley, et al., 1999; Carlsson, Wendt, & Risberg,

2000; Kowatari et al., 2009). A study of interest conducted by Atchley et al. (1999) investigated the time course of ambiguity resolution in high and low creative subjects. Results suggested that both hemispheres maintain activation of multiple meanings in high creative individuals while low creative individuals only show subordinate priming in the RH. A view of the RH as the "seat of creativity" certainly does not match with these data. Because activation of both dominant and subordinate meanings was found in the LH (as well as the RH), it may be the case that subordinate representations are more salient to high creative individuals. Alternatively, there may be a lack of inhibition of subordinate meanings in the LH in individuals who score high on measures of creativity.

The ability to maintain activation of distantly related concepts in the context of ambiguity is referred to as ambiguity tolerance (Atchley, et al., 1999; Tegano, 1990). It was proposed that high creative individuals have a higher tolerance for ambiguity than individuals who scored lower on measures of creativity, and it's possible that this tolerance is the results of the organization of the mental lexicon. As posited by Giora (1997, 2000, 2002), the mental lexicon is organized by the degree of salience of a word or phrase, and it's possible that high creative individuals find distantly related concepts more salient in the LH.

Burgess and Simpson proposed that the LH has a selection process in which the inappropriate, and in most cases the subordinate, word meaning is inhibited (Burgess & Simpson, 1988a; Simpson & Burgess, 1985). Following this theory, it is also possible that high creative individuals are not inhibiting the subordinate representations in the LH. As measures of personality research have shown, one

characteristic of schizophrenia and schizotypal personality disorder is loose associations similar to that seen in high creative individuals. Researchers have hypothesized that reduced cognitive inhibition could be responsible for widening associative connections in individuals with schizotypy (Batey & Furnham, 2006; Grimshaw, Bryson, Atchley, & Humphrey, 2010). While no firm conclusions about higher salience or lack of inhibition for subordinate items can be drawn from this study, this premise provides a foundation upon which future research can be built.

It would be of interest to examine individual differences in processing ambiguity with more contextual information, such as in sentences containing an ambiguous word, instead of a priming paradigm using single word presentation to further investigate this theory. Furthermore, this study only used one measure of creativity, a subtest of the Wallace & Kogan Creative battery (Wallach & Kogan, 1965), to identify high and low creative participants. Future research would benefit from assessing participants who have been identified as high creative through a more extensive series of tests compared to a normal population.

Insight

In addition to ambiguity resolution, the study of insight is of importance in the field of creativity and divergent thinking. Performance on insight problems is associated with creative thinking and other cognitive abilities different from those associated with performance on non-insight problems (Schooler & Melcher, 1995). It has been suggested that insight problems contain features that bias retrieval towards solution irrelevant interpretations of critical words in problems, and away from interpretations that would lead to a solution (Beeman, Bowden, & Gernbacher,

2000; Bowden & Beeman, 1998; Bowden & Jung-Beeman, 2003). When attempting to solve an insight problem individuals are often misled by ambiguous information, and when finally arriving at a solution, the experience is often sudden and surprising (the Aha! Moment). Furthermore, individuals solving insight problems often have difficulty reporting the steps that led them toward the solution (Bowden & Jung-Beeman, 2003; Schooler & Melcher, 1995).

"Insight solutions are often viewed as more creative than non-insight solutions because the rely on retrieval of unusual interpretations of problem elements, or on information that may seem only distantly related to the original problem." (Bowden & Beeman, 1998; p. 435). Bowden and Jung-Beeman (2003) propose that people experience insight when they suddenly recognize that some information, which has already been semantically activated, either is the solution or directs them toward the solution path. Coarse semantic coding (RH) is more likely than fine semantic coding (LH) to activate non-dominant information and maintain this activation (Beeman, 1993, 1998; Beeman, et al., 1994; Beeman, et al., 2000). The LH quickly begins to narrow its focus, possibly at the expense of solution relevant information, while in the RH semantic activation is extensive and sensitive to semantic overlap. Unconscious processing might also play a role in solving insight problems because solution-relevant RH activation might be too weak to reach consciousness (Beeman, et al., 1994). This may be a possible explanation for the inability to report the steps taken to arrive at the solution. While neither hemisphere alone is responsible for creativity or insight, the RH seems to engage in

cognitive processes that specifically facilitate divergent thinking, and in turn, solving insight problems.

Figurative Language

Both the coarse semantic coding theory and the graded salience hypothesis have implications for the study of figurative language processing within the two hemispheres. The nature of figurative language is such that the intended meaning differs from the meaning of what is literally expressed. Consequently, comprehension of figurative language requires some sort of meaning extension between disparate concepts. Mednick (1962) defines the creative thinking process as "the forming of associative elements into new combinations which either meet specific requirements or are in some way useful. The more mutually remote the elements of new combinations, the more creative the process or solution." (p. 221). Based on these definitions, it is clear that understanding the processing of figurative/non-literal language comprehension not only contributes to our understanding of semantic access in the cerebral hemispheres but is also relevant for an understanding of verbal creativity (Coulson & Severens, 2007).

Much of the research on figurative language comprehension has focused on metaphor comprehension. Metaphor comprehension is a complex process because, compared to literal language, it is much less evident which aspect of meaning will ultimately be relevant for comprehension (Kacinik & Chiarello, 2007). Metaphors have both literal and figurative meanings and these dual meanings differ from literal text on factors such as novelty, ease of integration, and valence (Diaz, Barrett, & Hogstrom, 2011). This is especially true in the case of novel metaphors, as

comprehension requires recognition and integration of novel, non-salient connections or associations between multiple, disparate concepts (Faust & Mashal, 2007; Mashal, Faust, & Hendler, 2005; Mashal, Faust, Hendler, & Jung-Beeman, 2007; Schmidt, DeBuse, & Seger, 2007). Familiar metaphors are likely to be encoded in the lexicon and have close semantic relationships that may not benefit from activation of loosely related concepts (Diaz, et al., 2011). While early research implicated the RH as the "metaphor-processing hemisphere" (Anaki, Faust, & Kravetz, 1998; Martindale & Greenough, 1973; Martindale, Hines, Mitchell, & Covello, 1984; Winner & Gardner, 1977), further research into this topic has revealed that the RH does seem to have an advantage in novel metaphor processing while the LH may be involved more in familiar metaphor processing (Faust & Mashal, 2007; Mashal, et al., 2005; Mashal, et al., 2007; Schmidt, et al., 2007). Much of this research investigates differences in processing meanings of word pairs that are either literal (*problem resolution*), conventional-metaphoric (*transparent intention*), novel-metaphoric (*conscious storm*) or unrelated (*wisdom wash*) using lateralized presentation (Faust & Mashal, 2007; Mashal, et al., 2005; Mashal, et al., 2007; Pobric, Mashal, Faust, & Lavidor, 2008). In one such study, Pobric and colleagues (2008) conducted a rapid transcranial magnetic stimulation (rTMS) study where participants performed a semantic relatedness judgment to literal, conventional-metaphoric, novel-metaphoric and unrelated word pairs. Results showed that rTMS to right posterior superior temporal sulcus disrupted processing of novel but not conventional metaphors, while rTMS over left inferior frontal gyrus

impaired processing of literal word pairs and conventional, but not novel metaphors.

Furthermore, a recent study by Gold, Faust, Ben-Artzi (2012) directly studied the relationship between novel and conventional metaphor processing in the hemispheres and verbal creativity. Participants who scored higher on the RAT as a measure of creativity required less time to process both conventional and novel metaphors. For novel metaphors, a significant negative correlation was found between RT and RAT performance only in the RH, and specifically those who performed better on the RAT had faster RTs to novel metaphors only in the RH. For conventional metaphors, a significant negative correlation was found in both hemispheres, and specifically those who performed better on the RAT had faster RTs to conventional metaphors in both hemispheres.

Because metaphors require integration between unrelated or very distantly related concepts, the coarse semantic coding theory correctly predicts that the RH plays a large role in comprehension due to the of the activation of a broad semantic network. It has further been suggested that the RH plays a key role in the ambiguity resolution and reinterpretation of an utterance with multiple meanings (Atchley & Burgess, 1998; Jung-Beeman, 2005). The graded salience hypothesis provides an explanation for the findings that the RH shows an advantage for processing novel metaphors over familiar metaphors as novel metaphors are much less salient (Faust & Mashal, 2007; Giora, 1997; Mashal, et al., 2005; Mashal, et al., 2007; Schmidt, et al., 2007; Schmidt & Seger, 2009).

The research on figurative language is not only limited to the study of metaphor comprehension but also has been extended to research on the processing of other facets of language such as joke comprehension (Coulson & Severens, 2007; Coulson & Williams, 2005; Coulson & Wu, 2005), and sarcasm (Voyer, Bowes, & Techentin, 2008). The common characteristic of these aspects of language is that the literal message is most often not the meaning that is intended and, therefore, requires disambiguation and/or reinterpretation. While research on humor and sarcasm do not support the claim that the RH is the sole hemisphere for processing figurative language, this body of research does uphold the theory that the RH plays a special role in processing figurative language, particularly when the message is novel/unexpected/less salient.

Patients with right hemisphere damage (RHD) can provide further support regarding the differences in semantic access and figurative language processing between the two hemispheres. Individuals with damage to their RH have been found to exhibit deficits in comprehending and/or using humor (Bihrle, Brownell, & Powelson, 1986; Brownell, Michel, Powelson, & Gardner, 1983; Heath & Blonder, 2005; Shammi & Stuss, 1999), metaphors (Brownell, Potter, Michelow, & Gardner, 1984; Pobric, et al., 2008; Rinaldi, Marangolo, & Baldassari, 2004; Winner & Gardner, 1977), and sarcasm (Fournier, Calverley, Wagner, Poock, & Crossley, 2008; Giora, Zaidel, Soroker, Batori, & Kasher, 2000; Kaplan, Brownell, Jacobs, & Garner, 1990), which suggests the special, but not necessarily dominant, role of the RH in figurative language processing.

Cognitive Control

Cognitive control is defined as the regulation of mental activity that supports flexible behavior across domains such as attention, working memory, and language processing (Chrysikou, Novick, Trueswell & Thompson-Schill, 2011). Many different tasks have been used to assess cognitive control, one such task is the Stroop paradigm (Stroop, 1935). In this task, an individual is required to provide a correct response to incongruent stimuli. The classic task consists of naming the ink color in which a word, such as *blue,* has been printed. In the congruent version of this task, the word *blue* is printed in the color blue. In the incongruent version, the word *blue* is printed in a different color, such as red. Response latencies are usually significantly longer in the incongruent condition compared to the congruent condition due to the two competing processes of reading and color naming. In the Stroop task, if the interference effect is small, a person's cognitive control is proposed to be stronger as the individual can devote less effort to suppress one of the competing processes (Groborz & Necka, 2003). Some studies have shown creative individuals (defined by the RAT, the Improvements Test, and the Matchstick Test) perform significantly better on the Stroop task (Gamble and Kellner, 1968; Golden, 1975).

A more recent study that supports the proposal that high creative individuals have a more flexible cognitive style was conducted by Zabelina & Robinson (2010). Participants completed an abbreviated form of the TTCT as well as the creative achievement questionnaire (CAQ) to assess creativity, and also performed the Stroop task. High creative individuals displayed higher levels of flexible cognitive control. Creative individuals demonstrated larger Stroop interference after

congruent Stroop trials, while demonstrating less interference after incongruent trials. Zabelina and Robinson (2010) proposed that the creative individuals relax cognitive control more so than less creative participants when such resources are not apparently needed.

The ability to defocus attention during certain phases of creativity, such as the ideation phase, and devote more focused attention during other phases of the creative process, such as the evaluation of those ideas, may be a hallmark of high creative individuals (Groborz & Necka, 2003). Creativity, as defined at the beginning of this paper, is "The ability to produce work that is both novel (i.e. original, unexpected) and appropriate (i.e. useful, adaptive concerning task constraints)" (Sternberg & Lubart, 1999, p. 3). So, while defocused attention may lead to novel ideas, the ability to focus and evaluate those ideas as appropriate and adaptive is equally important. Therefore, a high creative individual is likely to have flexible cognitive style in order to support these two processes.

Neuralcorrelates of creativity

Much of the recent literature on creativity is concerned with identifying the neuralcorrelates of verbal creativity in the brain. Several methods have been employed to study this construct including electroencephalography (EEG), functional magnetic resonance imaging (fMRI), and positron emission tomography (PET) techniques as well as lesion studies. Multiple themes emerge from this body of research including investigations of hemispheric differences in creativity, differences in levels of cortical arousal, and investigations of specific brain areas

involved in creative cognition with a particular emphasis on the role of the prefrontal cortex.

EEG/ERP evidence

EEG is a measure of electrical brain activity in which excitatory and inhibitory postsynaptic potentials are recorded from different points on the scalp. This signal is created when the electrical potentials of a large number of neurons that are arranged in a systematic fashion and activated in synchrony summate to create a signal large enough to be measured (Federmeier & Laszlo, 2009; Kutas & Dale, 1997). The EEG literature on creative cognition investigates issues of hemispheric differences as well as changes in power and synchrony of various frequencies. EEG contains different frequency ranges, and there are specific ranges that are of interest to the research of creativity. The primary range of interest is known as alpha activity, which is prominent when an individual is minimally aroused (awake, but relaxed). Other bands of interest include gamma activity, which is associated with the binding of perceptual information, and beta activity, which occurs during alertness and active thinking (Dietrich & Kanso, 2010). When analyzing and interpreting EEG data, changes in synchronization are of particular interest. EEG synchrony reflects how the signals from different electrodes are related to each other, and are reported in terms of event-related synchronization (ERS), and event-related desynchronization (ERD).

Hemispheric differences

The RHs role in creative cognition has been of interest in both theoretical models of creativity as well as electrophysiological and neuroimaging investigations.

While some EEG research reports results that support the primary role of the RH in creative cognition (Bowden & Jung-Beeman, 2003; Grabner, et al., 2007; Jung-Beeman et al., 2004; Martindale & Hines, 1975; Martindale, et al., 1984; Mihov, Denzler, & Forster, 2010; Razoumnikova, 2004), others have shown bilateral activation (Aghababyan, Grigoryan, Stepanyan, Arutyunyan, & Stepanyan, 2007; Bekhtereva, Dan'ko, Starchenko, Pakhomov, & Medvedev, 2001; Molle, et al., 1999; Petsche, 1996; Tarasova, Volf, & Razoumnikova, 2010) during tasks involving creativity and divergent thinking. Based on the theoretical and EEG evidence, there seems to be much support for the theory of cooperation between the two hemispheres during creating thinking, rather than dominance of the RH in such tasks.

Alpha synchronization

The alpha band consists of lower and upper frequency bands, the lower band is thought to reflect attentional task demands such as alertness or arousal, and the upper band is thought to reflect more specific demands such as semantic memory processes (Grabner, et al., 2007; Grabner, Fink, Stipacek, Neuper, & Neubauer, 2004; Klimesch, Sauseng, & Hanslmayr, 2007). Changes in power and synchrony have been proposed to reflect low cortical arousal and defocused attention (Eysenck, 1995; Martindale, 1999; Mendelsohn, 1976). Some researchers have characterized creative individuals as having more defocused attention than non-creative people (Eysenck, 1995; Martindale, 1999; Mendelsohn, 1976). Studies of cortical arousal have shown creative people to have less cortical arousal during tests of creativity, and more cortical arousal on intelligence tests (Martindale & Hines, 1975).

Martindale (1999) proposed that creative people are able to adjust their focus depending on task demands. During early stages of creativity, such as thinking about/creating a story (inspirational phase), lower activity is observed, but not when writing it down (elaboration phase; Martindale & Hasenfus, 1978). This proposal converges with Groborz & Necka's (2003) theory on cognitive control and creativity discussed above.

While there is some support for changes in the alpha band reflecting defocused attention, alpha band activity in many EEG studies of divergent thinking has produced mixed results. While some research has reported increases in synchronization of the alpha band at frontal, temporal and parietal sites (Fink, 2006; Fink, 2009; Grabner, et al., 2007; Jausovec, 2000; Razumnikova, 2004), others have reported decreases (Jausovec & Jausovec, 2000; Razumnikova, 2007; Shemyakina, Danko, Nagornova, Starchenko & Bechtereva, 2007). EEG studies of insight have also shown decreased alpha power reported in frontal, temporal and parietal sites (Kounios & Beeman, 2009; Kounios et al., 2008; Kounios et al., 2006). Changes to the beta and gamma frequencies have also been reported in the literature, however, reports are largely inconsistent and a clear pattern has yet to emerge with respect to EEG frequency bands and divergent thinking (for reviews see Dietrich & Kanso, 2010; Arden, Chavez, Grazioplene, & Jung, 2010).

Event-related potential (ERP) studies have been lacking in the research on divergent thing and creativity (Dietrich & Kanso, 2010). EEG has been the primary means of which to study electrophysiological correlates of creative thinking because tasks of divergent thinking make it difficult to time lock the EEG signal to a specific

event, a necessity of ERP. The nature of creativity is often more of a continuous process when engaged in creative tasks such as generating a story, or thinking of alternative uses for everyday objects. ERPs have been used to study two domains of verbal creativity, the processing of figurative language and insight.

The amplitude of the N400, a component sensitive to semantic violation (Kutas & Hillyard, 1980), has been shown to be larger during metaphor processing as compared to processing of literal statements (Coulson & Severens, 2007; Coulson & Van Petten, 2002; Kazmerski, Blasko, & Dessalegn, 2003; Lai, Curran, & Menn, 2009; Proverbio, Crotti, Zani, & Adorni, 2009), suggesting that interpretation of this type of stimuli is more difficult. Studies of joke comprehension have investigated laterality differences and found that the RH shows smaller N400s to jokes than the LH, which may suggest that semantic activations in the RH facilitate joke comprehension (Coulson & Williams, 2005; Coulson & Wu, 2005). While these studies reflect semantic processing of creative language and not the individual's participation in an act of creativity, they may give us some possible clues as to how to utilize this technology in future studies of verbal creativity.

One avenue of divergent thinking in which ERP is appropriate is in the case of insight, as it often comes as a sudden Aha! moment (e.g. as is found in the remote associates test) that might be more amenable to the requirement of time locking to an event. There have been a limited number of experiments using ERPs to study the process of insight, most of them requiring participants to solve Chinese anagrams, and once again the results are inconsistent. There was a negative deflection peaking between 300-400 ms identified in two ERP insight studies (Mai, Luo, Wu, & Luo,

2004; Qiu, Luo, Wu, & Zhang, 2006), however, a single, reliable component has yet to be identified across multiple studies (Mai, et al., 2004; Qiu, et al., 2010; Qiu, Li, Jou, Wu, & Zhang, 2008; Qiu et al., 2008; Qiu, et al., 2006). Clearly the ERP technique has value in the investigation of certain types of verbal creativity processing, and there is a very limited body of research using this technique thus far. Future research, particularly in the areas of divergent thinking and insight, could benefit from the use of this method as the EEG results seem to be quite inconsistent.

Neuroimaging evidence

Neuroimaging techniques have been applied to the study of divergent thinking to investigate hemispheric differences, as well as the special role of the prefrontal cortex, and other brain structures. While the data using neuroimaging techniques shows more consistency than the EEG data, there are still disparities that make creating any definitive conclusions a challenge.

Hemispheric differences

Again, no clear evidence implicates the RH as the sole seat of creativity. While there have been studies that found more activation in areas of the RH for divergent thinking tasks (Folley & Park, 2005; Howard-Jones, Blakemore, Samuel, Summers, & Claxton, 2005; Jung-Beeman, et al., 2004), many others report bilateral patterns of activation (Aziz-Zadeh, Kaplan, & Iacoboni, 2009; Bechtereva et al., 2004; Carlsson, et al., 2000; Chavez-Eakle, 2007; Kounios, et al., 2006; Kowatari, et al., 2009; Sieborger, Ferstl, & von Cramon, 2007; Starchenko, Bekhtereva, Pakhomov, & Medvedev, 2003). Divergent thinking does not seem to be associated

with dominance of one hemisphere, but a process that recruits both hemispheres in order to perform optimally and efficiently.

The Prefrontal Cortex

Neuroimaging studies consistently implicate the prefrontal cortex in divergent thinking tasks (Aziz-Zadeh, et al., 2009; Bechtereva, et al., 2004; Bekhtereva et al., 2000; Carlsson, et al., 2000; Chrysikou & Thompson-Schill, 2011; Fink et al., 2009; Folley & Park, 2005; Howard-Jones, et al., 2005; Kowatari, et al., 2009; Sieborger, et al., 2007). It is not entirely clear which specific areas of the prefrontal cortex are attributed to creativity as studies reported various different sites, and both activations and deactivations of this cortical area have been reported. Based on our knowledge of functions typically ascribed to the prefrontal cortex, it makes sense that this particular area of the cortex would be implicated in creative cognition. Areas of the frontal cortex contribute to the conscious experience and are responsible for the flexibility that is necessary for divergent thinking, attentional resources that make us conscious of novel ideas, and the evaluation of the appropriateness of an idea (Dietrich, 2004; Grabner, et al., 2007).

Other brain areas

Many researchers have also reported activity in parietal (Bechtereva, et al., 2004; Bekhtereva, et al., 2000; Fink, et al., 2009; Kounios, et al., 2006; Kowatari, et al., 2009; Sieborger, et al., 2007; Starchenko, et al., 2003), temporal (Bechtereva, et al., 2004; Bekhtereva, et al., 2000; Fink, et al., 2009; Kounios, et al., 2006; Kowatari, et al., 2009; Starchenko, et al., 2003), visual, (Bechtereva, et al., 2004; Fink, et al., 2009; Howard-Jones, et al., 2005), cerebellar (Chavez-Eakle, 2007; Fink, et al.,

2009), and hippocampal (Fink, et al., 2009; Kowatari, et al., 2009) regions. Again, consistent results have not been reported across studies other than the prefrontal regions of the cortex.

The anterior cingulated cortex (ACC) has been of particular interest in the domain of insight. Several studies have reported increased activity of the ACC when solving insight problems (Aziz-Zadeh, et al., 2009; Bechtereva, et al., 2004; Fink, et al., 2009; Howard-Jones, et al., 2005; Kounios, et al., 2006; Starchenko, et al., 2003). This area may be important in conflict monitoring and/or switching attentional focus to initiate processing that leads to breaking the mental mindset that keeps one from discovering the solution (Aziz-Zadeh, et al., 2009; Dietrich & Kanso, 2010; Kounios, et al., 2006). The experience of insight has also been shown to correlate with activity in the superior temporal gyrus (STG) (Bowden & Jung-Beeman, 2003; Jung-Beeman, et al., 2004; Kounios et al., 2008), yet not all studies have reported activation in this area (Kounios, et al., 2006; Mai, et al., 2004; Qiu, et al., 2008; Qiu, et al., 2008). It was proposed that activation of the STG, particularly the right STG, is a reflection of coarse semantic coding processes (Bowden & Jung-Beeman, 2003; Jung-Beeman, et al., 2004), however no definitive conclusions can be made as of yet.

Lesion studies

Investigations on the effect of brain damage and performance on divergent thinking tasks have shown that frontal lobe damage has been linked to impairments in divergent thinking and creativity (Heilman, 2005; Shamay-Tsoory, Adler, Aharon-Peretz, Perry, & Mayseless, 2011). Shamay-Tsoory and colleagues (2011) showed that patients with medial prefrontal cortex (mPFC) lesions were impaired on the

TTCT and AU. Lesions in the RH were associated with more deficits in originality than lesions in the LH. Originality scores of patients with left PC and left inferior frontal and posterior lesions were somewhat higher than those of other participants. Again, this evidence provides support not for the sole contribution of the right hemisphere in divergent thinking, but a collaborative interhemispheric process that contributes to creativity.

Part of the reason there are such heterogeneous findings in the literature is due to the variety of tasks employed to study the constructs of divergent thinking and creativity. As such, conclusions drawn from this data must take these limitations into account. While there does seem to be consistency in a small number of findings, particularly the collaboration between the hemispheres and the special role of the prefrontal cortex in creative cognition, a review by Dietrich and Kanso (2010) concluded that "not a single currently circulating notion on the possible mechanisms underlying creative thinking survives close scrutiny…For nearly every proposal on the neural underpinning of creativity one cares to press, there is as much evidence for as there is against it." (p. 845).

Summary

While many questions remain unanswered in the domain of creative cognition, tests of divergent thinking, personality measures, models of semantic access, cognitive flexibility, and neuroscience research has provided a good knowledge base on which to build. There have been multiple, fairly complementary, theories with regard to semantic access in the two hemispheres that have implications for the study of verbal creativity (Giora, 1997; Jung-Beeman, 2005;

Mednick, 1962). On the basis of these theories, I propose a view of the two hemispheres in which LH and RH represent distinct and parallel semantic processing systems and asymmetries arise due to processing differences of each hemisphere. The LH quickly activates dominant representations of verbal stimuli that are highly salient, while the RH shows somewhat slower and weaker, but more diverse activation of both dominant and subordinate representations as well as distantly related and less salient meanings.

This collaboration between the two hemisphere seems to be particularly efficient because the RHs ability to maintain activation of this information is particularly useful in the event of lexical ambiguity or meaning misassignment during online comprehension that requires reinterpretation. Definitions of verbal creativity emphasize the forming of associative elements that are combined in new and useful ways as reflected by a flat associative hierarchy in which activation of a diverse semantic network is maintained (Mednick, 1962). This might seem to suggest that the RH is dominant in tasks of verbal creativity, yet, both behavioral, electrophysiological, and neuroimaging research seem to suggest a more collaborative view of hemispheric processing during tests of creativity and divergent thinking. In fact, based on the finding that high creative subjects show priming for both dominant and subordinate representations in the LH (similar to the RH; Atchley, et al., 1999), it may be the case that differences in semantic access in the LH are responsible for the differences in ambiguity resolution between high and low creative groups.

While investigations of insight, and ambiguous and figurative language processing have proven to be important in the study of verbal creativity, the literature directly examining divergent thinking and creativity is relatively small. The vast majority of studies that compare individual differences in semantic access have conducted one or two tests of divergent thinking and creativity and classified their random sample of subjects as either high or low creative individuals. Future research in understanding differences in semantic access among high creative and low creative individuals would benefit from performing a wider variety of tests to categorize subjects. These tests should include measures of convergent and divergent thinking as well as personality measures.

The largest disparity in this literature seems to be in the investigation of the neurocorrelates of creativity. The theoretical distinctions made between right versus left brain processing and focused versus defocused attention are too simplistic (Dietrich & Kanso, 2010). Once again the evidence suggests a collaborative view of the hemispheres rather than RH dominance, and measurements of cortical arousal and creativity have not been reliable. While there is converging evidence that the prefrontal cortex has a special role in creative cognition, "Creativity, as a general construct, does not seem to be localizable." (Dietrich & Kanso, 2010, p. 834). Clearly the literature on creativity is a diverse and at times contradictory body of research, however, a solid foundation has been established for new lines of research that can increase our knowledge base in the field of creative cognition.

Current Study

The current studies were designed to further investigate the underlying processes of hemispheric differences in ambiguity resolution in subjects who vary on measures of creativity. Both experiments utilized a divided visual field (DVF) paradigm to study hemispheric processing of sentences containing an ambiguous word followed by a lateralized target word. In Experiment 1 the subjects were presented with sentences that bias the reader to either the dominant (Ex. The boy could not catch the BALL.) or subordinate meaning (Ex. She bought a new dress for the BALL.) of the ambiguous word. In Experiment 2, the initial context of the sentence provided a bias towards one meaning of the word (subordinate or dominant). After the ambiguous word occurred, the end of the sentence switched the context to the alternative meaning of the ambiguous word. If the initial context biased the reader toward the subordinate meaning, the context switched to dominant meaning (Ex. The southern belle was not pleased at all with how the BALL had been served but she still gave it her best effort.). In contrast, if the initial context biased the reader toward the dominant meaning, the context switched to subordinate meaning (Ex. My little brother threw a horrible temper tantrum and ruined everything because he wanted the BALL to be over soon.). In both experiments, the sentences were followed by a lateralized target word that was either related to the dominant meaning (ROUND), subordinate meaning (DANCE), or unrelated. The participants made a relatedness judgment to the target word.

The vast majority of studies on hemispheric asymmetries and semantic processing have employed the lexical decision task in which participants are asked

to decide if a string of letter is a word or a nonword. Balota & Paul (1996) conducted a series of experiments involving lexical decision, naming, and relatedness judgment tasks. Based on their findings they have argued that the lexical decision task may fail to tap into inhibitory semantic processing because there is no need to select one interpretation of the ambiguous word in order to complete the task. This study did, however find semantic-level inhibition using a relatedness judgment task. Because the current study is particularly interested in inhibition (or lack there of) of the alternative meanings of ambiguous words, the task chosen is a relatedness judgment task. This task may also motivate the participants to attend to the semantic content of the sentence instead of just focusing on the lexical nature of the target.

Specific aims for this study were to replicate previous research that high creative individuals show a higher tolerance for ambiguity compared to low and moderate creative individuals (Atchley, et al., 1999; Tegano, 1990); and extend previous research to determine whether differences in ambiguity resolution in high creative subjects is due to a lack of inhibition in the LH or to a higher salience of the subordinate representation in the LH. It was predicted that the high creative subjects would show a lack of inhibition in the LH, which will result in an advantage during ambiguity resolution when compared to the moderate and low creativity groups. The moderate creative individuals were predicted to maintain activation for the contextually appropriate meanings in the LH, and therefore, had to rely on the RH for ambiguity resolution, as the RH maintains activation of multiple meanings of ambiguous words. Furthermore, the individuals in the low creativity

group were predicted to show great difficulty in ambiguity resolution because they are not able to maintain activation of multiple meanings in either hemisphere, and will only activate the contextually appropriate meaning.

Methods

Creativity Assessment

Creativity was assessed through tests of both convergent and divergent thinking as well as a personality test. The Remote Associates Test (RAT; Mednick, 1962) was administered in which participants are presented with three cue words (e.g. tooth, potato, heart) and are asked to produce a solution word (e.g. sweet) that is related to all three words. The test was administered in pencil-and-paper form and was comprised of 20 items. Participants were instructed to solve as many problems as possible in 10 minutes.

The RAT is often used in the study of insight (Beeman, et al., 2004; Bowden & Beeman, 2003). The study of insight is of importance in the field of creativity and divergent thinking. Performance on insight problems is associated with creative thinking and other cognitive abilities different from those associated with performance on non-insight problems (Schooler & Melcher, 1995). "Insight solutions are often viewed as more creative than non-insight solutions because the rely on retrieval of unusual interpretations of problem elements, or on information that may seem only distantly related to the original problem." (Bowden & Beeman, 1998, p. 435). Bowden and Jung-Beeman (2003) propose that people experience insight when they suddenly recognize that some information, which has already

been semantically activated, either is the solution or directs them toward the solution path. For this reason, the RAT was included as one measure of creativity.

The Alternative Uses task (AU; Guilford, 1967) was also administered as a test of divergent thinking. This measure requires participants to name alternative uses for everyday objects (e.g. a brick). Participants had three minutes per item to name as may uses as possible for 5 items. The dependent variables in the assessment of the AU task included ideation fluency (the number of ideas), flexibility (the number of categories or ideas), novelty (uniqueness or originality), and elaboration (the amount of detail in the response).

Individual differences in creativity were described by Mednick (1962) in terms of differences in the gradient of an associative hierarchy. When presented with a word such as "table," the associate response(s) one makes is an indication of their associative hierarchy. If the individual makes one or two conventional responses, they are said to have a relatively steep associative hierarchy, however, if an individual, usually along with the conventional response, provides less probable responses, they are said to have a flat associative hierarchy. The AU task provides a sophisticated measure of Mednick's associative model of creativity, and thus, was be included as the second measure of creativity.

Due to the multi-faceted nature of creativity, assessment of creativity would benefit from utilizing measures of both cognition (process), as measured by the tasks described above, and personality (person). The personality characteristic that has been most consistently linked to creativity is openness to experience (for reviews see Feist, 1998; Batey & Furnham, 2006). It has been suggested that

openness is closely related to having a flexible cognitive style (McCrae, 1987), which may lend itself to divergent thinking. Extroversion has also been found by many to be correlated with tests of divergent thinking using both the five-factor model of personality (McCrae & Costa, 1984, 1985) and the Gigantic 3 (Aguilar-Alonso, 1996; Batey & Furnham, 2006; King, Walker and Broyles, 1996; Martindale & Dailey, 1996).

The five-factor model of personality (McCrae & Costa, 1984, 1985) was measured using the 44-item version of the Big Five Inventory (BFI; John, Donahue, & Kentle, 1991). Participants were instructed to indicate how much items pertain to them on a scale of 1 (very uncharacteristic of myself) to 5 (very characteristic of myself). Eight items pertain to neuroticism, eight pertain to extraversion, ten pertain to openness to experience, nine pertain to agreeableness and nine pertain to conscientiousness. High creative individuals were expected to show positive correlations with the RAT and AU and the FFM factor of openness to experience. Based on the scores from these three measures, participants were classified as either high, moderate, or low creative individuals (selection criteria is discussed below).

Creativity Prescreen

Participants were selected using a prescreen that was made up of a sub-set of items from the creativity assessment described above. Participants completed ten items from the RAT, one item from the AU, and eight items from the BFI that measure openness to experience. These items were administered online using the University of Kansas Sona Systems online survey system. The prescreen derived

selection criteria that was used to recruit participants to the study (outlined in Table 1). For normal individuals, average scores for the RAT usually range between four to five items out of ten (Bowden & Jung-Beeman, 2003; Mednick, Mednick, Jung, 1964), average fluency scores for the AU task are between six to eight items (Furnham, et al., 2008; Molle, et al., 1999), and mean ratings for high creative individuals on the BFI for openness to experience are around 4.5 (John, et al., 1991; John & Srivastava, 1999). Participants were required to meet all three selection criteria to be included in one of the experimental groups. If a participant met the criteria to be included in one of the groups, they had the ability to signup for the main experiment.

Creativity measurement during experimental session

At the time of the main Experimental session, participants completed a full battery of creativity assessment items. The RAT measure, used to assess convergent and divergent thinking as well as insight components of creativity, was comprised of 10 additional items. The AU task (Guilford, 1967), which was also administered as a test of divergent thinking , was made up of four items. For both the RAT and AU tasks, the specific items included during the experimental session were items that were not presented during the prescreen. Though there may have been a slight advantage during this retest phase, given that the tasks were repeated, we do not believe there were significant practice effects as we used unique items in each phase of the study. Personality was assessed using the 44-item version of the Big Five Inventory (John, et al., 1991). The administration of these creativity measures took about a half hour to complete. Ultimate inclusion of a participant in the final

analysis of this study was based on their responses to the creativity measures administered during the experimental session.

Table 1. Inclusion criteria for recruitment of the three experimental groups based on performance on the prescreen items

	High Creative Group	Moderate Creative Group	Low Creative Group
AU fluency (mean)	7.0+	4.0 to 6.9	<4.0
RAT (number correct out of 10)	6.0+	3.0 to 5.9	<3.0
BFI-O (mean)	3.5+	<3.5	<3.5

Participants

A total of 403 participants completed the creativity prescreen. Of those participants, 120 (67 male) University of Kansas undergraduates were recruited to participate in the experiment. A total of 86 (41 males) participants were included in the final analysis between the ages of 18-23 (M=18.76; 1.12). Three participants were eliminated because their overall accuracy was below 50%, indicating that they were not fully engaged in the task. The remaining 31 participants did not meet the requirements to be included in one of the creativity groups based on their scores during the creativity assessment conducted during the experimental session. The participants were recruited from the Introduction to Psychology participant pool and received course credit for their participation. All participants were right-handed as assessed by the Edinburgh Handedness Inventory (Oldfield, 1971) with an average score of 8.22 (1= strongly left handed, 9= strongly right handed), native-English speakers, with normal or corrected to normal vision, no history of neurological trauma or disease, and were not taking any psychoactive medications based on self-report.

Performance on the creativity assessment

Based on the creativity assessment, 25 participants met the requirements to be included in the high creativity group. The mean performance on the RAT for the high creative participants was 7.32 (SD=1.14). With regard to their AU performance, the average frequency for the high creative participants was 9.50 (SD= 1.38) their average flexibility was 5.91 (SD=1.60), average elaboration was 1.23 (SD=.32), and their average novelty score was 2.05 (SD=1.7). The average openness to experience score was 3.82 (SD=.55).

Based on the creativity assessment, 33 participants met the requirements to be included in the moderate creativity group. The mean performance on the RAT for the moderate creative participants was 4.63 (SD=0.69). With regard to their AU performance, the average frequency for the moderate creative participants was 5.76 (SD= 1.04), their average flexibility was 3.86 (SD=1.37), average elaboration was 1.21 (SD=.34), and their average novelty score was 1.65 (SD=1.80). The average openness to experience score was 3.60 (SD=.45).

Based on the creativity assessment, 28 participants met the requirements to be included in the low creativity group. The mean performance on the RAT for the low creative participants was 1.89 (SD=1.10). With regard to their AU performance, the average frequency for the low creative participants was 3.45 (SD= 0.73), their average flexibility was 2.88 (SD=1.67), average elaboration was 1.20 (SD=.37), and their average novelty score was 1.16 (SD=1.04). The average openness to experience score was 3.53 (SD=.53).

Study Design

Experiment 1

Each participant took part in a DVF relatedness judgment task to sentences that contained an ambiguous word. There were 64 critical sentences, half were bias to the dominant meaning and half were bias to the subordinate meaning of the ambiguous word. After the sentence was presented it was followed by a lateralized target word that was either related to the dominant meaning or the subordinate meaning of the ambiguous word. Participants were also presented with 64 filler sentences that were followed by unrelated targets. Presentation was randomized.

Experiment 2

Each participant took part in a DVF relatedness judgment to sentences that contained an ambiguous word. There were 64 critical sentences as well as 64 filler sentences. The critical sentences contained an ambiguous word. The initial context of the sentence provided a bias towards one meaning of the word. After the ambiguous word occurred, the end of the sentence switched the context to the alternative meaning of the ambiguous word. The sentence was then followed by a lateralized target word that was either related to the dominant meaning or the subordinate meaning of the ambiguous word. In addition to the 64 critical sentences there were also 64 filler sentences that, like the experimental trials were longer and had a complex syntactic structure. The targets for the filler sentences were all unrelated. Each ambiguous word was presented once in the context of either the subordinate to dominant meaning or the context of the dominant to subordinate meaning.

Each ambiguous prime word was presented twice, once in Experiment 1 and once in Experiment 2. The presentation of the target meaning (dominant/subordinate), semantic relatedness (for only Experiment 1), and visual field (LVF/RVF) were also counterbalanced across participants. With practice blocks included, the two sentence experiments took about 50-55 minutes to complete.

Assessment of Cognitive Control

Due to my prediction that the high creative subjects may show more flexible cognitive control, it is beneficial to include a measure of executive control in the form of a Stroop task (Stroop, 1935). After Experiments 1 and 2 participants completed a modified Stroop task (Stroop, 1935; Flowers, Warner, & Polansky, 1979). This task was a variant on the original Stroop task involving numbers rather than colors. This alternative Stroop measure avoids the potential problem of having some participants being colorblind. Participants selected the number written on the screen, or the number of words on the screen. For instance, if they were supposed to select the number, and the screen shows "one one one", they would select "one", whereas if they were supposed to count the numbers, "one one one" would be "three". The high creative subjects could potentially show faster reaction times to the items in the Stroop task due more flexible cognitive control (Zabelina & Robinson, 2010).

Stimuli

A norming study was conducted for all the critical sentences in both experiments. Eighty ambiguous words were chosen and dominant and subordinate

targets were selected for each word. There were 80 dominant biased sentences (length M=11.3, SD=2.7), 80 subordinate biased sentence (length M=11.8, SD=1.9), 80 sentences in which there was a bias towards the subordinate meaning of the sentences that switched to the dominant meaning (length M=16.4, SD=5.0), and 80 sentences in which there was a bias towards the dominant meaning of the sentences that switched to the subordinate meaning (length M=17.5 SD=4.0). A small subset of the subordinate sentences were chosen from a previous study (Titone, 1998).

For the Experiment 1 norming study, 50 participants were recruited from the Introduction to Psychology participant pool and received course credit for their participation. For the Experiment 2 norming study, 45 participants were recruited from the Introduction to Psychology participant pool and received course credit for their participation. Subjects read each sentence and provided a rating of comprehensibility of the sentence with a response of 1 (very hard to understand) to 5 (fully understandable) indicating how understandable they believed the sentence to be. For each ambiguous word, an average score was calculated based on the sentences for all four conditions (subordinate, dominant, subordinate to dominant, dominant to subordinate). Sixty-four ambiguous words with the highest ratings were chosen to be included in the experiments.

Understandability ratings for the subordinate sentences ranged from 4.24 to 4.94, while ratings for the dominant sentences ranged from 4.52 to 5. The ratings of the dominant and subordinate sentences were significantly different: $F(63) = 50.4$, ($p<.01$), dominant sentences (M= 4.88, SD= 0.09) were rated as more understandable than subordinate sentences (M= 4.69, SD= 0.18). While there is a

concern that the ratings for these sentences were significantly different, the sentences were all rated above 4.0, indicating that they were relatively easy to understand. Understandability ratings for the subordinate to dominant sentences ranged from 2.9 to 4.45, while ratings for the dominant to subordinate sentences ranged from 3.1 to 4.5. The ratings of the subordinate to dominant and the dominant to subordinate sentences were not significantly different: $F(63) = 2.2$, (p=0.14), subordinate to dominant (M= 3.79, SD= 0.27), dominant to subordinate (M= 3.72, SD= 0.27).

Sentence length of the subordinate sentences ranged from 8 to 16 words, while length of the dominant sentences ranged from 7 to 19 words. The length of the dominant and subordinate sentences were not significantly different: $F(63) = 3.02$, (p=0.09), subordinate (M= 11.8, SD= 1.83), dominant (M= 11.2, SD=2.52). Sentence length of the subordinate to dominant sentences ranged from 9 to 27, while length of the dominant to subordinate sentences ranged from 8 to 27. The length of the subordinate to dominant and the dominant to subordinate sentences were not significantly different: $F(63) = 2.33$, (p=0.13), subordinate to dominant (M= 16.1, SD= 4.84), dominant to subordinate (M= 17.4, SD= 4.04).

Data on all the normed ambiguous words and their targets were collected with respect to forward and backward association strength, and frequency according to the University of South Florida free association norms (Nelson, McEvoy, & Schreiber, 1982). All ambiguous prime words as well as the dominant and subordinate targets were 3 to 8 characters in length. The primes and targets were equated with respect to word length, $F(63) = 0.846$, (p=0.432), prime length

(M= 4.67, SD= 1.16), dominant target length (M= 4.84, SD= 1.38), subordinate target length (M= 4.94, SD= 1.28).

Frequency ratings for the ambiguous prime words ranged between 0 and 362 (M=55.7, SD=68.8). The frequency ratings of the dominant and subordinate targets were significantly different: $F(63) = 5.501$, (p=0.02), which is to be expected as dominant targets (M= 139.9, SD= 254.0) are more frequent than subordinate targets (M= 61.4, SD= 79.9). Forward association strength of the ambiguous word to the dominant meaning and the ambiguous word to the subordinate meaning was significantly different: $F(63) = 93.8$, (p<.0001), with higher association strength to dominant targets (M= 0.24, SD= 0.17) than subordinate targets (M= 0.03, SD= 0.05). Backward association strength of the ambiguous word to the dominant meaning and the ambiguous word to the subordinate meaning was not significantly different: $F(63) = 14.5$, (p<.0001), dominant targets (M= 0.10, SD= 0.17), subordinate targets (M= 0.02, SD= 0.05). Again, association strength is expected to differ as the dominant meanings are more highly associated to the ambiguous words than the subordinate meanings.

Procedure

After completing a consent form and the Edinburgh Handedness Inventory (Oldfield, 1971), participants performed both Experimental tasks (order was counterbalanced across participants). After the Experimental tasks they completed the Stroop task, and finally the pencil and paper creativity assessments. For Experiments 1 and 2 as well as the Stroop tasks, participants were seated directly in front of an LCD color monitor connected to a Dell personal computer, 50 cm from

the screen. Their heads were immobilized through the use of a chin rest. All stimuli were presented via E-Prime 2.0 software. A trial consisted of a 450 ms fixation point, followed by sentences that were presented one word at a time for 350 ms each, in black Courier New 18 point font on a white background in the center of the screen (central visual field – CVF). Following the presentation of the sentence, a lateralized target word was presented for 180 ms. Target words were related to either the dominant or subordinate meaning of the critical sentences while all targets for the filler sentences were unrelated. Participants were asked provide a relatedness judgment (e.g. Does the target word relate to the meaning of the previously viewed sentence) and had 2000 ms to do so.

Analysis Methods

Mean response accuracy (0=related; 1=unrelated) and mean response time (RT: ms) was measured for each condition. A four-way Sentence (Dominant, Subordinate) by Target (Dominant, Subordinate) by Visual Field (Right Visual Field/ Left Hemisphere; Left Visual Field/ Right Hemisphere) by Group (High creative; Moderate Creative, Low creative) mixed model ANOVA was conducted for each dependent variable.

Order effects were examined as all participants completed both experiments 1 and 2, counterbalanced for order. Results indicated a main effect in order, in that when participants completed Experiment 1 first, it resulted in higher accuracy. This effect was most pronounced for the low creative group.

Results

Correlation of Creativity Measures

Pearson correlations were calculated for the results of the creativity tests used to classify the participants into one of three creativity groups as well as their responses on the Big 5 questionnaire. All correlations are reported in Table 2. Consistent with the existing literature there are reliable relationships between the individual Big 5 factors. This will not be the focus of the current discussion, though they are reported in Table 2.

The RAT scores were positively correlated with AU flexibility, $r(85)=+.21$, $p=.05$, two-tailed. This suggests that the remote associates test and the flexibility measure generated by the alternative uses test both tap into a related construct, which we would argue is verbal creativity. AU flexibility was positively correlated with novelty, $r(85)=+.61$, $p<.01$, two-tailed. AU frequency was also found to be positively correlated with AU flexibility, $r(85)=+.91$, $p<.01$, as well as AU novelty, $r(85)=+.70$, $p<.01$, two-tailed. So all the measures derived from the AU test have some degree of relationship. The RAT scores were negatively correlated with the Big 5 factors of agreeableness, r(85), -.21, $p=.05$, and extroversion, r(85), -.29, $p<.01$, two-tailed. The RAT scores were expected to be related, via a positive correlation, with openness, but this was not observed in the current sample. The openness scores from this sample may have been abnormally low, as compared to reported values in the literature. Agreeableness was negatively correlated with AU frequency, $r(85)=-.22$, $p=.04$, two-tailed.

Table 2. Pearson correlations for the creativity measures.

		RAT	Agreeableness	Conscientiousness	Extroversion	Neuroticism	Openness
RAT	Pearson Correlation	1	-.21*	-0.13	-.29**	0.1	0.11
	Sig. (2-tailed)		0.05	0.21	0.01	0.36	0.34
Agreeableness	Pearson Correlation	-.21*	1	0.16	.22*	-0.12	-0.04
	Sig. (2-tailed)	0.05		0.14	0.05	0.26	0.71
Conscientiousness	Pearson Correlation	-0.14	0.16	1	0.11	-0.16	.22*
	Sig. (2-tailed)	0.21	0.14		0.3	0.15	0.05
Extroversion	Pearson Correlation	-.29**	.22*	0.11	1	-.34**	0.09
	Sig. (2-tailed)	0.01	0.05	0.3		0.01	0.42
Neroticism	Pearson Correlation	0.1	-0.12	-0.16	-.34**	1	0.11
	Sig. (2-tailed)	0.36	0.26	0.14	0.01		0.33
Openness	Pearson Correlation	0.11	-0.04	.22*	0.09	0.11	1
	Sig. (2-tailed)	0.34	0.71	0.05	0.42	0.33	
Mean Freq.	Pearson Correlation	0.18	-.22*	0.02	-0.05	-0.06	0.21
	Sig. (2-tailed)	0.1	0.04	0.88	0.64	0.59	0.06
Mean Flex.	Pearson Correlation	.21*	-0.21	0.07	-0.08	-0.04	0.16
	Sig. (2-tailed)	0.05	0.05	0.54	0.46	0.7	0.14
Mean Elab.	Pearson Correlation	-0.02	.27*	0.12	0.13	-0.11	-0.08
	Sig. (2-tailed)	0.86	0.01	0.28	0.25	0.34	0.42
Mean Novelty	Pearson Correlation	0.15	-0.18	-0.14	0.03	-0.02	0.14
	Sig. (2-tailed)	0.16	0.1	0.2	0.77	0.84	0.21

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table Continued on next Page

		Mean Freq.	Mean Flex.	Mean Elab.	Mean Novelty
RAT	Pearson Correlation	0.18	.21*	-0.02	0.15
	Sig. (2-tailed)	0.1	0.05	0.86	0.16
Agreeableness	Pearson Correlation	-.22*	-0.21	.27*	-0.18
	Sig. (2-tailed)	0.04	0.05	0.01	0.1
Conscientiousness	Pearson Correlation	0.02	0.07	0.12	-0.14
	Sig. (2-tailed)	0.88	0.54	0.28	0.2
Extroversion	Pearson Correlation	-0.05	-0.08	0.13	0.03
	Sig. (2-tailed)	0.64	0.46	0.25	0.77
Neroticism	Pearson Correlation	-0.06	-0.04	-0.11	-0.02
	Sig. (2-tailed)	0.59	0.7	0.34	0.84
Openness	Pearson Correlation	0.21	0.16	-0.09	0.14
	Sig. (2-tailed)	0.06	0.14	0.42	0.21
Mean Freq.	Pearson Correlation	1	.91**	0.13	.70**
	Sig. (2-tailed)		0.01	0.25	0.01
Mean Flex.	Pearson Correlation	.91**	1	0.21	.61**
	Sig. (2-tailed)	0.01		0.06	0.01
Mean Elab.	Pearson Correlation	0.13	0.21	1	0.15
	Sig. (2-tailed)	0.25	0.06		0.17
Mean Novelty	Pearson Correlation	.70**	.61**	0.15	1
	Sig. (2-tailed)	0.01	0.01	0.17	

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Experiment 1

Unrelated Trials

No significant effects were found when examining the RT data for the unrelated trials in Experiment 1. Examining the accuracy results for the unrelated trials, a main effect of creativity was found, $F(2, 85)=7.99$, $p<.01$, $\eta_{p^2}=.05$. A post hoc Bonferroni test ($p<.05$) revealed that the high creative ($M=.95$, $SE=.01$) participants had significantly higher accuracy for unrelated targets than the low creative participants ($M=.91$, $SE=.01$). The moderate creative participants ($M=.93$, $SE=.01$) were not significantly different from the other two groups. A main effect of visual field was also found, $F(1, 85)=6.73$, $p=.01$, $\eta_{p^2}=.02$. Targets presented to the RVF/LH ($M=.94$, $SE=.01$) had significantly higher accuracy than targets presented to the LVF/RH ($M=.94$, $SE=.01$). This finding is what would be expected in any VF study using words.

Related Trials

Examining the RT data for Experiment 1, the only significant main effect was found in the sentence data, $F(1, 85)=13.26$, $p<.01$, $\eta_{p^2}=.04$. Dominant sentences ($M=797.83$, $SE=17.40$) had significantly faster RTs than subordinate sentences ($M=887.43$, $SE=17.40$). No significant higher order interactions were found in the RT data.

Examining the accuracy data for the related trials, two significant main effects were found. There was a main effect of creativity, $F(2, 85)=4.85$, $p=.01$, η_{p^2}

=.03. Post hoc Bonferroni tests (p<.05) revealed that the moderate creative participants (M=.75, SE = .02) had significantly higher accuracy scores than the low creative participants (M=.68, SE=.02). The high creative participants (M=.74, SE=.02) were not significantly different from the other two groups. A main effect of sentence was also found, F(1, 85)=114.27, p<.01, η_{p^2} =.26. Consistent with the ambiguity literature, dominant biased sentences (M=.83, SE=.01) had significantly higher accuracy than subordinate biased sentences (M=.62, SE=.01).

A sentence by target interaction was found, F(1, 85)=11.70, p<.01, η_{p^2} =.04. Post hoc Bonferroni tests (p<.05) revealed that dominant sentences followed by a subordinate target (M=.90, SE=.02) had significantly higher accuracy than when followed by a dominant target (M=.78, SE=.02). Subordinate sentences followed by a dominant target (M=.64, SE=.02) were not significantly different than when followed by subordinate targets (M=.60, SE=.02).

A sentence by visual field interaction was found, F(1, 85)=14.63, p<.01, η_{p^2} =.04. Post hoc Bonferroni tests (p<.05) revealed subordinate sentences with LVF/RH presentation (M=.67, SE=.02) had significantly higher accuracy than RVF/LH presentation (M=.58, SE=.02). Dominant sentences with LVF/RH presentation (M=.86, SE=.02) were not significantly different than RVF/LH presentation (M=.80, SE=.02).

A three-way creativity by sentence by visual field interaction was found, F(2, 85)=4.13, p=.02, η_{p^2} =.03. A creativity by target by visual field interaction was also found, F(2, 85)=3.15, p=.05, η_{p^2} =.02. No other higher order interactions were

observed. To provide a clearer discussion of these two important three-way interactions, the results from each of the three creativity groups will be discussed separately below.

Low Creative Group

For the sentence by visual field interaction for the low creative participants, there was simply an overall advantage for the targets preceded by dominant sentences in both visual fields. The Bonferroni test ($p<.05$) of the LVF/RH targets indicate that the dominant sentences (M=.81 SE=.03) are more accurate then targets preceded by the subordinate sentences (M=.59 SE=.03). Likewise for the RVF/LH targets, the dominant sentences (M=.76 SD=.03) are more accurate then targets preceded by the subordinate sentences (M=.58 SD=.03; see Figure 1). This finding is not consistent with our predictions. For the target by visual field interaction both target types resulted in the same level of accuracy, regardless of visual field (see Figure 2). So there was no effect of either target type or visual field for target accuracy.

Figure 1. Low creative group, mean accuracy for the sentence by visual field interaction in Experiment 1.

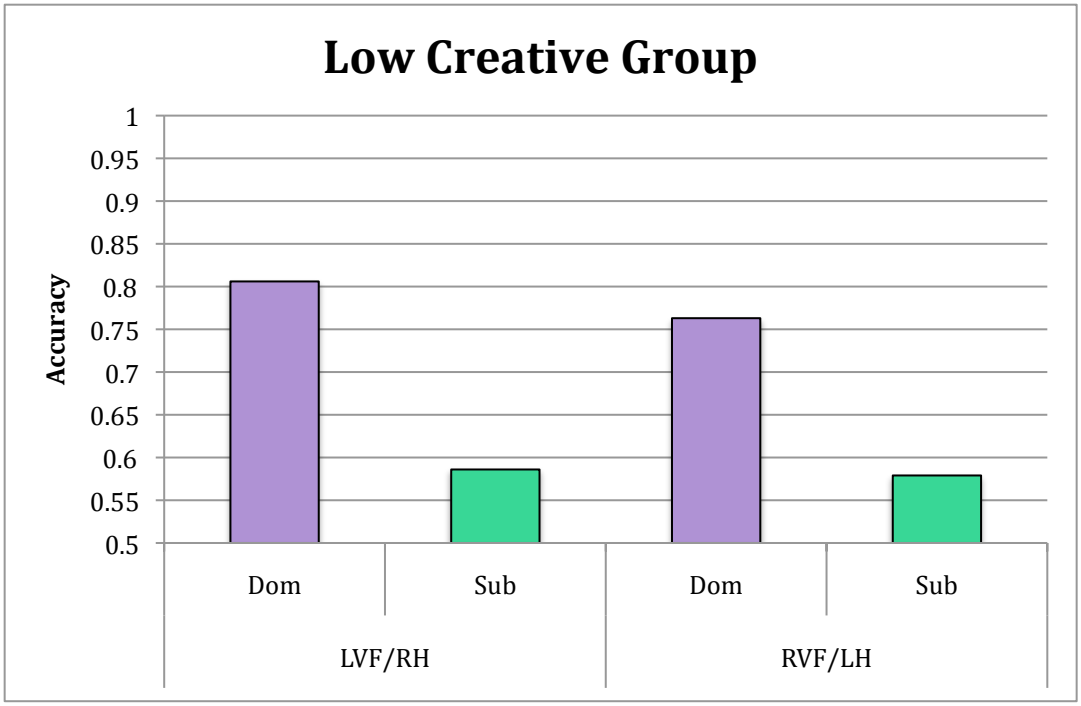
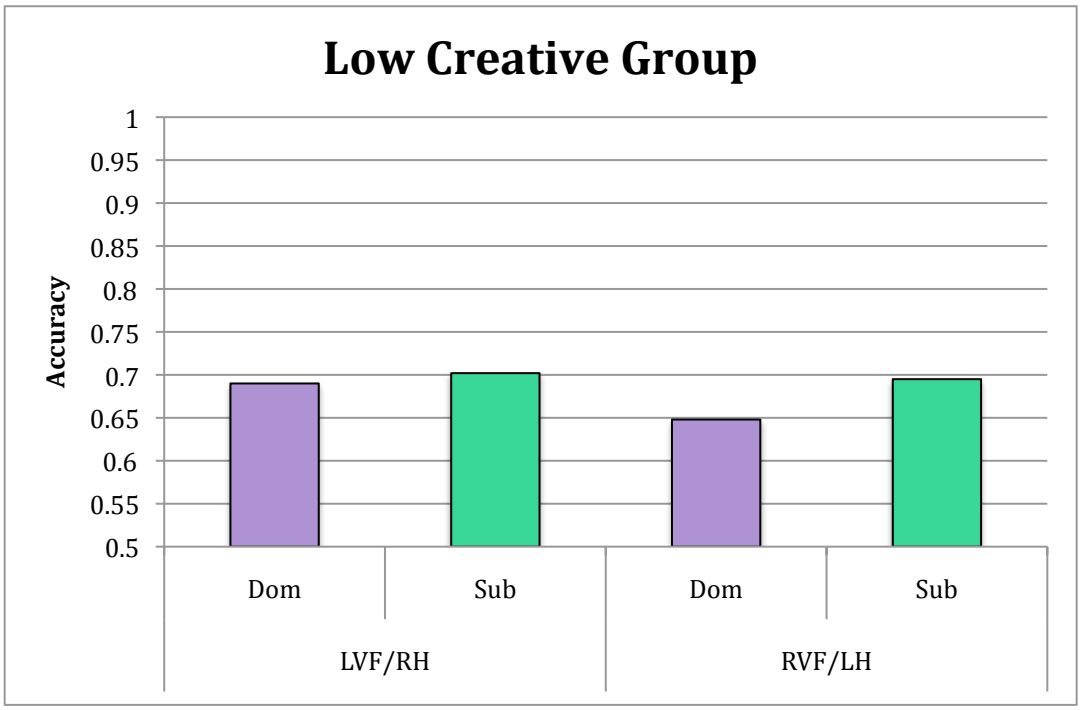


Figure 2. Low creative group, mean accuracy for the target by visual field interaction in Experiment 1.



Moderate Creative Group

For the sentence by visual field interaction for the moderate creative participants, there was also an overall advantage for the targets preceded by dominant sentences in both visual fields. Bonferroni tests ($p<.05$) revealed that for the moderate creative participants, targets presented to the LVF/RH that were preceded by dominant sentences (M=.84, SE=.03) were significantly more accurate than when preceded subordinate sentences (M=.60, SE=.03). Targets presented in the RVF/LH that were preceded by dominant sentences (M=.84, SE=.03) were significantly more accurate than when preceded by subordinate sentences (M=.70, SE=.03; see Figure 3). Again, this is not what we would have expected based on a-priori predictions. For the target by visual field interaction both target types resulted in the same level of accuracy, regardless of visual field (see Figure 4). So there was no effect of either target type or visual field for target accuracy.

Figure 3. Moderate creative group, mean accuracy for the sentence by visual field interaction in Experiment 1.

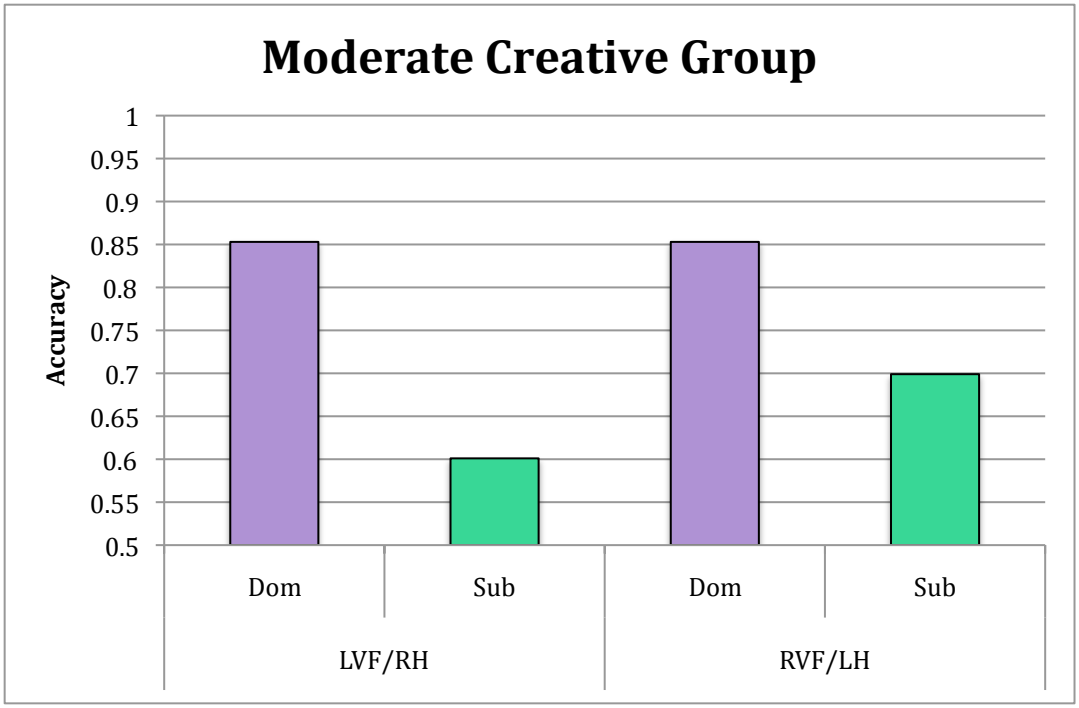
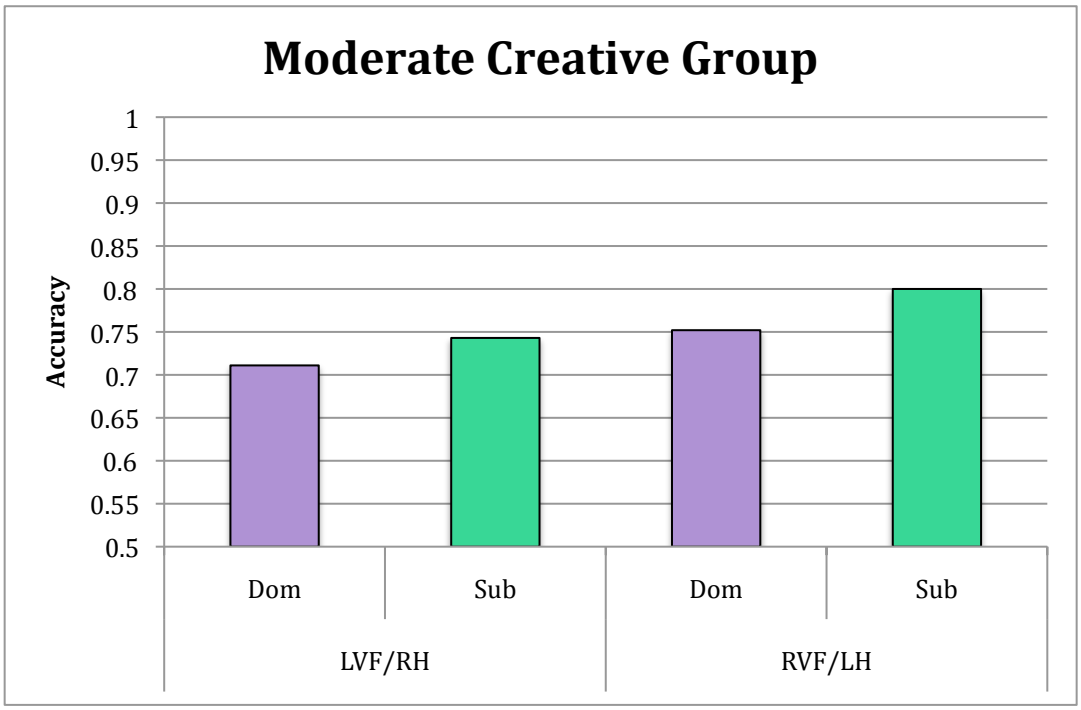


Figure 4. Moderate creative group, mean accuracy for the target by visual field interaction in Experiment 1.



High Creative Group

For the sentence by visual field interaction for the high creative participants, there was an overall advantage for the targets preceded by dominant sentences in the LVF/RH. Bonferroni tests ($p<.05$) revealed that dominant sentences with targets presented to the LVF/RH that were preceded by a dominant sentence (M=.91, SE=.04) were significantly more accurate than when preceded by a subordinate sentence (M=.55, SE=.04). Unlike the low and moderate creative groups, dominant sentences (M=.77, SE=.04) with targets presented to the RVF/LH show no differences in accuracy compared to the subordinate sentences (M=.72, SE=.04; see Figure 5). For the target by visual field interaction both target types resulted in the same level of accuracy, regardless of visual field (see Figure 6). So there was no effect of either target type or visual field on target accuracy.

Figure 5. High creative group, mean accuracy for the sentence by visual field interaction in Experiment 1.

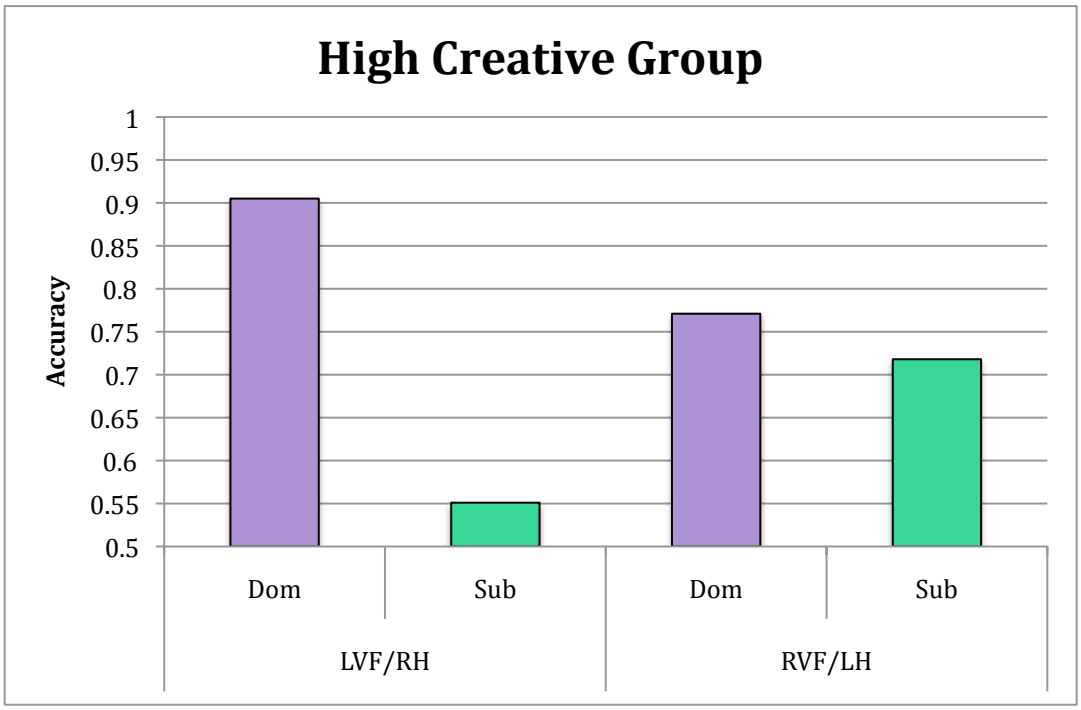
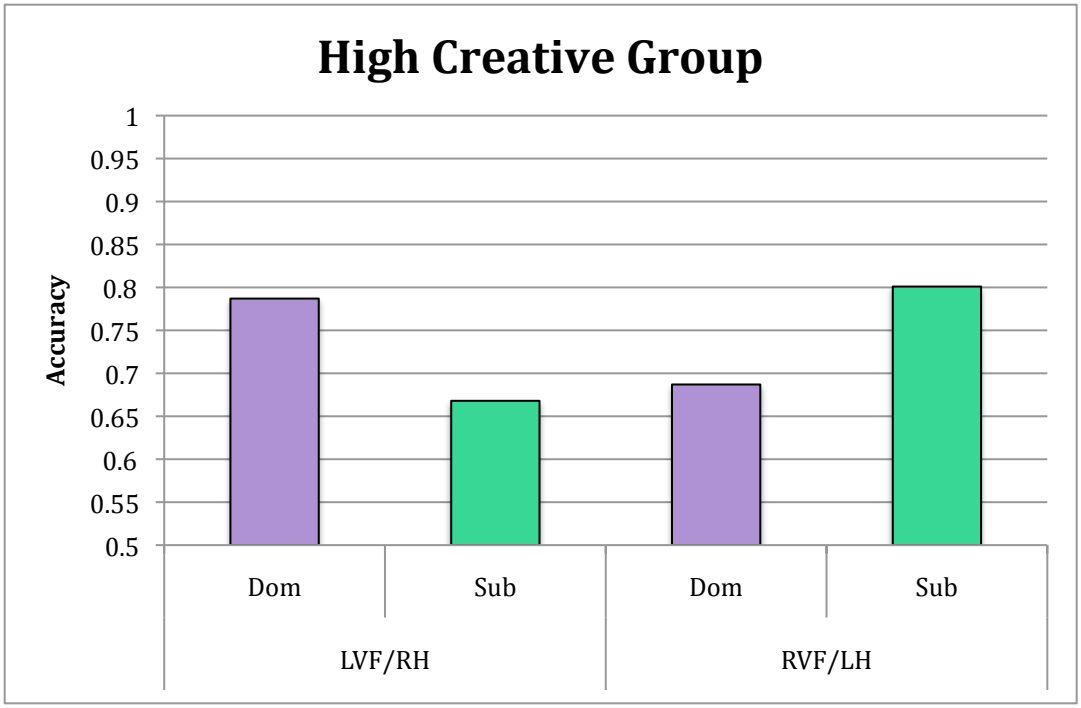


Figure 6. High creative group, mean accuracy for the target by visual field interaction in Experiment 1.

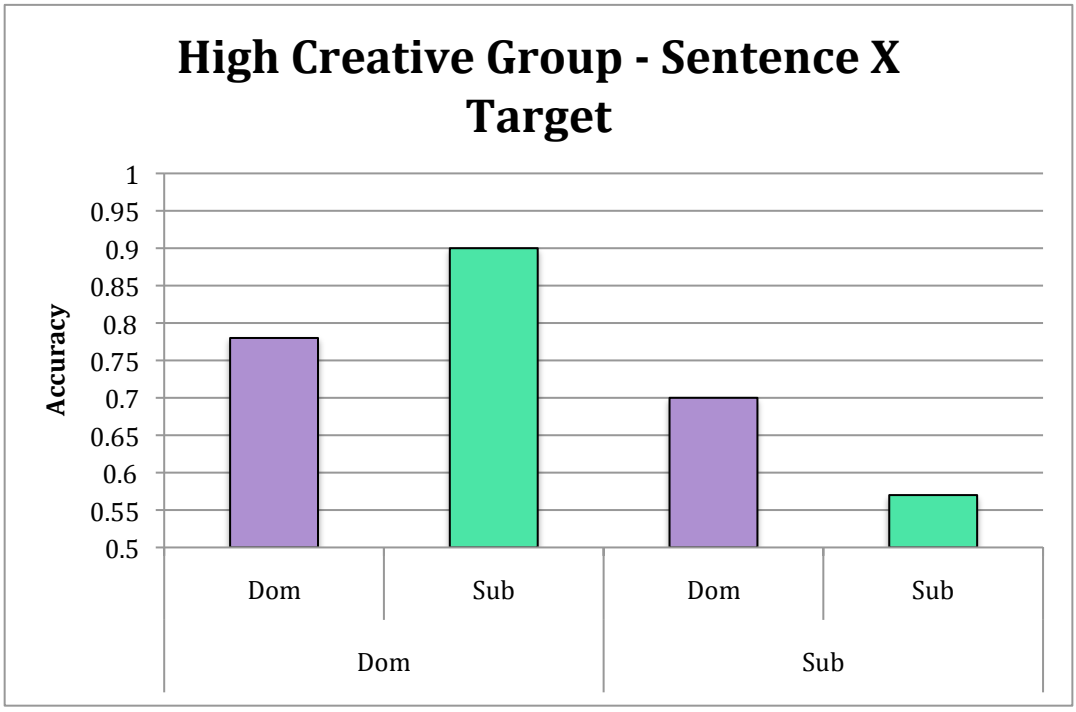


An ANOVA was conducted for each creativity group on the related trials in Experiment 1. For all three groups, a main effect of sentence was found. As indicated above, the dominant sentences produced higher accuracies than the subordinate sentences. There was also a sentence by visual field interaction and a target by visual field interaction in the high creative group. The results of these interactions are reported in the post hoc tests conducted on the creativity by sentence by visual field interaction and the creativity by sentence by target interaction reported above.

An additional sentence by target interaction was found in the high creative group, $F(1, 24)=13.52$, $p<.01$, $\eta_{p^2}=.13$ (see Figure 7). A post hoc Bonferroni test ($p<.05$) revealed that dominant sentences followed by a subordinate target ($M=.90$,

SE=.03) had a nearly significantly effect in the form of higher accuracies compared to dominant target (M=.78, SE=.03). Subordinate sentences followed by a dominant target (M=.70, SE=.03) had significantly higher accuracies than when followed by a subordinate target (M=.57, SE=.03). So, the high creative group had higher accuracies when the biased sentence was followed by targets of the alternative meaning of the ambiguous word.

Figure 7. High creative group, mean accuracy for the sentence by target interaction in Experiment 1.



Experiment 2

Unrelated trials

No significant effects were found for the unrelated trials in the accuracy and RT data in Experiment 2.

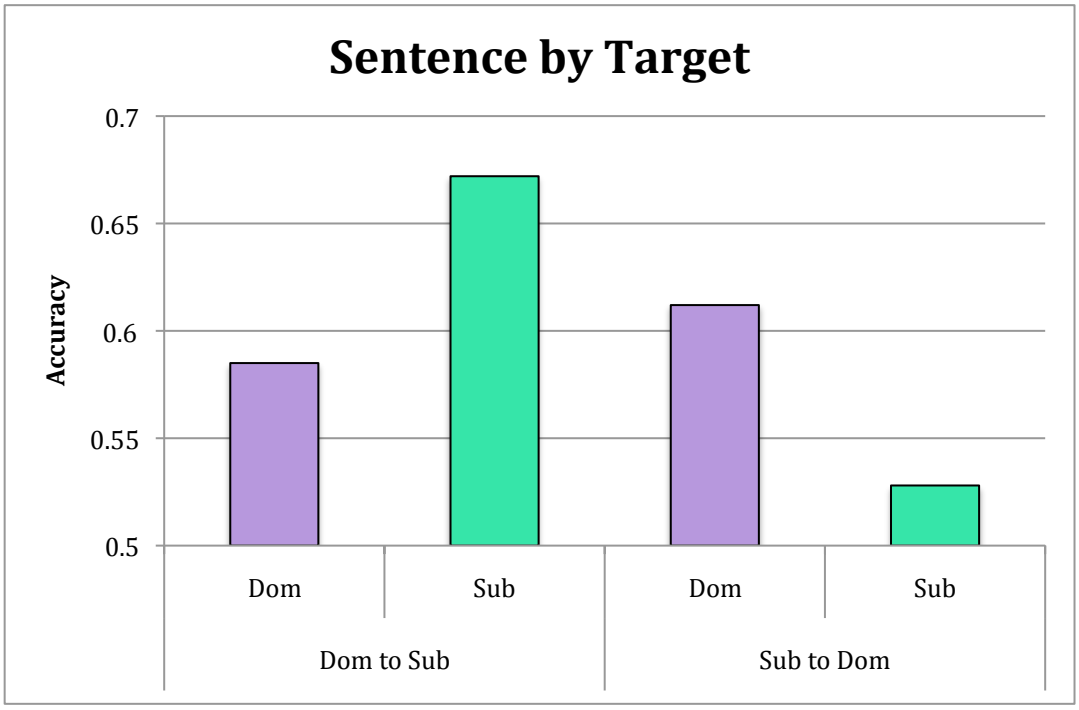
Related Trials

No significant effects were found for the RT data in Experiment 2.

Examining the accuracy data, a main effect of creativity was found, F(2, 85)=3.46, p=.04, η_{p^2}=.02. A post hoc Bonferroni test (p<.05) revealed that the high creative (M=.63, SE=.02) participants had significantly higher accuracy for related targets than the low creative participants (M=.56, SE=.02), much like we found for Experiment 1. The moderate creative participants (M=.61, SE=.02) were not significantly different from the other two groups. A main effect of sentence was also found, F(1, 85)=8.20, p<.01, η_{p^2}=.03. Dominant to subordinate sentences (M=.63, SE=.02) had significantly higher accuracy than subordinate to dominant sentences (M=.57, SE=.02). No other main effects were observed.

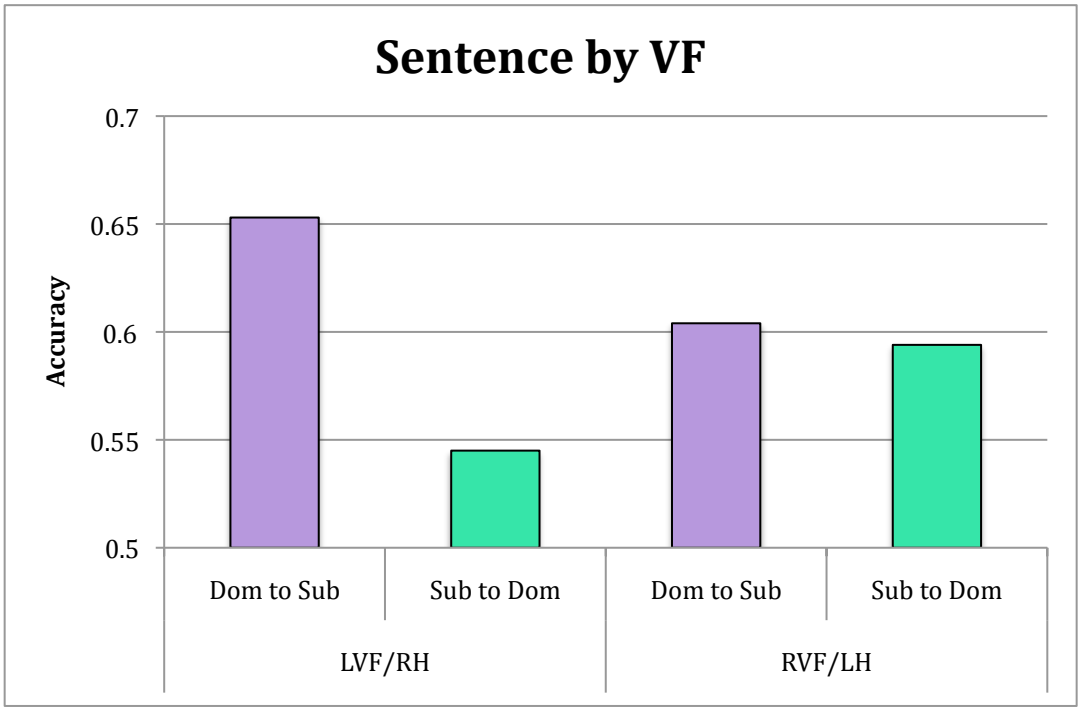
Only two higher order interactions were observed. There was a sentence by target interaction, F(1, 85)=17.50, p<.01, η_{p^2}=.05 (see Figure 7). A post hoc Bonferroni test (p<.05) revealed that dominant to subordinate sentences followed by a subordinate target (M=.67, SE=.02) had significantly higher accuracy then when followed by a dominant target (M=.59, SE=.02). Subordinate to dominant sentences followed by a dominant target (M=.61, SE=.02) had significantly higher accuracy then when followed by a subordinate target (M=.53, SE=.02). This suggests that the participants were effectively able to resolve the ambiguity correctly.

Figure 8. Mean accuracy for the sentence by target interaction Experiment 2.



An interesting sentence by visual field interaction was also found, F(1, 85)=5.72, p=.02, η_{p^2} =.02 (see Figure 8). In the RVF/LH there was no difference observed based on sentence type (Dom to Sub M=.60, SE=.02; Sub to Dom M=.59, SE=.02). In contrast when targets are presented to the LVF/RH participants were more accurate if the sentence began with the dominant meaning and then switched to the subordinate (M=.65, SE=.02), then the reverse sentence type (M=.55, SE=.02).

Figure 9. Mean accuracy for the sentence by visual field interaction in Experiment 2.



Importantly, there was no interaction involving creativity group. Thus, further analysis of the three creativity groups is not truly warranted based on the results from our ANOVA. However, we did conduct this analysis because this was the purpose of the current research and we had clear a-priori predictions. However, for none of the groups was VF a significant variable for either the main effect or interaction analyses. So no further post-hoc analyses were conducted.

Stroop Data

A main effect of creativity was found in accuracy data for Stroop performance, $F(2, 85)=3.20$, $p=.05$. A post hoc Tukey test ($p<.05$) revealed that the high creative group ($M=.89$, $SE=.02$) showed a nearly significant effect in the form of higher accuracy compared to the low creative group ($M=.83$, $SE=.02$). A similar main effect of creativity was found in the RT data, $F(2, 85)=7.45$, $p<.01$. A post hoc

Tukey test ($p<.05$) revealed the low creative participants (M=869.05, SE=32.06) had significantly slower RTs than both the high (M=706.26, SE=33.93) and the moderate creative participants (M=729.96, SE=29.53). The high and moderate creative participants were not significantly different from each other.

Discussion

Major findings

There was a clear relationship between creativity level (as measured using the RAT and AU task) and performance on this DVF sentence priming study in Experiments 1 and 2. The high creative participants had significantly higher accuracy for unrelated targets than the low creative participants in Experiment 1. While high creative participants were not significantly different from the other two groups on the related trials for Experiment 1, they did show significantly higher accuracies for related trials over the low creative participants in Experiment 2. In Experiment 1, the moderate creative participants had significantly higher accuracy for related targets than the low creative participants. However, they were not significantly different from the other two groups on the unrelated trials in Experiment 1 or for either the related or unrelated trial in Experiment 2. So it seems as though overall, the low creative participants performed significantly worse than the other two groups on DVF sentence priming for both the simple and complex sentences.

With regard to Stroop performance, there was also a clear relationship between performance and creativity. The high and moderate creative participants show significantly faster RTs than the low creative group. So again, we find that the

low creative participants performed significantly worse than the other two groups. A discussion of the relationship between creativity, performance on the DVF priming study, and Stroop performance is provided below.

Experiment 1

Overall, the high creative participants outperformed the low creative participants in the DVF priming and Stroop tasks. The high creative group showed an overall advantage for the targets preceded by dominant sentences in the LVF/RH in Experiment 1. Dominant sentences with targets presented to the RVF/LH show no differences in accuracy compared to the subordinate sentences, which differs from the performance of the low and moderate creative groups. So it seems that the laterality effects help to differentiate the high creative participants from the other two groups (further discussion found below in *Lateralized Semantic Processing and Creativity*).

In the high creative group, subordinate sentences followed by a dominant target had significantly higher accuracies than when followed by a subordinate target. Dominant sentences followed by a subordinate target had a nearly significant effect of higher accuracy than when followed by a dominant target. While not initially predicted, this is a very interesting finding. It seems that in the high creative group, when a biased sentence is presented, they activate the alternative meaning of the ambiguous word. This seems to be evidence of a broad pattern of activation and may be a reflection of the role of the LH in the high creative group. Dominant sentences with targets presented to the RVF/LH show no differences in accuracy compared to the subordinate sentences for the high creative group. The LH

seems to be maintaining both representations of the ambiguous word. It may be that the high creative subjects do in fact show greater salience for both dominant and subordinate meanings in the LH, which could be why there was no difference in accuracy for sentence type.

In Experiment 1, the moderate creative group showed overall better performance than the low creative group on both the DVF priming task and the Stroop task. When examining the sentence by visual field interaction, this group showed an overall advantage for the targets preceded by dominant sentences in both visual fields. There was no effect of either target type or visual field for target accuracy.

The low creative groups performed worse than both the high and moderate creative group on the DVF priming and Stroop tasks. We found an overall advantage for targets preceded by dominant sentences in both visual fields. There was no effect of either target type or visual field for target accuracy. The results of the low creative participants were quite similar to the moderate creative participants when examining the higher order interactions in Experiment 1.

Experiment 2

Turning now to the results in Experiment 2, there was a main effect of creativity. The high creative group outperformed the low creative group on the DVF priming study using complex sentences. It was predicted that high creative individuals will have a higher ambiguity tolerance, i.e. they will be faster and more accurate when responding to the target word preceded by context switching sentences. Therefore, this finding is not surprising as those who score low on

creativity measures have previously shown lower accuracy rates under measures of ambiguity tolerance (Atchley, Keeney & Burgess, 1999).

Dominant to subordinate sentences had significantly higher accuracies than subordinate to dominant sentences. Again, this suggests a preference for dominance similar to Experiment 1. It seems the participants were better able to resolve ambiguity when the sentence began with a dominant bias. Previous studies within the ambiguity literature have shown an advantage for dominance as discussed above (Burgess & Simpson, 1988a; Atchley, Burgess, & Keeney, 1999; Titone, 1998). This advantage seems to hold true even in the presence of the context switching sentences that were presented in Experiment 2.

Dominant to subordinate sentences followed by a subordinate target had significantly higher accuracy than when followed by a dominant target. Subordinate to dominant sentences followed by a dominant target had significantly higher accuracy than when followed by a subordinate target. This finding was expected and suggests that the participants were effectively able to resolve the ambiguity correctly.

In the RVF/LH there was no difference observed based on sentence type. In contrast, when targets are presented to the LVF/RH, participants were more accurate if the sentence began with the dominant meaning and then switched to the subordinate, than the reverse sentence type. So in the RH, the initial activation of only the dominant meaning leads to an advantage when presented with a sentence that begins with a bias towards the dominant meaning that later switches to the

subordinate meaning (further discussion found below in *Lateralized Semantic Processing and Creativity*).

Simple versus Complex Sentences

Experiment 1, which used the simpler sentences, seemed to produce better results compared to Experiment 2. The complex nature of the sentences in Experiment 2 produced a floor effect, as accuracies were much lower than Experiment 1 and in some conditions just above chance. These sentences were significantly longer than the simple sentences in Experiment 1. While comprehensibility ratings in the norming study suggest that the sentences were understandable, it's possible that the one word presentation made them more difficult to comprehend. When providing comprehensibility ratings during the norming study the participants were able to see the whole sentence and read it multiple times before providing a rating. Proposed modifications to this task will be provided in *Future Directions* discussed below.

Consistent with the ambiguity literature, dominant biased sentences had significantly higher accuracies and faster RTs than subordinate biased sentences (Burgess & Simpson, 1988a; Atchley, Burgess, & Keeney, 1999; Titone, 1998). Also consistent with previous literature on DVF studies, targets presented to the RVF/LH had significantly higher accuracy than targets presented to the LVF/RH (Burgess & Simpson, 1988a; Atchley, Burgess, & Keeney, 1999; Titone, 1998; Hasbrooke & Chiarello, 1998).

Accuracy rates were higher to unrelated compared to related stimuli in both Experiments 1 and 2. This was unexpected as related trials usually show higher

accuracy rates than unrelated trials (McNamara, 2005). It may be that this result is due to the nature of the stimuli presented and the semantic judgment task that participants performed. This task was chosen because research suggests that the semantic judgment task may be better able to tap into inhibitory semantic processing because participants are forced to select one interpretation of the ambiguous word in order to complete the task. We found no evidence of semantic inhibition in the current study. It's possible that when participants performed the semantic relatedness task they developed a bias towards choosing the "unrelated" response, as half the trials were unrelated and in half of the critical trials the appropriate response was "unrelated." Using a lexical decision task for Experiments 1 and 2 may provide additional insight into the processes of semantic activation in the hemispheres.

Measuring Creativity

With respect to the creativity measures used to group participants into one of three creativity groups, high moderate and low creativity, the RAT and the flexibility measure generated by the AU test were positively correlated. This suggests that both tap into a related construct, which we would argue is verbal creativity. All the measures derived from the AU test except for elaboration were shown to have some degree of relationship. It's possible that elaboration was not correlated with the other AU measures because of the timed nature of the test. Participants were likely focused on generating as many novel uses of the object as possible in the three minutes provided, and less concerned with providing an elaborative explanation.

The RAT and AU scores were expected to be related via a positive correlation with Openness, but this was not observed in the current sample. Many studies have found Openness to experience to be positively correlated to creative ability as measured by the TTCT and other divergent thinking measures (King, Walker and Broyles, 1996; King and Pope, 1999; McCrae, 1987; Furnham, Batey, Anand, & Manfield, 2008). However, the absence of a positive correlation between the creativity measures used in this study and Openness to experience is not entirely unusual, as some research has failed to find correlations between the TTCT and AU and this personality trait (Strong, Nowakowska, Santosa, Wang, Kraemer et al., 2007; Batey, Furnham, and Safiullina, 2010). Based on past findings, one would predict a correlation between creativity and Openness. This trait has been suggested to be related to a flexible cognitive style, preference for open-ended problem solving, and openness to new experiences (McCrae, 1987; Feist, 1998; Batey & Furnham, 2006). Likely, the failure to find a correlation between creativity and Openness in the current study reflected the abnormally low scores in the current sample.

The RAT and AU frequency measures were negatively correlated with Agreeableness, a finding that has been supported by previous studies (for reviews see Batey and Furnham, 2006; Feist, 1998). The RAT was also negatively correlated with Extroversion. While some have found Extroversion to be positively correlated with creativity (King, Walker and Broyles, 1996; Martindale & Dailey, 1996; Aguilar-Alonso, 1996; Batey & Furnham, 2006), others have found negative correlations (Feist, 1998). There is a possible relationship between Extroversion and

Agreeableness with respect to creativity. Feist (1998) proposed that having a greater desire to remove oneself from social interactions (introversion) and a tendency to question social norms and be independent of group influence are characteristics often found in creative people. The creative process often requires solitude as individuals are required to focus their attention and energy inward. Creative individuals also benefit from a nonconforming disposition that can lead to independent thought and novel ideation.

Creativity and Stroop Performance

The Stroop task was chosen as a measure of cognitive control. Performance on this task has been shown to be linked to creativity in a number of studies (Gamble & Kellner, 1968; Golden, 1975; Zabelina & Robinson, 2010). It has been suggested that high creative individuals are more flexible in their cognitive control and this flexibility contributes in different ways to the creative process with respect to ideation and evaluation (Groborz & Necka, 2003). During idea generation, creative individuals are able to defocus their attention, which can lead to uninhibited, creative thought. This has been supported by the EEG literature which has found that changes in power and synchrony may reflect low cortical arousal and defocused attention (Eysenck, 1995; Martindale, 1999; Mendelsohn, 1976). Studies of cortical arousal have shown creative people to have less cortical arousal during tests of creativity (Martindale & Hines, 1975). During the evaluation phase, creative individuals must appraise their new ideas in order to judge which ideas are worth developing and undertaking (Groborz & Necka, 2003). Again, the EEG literature has found that creative people actually show more cortical arousal on intelligence tests

(Martindale & Hines, 1975). Martindale (1999) proposed that creative people are able to adjust their focus depending on task demands. During early stages of creativity, such as thinking about/creating a story (inspirational phase), lower activity is observed, but not when writing it down (elaboration phase) (Martindale & Hasenfus, 1978). Thus, flexible cognitive control seems to be a hallmark of creative individuals.

While the high creative group did not differ from the moderate creative groups as initially predicted, both groups outperformed the low creative group. The low creative participants had significantly slower RTs and a nearly significant effect of lower accuracy than the high and the moderate creative participants. This finding may reflect weaker cognitive control in the low creative participants as compared to the other two groups. Interestingly, performance on the Stroop task parallels overall performance on both DVF tasks. The high and moderate creative groups did not differentiate from each other, however both groups outperformed the low creative group. It seems that the low creative participants show a hyper-influence of automatic processes. In the DVF tasks, there was an overall preference for dominance due to automatic activation of the dominant meaning. These participants also showed difficulty inhibiting automatic processing in the Stroop task. Taken together, this suggests that the low creative group is more bottom-up driven than the high and moderate creative groups.

Lateralized Semantic Processing and Creativity

Multiple theories have been proposed with regard to semantic access in the two hemispheres that have implications for the study of verbal creativity (Giora,

1997; Mark Jung-Beeman, 2005; Mednick, 1962). On the basis of these theories, I propose a view of the two hemispheres in which the LH and RH represent distinct and parallel semantic processing systems, and asymmetries arise due to processing differences of each hemisphere. In normal individuals, the LH has been shown to quickly activate the contextually appropriate representation and inhibit the contextually inappropriate representation, while the RH has shown somewhat slower and weaker, but more diverse activation of both dominant and subordinate representations, as well as distantly related and less salient meanings. This collaboration between the two hemispheres seems to be particularly efficient because the RH's ability to maintain activation of this information is useful in the event of lexical ambiguity or meaning misassignment during online comprehension that requires reinterpretation.

The ability to maintain activation of distantly related concepts in the context of ambiguity is referred to as ambiguity tolerance (Atchley, Keeney, et al., 1999; Tegano, 1990). Evidence suggests that high creative individuals maintain activation of multiple meanings in both hemispheres, which can result in a higher tolerance for ambiguity (Atchley, Keeney, and Burgess, 1999). It may be the case that high creative individuals have an advantage in ambiguity resolution because subordinate representations are more salient to these individuals.

Right Hemisphere Performance

Previous studies have shown that in the presence of context, the RH activates both meanings of the ambiguous word, which suggests that this hemisphere is not engaged in controlled meaning selection (Grindrod & Baum, 2003; Faust and

Chiarello, 1998). In Experiment 1, all three groups showed an overall advantage for the targets preceded by dominant sentences in the LVF/RH. This finding is not consistent with our predictions. Based on the results of these previous studies, it was predicted that both moderate and high creative subjects would show equal priming of both the dominant and subordinate targets in the LVF/RH. However, it seems that all participants showed an advantage when presented with the dominant bias sentences in the RH. This finding may be a reflection of the short SOA (350 ms) used in the current study. Because Burgess and Simpson (1988a) showed RH activation of only the dominant meaning in the RH at the short SOA, it may be that a longer SOA would result in equivalent accuracies to the subordinate and dominant sentences. To illuminate the time course of semantic activation in the presence of context, future studies would benefit from the use of multiple SOAs, both short (e.g. 0-350 ms) and long (e.g. ≥750).

In Experiment 2, when targets are presented to the LVF/RH, participants were more accurate if the sentence began with the dominant meaning and then switched to the subordinate, then the reverse sentence type. Burgess and Simpson (1998a) showed that in RH, only the dominant meaning was activated at the short SOA. It seems that in the RH, the initial activation of only the dominant meaning leads to an advantage when presented with a sentence that begins with a bias towards the dominant meaning that later switches to the subordinate meaning. Because the RH does not rapidly activate the subordinate meaning, no such advantage is seen when a sentence begins with a bias towards the subordinate meaning, and then switches to the dominant meaning.

Left Hemisphere Performance

The LH has been shown to activate only the contextually appropriate meaning (i.e. following dominant biased sentence context, only dominant meanings were activated, and following subordinate biased sentence context, only subordinate meanings were activated; Faust and Chiarello, 1998). Thus, the results from previous studies of LH activation in the presence of context suggest that both message level and intra-lexical level mechanisms can influence word recognition in the LH. The low and moderate creative participants showed an overall advantage for the targets preceded by dominant sentences in the RVF/LH. However, in high creative participants, dominant sentences with targets presented to the RVF/LH show no differences in accuracy compared to the subordinate sentences. It may be that the high creative subjects do show greater salience for both dominant and subordinate meanings in the LH, which could be why there was no difference in sentence type.

Concerning Experiment 2, no difference was observed in the RVF/LH based on sentence type. Therefore the LH seems to have the ability to resolve ambiguity regardless of sentence type. Burgess and Simpson (1998a) found priming for the dominant and subordinate meaning at the short SOA in the RVF/LH. Because of the pattern of results, it seems to be the case that the initial activation of both the subordinate and dominant meaning in the LH leads to an advantage in ambiguity resolution when the sentence context later switches to the alternative meaning.

A possible explanation for the differences between the high and low creative groups may be due to representational differences between these two groups

(Atchley, Keeney, & Burgess, 1999). Semantic representations that a person has more experience with lead to richer representations that are more easily accessed. The low creative participants seem to have an overall preference for dominance in the DVF task. This is because the dominant representation is more stable due to the more frequent experience one has with the dominant meaning of an ambiguous word. This finding in conjunction with their low performance on the Stroop task seems to suggest that low creative individuals rely on more automatic activation in the DVF priming task.

In contrast, the high creative participants seem to activate a broader network of semantic representations, particularly in the LH. Subordinate meanings of ambiguous words are, by definition, more infrequent, so most individuals have less experience with them, which leads to a less stable representation. The results of the current study along with previous research (Atchley, Keeney & Burgess, 1999) suggest that the high creative individuals may have a more stable representation of these subordinate meanings. This could reflect a higher salience for subordinate meanings in the LH for high creative individuals.

Future Directions

While the current study provided some very interesting findings, especially with respect to the high and low creative groups, certain modifications could help to illuminate the relationship between verbal creativity and ambiguity resolution in the hemispheres. While there were empirically supported justifications for using the semantic judgment task, a lexical decision task may provide additional information as to the nature of semantic access in the hemispheres. One initial concern of using

a lexical decision task was that participants might just focus on the lexical nature of the target instead of attending to the semantic content of the sentence. Using comprehension questions after the presentation of the sentences may help to avoid this problem. It seems the participants developed a bias toward responding "unrelated" in the current study. Including unambiguous related filler sentences in order to keep the relatedness proportion at 50% would help to avoid this bias.

Another important modification to include is a varying SOA. An investigation of temporal aspects of semantic activation is essential for a comprehensive understanding of semantic access in the hemispheres (Federmeier & Laszlo, 2009; Atchley, Burgess and Keeney, 1999; Burgess and Simpson, 1988a). While the current study provides information as to the nature of verbal creativity as it relates to ambiguity resolution in the hemispheres at a short SOA, future studies would benefit from investigating these processes at a later point in time.

Finally, task modifications to Experiment 2 may help to avoid the floor effect seen in the accuracy data. It seems that the one word presentation made the complex sentences difficult to comprehend. Centrally presenting clauses of the sentence instead of single words may help with comprehensibility. Furthermore, a cross-modal task may provide more information as to the time course of semantic access and ambiguity resolution during the presentation of the complex sentences. Presenting the sentence in an auditory modality with a lateralized visual target lexical decision task would allow us to vary the temporal aspects of target presentation. Half of the trials would consist of the presentation of an auditory sentence with DVF target presentation directly after the ambiguous word in order to

examine semantic activation during initial interpretation. Target presentation on the other half of trials would be presented after the sentence final word in order to examine ambiguity resolution. In order to avoid the participant passively listening to the sentence and focusing solely on the lexical nature of the target, comprehension questions would be presented after the presentation of the sentences. I believe this alternative task would not only help increase comprehensibility of the complex sentences, but also provide important information on the time course of semantic activation and ambiguity resolution in the hemispheres.

Conclusions

Overall, the low creative participants performed worse on the DVF priming study as well as the Stroop task. Both the low and moderate creative participants had a preference for dominance in the DVF sentence-priming task. The low creative group also had more difficulty resolving ambiguity than the high and moderate creative participants. These findings seem to suggest that the low creative individuals show representational differences compared to the high creative group and also rely on more automatic/bottom-up activation.

With respect to the high creative group, when a biased sentence was presented, these individuals activated the alternative meaning of the ambiguous word. This seems to be evidence of a broad pattern of activation and may be a reflection of the role of the LH in the high creative group. The LH seems to be maintaining both representations of the ambiguous word. It may be that the high

creative subjects do in fact show greater salience for both dominant and subordinate meanings in the LH.

The use of semantic access models to understand ambiguity resolution within the hemispheres has proven beneficial in the investigation of individual differences in creativity. Further study into the nature and time course of ambiguity resolution in the two hemispheres is needed in order to understand differences in semantic activation for those who vary on measures of creativity. An understanding of individual differences in semantic access can illuminate underlying processes that lead to creative cognition.

References

Aghababyan, A. R., Grigoryan, V. G., Stepanyan, A. Y., Arutyunyan, N. D., & Stepanyan, L. S. (2007). EEG reactions during creative activity. *Human Physiology, 33*(2), 252-253. doi: 10.1134/s0362119707020193

Aguilar-Alonso, A. (1996). Personality and creativity. *Personality and Individual Differences, 21*, 959-969.

Anaki, D., Faust, M., & Kravetz, S. (1998). Cerebral hemisphere asymmetries in processing lexical metaphors. *Neuropsychologia, 36*(7), 691-700. doi: 10.1016/s0028-3932(97)00141-3

Arden, R., Chavez, R. S., Grazioplene, R., & Jung, R. E., (2010). Neuroimaging creativity: A psychometric view. Behavioural Brain Research, 214(2), 143-156.

Atchley, R. A., & Burgess, C. (1998). Contextual influences on meaning retrieval in the cerebral hemispheres. *Brain and Cognition, 37*(1), 63-66.

Atchley, R. A., Burgess, C., & Keeney, M. (1999). The effect of time course and context on the facilitation of semantic features in the cerebral hemispheres. *Neuropsychology, 13*(3), 389-403. doi: 10.1037/0894-4105.13.3.389

Atchley, R. A., Keeney, M., & Burgess, C. (1999). Cerebral hemispheric mechanisms linking ambiguous word meaning retrieval and creativity. *Brain and Cognition, 40*(3), 479-499. doi: 10.1006/brcg.1999.1080

Aziz-Zadeh, L., Kaplan, J. T., & Iacoboni, M. (2009). "Aha!": The neural correlates of verbal insight solutions. *Human Brain Mapping, 30*(3), 908-916. doi: 10.1002/hbm.20554

Balota, D. A., Paul, S. T., (1996). Summation of Activation: Evidence from multiple primes that converge and diverge within semantic memory. *Journal of Experimental Psychology: Learning, Memory and Cognition, 22(4),* 827-845.

Baruch, I. Hemsley, D. R., & Gray, J. A. (1988). Latent inhibition and "psychotic proneness" in normal subjects. *Personality and Individual Differences, 9,* 777-783.

Batey, M., Furnham, A., Safiullina, X. (2010). Intelligence, general knowledge, and personality as predictors of creativity. *Learning and Individual Differences, 20*, 532-535.

Batey, M. & Furnham, A. (2006). Creativity, intelligence, and personality: A critical review of the scattered literature. *Genetic, Social, and General Psychological Monographs, 132(4)*, 355-429.

Bechtereva, N. P., Korotkov, A. D., Pakhomov, S. V., Roudas, M. S., Starchenko, M. G., & Medvedev, S. V. (2004). PET study of brain maintenance of verbal creative activity. *International Journal of Psychophysiology, 53*(1), 11-20. doi: 10.1016/j.ijpsycho.2004.01.001

Beeman, M. (1993). Semantic processing in the right hemisphere may contribute to drawing inferences from discourse. *Brain and Language, 44*(1), 80-120. doi: 10.1006/brln.1993.1006

Beeman, M., Friedman, R. B., Grafman, J., Perez, E., & et al. (1994). Summation priming and coarse semantic coding in the right hemisphere. *Journal of Cognitive Neuroscience, 6*(1), 26-45. doi: 10.1162/jocn.1994.6.1.26

Beeman, M. (1998). Coarse semantic coding and discourse comprehension. *Beeman, Mark*.

Beeman, M. J., & Chiarello, C. (1998). Complementary right- and left-hemisphere language comprehension. *Current Directions in Psychological Science, 7*(1), 2-8. doi: 10.1111/1467-8721.ep11521805

Beeman, M. J., Bowden, E. M., & Gernbacher, M. A. (2000). Right and left hemisphere cooperation for drawing predictive and coherence inferences during normal story comprehension. *Brain and Language, 71*(2), 310-336. doi: 10.1006/brln.1999.2268

Bekhtereva, N. P., Dan'ko, S. G., Starchenko, M. G., Pakhomov, S. V., & Medvedev, S. V. (2001). Study of the brain organization of creativity: III. Brain activation assessed by the local cerebral blood flow and EEG. *Human Physiology, 27*(4), 390-397. doi: 10.1023/a:1010946332369

Bekhtereva, N. P., Starchenko, M. G., Klyucharev, V. A., Vorob'ev, V. A., Pakhomov, S. V., & Medvedev, S. V. (2000). Study of the brain organization of creativity: II. Positron-emission tomography data. *Human Physiology, 26*(5), 516-522. doi: 10.1007/bf02760367

Bihrle, A. M., Brownell, H. H., & Powelson, J. A. (1986). Comprehension of humorous and nonhumorous materials by left and right brain-damaged patients. *Brain and Cognition, 5*(4), 399-411. doi: 10.1016/0278-2626(86)90042-4

Bogen, J. E., & Bogen, G. M. (1969). The Other Side of the Brain III: The Corpus Callosum and Creativity. . *Bulletin of the Los Angles Neurological Society, 34*(4), 191-220.

Bowden, E. M., & Beeman, M. J. (1998). Getting the right idea: Semantic activation in the right hemisphere may help solve insight problems. *Psychological Science, 9*(6), 435-440. doi: 10.1111/1467-9280.00082

Bowden, E. M., & Jung-Beeman, M. (2003). Aha! Insight experience correlates with solution activation in the right hemisphere. *Psychonomic Bulletin & Review, 10*(3), 730-737.

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*(1), 20-27. doi: 10.1016/0093-934x(83)90002-0

Brownell, H. H., Potter, H. H., Michelow, D., & Gardner, H. (1984). Inference deficits in right brain damaged patients. *Brain and Language, 27*, 310-321.

Burgess, C., & Simpson, G. B. (1988a). Cerebral hemispheric mechanisms in the retrieval of ambiguous word meanings. *Brain and Language, 33*(1), 86-103. doi: 10.1016/0093-934x(88)90056-9

Burgess, C., & Simpson, G. B. (1988b). Neuropsychology of Lexical Ambiguity Resolution: Contribution of Divided Visual Field Studies, In Small, S., Cottrell, G., & Tanenhaus, M. (Eds.), *Lexical Ambiguity Resolution in the Comprehension of Human Language.* Los Altos, CA: Morgan Kaufmann.

Carlsson, I., Wendt, P. E., & Risberg, J. (2000). On the neurobiology of creativity. Differences in frontal activity between high and low creative subjects. *Neuropsychologia, 38*(6), 873-885. doi: 10.1016/s0028-3932(99)00128-1

Chavez-Eakle, R. A. (2007). From incubation to insight: Working memory and the role the cerbellum. *Creativity Research Journal, 19*(1), 31-34.

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

Chiarello, C. (2003). Parallel systems for processing language: Hemispheric complementarity in the normal brain. In Banich, M. T. & Mack, M. (Eds.), Mind, Brain & Language: Multidiciplinary Perspectives. Mahwah, NJ: Lawrence Erlbaum Associates.

Chrysikou E. G., Novick J. M., Trueswell, J. C., & Thompson-Schill, S. L., (2011). The other side of cognitive control: Can a lack of cognitive control benefit langauge and cognition? Topics in Cognitive Science, 3, 253-256. doi:10.1111/j.1756-8765.2011.01137.x

Chrysikou, E. G., Thompson-Schill, S. L. (2011). Dissociable brain states linked to common and creative object use. *Human Brain Mapping, 32,* 665-675.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd edition). Hillsdale, NJ: Erlbaum.

Coney, J., & Evans, K. D. (2000). Hemispheric asymmetries in the resolution of lexical ambiguity. *Neuropsychologia, 38*(3), 272-282. doi: 10.1016/s0028-3932(99)00076-7

Costa, P. T. & McCrae, R. R. (1985). *The NEO personality inventory manual.* Odessa, FL: Psychological Assessment Resources.

Coulson, S., & Severens, E. (2007). Hemispheric asymmetry and pun comprehension: When cowboys have sore calves. *Brain and Language, 100*(2), 172-187. doi: 10.1016/j.bandl.2005.08.009

Coulson, S., & Van Petten, C. (2002). Conceptual integration and metaphor: An event-related potential study. *Memory & Cognition, 30*(6), 958-968.

Coulson, S., & Williams, R. F. (2005). Hemispheric asymmetries and joke comprehension. *Neuropsychologia, 43*(1), 128-141. doi: 10.1016/j.neuropsychologia.2004.03.015

Coulson, S., & Wu, Y. C. (2005). Right Hemisphere Activation of Joke-related Information: An Event-related Brain Potential Study. *Journal of Cognitive Neuroscience, 17*(3), 494-506. doi: 10.1162/0898929053279568

Diaz, M. T., Barrett, K. T., & Hogstrom, L. J. (2011). The influence of sentence novelty and figurativeness on brain activity. *Neuropsychologia, 49*(3), 320-330. doi: 10.1016/j.neuropsychologia.2010.12.004

Dietrich, A. (2004). The cognitive neuroscience of creativity. *Psychonomic Bulletin & Review, 11*(6), 1011-1026.

Dietrich, A., & Kanso, R. (2010). A review of EEG, ERP and neuroimaging studies of creativity and insight. *Psychological Bulletin, 136*(5), 822-848.

Erdfelder, E., Faul, F., & Buchner, A. (1996). GPOWER: A general power analysis program. *Behavior Research Methods, Instruments, & Computers*, *28*, 1-11.

Eysenck, H. J. (1967). The biological basis of personality. Springfield, IL: Charles C. Thomas Publ.

Eysenck, H. J. & Eysenck, S. B. G. (1976). *Psychoticism as a dimension of personality.* London: Hodder and Stoughton.

Eysenck, H. J. , Eysenck, S. B. G., & Barrett, P. (1985). Revised version of the Psychoticism Scale. *Personality and Individual Differences, 6*, 21-29.

Eysenck, H. J. (1993). Creatvity and personality: Suggestions for a theory. *Psychological Inquiry, 4*, 147-178.

Eysenck, H. J. (1995). *Genius: The natural history of creativity.* Cambridge: Cambridge University Press.

Faust, M., Bar-lev, A., & Chiarell, C. (2003). Sentence priming effects in the two cerebral hemispheres: Influences of lexical relatedness, word order, and sentence anomaly. *Neuropsychologia, 41*(4), 480-492. doi: 10.1016/s0028-3932(02)00138-0

Faust, M., Ben-Artzi, E., & Harel, I. (2008). Hemispheric asymmetries in semantic processing: Evidence from false memories for ambiguous words. *Brain and Language, 105*(3), 220-228. doi: 10.1016/j.bandl.2007.12.002

Faust, M. E. & Gernsbacher, M. A. (1996). Cerebral mechanisms for suppression of inappropriate information during sentence comprehension. Brain and Language, 53(2), 234-259.

Faust, M., & Chiarello, C. (1998). Sentence context and lexical ambiguity resolution by the two hemispheres. *Neuropsychologia, 36*(9), 827-835. doi: 10.1016/s0028-3932(98)00042-6

Faust, M. & Kahana, A. (2002). Priming summation in the cerebral hemispheres: Evidence from semantically convergent and semantically divergent primes. Neuropsychologia, 40(7), 892-901.

Faust, M., & Lavidor, M. (2003). Semantically convergent and semantically divergent priming in the cerebral hemispheres: Lexical decision and semantic

judgment. *Cognitive Brain Research, 17*(3), 585-597. doi: 10.1016/s0926-6410(03)00172-1

Faust, M., & Mashal, N. (2007). The role of the right cerebral hemisphere in processing novel metaphoric expressions taken from poetry: A divided visual field study. *Neuropsychologia, 45*(4), 860-870. doi: 10.1016/j.neuropsychologia.2006.08.010

Federmeier, K. D., Wlotko, E. W., Meyer, A. M. (2007). What's 'right' in language comprehension: Event-related potentials reveal right hemisphere language capabilities. *Language and Linguistic Compass 2(1)*, 1-17. doi: 10.1111/j.1749-818x.2007.00042.x

Federmeier, K. D. & Laszlo, S. (2009). Time for meaning: Electrophysiology provides insights into the dynamics of representation and processing in semantic memory. In B. H. Ross (Ed.), *Psychology of Learning and Motivation, 51,* 1-44. Burlington: Academic Press. doi: 10.1016/S0079-7421(09)51001-8

Feist, G. J. (1998). A meta-analysis of the impact of personality on scientific and artistic creativity. *Personality and Social Psychological Review, 2*, 290-309.

Fink, A., Grabner, R. H., Benedek, M., Reishofer, G., Hauswirth, V., Fally, M., et al. (2009). The creative brain: Investigation of brain activity during creative problem solving by means of EEG and fMRI. *Human Brain Mapping, 30*(3), 734-748. doi: 10.1002/hbm.20538.

Flowers, J. H., Warner, J. L., Polansky, M. L. (1979). Response and encoding factors in ignoring irrelevant information. Memory and Cognition, 7(2), 86-94.

Folley, B. S., & Park, S. (2005). Verbal creativity and schizotypal personality in relation to prefrontal hemispheric laterality: A behavioral an near-infrared optical imaging study. *Schizophrenia Research, 80*, 271-282.

Fournier, N. M., Calverley, K. L., Wagner, J. P., Poock, J. L., & Crossley, M. (2008). Impaired social cognition 30 years after hemispherectomy for intractable epilepsy: The importance of the right hemisphere in complex social functioning. *Epilepsy & Behavior, 12*(3), 460-471. doi: 10.1016/j.yebeh.2007.12.009

Furnham, A., Batey, M., Anand, K., & Manfield, J. (2008). Personality, hypomania, intelligence, and creativity. *Personality and Individual Differences*, 44, 1060-1069.

Gamble, K. R., & Kellner, H. (1968). Creative functioning and cognitive regression. *Journal of Personality and Social Psychology, 9,* 266-271.

Giora, R. (1997). Understanding figurative and literal language: The Graded Salience Hypothesis. *Cognitive Linguistics, 8*(3), 183-206.

Giora, R. (2002). Literal vs. figurative language: Different or equal? *Journal of Pragmatics. Special Issue: Literal, minimal and salient meanings, 34*(4), 487-506. doi: 10.1016/s0378-2166(01)00045-5

Giora, R., Zaidel, E., Soroker, N., Batori, G., & Kasher, A. (2000). Differential effect of right- and left-hemisphere damage on understanding sarcasm and metaphor. *Metaphor and Symbol. Special Issue: The uses of processing of irony and sarcasm, 15*(1-2), 63-83. doi: 10.1207/s15327868ms151&2_5

Gold, R., Faust, M., Ben-Artzi, E. (2012). Metaphors and verbal creativity: The role of the right hemisphere. *Laterality: Asymmetries of Brain, Body and Cognition, 17(5)*, 602-614. doi: 10.1018/1357650X.2011.599936

Golden, C. J. (1975). The measurement of creativity by the Stroop color and word test. *Journal of Personality Assessment, 39,* 386-390.

Grabner, R. H., Fink, A., & Neubauer, A. C. (2007). Brain correlates of self-rated originality of ideas: Evidence from event-related power and phase-locking changes in the EEG. *Behavioral Neuroscience, 121*(1), 224-230. doi: 10.1037/0735-7044.121.1.224

Grabner, R. H., Fink, A., Stipacek, A., Neuper, C., & Neubauer, A. C. (2004). Intelligence and working memory systems: Evidence of neural efficiency in alpha band ERD. *Cognitive Brain Research, 20*(2), 212-225. doi: 10.1016/j.cogbrainres.2004.02.010

Grimshaw, G. M., Bryson, F. M., Atchley, R. A., & Humphrey, M. K. (2010). Semantic ambiguity resolution in positive schizotypy: A right hemisphere interpretation. *Neuropsychology, 24(1)*, 130-138.

Grindrod, C.M. & Baum, S.R. (2003). Sensitivity to local sentence context information in lexical ambiguity resolution: Evidence from left- and right-hemisphere-damaged individuals. Brain and Language, 85, 503-523.

Groborz, M., Necka, E. (2003). Creativity and cognitive control: Explorations of generation and evaluation Skills. *Creativity Research Journal, 15(2&3)*, 183-197.

Guilford, J. P. (1950). Creativity. *American Psychologist, 5*(9), 444-454. doi: 10.1037/h0063487

Guilford, J. P. (1967). *The nature of human intelligence.* New York, NY: McGraw-Hill.

Hasbrooke, R. E., & Chiarello, C. (1998). Bihemispheric processing of redundant bilateral lexical information. *Neuropsychology, 12*(1), 78-94. doi: 10.1037/0894-4105.12.1.78

Heath, R. L., & Blonder, L. X. (2005). Spontaneous humor among right hemisphere stroke survivors. *Brain and Language, 93*, 267-276.

Heilman, K. M. (2005). Creativity and the brain. *New York, NY, US: Psychology Press, 205*.

Howard-Jones, P. A., Blakemore, S.-J., Samuel, E. A., Summers, I. R., & Claxton, G. (2005). Semantic divergence and creative story generation: An fMRI investigation. *Cognitive Brain Research, 25*(1), 240-250. doi: 10.1016/j.cogbrainres.2005.05.013

Jausovec, N. (2000). Differences in cognitive processes between gifted, intelligent, creative, and average individuals while solving complex problems: An EEG study. Intelligence, 28(3), 213-237.

Jausovec, N. & Jausovec, K. (2000). EEG activity during the performance of complex mental problems. International Journal of Psychophysiology, 36, 73-88.

John, O. P., Donahue, E. M., & Kentle, R. L. (1991). *The big five inventory-Versions 4a and 4 b*. Technical Report, Institute of Personality and Social Research, University of Claifornia, Berkley, CA.

John, O. P. Srivastava, S. (1999). *The big five trait taxonomy: History, measurement,*

and theoretical perspectives. In Handbook of Personality: Theory and Research. Pervin, Lawrence A. (Ed.); John, Oliver P. (Ed.); New York, NY, US: Guilford Press

Jung-Beeman, M. (2005). Bilateral brain processes for comprehending natural language. *Trends in Cognitive Sciences, 9*(11), 712-718.

Jung-Beeman, M., Bowden, E. M., Haberman, J., Frymiare, J., Aramber-Lui, S., Greenbalt, R., et al. (2004). Neural activity when poeple solve problems with insight. *PloS Biology, 2*, 500-510.

Kacinik, N. A., & Chiarello, C. (2007). Understanding metaphors: Is the right hemisphere uniquely involved? *Brain and Language, 100*(2), 188-207. doi: 10.1016/j.bandl.2005.10.010

Kaplan, N. A., Brownell, H. H., Jacobs, R., & Garner, H. (1990). The effects of right hemisphere damage on pragmatic interpretation of conversational remarks. *Brain and Language, 38*, 315-333.

Kazmerski, V. A., Blasko, D. G., & Dessalegn, B. G. (2003). ERP and behavioral evidence of individual differences in metaphor comprehension. *Memory & Cognition, 31*(5), 673-689.

Kerr, B., & Gagliardi, C. (2003). Measuring creativity in research and practice. In Lopez, Shane J. & Snyder, C. R. (Eds.), Positive psychological assessment: A handbook of models and measures. (pp. 155-169). Washington, DC, US: American Psychological Association. xvii

King, L. A., Walker, L. M., Broyles, S. J. (1996). Creativity and the Five-Factor Model. *Journal of Research in Personality, 30*, 189-203.

King, B. J. and Pope, B. (1999). Creativity as a factor in psychological assessment and healthy psychological functioning. *Journal of Personality Assessment, 72*, 200-207.

Klimesch, W., Sauseng, P., & Hanslmayr, S. (2007). EEG alpha oscillations: The inhibition-timing hypothesis. *Brain Research Reviews, 53*(1), 63-88. doi: 10.1016/j.brainresrev.2006.06.003

Kline, P. & Cooper, C. (1986). Psychoticism and creativity. *The Journal of Genetic Psychology, 147*, 183-188.

Kounios, J., & Beeman, M. (2009). The aha! Moment: The cognitive neuroscience of insight. *Current Directions in Psychological Science, 18*(4), 210-216. doi: 10.1111/j.1467-8721.2009.01638.x

Kounios, J., Fleck, J. I., Green, D. L., Payne, L., Stevenson, J. L., Bowden, E. M., et al. (2008). The origins of insight in resting-state brain activity. *Neuropsychologia, 46*(1), 281-291. doi: S0028-3932(07)00262-X [pii]
10.1016/j.neuropsychologia.2007.07.013 [doi]

Kounios, J., Fleck, J. I., Green, D. L., Payne, L., Stevenson, J. L., Bowden, E. M., et al. (2008). The origins of insight in resting-state brain activity. *Neuropsychologia, 46*(1), 281-291. doi: 10.1016/j.neuropsychologia.2007.07.013

Kounios, J., Frymiare, J. L., Bowden, E. M., Fleck, J. I., Subramaniam, K., Parrish, T. B., et al. (2006). The prepared mind: neural activity prior to problem presentation predicts subsequent solution by sudden insight. *Psychol Sci, 17*(10), 882-890. doi: PSCI1798 [pii]

10.1111/j.1467-9280.2006.01798.x [doi]

Kowatari, Y., Lee, S. H., Yamamura, H., Nagamori, Y., Levy, P., Yamane, S., et al. (2009). Neural networks involved in artistic creativity. *Human Brain Mapping, 30*(5), 1678-1690. doi: 10.1002/hbm.20633

Kutas, M. & Dale, A. (1997). Electrical and magnetic readins of mental functions. In M. D. Rugg (Ed.), *Cognitive Neuroscience* (pp. 197-242). Hove, East Sussex: Psychology Press.

Kutas, M., & Hillyard, S. A. (1980). Reading between the lines: Event-related brain potentials during natural sentence processing. *Brain and Language, 11*(2), 354-373. doi: 10.1016/0093-934x(80)90133-9

Lai, V. T., Curran, T., & Menn, L. (2009). Comprehending conventional and novel metaphors: An ERP study. *Brain Research, 1284*, 145-155. doi: 10.1016/j.brainres.2009.05.088

Lubow, R. E., Ingberg-Sacha, Y., Zalstein-Orda, N., & Gerwitz, J. C. (1992). Latent inhibition in low and high "psychotic-prone" normal subjects. *Personality and Individual Differences, 15*, 563-572.

Mai, X.-Q., Luo, J., Wu, J.-H., & Luo, Y.-J. (2004). Erratum: "Aha!" Effects in a Guessing Riddle Task: An ERP Study. *Human Brain Mapping, 23*(2), 128. doi: 10.1002/hbm.20066

Martindale, C., & Greenough, J. (1973). The differential effect of increased arousal on creative and intellectual performance. *The Journal of Genetic Psychology: Research and Theory on Human Development, 123*(2), 329-335.

Martindale, C., & Hasenfus, N. (1978). EEG differences as a function of creativity, stage of the creative process, and effort to be original. *Biological Psychology, 6*(3), 157-167. doi: 10.1016/0301-0511(78)90018-2

Martindale, C., & Hines, D. (1975). Creativity and cortical activation during creative, intellectual and EEG feedback tasks. *Biological Psychology, 3*(2), 91-100. doi: 10.1016/0301-0511(75)90011-3

Martindale, C., Hines, D., Mitchell, L., & Covello, E. (1984). EEG alpha asymmetry and creativity. *Personality and Individual Differences, 5*(1), 77-86. doi: 10.1016/0191-8869(84)90140-5

Martindale, C., & Dailey, A. (1996). Creativity: Primary process cognition and personality. *Personality and Individual Differences, 20*, 409-414.

Martindale, C. (1999). Biological bases of creativity. *Sternberg, Robert J*.

Mashal, N., Faust, M., & Hendler, T. (2005). The role of the right hemisphere in processing nonsalient metaphorical meanings: Application of Principal Components Analysis to fMRI data. *Neuropsychologia, 43*(14), 2084-2100. doi: 10.1016/j.neuropsychologia.2005.03.019

Mashal, N., Faust, M., Hendler, T., & Jung-Beeman, M. (2007). An fMRI investigation of the neural correlates underlying the processing of novel metaphoric expressions. *Brain and Language, 100*(2), 115-126. doi: 10.1016/j.bandl.2005.10.005

McCrae, R. R. & Costa, P.T., Jr. (1984). *Emerging lives, enduring dispositions: Personality in adulthood*. Boston: Little, Brown.

McCrae, R. R. & Costa, P.T., Jr. (1985). Openness to experience. In R. Hogan & W. H. Jones (Eds.), Perspectives in Personality, 1, 145-172. Greenwich, CT: JAI Press.

McCrae, R. R. (1987). Creativity, divergent thinking and openness to experience. *Journal of Personality and Social Psychology, 52*(6), 1258-1265.

McNamara, T. P. (2005). *Semantic Priming: Perspectives from Memory and Word Recognition*. New York, NY: Taylor & Francis.

Mednick, S. A. (1962). The associative basis of the creative process. *Psychological Review, 69*(3), 220-232.

Mednick, M. T., Mednick, S. A., Jung, C. C. (1964). Continual association as a function of level of creativity and type of verbal stimulus. Journal of Abnormal Psychology, 69(5), 511-515

Mendelsohn, G. A. (1976). Associative and attentional processes in creative perfromance. *Journal of Personality, 36*, 95-104.

Merten, T. & Fischer, I. (1999). Creativity, personality and word-association responses: Associative behavior in forty supposedly creative persons. *Personality and Individual Differences, 27,* 933-942.

Michael, M. (2009). Responses on a lateralized lexical decision task relate to both reading times and comprehension. *Brain and Cognition, 71*(3), 416-426. doi: 10.1016/j.bandc.2009.05.005

Mihov, K. M., Denzler, M., & Forster, J. (2010). Hemispheric specialization and creative thinking: A meta-analytic review of lateralization of creativity. *Brain Cogn*. doi: S0278-2626(09)00237-1 [pii]

10.1016/j.bandc.2009.12.007

Molle, M., Marshall, L., Wolf, B., Fehm, H., L., & Born, J. (1999). EEG complexity and performance measures of creative thinking. *Psychophysiology, 36*, 95-104.

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: Lawrence Erlbaum Associates.

Nelson, D. L., McEvoy, C. L., & Schreiber, T. A. The University of South Florida word associations, rhyme, and word fragment norms.

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia, 9*(1), 97-113. doi: 10.1016/0028-3932(71)90067-4

Petsche, H. (1996). Approaches to verbal, visual and musical creativity by EEG coherence analysis. *International Journal of Psychophysiology, 24*(1-2), 145-159. doi: 10.1016/s0167-8760(96)00050-5

Pobric, G., Mashal, N., Faust, M., & Lavidor, M. (2008). The role of the right cerebral hemisphere in processing novel metaphoric expressions: A transcranial magnetic stimulation study. *Journal of Cognitive Neuroscience, 20*(1), 170-181. doi: 10.1162/jocn.2008.20005

Proverbio, A. M., Crotti, N., Zani, A., & Adorni, R. (2009). The role of left and right hemispheres in the comprehension of idiomatic language: An electrical neuroimaging study. *BMC Neuroscience, 10*. doi: 10.1186/1471-2202-10-116

Qiu, J., Li, H., Jou, J., Liu, J., Luo, Y., Feng, T., et al. (2010). Neural correlates of the ‚Äúaha‚Äù experiences: Evidence from an fMRI study of insight problem solving. *Cortex: A Journal Devoted to the Study of the Nervous System and Behavior, 46*(3), 397-403. doi: 10.1016/j.cortex.2009.06.006

Qiu, J., Li, H., Jou, J., Wu, Z., & Zhang, Q. (2008). Spatiotemporal cortical activation underlies mental preparation for successful riddle solving: an event-related potential study. *Exp Brain Res, 186*(4), 629-634. doi: 10.1007/s00221-008-1270-7 [doi]

Qiu, J., Li, H., Yang, D., Luo, Y., Li, Y., Wu, Z., et al. (2008). The neural basis of insight problem solving: An event-related potential study. *Brain and Cognition, 68*(1), 100-106. doi: 10.1016/j.bandc.2008.03.004

Qiu, J., Luo, J., Wu, Z., & Zhang, Q. (2006). A further study of ERP effects of "insight" in a riddle guessing task. . *Acta Psychologica, Sinica, 38*, 507-514.

Rawlings, D. (1985). Psychoticism, creativity, and dichotic shadowing. *Personality and Individual Differences, 6,* 737-742.

Razumnikova, O. M. (2007). The functional significance of a alpha-2 frequency range for convergent and divergent verbal thinking. Human Physiology, 33(2), 146-156

Razumnikova, O. M. (2004). Gender-Dependent Frequency-Spatial Organization of the Brain Cortex Activity during Convergent and Divergent Thinking: I. Analysis of the EEG Power. *Human Physiology, 30*(6), 637-646. doi: 10.1023/b:hump.0000049580.11362.08

Rinaldi, M. C., Marangolo, P., & Baldassari, F. (2004). Metaphor processing in right brain-damaged patients with visuo-verbal and verbal material: A dissociation (re)considered. *Cortex, 40*, 479-490.

Schmidt, G. L., DeBuse, C. J., & Seger, C. A. (2007). Right hemisphere metaphor processing? Characterizing the laterization of semantic processes. *Brain and Language, 100*, 127-141.

Schmidt, G. L., & Seger, C. A. (2009). Neural correlates of metaphor processing: The role of figurativeness, familiarity and difficulty. *Brain and Cognition, 71*, 375-385.

Schooler, J. W., & Melcher, J. (1995). The ineffability of insight. *Smith, Steven M.*

Shamay-Tsoory, S. G., Adler, N., Aharon-Peretz, J., Perry, D., & Mayseless, N. (2011). The origins of originality: The neural basis of creative thinking and originality. *Neuropsychologia, 49*, 178-185.

Shammi, P., & Stuss, D. T. (1999). Humor appreciation: a role of the right frontal lobe. . *Brain, 122*(4), 657-666.

Shemyakina, N. V., Danko, S. D., Nagornova, Zh. V., Starchenko, M. G., & Bechtereva, N. P., (2007). Changes in the power and coherence spectra of the EEG rhythmic components during solution of a verbal creative of overcoming a stereotype. Human Physiology, 33(5), 524-530.

Sieborger, F. T., Ferstl, E. C., & von Cramon, D. Y. (2007). Making sense of nonsense: An fMRI study of task induced inference processes during discourse comprehension. *Brain Research, 1166*, 77-91. doi: 10.1016/j.brainres.2007.05.079

Simpson, G. B., & Burgess, C. (1985). Activation and selection processes in the recognition of ambiguous words. *Journal of Experimental Psychology: Human Perception and Performance, 11*(1), 28-39. doi: 10.1037/0096-1523.11.1.28

Starchenko, M. G., Bekhtereva, N. P., Pakhomov, S. V., & Medvedev, S. V. (2003). Study of the Brain Organization of Creative Thinking. *Human Physiology, 29*(5), 652-653. doi: 10.1023/a:1025836521833

Sternberg, R. J., & Lubart, T. I. (1999). The concept of creativity: Prospects and paradigms. *Sternberg, Robert J*.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. Journal of Experimental Psychology, 18(6), 643-662.

Strong, C. M., Nowakowska, C., Santosa, C. M., Wang, P. W., Kraemer, H. C., Ketter, T. A. (2007). Temperament-creativity relationships in mood disorder patients, healthy controls and highly creative individuals. *Journal of Affective Disorders, 100*, 41-48.`

Tarasova, I. V., Volf, N. V., & Razoumnikova, O. M. (2010). Parameters of cortical interactions in subjects with high and low levels of verbal creativity. *Human Physiology, 36*(1), 80-85. doi: 10.1134/s036211971001010x

Tegano, D. W. (1990). Relationship of tolerance of ambiguity and playfulness to creativity. *Psychological Reports, 66*(3, Pt 1), 1047-1056. doi: 10.2466/pr0.66.3.1047-1056

Titone, D. (1998). Hemispheric differences in context sensitivity during lexical ambiguity resolution. *Brain and Language, 65*(3), 361-394. doi: 10.1006/brln.1998.1998

Titone, D. A., & Salisbury, D. F. (2004). Contextual modulation of N400 amplitude to lexically ambiguous words. *Brain and Cognition, 55*(3), 470-478. doi: 10.1016/j.bandc.2004.02.073

Torrance, E. P. (1974). *Torrance Test of Creative Thinking*. Lexington, MA: Personal Press.

Voyer, D., Bowes, A., & Techentin, C. (2008). On the perception of sarcasm in dichotic listening. *Neuropsychology, 22*(3), 390-399. doi: 10.1037/0894-4105.22.3.390

Wallach, M. A., & Kogan, N. (1965). *Modes of thinking in young children.* New York, NY: Holt, Rinehart & Winston.

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

Woody, E. & Claridge, G. (1977). Psychoticism and thinking. British Journal of Clinical Psychology, 16(3), 241-248.

Zabelina, D. L., Robinson, M. D., (2010). Creativity as flexible cognitive control. *Psychology of Aesthetics, 4(3),* 136-143. doi:10.1037/a0017379

Appendix A

Primes and Targets used in Experiments 1 and 2

Ambiguous Primes	Dominant Targets	Subordinate Targets
ACE	CARDS	EXPERT
BALL	ROUND	DANCE
BAND	MUSIC	RING
BANK	MONEY	RIVER
BARK	DOG	TREE
BILL	PAYMENT	LAW
BLUFF	LIE	CLIFF
BOW	ARROW	RIBBON
BUG	INSECT	SPY
BULBS	LIGHT	TULIP
CANCER	DISEASE	CRAB
CARDINAL	BLUEJAY	BISHOP
CASE	COURT	BAG
CELL	JAIL	NUCLEUS
CHARM	BRACELET	WIT
CHOP	CUT	MEAT
CLUB	GROUP	BAT
COACH	TEAM	HORSE
CORN	COB	FOOT
COURT	LAWYER	TENNIS
CRAB	LOBSTER	GROUCH
CRANE	BIRD	LIFT
DATE	TIME	FRUIT
DIAMOND	RING	BASEBALL
FAN	AIR	CLUB
FIGURE	BODY	MATH
FILE	FOLDER	TOOL
FORMULA	BABY	EQUATION
GLASSES	SEE	DRINK
GRADE	SCHOOL	SLOPE
GRILL	BARBECUE	QUESTION
HORN	HONK	ANTLER
JAM	JELLY	BAND
JOINT	SMOKE	KNEE
LOCK	DOOR	TUFT
LOG	CABIN	JOURNAL
MATCH	FIRE	GAME
MOLD	FUNGUS	SHAPE
NAILS	FINGER	SCREW
ORGAN	DONOR	PIANO
PACK	BACK	ANIMAL
PARTY	FUN	POLITICS
PIT	HOLE	PEACH
PITCH	THROW	NOTE
PLANT	GREEN	POWER
PLOT	STORY	LAND
PLUG	OUTLET	CORK
POT	PAN	WEED
PRESS	MEDIA	IRON

PUNCH	HIT	BOWL
RACE	WIN	CULTURE
RACKET	BALL	NOISE
RING	GOLD	CHIME
RULER	MEASURE	KING
SENTENCE	WORDS	PRISON
SHOWER	CLEAN	BRIDE
SPARE	TIRE	STRIKE
SPRING	SUMMER	BOUNCE
STAFF	FACULTY	ROD
STAR	SKY	MOVIE
SUIT	TIE	CASE
TABLE	CHAIR	GRAPH
TOAST	BREAD	CHEERS
VESSEL	SHIP	BLOOD

Appendix B
Sentence Stimuli used in Experiment 1

Subordinate Sentences

Paul's boss knew the presentation would go well because Peter is an ace.
Because it featured a great orchestra, they really liked the ball.
The jewelry had a beautiful setting and a shiny gold band.
Because it was a good fishing spot, everyone went to that bank.
Because it scraped his hand, Larry was annoyed by the bark.
Hoping the President would use the veto, Tom was unhappy about the bill.
While walking on the sandy beach, Ben finally noticed the bluff.
The girl's mother tied her hair up in a red bow.
As it recorded the entire conversation, she barely noticed the bug.
Jenny spent her morning in the garden planting bulbs.
The fortune-teller told Amy that she was introverted and nurturing because she was a cancer.
Admiring a strong religious viewpoint, Helen looked for the cardinal.
Debbie stored all her belongings in the case.
In biology class, Pedro learned all about the anatomy of a cell.
Sarah was very charismatic and full of charm.
Before the dinner party, Joe went to the butcher to pick out the perfect chop.
Because it was a very effective weapon, they were happy about the club.
While it transported the prince to his wedding, they easily spotted the coach.
Initially believing it was a bunion, Barbara examined the corn.
Since the championship game was about to begin, there were many TV cameras at the court.
Loudly complaining about the service, everyone noticed the crab.
The construction worker raised the heavy beam with a crane.
Since it tasted so sweet, she really enjoyed the date.
Noticing the shortstop was at bat, they all looked at the diamond.
Screaming cheers for the football team, everyone heard the fan.
Numerically depicting last year's income, she couldn't see the figure.
Since she wanted to groom her nails, Betty searched for the file.
Lisa was having trouble solving the algebra problem because she couldn't find the right formula.
Since she had just served milkshakes to her guests, Joan needed to clean her glasses.
Since his car had trouble climbing hills, Mike didn't like the grade.
The Sheriff put the suspect in the interview room to grill.
Since it was taken from a very large deer, Julie examined the horn.
Because it included excellent musicians, we really liked the jam.
Ever since he broke his shoulder, he had a bad joint.

Beth tied her hair up in a bow except for one curled lock.
Since it recounted the ship's history, he closely examined the log.
Since they were great tennis players, she closely examined the match.
Having produced many clay figurines, Jane wanted to look at the mold.
Since they kept falling out of the wall, George examined his nails.
Since the music sounded extremely out of tune, Peter needed a new organ.
Consisting of more than a dozen wolves, Erik saw the pack.
The democrates were looking for a new leader to run the party.
Since she only wanted to eat the sweet fruit, Rose tried to avoid the pit.
Jack was happy because the advertizing agency loved his pitch.
Having been an employee for years, Susan wanted to buy the plant.
Since their house overlooked the valley, they really liked the plot.
The leak almost flooded the basement, but luckily Jim found a plug.
Being able to recognize dangerous drugs, George inspected the pot.
Since he got the wrinkles out of his shirt, he was happy about the press.
Since he drank so much of it, he knew it was a good punch.
People can be quite sensitive when it comes to the topic of race.
My brother just started playing the drums and he causes quite a racket.
The teacher ended class late because she didn't hear the bell ring.
Since he was a very prominent leader, Jen easily saw the ruler.
Because the crime was so awful, it was a very bad sentence.
Before giving birth, Emily's friends threw her a shower.
Alex wasn't a very good bowler, so he was quite happy with a spare.
Making the bed much more comfortable, Paul was pleased with the spring.
Having sprained his ankle last week, Tom finally used his staff.
Since he acted in a number of films, she was excited to meet the star.
Since he thought the judge was unfair, Harry didn't like the suit.
Since the numbers didn't add up, Fred closely examined the table.
Honoring our parent's anniversary, we really enjoyed the toast.
To prevent Mason from dying, the EMT put pressure on the vessel.

Dominant Sentences

Jake was confident in his hand because he had an ace.
Jordan didn't have a shot, so he decided to pass the ball.
Jeff had a great time at the concert because it was his favorite band.
Laura was out of cash, so she stopped by the bank.
The basset hound has a very distinctive bark.
Tracy was feeling generous and decided to cover the bill.
Sam only had a pairs of twos, so she decided to bluff.
The archer next left the house without his bow.
Stephanie jumped on the chair because she was scared of the bug.
The room was very dim so Curtis changed the bulbs.
John had to go to the hospital to get treatment for his cancer.
Scott went bird watching in the forest and spotted a cardinal.
The lawyer was confident that she had won the case.
The sheriff locked Jax in his cell.
Allison loved her jewelry, so for her birthday Adam gave her a new charm.
Al put a carrot on the board and gave it a chop.
Dwayne paid the membership dues so he could stay in the club.
The university was very happy when the athletic director hired a new coach.
Living in Kansas, it's easy to get fresh corn.
The judge was so bored, he almost nodded off during court.
At the seafood restaurant, Zach ordered fresh crab.
Donna went to the Everglades and spotted a white crane.

Jody became very excited for the wedding when she and her fiancé finally set a date.
Brad was finally ready to propose when he found the right diamond.
It was stuffy in the office, so Kathy turned on the fan.
After losing weight, Connie was much happier with her figure.
After shuffling through the papers Ruth finally found the right file.
Tasha heard the infant crying and went to the kitchen to warm up the formula.
Courtney couldn't make out the writing on the board, so she dug through her bag to find her
Stella forgot to study for the test and earned a very bad grade.
Dustin's favorite part of summer is cooking burgers on the grill.
Don was aggravated with the driver in front of him and blasted his horn.
Melissa preserves and bottles her own jam.
At the concert, the hippies lit up a joint.
After the break-in Tony installed a new lock.
The fire was dying, so Barbara threw on another log.
To light the cigar Mark struck a match.
Todd was disgusted when he noticed the bread had grown mold.
The manicurist did a beautiful job on Kelly's nails.
Ken learned in biology that the liver is a very important organ.
Before hiking Aaron made sure that he had all his supplies in his pack.
After graduating Lindsey celebrated with a party.
Louis couldn't reach his toy because it had fallen into the pit.
Before swinging the bat, Bobby waited for the perfect pitch.
Before leaving town Randy hired Maggie to water his plant.
The tale had twists and turns which made it difficult to follow the plot.
The blender was battery powered so there was no need for a plug.
Chris boiled the pasta in a large black pot.
The movie star wore a hat and sunglasses to try and hide from the press.
The boxer was knocked out with one strong punch.
The track star was excited when he triumphed in the race.
Andy knew his tennis game would improve as soon as he could afford the right racket.
Rita's favorite piece of jewelry was a silver ring.
Matt didn't know the length of the board because he lost his ruler.
The teacher corrected Keith's essay when he used incorrect grammar in a sentence.
After playing in the dirt all day the little boy needed a shower.
Jim got a flat so he opened his trunk to get the spare.
The flowers began to bloom in the spring.
After having a prosperous year the owner gave a raise to his whole staff.
Every night before bed, Peter made a wish upon a star.
Before his first day of work Chris decided to buy a new suit.
Before eating dinner Kyle set the table.
Mike likes to put butter and jam on his toast.
The luxury yacht was a very impressive vessel.

Appendix C
Sentence Stimuli used in Experiment 2

Subordinate to Dominant Sentences

Because Bill was such a good employee, the ace he drew to win the game didn't upset his boss.
The southern belle was not at all pleased with how the ball had been served, but she still gave it her best effort.
Before the wedding the groom went shopping for the perfect band but none of them sounded quite right
Jessie fished at the bank to try and find a pen in her purse.

On a trip to the Brazilian rainforest, we were studying the very strange bark from a species of dog that lived along the banks of the Amazon.
In the congressional meeting there was a good deal of argument about the bill from the deli because no one wanted to pay for it.
After climbing for two hours, the bluff Max told was that he had climbed all day.
The Indian quickly grabbed for the bow because the hair tie was meant for his daughter.
The private detective planted a bug in Lenny's house because he knew Lenny was sacred of spiders.
In the early spring my mother bought a bunch of special bulbs that were for the fixtures along the front walkway.
The astrologist told me all about the sign of cancer she had before she was diagnosed.
I was at church when a cardinal flew into the sanctuary.
Kim was carrying the case all alone and she was nervous about being in court.
The warden was very upset when he examined the cell during the biology exam and he realized that he was mistaken.
Mary's grandmother had given her many pieces of jewelry and Mary realized that the charm that she had learned from her grandmother was also very valuable.
I got a beautiful cut of lamb and the chop I gave it with the cleaver split it in two.
The group beat Joe with a club vote that vetoed his idea.
The horses led the coach and his team out onto the field.
My toe was aching because of the corn I tripped on when walking through the kitchen.
Steven ran down the court aisle because he was late for the start of the trial.
Hal wouldn't stop complaining, but the crab he got for dinner wasn't so bad in my opinion.
The construction manager watched the crane fly overhead as the workers put up the wall.
I wanted something sweet so I found a date for the next farmer's market to buy some goodies.
At the ball field Charlie stared at the diamond he was about to propose with at the game.
Living in Arizona, Jacob was glad he had a fan to boost his ego when he was getting low.
After crunching all the numbers Stella worked on a figure that was closer to her ideal weight.
At the hardware store I picked up a file that is used to record the huge variety of woods that are available.
When caring for an infant it is important to use the proper formula containing lots of love so the infant will grow up happy and healthy.
The group was thirsty so Lisa grabbed her glasses in order to read the list of beverages.
Josh hiked up the grade from a C to an A.
Bob watched the detective grill a delicious steak.
During the competitions between native tribes, hundreds of elephants were killed in order to get the horn, which was blown during the ceremony after the hunt.
The crowd was totally into the jam that Bonnie made for the occasion.
I bent the joint and when it broke I had to roll a new one.
Tara pulled on the long brown lock but she couldn't get it open.
During the journey the Captain kept a log by his bed to throw on the fire.
Nick was prepared for the match to light, but it didn't.
In pottery class Hannah realized the mold began to grow on the clay again.
The construction worker wanted the highest quality nails so he got a manicure.
The music coming out of the organ was beautiful because Angie had a beautiful voice.
The dog ran with the pack in his mouth so he could take it back to his master.
The election didn't go their way so the party afterwards wasn't very good.
Carl really likes cherries, but he discovered that the pit was too hard to climb into so he decided not to pick the fruit.
The singer didn't have a very good pitch during the company softball game.
The safety inspector knew that he would have trouble with the CEO because the new plant was not safe to eat.
The surveyor examined the plot and decided the novel was too complicated.
The water leaked all over the floor so I found a plug for the heat lamp to dry it.
The dealer sold the pot to a chef who needed it to complete his kitchen set.
The dry-cleaner made sure the press covered his store opening.

Chris threw the punch into a big pitcher before the party.
After integrating the schools, the race was attended by a lot more people.
My neighbor made quite a racket, which I brought from him because I love tennis.
As the bell sounded, the ring fell to the ground and rolled across the floor.
The peasant consulted the ruler to find the length of the board.
The convict waited as the long sentence was finished by the judge.
Before giving birth, the mother-to-be had a shower to make sure she was clean.
During the bowling tournament Stan kept thinking about the spare he needed for his truck and became very worried.
Playing on the trampoline is best when the spring air is nice and warm.
My grandfather walked with the staff of his company.
After the premiere, the star seemed to twinkle in the heavens.
The attorney brought the suit to the dry-cleaners.
The statistician created a table out of cedar wood.
At the anniversary party, Mary rose when the toast was being served.
Even though all signs seem positive now, the doctor was still concerned about the wall of the vessel because the boat could still suddenly spring a leak.

Dominant to Subordinate Sentences

As the card game began Rich was really feeling lucky when he got an ace as his partner in the game
My little brother threw a horrible temper tantrum and ruined everything because he wanted the ball to be over soon
I was at a concert when I saw a really wonderful band, that had rhinestones on it.
Brady was annoyed because he stood in line at the bank for almost an hour before it was his turn to bait his hook.
Our dog seemed to recognize the bark, as though he knew it came from his favorite elm.
The storeowner was very careful to keep track of the bill because he thought the amendment was important.
Max held up the poker game because he was thinking of a good bluff that he climbed in the Cayman Islands.
The little girl never left the house without her pink purse and the red bow she used for target practice.
Allison found it very creepy when she noticed the bug on the wall that the detective planted.
To illuminate the front porch Eva bought special bulbs and planted them along the entrance.
Frank sat in the waiting room of the hospital thinking about his girlfriend and cancer, she sure matched her astrological sign
While taking a nature walk Becca spotted a cardinal baptizing a boy in the river.
The lawyer was nervous about her big case because she was afraid it was too heavy to carry.
The scientist was terrified that he would collapse the cell when he blew up the wall of the terrorist's jail
Paula wished that she had inherited her mother's charm because her antique cameo was very valuable
The karate instructor knew he needed a particular kind of chop for the pork dish
After going to a few meetings Ann decided the club she carried with her was too heavy and left it at home.
The fans sat quietly as the coach marched on to the field pulled by a group of horses.
The farmer called his neighbor who worked at the grainery to ask for advise about his corn that was on his left toe.
The litigator went to the court to play a game of racket ball before work.
At dinner, Tom disliked the crab because he wouldn't stop complaining.
The hiker spotted a crane raising a heavy beam.
Kristy couldn't stop thinking about her wedding after she set the date on the table.
Leah longingly gazed at the diamond and wished she could play on a professional field.
The band enjoyed spending time with the fan on because it was hot onstage.

Ann worked hard to make sure that she had the perfect figure for her class presentation.
The teacher searched through her desk drawers looking for the file, because she had broken her nail
The mathematician had a problem with the new formula for his new born baby
Before Curt's books reading he grabbed his glasses just incase he got thirsty on stage.
The teacher first looked at her students, then looked down at the grade and decided to take a different path down the hill
Before dinner Andrew decided to grill the chef for his secret recipe.
The musician knew of only one specialty shop that would sell a horn from a rhinoceros
During brunch Ted enjoyed the jam between the drummer and guitarist.
Donny got in trouble with a joint when he sprained his elbow.
The convicted safecracker showed his cell mate the lock of his child's hair
While building his house Colin used a special log to keep track of his progress.
The camping trip was ruined because they did not have a single good match between the personalities of the people that went
Pat was disgusted by the mold because it was made in the form of an offensive object.
The manicurist took great care with the nails because she only had a few left for her construction project.
The doctor was looking at the organ in the front of the church.
Louis was frustrated before school because he couldn't find his pack of dogs to feed before he left.
Aubrey enjoyed the party because she agreed with their ideology.
While hiking Nora finally reached the pit of the plum she was eating on her walk.
The batter could almost instinctively tell the difference in the pitch and so knew that the girl was singing off key
A large number of botanists were very interested in the progress of the new plant that was being built on protected wetlands
Richard had trouble following the plot because the boundaries of the area were confusing.
The electrician felt it was best just to throw away the old one and buy a new plug, but without it he couldn't stop up the drain
Frank knew exactly where, in the kitchen, to find the pot because his informant had helped a lot with this drug bust
The movie star really didn't like the press, but she was late for her premier so she worn the dress wrinkled.
At the party, Brian thought the punch Jeremy threw was completely unnecessary.
As the man pulled on his running shoes he was thinking very intently about his race particularly about his ethnic heritage
I was getting ready for my tennis game when the racket from my neighbors gave me a fright.
The bride couldn't wait for the ring of the church bells to sound when the ceremony was over.
In class Ben used the ruler of the empire as a scapegoat for the brutal war.
The English teacher stood up and read the sentence because she was the jury's foreman
The plumber needed to run to the store to pick up a specific item for the shower that was being held for his daughter's wedding.
Fred stood in the parking lot kicking himself for not getting a spare in the bowling tournament
It was a beautiful day and the spring from the girl's pogo stick echoed as she bounced along the sidewalk.
Patricia was called into an important meeting at the museum because she was the expert on the staff and it's religious significance in ancient culture
The astronomers were excited to look up and see the big star that was walking towards them
As the CEO got dressed in the morning he thought about how happy he was with the suit his company had won in court.
The carpenter worked hard to create the table of his business finances.
Stan passed the butter before he made his toast making the entire wedding party wait
The Captain needed to get his vessel repaired because he had a heart condition.