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# The Metaphor Interpretation Test: Cognitive Processes Involved and Age Group Differences in Performance

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# The Metaphor Interpretation Test: Cognitive Processes Involved and Age Group Differences in Performance

By

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# DECLARATION OF ORIGINALITY

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# ABSTRACT

It is well known that aging affects fluid cognitive processes while leaving crystallized processes largely intact. When it comes to language abilities, figurative language tends to be more associated with fluid abilities and literal language with more crystallized abilities. Fluid abilities involve short-term storage of information and mental manipulation, which are associated with metaphor interpretation. Eighty participants (40 adults over fifty years old, and 40 young adults) completed the Metaphor Interpretation Test (Iskandar & Baird, 2013). The test includes 17 items chosen from a list of metaphors by Katz et al. (1988). Answers were coded as abstract complete (AC), abstract partial (AP), concrete (CT), or other/unrelated (OT) response. On a multiple choice version of the test, each option represented one of these categories. Participants also completed cognitive tests measuring estimated verbal IQ, short-term memory, working memory, processing speed, mental flexibility, verbal abstraction, and visual abstraction. Overall, younger adults produced a greater number of and chose more AC responses on free and multiple-choice formats of the test, respectively, than older adults. Conversely, older adults produced a greater number of and chose more CT responses on free and multiple-choice formats, respectively, than younger adults. Several measures were associated with aspects of performance on the Metaphor Interpretation Test Verbal short-term memory span most often emerged as a predictor in these analyses.  Co-varying on verbal short-term memory span eliminated age-group effects, while co-varying on estimated verbal IQ increased age group differences. Results suggest that aging adversely affects novel metaphor interpretation through age-related limitations in the ability to hold information in mind long enough to search for and link similar cognitive networks.

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TABLE OF CONTENTS

DECLARATION OF ORIGINALITY .......... iii

ABSTRACT .......... iv

ACKNOWLEDGEMENTS .......... v

LIST OF TABLES .......... vii

LIST OF FIGURES .......... viii

CHAPTER 1: Introduction .......... 1

*What are Metaphors?* .......... 2

*Neuropsychology of Figurative Language* .......... 14

*Metaphorical Processing Across the Lifespan* .......... 45

CHAPTER 2: The Present Study .......... 51

CHAPTER 3: Methods .......... 55

*Participants* .......... 55

*Materials and Procedures* .......... 57

*Statistical Analysis* .......... 64

CHAPTER 4: Results .......... 65

*Preliminry Analysis* .......... 65

*Hypothesis 1: Age Differrences on the Metaphor Interpretation Test* .......... 67

*Hypothesis 2/Correlational Analyses* .......... 69

*Hypothesis 3/Regression Analyses* .......... 73

*Hypothesis 4/Covariance Analyses* .......... 77

*Hypothesis 5: Effects of Perceived Familiarity* .......... 79

CHAPTER 5: Discussion .......... 81

REFERENCES/BIBLIOGRAPHY .......... 95

APPENDICES .......... 118

Appendix A .......... 118

Appendix B .......... 128

VITA AUCTORIS .......... 129

LIST OF TABLES

TABLE 1: Sample Demographics ....................................................................................55

TABLE 2: Tests and Test Scores ...................................................................................64

TABLE 3: Neuropsychological Test and Metaphor Interpretation Test Age Differences .66

TABLE 4: Correlations of MIT Response Type with Neuropsychological Measures in Older Adults .........................................................................................................70

TABLE 5: Correlations of MIT Response Type with Neuropsychological Measures in Younger Adults ......................................................................................................71

TABLE 6: Correlations of MIT Response Type in Older Adults .....................................72

TABLE 7: Correlations of MIT Response Types in Younger Adults ...............................72

TABLE 8: Regression Analyses for Variables Predicting Free Responses in Younger Adults ......................................................................................................................74

TABLE 9: Regression Analyses for Variables Predicting Multiple Choice Responses in Younger Adults ......................................................................................................75

TABLE 10: Regression Analyses for Variables Predicting Free Responses in Older Adults ......................................................................................................................76

TABLE 11: Regression Analyses for Variables Predicting Multiple Choice Responses in Older Adults .........................................................................................................76

LIST OF FIGURES

FIGURE 1: Number of Abstract Complete Answers Provided by Younger and Older Adults in Free Response Versus Multiple Choice Formats ................................68

FIGURE 2: Number of Concrete Answers Provided by Younger and Older Adults in Free Response Versus Multiple Choice Formats .......................................................69

FIGURE 3: Number of Abstract Complete Answers Provided by Younger and Older Adults in Free Response Versus Multiple Choice Formats with Sentence Repetition Total Score Co-varied .........................................................................79

FIGURE 4: The Effect of Estimated Premorbid Verbal IQ (Estimated by NAART35) on Production of Abstract Complete Responses on the MIT- Free Response ........79

FIGURE 5: The Effect of Perceived Familiarity on Abstract Complete Response Production or Selection (Based on an Aggregate of Free Response and Multiple Choice Responses) ...........................................................................................81

# CHAPTER 1

## Introduction

In fields emphasizing technical writing, researchers are encouraged to be as literal as possible in describing and explaining natural phenomena. In the course of daily life, however, we often use figurative language that leaves much room for interpretation. Figurative language usages linking physical sensations with abstract concepts, such as *credit freeze, credit squeeze,* and *credit crunch* were dominant in the $20^{th}$ century (Glucksberg, 2011). In fact the term *credit crunch* was used in over 400 New York Times articles published between 1981 and 2008 (Ahmad, 2011). Not until recently has cognitive neuropsychology focused on brain areas and functions that relate to the understanding and production of figurative language rather than literal language. The study of metaphorical thinking as related to other cognitive functions is becoming more popular as computer models become more sophisticated, neuropsychological cases of impaired metaphorical processing arise, and different styles of interpreting metaphors are found.

In the present study, an expansion of this research area was attempted by assessing how responses on a newly-created English-language test of metaphorical processing with free response and multiple choice components (Iskandar & Baird, 2013) were associated with performance on clinical neuropsychological tasks tapping working memory, visual abstraction, verbal abstraction, processing speed, and attention switching in older and younger adults. Iskandar and Baird showed that the success of university students in providing abstract interpretations of metaphors was associated with working memory, presumably reflecting the respondent's capacity to hold information on-line long enough for a semantic comparison or link to be made. The purpose of the present study was to build on these findings and consolidate them with work showing that older adults tend to exhibit difficulties with complex and ambiguous language comprehension more generally (Hasher & Zacks, 1988; Just & Carpenter, 1992), and with abstract thinking in figurative language specifically (Nippold, Uhden, & Schwarz, 1997; Uekermann, Thoma, and Daum (2008).

**What Are Metaphors?**[1]

A metaphor can be defined in several ways. The term *metaphor* comes from the Greek *metapherein*, which means *to transfer* (Gove, 1966). The etymology of the word is in itself interesting in that it implies that a property of one item is conceptually transferred to another. In philosophy, the classical view of metaphors is that “a metaphor is an elliptical simile useful for stylistic, rhetorical, and didactic purposes, but which can be translated into a literal paraphrase without any loss of cognitive content” (Johnson, 1981, p. 4). This view of metaphor dismisses it as a linguistic tool that can enhance understanding, but that is easily replaceable by an alternative literal statement such as a simile. Similarly, according to traditional psycholinguistic models (see Ortony, 1993), a metaphor is construed as a similarity between a vehicle and a topic. That is, in a metaphor such as *love is a battlefield*[1], *battlefield* is the vehicle and *love* is the topic. The similarity that the reader infers between these two concepts is the ground on which the metaphor is based.

These models fail to take into account what seems to be the most important role of metaphors: metaphors link disjointed domains of experience; a role which was

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[1] Note. Throughout this document, common metaphors are typed in italics, whereas original metaphors are cited in quotation marks with the source and page number.

highlighted in the etymology of the word and has resurfaced in more modern cognitive linguistic models Dent-Read and Szokolszky (1993) argued that metaphorical processing involves "seeing or understanding one kind of thing as if it were a different kind of thing and that this process is fundamentally perceptual" (p. 227). This indicates that metaphorical processing involves an integration of language information with perceptual experiences. Dent-Reed and Szokolszky believed that the scope of metaphor can be expressed and understood in action and pictures as well as language. For example, one can make one's fingers walk and the headlights of a car can be seen as eyes. Additionally, metaphors can be interpreted differently in different languages. For example "Carloè un coniglio*,*" a metaphor used in an Italian study (Papagno & Vallar, 2001), literally means "Charles is a rabbit" (p. 516) but metaphorically means that he is a coward. In other languages, it may be interpreted as him being promiscuous or quick. On the other hand, university students with English as a Second Language (ESL) show the same level of cognitive sophistication in metaphor interpretation as native English speakers despite scoring lower on academic measures of English proficiency (Johnson & Rosano, 1993). That is, metaphors may enhance understanding for ESL students.

A metaphor also can be defined through its function. That is, metaphors function as bridges (metaphorically speaking) between two concepts and create new ideas that transcend what these concepts mean individually (Muran & DiGuiseppe, 1990). Muran and DiGuiseppe posit that metaphors have several necessary properties including novelty, incongruity, similarity, relation, and integration. From a neuropsychological perspective, metaphorical processing depends on more than an intact language system. It also requires "higher order" abilities through which one views language in relation to previous knowledge, the context of the conversation, and social cues from the co-conversant or author (Martin & McDonald, 2003). These abilities also involve integrating information from various cognitive and at times sensory-perceptual domains to generate novel inferences about what is meant. This may also be related to the neuropsychological process of *concept formation,* which is defined as the ability to integrate seemingly dissimilar stimuli and acquire a common response to both (Kendler, 1961; Sweetland & Childs-Quay, 1957). According to Schnitzer and Pedreira (2005), an explicit metaphor of the form "X is (a) Y" may be interpreted as an instruction for the listener or reader to link one connectionist network to another. It follows then that if networks between two concepts are already linked, an expression connecting them may no longer be perceived as metaphorical. For example, *life is a journey* will not seem metaphorical to most readers, because the links between networks representing "life" and "journey" are pre-connected. Such metaphors are quite common in everyday life. We may also encounter several novel metaphors in the course of a day. For example, Lloyd Bentsen, a U.S. vice-presidential candidate belittled his opponent by stating "you, sir, are no John Kennedy" (in Glucksberg, 2011, p. 11). Such a statement, if interpreted literally, would seem obvious and purposeless; on the other hand, it can be quite meaningful figuratively. Similarly, when the media refers to company X is referred to as "the next Enron," the listener must decipher the metaphorical meaning in order to understand the reference (Glucksburg, 2011).

Furthermore, it is important to state that non-literal or figurative language does not necessarily involve metaphors, and in the present paper, I will be discussing metaphorical processing specifically. That is, figural language also includes proverbs, idioms, irony, sarcasm, and metonymy. Although these processes are related, there is evidence to suggest that they are somewhat dissociable (e.g., the types of errors typically made in interpreting metaphors are different from those made in interpreting idioms, Papagno, 2001).

## Models in Metaphorical Processing

**Sequential approach.** There are two main models of metaphorical processing. The first, more traditional, model was alluded to by philosophers as early as Aristotle and established by John Searle (1979). This model suggests that understanding metaphors occurs in a series of steps. That is, all phrases are first processed literally, and then the meaning of the statement is judged for accuracy. If the literal meaning is found inaccurate, it is sent to a non-literal processing centre for decoding. This model assumes that understanding metaphorical language would always be more effortful than understanding of literal language. It is sometimes referred to as the *sequential approach* or the *indirect approach* to metaphorical processing. This suggests that it takes more mental effort to recognize two metaphorically-related concepts as going together than two literally-related concepts. In this model, literal interpretations would always take priority as that is the first step of processing. Further, the literal interpretation must be judged as *defective* before a figurative one is derived. As will be discussed in the following sections, these assumptions have been shown not to be true.

**Direct approach.** The second model of the way metaphors are understood is referred to as the *direct approach* or the *parallel processing* approach (see Honeck & Hoffman[1980] for a review of this literature). In support of this theory, Ortony et al. (1978) focused on the distinction between automatic language processing and effortful language processing of metaphors. They found that the level of processing of metaphorical language is largely dependent on context (e.g., the sentence “let the cat out of the bag” is automatically understood as figurative when preceded by “Dean spoiled the surprise that Joan had been planning for their mother’s birthday party,,”( p. 471).

Furthermore, metaphorical interpretations of expressions have been shown to occur automatically, and are not optional or dependent on a failure to understand the literal meaning of the expression. For example, Glucksberg, Gildea, and Bookin (1982) constructed a test in which sentences were presented with a target word and participants were told to judge if the literal meaning is true or false while ignoring the figurative meaning. Using this logic, an incongruent sentence would be one that is literally false but metaphorically true (e.g., “some offices are icebergs”). Four types of sentences were used: literally meaningful (e.g., “some fruits are apples”), literally meaningless (e.g., “some fruits are tables”), metaphorically meaningful (e.g., “some jobs are jails”), and scrambled metaphors that were metaphorically and literally meaningless (e.g., some jobs are butchers,” p. 88). This test is based on the Stroop (1935) colour-word interference test on which subjects must name the colour of the font of a word that denotes a different colour (a more difficult task that reading out the word or naming the ink colour of word that denotes the same colour). Glucksberg et al. proposed that if participants were truly able to ignore metaphorical meanings, the metaphorically meaningful sentences would take the same amount of time to reject as literally false as the scrambled metaphors. This was not the case. They found that metaphorically meaningful sentences showed an interference effect, taking longer to be judged as literally false than their scrambled counterparts or sentences in the literally false condition. These results suggest that understanding metaphors occurs automatically and that participants have trouble inhibiting this understanding.

In a variation of the study by Glucksberg et al., Keysar (1989) also showed that metaphors were difficult to ignore. In this study, a target word would make the statement either metaphorically true and literally false or metaphorically false and literally true. The interference effect would occur when the target word would be both metaphorically true and literally false. Reaction times were slower for the interference condition than the valid condition. That is, participants were unable to ignore the figurative meaning despite being able to focus on the literal meaning. This supports the idea that both meanings are processed by a parallel rather than a sequential system. According to Paivio (1978), language processing involves two processes (a verbal process and an imagery process) that "represent the activity of independent but interconnected systems that are specialized for picking up, storing, organizing, retrieving, and manipulating stimulus information" (p. 163).

Additionally, reaction time studies (e.g., Johnson, 1996) have found that participants respond quicker to metaphorical sentences such as *cigarettes are timebombs* rather than the simile counterpart (*cigarettes are like timebombs*). This finding suggests that metaphorical sentences are not necessarily converted into similes in order to be understood.

**Cognitive view.** Goodman (1976) pioneered the *cognitive view* of metaphorical processing. According to this view, understanding metaphors requires the transfer of properties across symbol systems. That is, my earlier example, *X is a warm person,* would require the transfer of feeling a warm temperature to the affect associated with being warm to a warm personality attribute. According to Seitz (1997), examples of symbol systems include language, music, and visual arts. Metaphors transfer properties of features or events from one symbol system to another. Therefore, I would posit that models that address the underlying cognitive mechanisms involved in processing metaphors should not focus solely on the linguistic aspects of the metaphor.

**Alignment theory of metaphor processing.** The alignment theory is concerned with the order in which people process a metaphorical expression. That is, there are two potential modes of processing metaphors: a mode that involves deriving an abstraction from a *base word* to a *target word*, and a mode that involves aligning the terms to a representation and then projecting inferences from the base to the target (Gentner & Wolff, 1997). The first mode is referred to as an *abstraction-first model.* Given the metaphor "life is a journey," the base (journey) is used to identify the category of which it is a prototypical member (e.g., an eventful period of time in which one passes from one stage or place to another). These properties are then conveyed to the target (life), by assigning it as a member of the same category as "journey." The second mode is referred to as the *alignment-first model.* In this mode, the relations between the elements and a representational structure are made. That is properties of both "life" and "journey" are aligned to overarching properties. Gentner and Wolff compared these two models by recording participants' time to interpret metaphors primed by either the base term or the target term. They also included conditions in which they were not primed by either of the words, or primed by both words. Alignment theory would predict that there would be no difference between the priming conditions, whereas abstraction theory would predict an advantage for priming the base.

Metaphors included were taken from four conditions: high conventionality/high similarity ("that argument is a war"), high conventionality/low similarity ("that conversation is a war"), low conventionality/high similarity ("that philanthropist is a fountain"), and low conventionality/low similarity ("that developer is a fountain;;" p. 351). It was found that in metaphors with high conventionality and low similarity, a base advantage did exist. However, in all other conditions, there was no base advantage. Gentner and Wolff (1997) took this to suggest that conventional metaphors are understood by abstraction, but that novel metaphors are understood by alignment. The abstraction model also can be shown not to be complete, because the same base can have different meanings depending on the target.

**The class-inclusion theory.** The class-inclusion theory was proposed by Glucksberg and Keysar (1990). The theory was developed in order to show that metaphors such as *cigarettes are timebombs* are not simply comparisons between the topic (i.e., "cigarettes") and a vehicle (i.e., timebombs). That is, saying "cigarettes are timebombs" is not the same as saying "cigarettes are like timebombs" (Gucksberg & Keysar, p.10). According to this theory, metaphors are *class-inclusion assertions*, in which the topic of the metaphor "is assigned to a diagnostic category" (p. 3). That is, in another example"my job is a jail" (Gucksberg & Keysar, p.10), a jail refers to the category of entities that confine one against one's will, are unpleasant, and are difficult to escape from. The topic (job) would then be a part of that category. Similarly, in the metaphor "my lawyer is a shark," the word shark refers to the super-ordinate category of predatory creatures (Glucksberg, 2011). This predatory property subsumes both lawyers and sharks. There is therefore a dual reference to the use of the word "shark." This dual reference is similar to that used in such statements as “boys will be boys,” where the first “boy” refers to young males, and the second to the stereotypically bad behaviours that are typical of boys (Glucksberg, 2011).

In the following example, Glucksberg and Keysar (1990) demonstrate that comparisons and class–inclusions are quite different. Consider the comparison “Canada is like the United States.”In comparisons, the predicate (United States) is more salient than the subject (Canada). Therefore, for most residents of the United States, this form of the statement is considered best because the United States is considered the prototype. For residents of Canada, the statement would be more apt as “the United States is like Canada..” In either case, both statements are easily interpretable. Now if we were to consider the metaphor “my job is a jail,,” we would see that “my job is like a jail” would work, but “a jail is like my job” would not be easily interpretable. Similarly, “Chicago’s linebackers are like tigers” is not as easily interpretable as “Tigers are like Chicago’s linebackers” (Glucksberg & Keysar, p. 5). Therefore, it appears that metaphoricity in language is mainly concerned with showing that one object fits into the same abstract category of another. In these cases, metaphors are not equivalent to similes and are more likely to be used in everyday language and literature.

Glucksburg and Catrinel (2006) asked university students to paraphrase statements in either metaphor (X is Y) or simile (X is like Y) format. It was found that when the statements were phrased as metaphors, students came up with more abstract explanations; contrastingly, they were more likely to come up with concrete explanations for similes. For example, the metaphor “some ideas are diamonds” elicited responses alluding to creativity; whereas the simile “some ideas are like diamonds” elicited responses alluding to value. It was also found that similes tended to elicit more negative responses than metaphors. For example, the statement “my lawyer was an old shark” tended to be interpreted as meaning experienced and competent; on the other hand, “my lawyer was like an old shark” tended to be interpreted as meaning ineffectual and toothless. These results are also in favour of the direct approach to understanding metaphorical language. I would this argue that understanding metaphors does not depend on the rejection of a literal meaning, and literal meanings of statements do not appear to have priority over figurative meanings. Instead, this understanding depends on a process of categorization that occurs in parallel to that used in understanding literal language.

Further support for the class-inclusion theory comes from a study by Gernsbacher, Keysar, Robertson, and Werner (2001). In this priming study, it was predicted that the vehicle in a metaphor would be better understood in terms of the super-ordinate category that it belongs to rather than for its basic-level meaning. Four types of primes were used. The first type was a metaphorically meaningful sentence, such as “That defense lawyer is a shark;” the second type was a literally meaningful sentence, such as “That hammerhead is a shark;” the third type was a nonsensical sentence, such as “His English notebook is a shark;” and the fourth type was a meaningful but unrelated sentence, such as “That new student is a clown” (p. 434). After being presented with the prime sentence, participants were asked to indicate whether a target property statement made sense. Two types of target property statements were provided: those that were relevant to the metaphorical super-ordinate category (e.g., *Sharks are tenacious*), and those that were not relevant to the metaphorical meaning but were meaningful at a basic level of the vehicle (e.g., *Sharks are good swimmers*). The authors were interested in the verification latency (time it took for participants to respond) following each type of prime-target combination. It was found that participants had slower verification latencies for property statements that were true but not relevant to the super-ordinate category of the vehicle following the metaphorical-sentence prime than the literally meaningful prime sentence, producing a suppression effect. On the other hand, participants had faster verification latencies for property statements that were relevant to the super-ordinate category of the vehicle following the metaphorical-sentence prime than the literally meaningful sentence prime, producing an enhancement effect. These results provide further credence to the class-inclusion theory in that metaphors appear to activate the super-ordinate categories that the two items being compared share (Gernsbacher et al., 2001).

**The conceptual metaphor theory.** According to Gibbs and Beitel (1995), when people process metaphors or proverbs, the literal meaning is bypassed altogether and the figurative meaning is accessed immediately. That is, people are equipped with cognitive maps of metaphorical information from various domains. More familiar source domains map on to less familiar or vaguer target domains in order to create meaning. Similar to the class-inclusion theory, these mappings are thought to be unidirectional (i.e., one domain of knowledge is used to structure another, but not the reverse). For example, in the metaphor *love is a journey*, one must understand one domain of experience (i.e., love) in terms of a very different and more concrete domain of experience (i.e., journeys). The experience of journeys is then mapped on to the target domain of love in order to enhance the meaning of this domain for that person. Note how the reverse "a journey is love" is not a helpful metaphor. This idea of conceptual mapping also extends to our collective mind in history (Gibbs, 1998). That is, Gibbs (1998) stated that "metaphoric thought plays some role in the historical evolution of what words and expressions mean" (p. 93). For example, the root word "gen-," which means to give birth, has been used metaphorically as a root of several words including "generate," "genocide," "gene," "degenerate," "engender," etc. I would imagine that such words required making new connections at some point in history, but that they became better integrated with time, losing their figurativeness and becoming more literal.

**Graded-saliency hypothesis (Giora, 1997).** Although these models are helpful in comparing literal and figurative language, they are not sufficient in explaining *how* figural language is processed. An important step in doing so appears to be recognizing a similarity between two concepts. The similarity may involve cross-modal association (e.g., between emotional and logical centres). For example, Fodor (1981) described that the brain's capacity to process relationships between two concepts may rely on a cognitive mechanism specialized in relating concepts across different cognitive domains and corresponding brain areas. Complicating the matter is that not all metaphors are processed in the same way. For example, Blasko and Connine (1993) have shown that metaphors that were rated as highly familiar are understood more quickly than those rated as novel. In fact, highly familiar metaphors are processed figuratively first. That is, metaphors such as "X is a warm person" and "Y is a cold person" are more easily understood as personality traits rather than temperatures. This suggests that once a person encodes the meaning of a metaphor and stores it in long-term memory, the cognitive mechanism responsible for finding a similarity between the two concepts in a metaphor may not be activated when the person encounters that metaphor subsequently. Giora (1997) posited that metaphors are only different from literal language when they are novel. That is, it is not the type of language used but rather the saliency of the expression that determines how easily it is processed. This is referred to as the *graded-saliency hypothesis,* in which saliency depends on conventionality, frequency, familiarity, and prototypicality (Giora, 1997). The differences between these factors and how they interact has not been well established in the literature. This hypothesis is also in line with the Goldberg & Costa (1981) model of language acquisition, which states that newly acquired descriptive systems are processed separately (in the right cerebral hemisphere) from those utilizing well-routinized codes (in the left cerebral hemisphere).It is noteworthy that saliency also depends on the individual, and one metaphor may be very salient to one participant and completely novel to another. Due to this, most recent research in metaphors tends to include a familiarity rating for each metaphor in question.

**Neuropsychology of Figurative Language**

The idea that novel items are processed differently than familiar items is related to the neuropsychological concept of executive functioning. According to Stuss & Alexander (2000), the concept refers to the abilities involved in performing actions that require the effortful control of more routine automatic processes. Executive functions are typically tested in one or more of these situations: (1) when the level of complexity of a task requires more than automatic processing, (2) when old information must be thought about in new ways, or (3) when the information to be processed is novel. Processing novel metaphors is therefore expected to load highly on these abilities. That is, the less familiar a metaphor is, the more executive control is needed to comprehend it. More conventional metaphors, therefore, may be processed automatically without necessarily requiring any abstract thinking skills needed to understand a novel metaphor.

Neuropsychologically, an important question relating to metaphorical processing is whether it fits more closely within the language domain or the executive functioning or working memory domain. For example, although it is known that children under four years of age are unable to comprehend and rarely produce metaphors (Vosniadou, 1987), it is less clear why this is the case. I would argue that this may be due to developing knowledge of concepts, developing linguistic facility, or developing executive functioning. From a Piagetian framework, children who produce poor interpretations of metaphors tend to be at the concrete or preoperational stages of cognitive development, and children who produce accurate interpretations tend to be at the formal operations stage (Smith, 1976). Furthermore, given the *graded-saliency hypothesis*, one would expect that neuropsychological processes such as verbal reasoning and executive functioning (abstraction and working memory) would be more taxed when the metaphor is novel. Neuroanatomically, such tasks are typically associated with the functioning of the prefrontal cortex (Stuss & Alexander, 2000).

The importance of understanding non-literal language for social interaction becomes evident when considering the clinical syndromes in which this ability is impaired ranging from autism to neurodegenerative diseases to schizophrenia (Thoma & Daum, 2006). Clinically, there is currently no English-language test of metaphorical processing specifically, and tests of figurative language generally consist of proverbs tests. The most commonly used test is Gorham's proverb test (Gorham, 1956). Also used is the Proverb subtest of the Delis-Kaplan Executive Function System (D-KEFS; Delis, Kaplan, & Kramer, 2001), which consists of only eight sayings that are presented in verbal expressive and multiple choice formats.

The utility of metaphorical processing tasks as tools in the differential diagnosis of neuropsychological disorders in adulthood remains largely unknown. Child neuropsychologists and speech-language pathologists have available the Test of Language Competence (Wiig & Second, 1985) to diagnose disorders of higher-level language disorders in children. On the other hand, a standardized measure to specifically evaluate metaphorical language in adults is not available. In adults, non-literal tasks (mainly proverbs) have been mainly been used in diagnosis is schizophrenia, followed by the differential diagnosis of dementia (Rapp & Wild, 2011). Research has shown that metaphorical processing can be specifically and differently affected by different lesions and syndromes. Therefore, it is important to develop a task of metaphorical processing of potential use in clinical settings.

**Evidence from lesion studies.** Neuropsychological studies of metaphorical processing suggest that figurative language processes involve different brain areas than literal language processes. For example, the first neuropsychological study of metaphors compared patients with left-hemisphere damage, patients with right-hemisphere damage, patients with bilateral damage, and healthy participants (Winner & Gardner, 1977). They presented participants with a figurative sentence (e.g., "he has a heavy heart", p. 719) and then they performed two tasks. One involved matching the sentence to one of four pictures: one showing a literal representation (i.e., a man carrying a heart), one showing a metaphorically correct representation (i.e., a man crying), one showing a quality of the adjective in the sentence (i.e., a 500lb weight), and one showing the noun (i.e., a heart). The second task required them to verbally explain their choice. It was found that participants with right-hemisphere damage were less likely to pick the metaphorically correct representation than those with left-hemisphere damage. However, when asked to explain their choice, those with right-hemisphere were able to explain their choices, whereas those with left-hemisphere damage had more trouble doing so. These findings suggest that literal language and figurative language are processed in parallel networks that can be dissociated. Alternatively, the right hemisphere may be responsible for linking imagery with language. Needless to say, these findings are not conclusive. That is, those with left-hemisphere damage may have had more difficulty with expressive language in general, and that may have caused them not to be able to verbalize their choices. Additionally, those with right-hemisphere damage may have had trouble processing visual information in general, not necessarily as they related to metaphors.

However, Brownell, Simpson, Bihrle, Potter, and Gardner (1990) showed that patients with right-hemisphere lesions performed poorly on a metaphoric task that did not involve visual stimuli. In this study, two groups were compared, an aphasic group with left-hemisphere stroke and a non-aphasic group with right-hemisphere stroke. The participants were asked to sort words that had two potential meanings. Some of the words were adjectives (e.g., “warm,” which has the alternative meaning *loving*) and some were nouns (e.g., “pen,” meaning writing utensil or cage). Stimuli were presented in triads (e.g, deep-wise-lake, crooked-deceitful-path, down-sad-elevator) and participants were asked to pick the two cards that would go together. The task is referred to as the Metaphor Triads Task, and several studies have adapted this task (discussed below). Patients with left-hemisphere lesions performed better on this task than those with right-hemisphere lesions. This study showed that metaphorical meanings of words are relatively spared after left-hemisphere damage and despite aphasia. It also showed a dissociation between metaphorical and concrete reasoning, with metaphorical reasoning being apparently more related to right-hemisphere functioning.

Giora, Zaidel, Soroker, Batori, and Kasher (2000) used highly conventional clichéd metaphors (e.g., “broken heart,” “lend a hand,” “warm heart”) and asked participants to provide an oral verbal explanation of four metaphors. Participants included people with left-brain damage, right-brain damage, and controls. It was found that for these types of metaphors, participants with right-brain damage performed as well as controls, whereas participants with left-brain damage performed worse than both groups. Among patients with left-brain damage, the extent of damage to the left middle temporal gyrus and the junctional area of the superior temporal and supramarginal gyri were negatively correlated with performance on the metaphor comprehension task. Damage to different areas in the right hemisphere was not correlated with performance on this task. These results suggest that the left-hemisphere is dominant when it comes to understanding highly familiar metaphors.

Overall, lesion studies seem to show that both the right and left hemispheres are involved in metaphorical processing to a certain extent. The differences in methodology, types of tasks used and patient groups likely influence the varying results of these studies. It is also clear that both familiarity and complexity play important parts in whether or not a metaphor is accurately understood, and these factors were not always controlled for in these studies.

**Evidence from clinical syndromes.** Neuropsychologists typically use figurative language tests to assess a patient’s abstract thinking abilities. However, there is currently little research on the diagnostic sensitivity, specificity, and reliability of these measures when it comes to different brain disorders or in cognitive processes. In the following studies, I will outline current research showing the potential benefits of a measure of metaphorical processing that does not place a demand on expressive language skills.

***Alzheimer's Disease.*** One clue about the nature of metaphors and their relationship with literal language can be found in studying patients with early stage Alzheimer's disease (Papagno, 2001). In this type of dementia, verbal communication difficulty is a frequent and early symptom. Specifically, phonemic structures of language are generally preserved whereas semantic structures may be affected. Papagno (2001) used an Italian metaphor comprehension test in which a metaphor is presented (e.g., "Marco e un leone," Mark is a lion) and participants are asked to offer a verbal explanation. These metaphors were selected to be familiar, with the presumption that patients with Alzheimer's disease would have known the meaning at some point, but have lost it due to the disease process. Their performance on this task was then compared to a normative group and performance on a test of (literal) verbal comprehension. Additionally, errors were then classified as a "concrete/literal interpretation" (25.59%), "opposite interpretation" (6.8%), "wrong/insufficient interpretation" (58.3%), and no response (9.2%; p. 1455).  Interestingly, these patients showed impairment on the literal comprehension task but showed no impairment on the metaphors task. It is possible that the metaphorical nature of the sentences in the figurative task may have provided a context that helped activate different pathways to meaning for these patients. This shows that metaphorical reasoning is not done in a step-wise progression, as would be predicted by Searle's (1979) model of metaphorical processing, because such a model requires that one understands the literal meaning of a phrase before rejecting it and examining its figurative meaning.

Amanzio, Geminiani, Leotta, and Cappa (2008) used the same stimuli as Papagno (2001) along with some novel metaphors in a sample of 20 patients with Alzheimer's disease. Consistent with Papagno's findings, Alzheimer's patients did not differ from age-matched in the conventional metaphors task. However, they were significantly impaired on the novel-metaphors task. This is likely due to the fact that executive dysfunction is present fairly early on in the course of Alzheimer's disease. In fact, the impairment in comprehension of novel metaphors was found to be related to performance on executive functioning tasks, but not to overall cognitive abilities. Furthermore, there was no relationship between performance on the conventional metaphors task and the executive functioning tasks used in this study (Behavioural Assessment of the Dysexecutive Syndrome, BADS; Wilson, Alderman, Burgess, Emsile, & Evans, 1996).

The results of this study were interpreted to support the graded-salience hypothesis.

Greene, Hodges, and Baddeley (1995) argue that the deficits in autobiographical memory in Alzheimer's disease are in part due to retrieval processes linked to executive functioning. It is also noteworthy that although one could argue that novel metaphors are simply more difficult, this is likely not the only explanation. In fact, normal controls performed equally well on the novel and conventional metaphors (Amanzio et al., 2008). This is likely because patients with Alzheimer's disease may have difficulty inhibiting the literal interpretation or coming up with a problem solving strategy for processing the novel metaphor. According to such an explanation, Alzheimer's patients would theoretically show less impairment on a task of metaphorical processing than patients with fronto-temporal dementias, in which prefrontal functions are one of the first to show a decline. Unfortunately, this type of study has yet to be conducted.

***Parkinson's Disease.*** Patients with Parkinson's disease have also been shown to have difficulties with metaphorical language processing (Monetta & Pell, 2007). Further this appears to be due to dysfunction of the fronto-striatal systems. Monetta and Pell administered a series of neuropsychological tests as well as a test of metaphor comprehension to patients with Parkinson's disease as well as healthy controls. This test included prime-target sentence pairs with prime sentences being either metaphorical or literal, and target sentences either metaphor-relevant or metaphor-irrelevant. It was found that not all patients were impaired on metaphorical processing relative to controls. However, those patients with impaired verbal working memory were also impaired in metaphorical processing. Because verbal working memory is highly dependent on intact fronto-striatal systems, it was posited that metaphorical processing is also dependent on the functioning of this system. Furthermore, it was shown that fronto-striatal systems for working memory are often, but not always, affected during the early course of Parkinson's disease.

***Down Syndrome.*** Papagno and Vallar (2001) investigated the pattern of cognitive impairment in a woman with Down syndrome, who had been able to acquire three languages including Italian, English, and French. Neuropsychologically, she had difficulty with visuospatial processing, abstract reasoning, and executive functioning; but she had average linguistic skills, including oral and reading comprehension as well as word-list learning and episodic memory. It was found that her performance was within normal limits on a task of literal language comprehension and in the impaired range on a task of metaphor comprehension and a task of idiom comprehension. Although not many conclusions can be drawn from case-study evidence, it appears that processing of literal and non-literal language involves dissociable brain mechanisms. I would argue that in order for a double dissociation to be made, however, it must be possible to have impaired literal processing and intact non-literal processing (i.e., a patient showing the opposite pattern). It is also unclear which neuropsychological process was responsible for inability to comprehend non-literal language in Papagno and Vallar's case.

***Learning Disabilities.*** Research has shown that children and adolescents with language-based learning disabilities tend to have more trouble with figurative language than literal language. For example, in a study examining metaphorical comprehension of adolescent boys (ages 16 to 18 years), Jones and Stone (1989) found that participants with a learning disability provided fewer correct metaphor interpretations than normal controls. In this study, there were two types of response modes: verbal explanation and paraphrase selection. An example of a metaphor used in this study was "A butterfly is a flying rainbow" (p. 252), for which the selections were: appropriate metaphorical (i.e., a butterfly is colourful), irrelevant factual (i.e., a butterfly is an insect), inappropriate perceptually based (i.e., a butterfly is wide), and inappropriate perceptually based in a different modality (i.e., a butterfly is fuzzy). It was found that paraphrase selection was significantly easier for both groups, but that adolescents with a learning disability performed worse on both tasks. Furthermore, this was not related to general vocabulary knowledge or to knowledge of task-specific vocabulary. Therefore, it was concluded that these differences were due to poor organization of semantic knowledge or deficient inferential skills rather than a deficiency in the amount of semantic knowledge or semantic memory.

Such differences are also found in younger children. Lee and Kamhi (1990) examined metaphoric processing in two groups of children (9 years 0 months to 11 years 0 months of age) with learning disabilities (one group with a history of speech difficulties and one group without) and a group of children without a learning disability. All participants were asked to complete three verbal metaphor processing tasks: metaphor comprehension, metaphor preference, and metaphor completion. They were also asked to complete a visual metaphor task (the Metaphor Triads Task; Brownell et al., 1990). As expected, the group with a history of expressive language impairment performed worst, and both groups with learning disabilities were worse than the group without a learning disability on all four metaphor tasks. Lee and Kamhi argued that the implications of this study are that children with a history of learning disabilities continue to have difficulty understanding metaphors even after they gain some competence in literal comprehension. Additionally, whereas giving context helped children without a learning disability understand metaphors, it did not help children with a learning disability. This occurred despite context helping children with learning disabilities understand literal meanings.

Nippold and Fey (1983) predicted that young children, who experience difficulty with literal language attainment as pre-schoolers, would later go on to have difficulty with figurative language attainment as pre-adolescents (9- to 11-years-old). Twelve pre-adolescent children with a history of language acquisition difficulties and 12 pre-adolescent children with normal language acquisition completed literal language tasks, non-verbal intelligence tasks, and a metaphorical comprehension task. The authors used the same list of metaphors as Billow (1975). Interestingly, it was found that these children showed a deficiency in their understanding of metaphorical sentences while performing as well as controls on measures of literal language comprehension and non-verbal intelligence.

Taken together, these findings suggests that tests of metaphorical comprehension may be more sensitive than commonly used language measures at detecting those difficulties that tend to linger in children with a history of language impairment.

***Autism.*** Understanding metaphors is also challenging for individuals with autism, and this is thought to be related to impairment in theory of mind (Happe, 1995). Theory of mind can be thought of as the ability to accurately guess another person's mental state, which is an essential cognitive process underlying people's ability to engage in complex social interactions (Stone, Baron-Cohen, & Knight, 1998). It is assessed with several social reasoning tests of varying levels of complexity. It then follows that such a skill is needed when decoding a figurative expression. That is, the listener must interpret figurative expressions as clues to the speaker's intended thought (Happe, 1995).

Happe (1993) conducted a study examining the relationship between theory of mind and metaphorical processing. Participants included three groups of children and adults with autism (based on theory of mind performance) and one group with an intellectual disability not caused by autism. One group of autistic patients failed all theory of mind tasks (as is the case with the majority of autistic individuals), one group passed first-order theory of mind tasks only, and one group passed all theory of mind tasks. The group of participants with an intellectual disability not caused by autism also passed all theory of mind tasks. Participants were presented with three types of sentences: synonym (e.g., “father was very cross, he really was... angry”), simile (e.g., “father was very cross, he really was like... a volcano”), and metaphor (e.g., “father was very cross, he really was... a volcano”, p. 108).

On this task, only those participants with autism who failed all the theory of mind tasks were impaired on the metaphorical processing task, performing at chance (Happe, 1993). These participants were not impaired on the synonym and simile conditions. The findings of this study suggest that just as there may be different levels of theory of mind, there are different levels of figurativeness and that patients may show impairment at some levels but not others. Furthermore, the group with an intellectual disability but no autism performed significantly better on this task than participants with autism. Given that the only difference between the conditions was replacing “really was like” with “really was,” it seems that lower VIQ in itself does not explain autistic participants’ poor performance on metaphorical comprehension tasks but not the simile comprehension tasks.

Patients with Asperger’s disorder also do not display the right hemisphere superiority typically seen when processing metaphors on a divided visual field task (Gold & Fust, 2010). In this experiment, participants with Asperger’s disorder and matched controls were presented with four types of word pairs: literal, conventional metaphors, novel metaphors, and unrelated. They were required to make a semantic judgement on whether or not the pair makes sense. When novel metaphors were presented to the right hemisphere (left visual field), control participants responded more quickly and were less likely to make errors. However, participants with Asperger’s disorder did not show this right hemisphere advantage as compared to the left hemisphere, and were less accurate and slower than the control group in all conditions.

These findings have not gone unchallenged (see Gernsbacher & Pripas-Kapit, 2012). Norbury (2005) showed that semantic ability rather than theory of mind best predicted performance on a metaphor comprehension task. That is, only children with language impairment, with or without concurrent autistic features, were impaired on the metaphor comprehension task. However, it is important to note that although this study included children with pragmatic language impairment, pervasive developmental disorder not otherwise specified, high functioning autism, and Asperger’s disorder, participants were not grouped according to these diagnostic categories. Instead, they were grouped into the following categories: language impaired only, language impaired with autistic features, autism spectrum only, and typically developing controls. The metaphor comprehension task used in this study was the same as that used by Happe (1993). It was found that possessing higher theory of mind did not predict performance on the metaphor task. This study’s results suggest that theory of mind development in early childhood may be necessary but not sufficient in later years.

In a recent article, Giora, Gazal, Goldstein, Fein, and Stringaris (2012) attempted to further support their graded-salience hypothesis (Giora, 1997) by comparing the interpretation of metaphorical and literal language in young adults diagnosed with Asperger’s disorder as well as in healthy controls. Participants were asked to decide whether word pairs from five conditions were meaningful or not. The conditions were: familiar metaphorical (e.g., flower bed), novel metaphorical (e.g., dying star), familiar literal (e.g., wooden table), novel literal (e.g., Tverian horse), and meaningless (e.g., bunny laundry). It was found that participants with Asperger's disorder generally performed worse than typically developing young adults on both the literal and metaphorical processing tasks. That is, both groups showed a similar pattern of performance, in which the degree of saliency improved performance. However, unlike what is generally reported about Asperger's disorder, the group in this study processed both literal and figurative language at a lower level, showing no advantage in literal processing. Given that individuals with Asperger's disorder must not show a clinically significant delay in language or cognitive development to be diagnosed (APA, 2000), it is likely that the overall worse performance on these tasks was due to difficulties acquired after childhood.

The conclusions of this study diverge from the widely held view that those with Asperger's disorder fail to make sense of non-literal language. However, the level of abstraction or figurativeness required in metaphorical word-pairs may be lower than that required in a direct metaphor in the form X is Y. It is also worth noting that complex theory of mind tasks are difficult for patients with Asperger's syndrome as well as for patients with bilateral damage to the orbito-frontal cortex, but not for patients with lesions affecting the left dorso-lateral prefrontal cortex (Stone et al., 1998). Additionally, in a functional Magnetic Resonance Imaging(fMRI) study examining brain activation in healthy adults, Gallagher et al. (2000) showed that the medial prefrontal cortex was more activated while participants read theory of mind stories or watched theory of mind cartoons than when shown control stories and cartoons. As will be discussed in the review of brain imaging literature subsequently presented, the prefrontal cortex has been shown to be quite important for metaphorical processing. This would suggest that neuropsychological tasks typically impaired with prefrontal damage (those requiring executive control and working memory) may be related to theory of mind as well as metaphorical processing.

***Schizophrenia.*** Patients with schizophrenia have long been known to have difficulties interpreting figurative language, with several studies examining these patients' understanding of proverbs (Benjamin, 1944; Goldstein, 1959). More recently, authors have specifically examined metaphorical processing within this population, and have shown that concreteness is a main feature of thought and language disturbance in schizophrenia. Cutting and Murphy (1990) compared the performance of patients with schizophrenia, depression, and mania on a task of metaphorical processing in which they were asked to select a pair of words from three cards that went together best. This method was first used by Brownell and colleagues (1990; see *Evidence from Lesion Studies* section above for a detailed description). Patients with schizophrenia were more likely to choose antonym pairs (e.g., cold and warm) as going together than patients with depression or mania. Those patients were more likely to choose metaphor pairs (e.g., cold and hateful) than patients with schizophrenia. Because it was assumed that metaphorical processing is a right-hemisphere process, the authors took these results to mean that patients with schizophrenia rely more on their left-hemisphere when processing language than other psychiatric patients. However, it is now clear that this right-left distinction of metaphorical processing does not account for the complexity of this process.

Using different methodology, Iakimova, Passerieaux, and Hardy-Bayle (2006) compared the performance of patients with schizophrenia with that of patients with depression on metaphor interpretation. In this French-language study, the performances of matched-samples of patients with major depression, schizophrenia, and healthy controls were compared on a task consisting of 10 metaphorical sentences.  Overall, both patient groups performed worse than normal controls on this task, with patients more likely to provide literal or concrete responses. It was also found that severity of the formal thought disorder in patients with schizophrenia was associated with more erroneous responses on the metaphors task. For those with depression, severity of depressive symptomatology and psychomotor retardation were associated with more erroneous responses.

Using a more open-ended approach, Drury, Robinson, and Birchwood (1998) compared the performance of patients with schizophrenia, patients with delusions caused by other psychiatric disorders, and depressed patients on a metaphor comprehension task. In this study, patients were presented with passages (e.g. about two boys arguing), and then were given a statement about each passage (e.g., the boy's mother said "Bill you really are a steam roller sometimes!"). Participants were then asked what the statement means. Interestingly, the test battery was performed once during the acute phase of schizophrenia and once following recovery. It was found that patients with schizophrenia performed worse than the other two groups during the acute episode. However, there was no significant difference in performance between groups on this task at recovery. In both cases, impairment in metaphorical processing was related to difficulties interpreting interpersonal contexts. Furthermore, these differences are considered state- rather than trait-dependent impairments.

The neural basis of this impairment in metaphorical comprehension was investigated by Kircher, Leube, Erb, Grodd, and Rapp (2007). In this German-language fMRI study, participants read sentences silently while in the scanner, and were asked to judge whether each sentence had a positive or negative connotation by pressing one of two buttons. Thirty short metaphorical sentences (e.g., “Die Worte des Liebhabers sind Harfenklänge” [the lovers words are harp sounds]) and their literal counter parts (e.g., (“Die Worte des Liebhabers sind Lügen” [the lovers words are lies]) were presented (p. 144). Participants were 12 patients with schizophrenia and 12 healthy controls. It was shown that the healthy controls showed the typical pattern when responding to metaphorical sentences, which is activation in the left inferior frontal gyrus (discussed in subsequent sections). Patients with schizophrenia had a weaker signal in this area and in the right superior/middle temporal gyrus than healthy controls. Additionally, activation of this area was negatively correlated with a measure of schizophrenia severity. This suggests that patients with schizophrenia show hypoactivation of areas necessary in metaphor comprehension.

*Improving metaphorical processing in clinical populations***.** Lundgren, Brownell, Roy, and Cayer-Meade (2006) were the first to show evidence of improving metaphorical processing in one patient with a right hemisphere lesion caused by a stroke. The intervention program was based on Thinking Maps (Hyerle, 1995), which is a tool typically used for children. Its main goal is to help the user represent semantic relations in words and narrative by making connections with visual representations of the features shared between words. In the case of metaphors, the two words shown can be linked through their figurative visual representations. The authors showed that this patient displayed improved performance on a metaphor comprehension task. This occurred despite showing no improvement on neuropsychological tests measuring language and visuo-spatial skills, indicating that the improvement in metaphorical processing was not due to general recovery.

More recently, researchers such as Mashal and Kasirer (2011) have attempted to improve metaphorical processing in children with autism and learning disabilities. In this Hebrew-language study, researchers also used Thinking Maps in order to draw explicit connections between words that are metaphorically related. It was noted that such an exercise would encourage flexible thinking and switching from one semantic feature to another, therefore enhancing the development of these children. After this training program, participants were presented with a list of conventional metaphoric pairs (e.g., defense line), novel metaphoric pairs (e.g., transparent moment), and unrelated pairs (e.g., sport lemon). They were then asked to choose from four interpretations: correct metaphorical, literal, unrelated, and a final choice stating “this expression is meaningless.” They also completed semantic and letter fluency tests to assess executive functioning. In the pre-intervention testing, it was shown that children with learning disabilities or with autism both performed worse than typically developing children on the metaphor interpretation task. This is consistent with previous research discussed in earlier sections of this paper (e.g., Happe, 1993, 1995; Jones & Stone, 1989; Lee & Kamhi, 1990).

Following intervention (Mashal & Kasirer, 2011), it was found that both groups improved overall. However, only the learning disability group improved on metaphors not previously encountered. It was also found that letter fluency performance predicted improvement after intervention, suggesting that executive functions are closely related to the comprehension of novel metaphors.

*Therapeutic applications of metaphorical language***.** Metaphorical language has been described as not only a vehicle for communication, but also a method for change (Muran & DiGiuseppe, 1990). In fact, studies have found that the use of metaphors can enhance understanding between client and therapist during psychotherapy (Robert and Kelly, 2010). That is, clients are encouraged to use metaphors to help them express and structure their experience by connecting it to a similar concept through their perception of the world. Barker (1992) advised that when faced with resistant clients, therapists may use metaphor as an indirect method of communication in order to offer their clients "ideas, instructions, solutions to consider, reframing, or other inputs which may or may not be immediately acceptable" (p. 38). In this way, clients do not have to delve into details in the literal sense, but still understand and confront difficult issues in their lives.

**Evidence from Imaging Studies of Healthy Adults.** To borrow a metaphor from Glucksberg (2003), neuroimaging has become a goldmine. Brain imaging studies are primarily involved in localization of metaphorical processing networks in the brain. These studies have focused on finding a left- vs. right-brain advantage, as well as localization of function within the frontal and temporal lobes.

***Event-related Potentials.*** Using event-related brain potentials (ERPs), Pynte, Besson, Robichon, and Poli (1996) studied brain activity of participants while they read short familiar metaphors (e.g., those fighters are lions), unfamiliar metaphors (e.g., those apprentices are lions), or literal control sentences (e.g., those animals are lions) in French. The ERP was measured at the last word of each sentence, which was the same in all three conditions (e.g., lion). In this two-part study, the authors were particularly interested in the ERP component: N400. This component is elicited by all words, and the amplitude of this component is typically associated with level of difficulty in literal sentences (for review, see Coulson, King & Kutas, 1998). It was found that a higher amplitude ERP was elicited with metaphorical sentences than literal sentences, although no difference between familiar and unfamiliar metaphors was found. This suggested that participants generally found metaphors more difficult to comprehend than literal sentences (i.e., that more processing was required to understand metaphorical sentences than literal ones). Additionally, more recent studies have shown that familiarity is dependent on participants and is typically assessed through individual ratings.

In the second part of the study, Pynte and colleagues (1996) presented the metaphors with context to a second group of participants. The contexts presented were either relevant (e.g. they are not cowardly: those fighters are lions) or irrelevant (e.g., they are not idiotic: those fighters are lions). It was found that providing relevant context lowered the amplitude of the ERP signal of terminal words in metaphorical sentences to that of literal sentences. The authors indicated that when relevant context is provided, only the metaphorical meaning of the sentence is accessed. These findings can also be interpreted in light of the *graded-salience hypothesis* previously discussed. That is, the provision of context likely made the metaphorical items more salient and therefore as easily interpretable as the literal items used in this study.

Coulson and van Petten (2002) replicated these findings with 18 healthy adults as they read sentences that ended with words used literally (e.g., he knows that whiskey is a strong intoxicant), metaphorically (e.g., he knows that power is a strong intoxicant), or in an intermediate literal mapping condition (e.g., he has used cough syrup as an intoxicant). In the literal mapping condition, the literal sense of the word was used in a way that was meant to prompt the participants to map the conceptual structure from a different domain. In the example above, the intoxicant concept would be activated reminding the participant of an alcoholic drink, and then linking this with cough syrup. As expected, literal endings elicited the smallest N400 and metaphors elicited the largest N400. These results were interpreted in terms of the conceptual blending theory (Fauconnier, 1998), which is a general model of human cognition suggesting that there are input mental spaces and a "blended" mental space. Information is processed in the input mental place, and if unfamiliar, it is projected to the blended mental space. There, the "blend" develops structure through completion and elaboration processes. This leads to modification of the initial inputs and future reaction to similar stimuli. Coulson and Petten suggested that metaphorical language places higher requirements on conceptual integration that literal language, hence producing a higher N400.

A Spanish-language study investigated the hypothesis that these N400 amplitudes would differ in the right hemisphere as compared to the left hemisphere (Sotillo et al., 2004). Participants were presented with metaphorical sentences (e.g., "Green lung of the city"), followed by words that could or could not be defined by the metaphor (e.g., "park" vs. "semaphore"). The ERPs associated with the follow-up words were analyzed using temporal principal components analysis and source-localization algorithms. It was found that metaphorically related key words showed higher N400 amplitudes than non-related key words. Source-localization algorithms showed that the metaphorical key words resulted in more activation in the right middle/superior temporal areas as compared to unrelated words.

***Positron Emission Tomography.*** Bottini et al. (1994) hypothesized that the right hemisphere would show more activation in healthy adults than the left hemisphere when brain activity was examined using Positron Emission Tomography (PET) scans. PET studies involve examining relative regional cerebral blood flow (rCBF) changes while participants complete different tasks. In this case, three linguistic tasks were used. The first involved metaphorical analysis of sentences, the second involved literal analysis of sentences, and the third was a lexical decision task (a control task). In the first task, participants were presented with sentences and then asked to indicate (by pressing one of two buttons) whether the sentence constituted plausible or implausible metaphors (e.g., the investors were squirrels collecting nuts vs. the investors were trams). On this task, significant activations were observed in the right frontal lobe (prefrontal region), right temporal lobe (middle temporal gyrus), and precuneus. In the second task, they were required to decide whether the sentences were plausible at a literal level (e.g., the boy used stones as paperweights vs. the boy used feathers as paperweights). On this task, significant activations were observed in the left prefrontal region and central cingulate.

The authors concluded that metaphor comprehension selectively activates the right hemisphere whereas literal sentence comprehension activates left hemisphere structures. Additionally, neuropsychological mechanisms involved in processing metaphors likely include imagery (given activation of the precuneus), abstract reasoning (given activation of the prefrontal region), and episodic memory (given activation of the middle temporal gyrus). It is noteworthy here that familiarity of these metaphors was not evaluated; however, the authors purposely chose metaphors that were novel and unconventional.

***Functional Magnetic Resonance Imaging (fMRI).*** Lee and Daprato (2006) argued that greater right-hemisphere involvement for metaphorical language is likely due to the fact that figurative language is more complex than literal language. In their fMRI study, they showed that in healthy adults, making semantic judgements about literal and figurative word meaning activated very similar networks. These networks included bilateral activation of Broca's area, Wernicke's areas, the dorsolateral prefrontal cortex, and the inferior parietal lobule as well as the left lingual gyrus and cerebellum. Although both conditions activated the same networks, the literal words condition showed greater levels of activation. In both conditions, only simple language was used. That is, in both conditions, participants listened to sets of three adjectives and were required to decide whether the last two adjectives had a similar meaning. An example of a stimulus from the first condition would be: hot, cold, chilly. An example from the figurative condition would be: hot, cold, unfriendly. Due to the lack of selective right-hemisphere involvement in processing figurative meanings, they concluded that the right-hemisphere is important for processing complex language materials and not metaphors per se.

Similarly, Rapp, Leube, Erb, Grodd, and Kircher (2004) found no right-hemisphere involvement using an fMRI paradigm. In this German-language study, short sentence pairs with either a metaphorical or literal meaning were presented. For example "Der Wecker ist ein Folterknecht" (the alarm clock is a torturer) and "Der Wecker ist ein Elektrogerät" (the alarm clock is an electric appliance) were stimuli used in this study. Participants in this study were asked to judge whether or not the sentence was metaphorical and whether the sentence had a positive or negative connotation. For both types of sentences, no significant differences in laterality were found in the regions of interest, which included the superior temporal gyrus, the middle temporal gyrus, the inferior temporal gyrus, the triangular and the opercular part of the inferior frontal gyrus, the precuneus, the temporal pole, and the hippocampus. In fact, left-hemisphere networks appeared to be more closely involved than the right-hemisphere networks on both tasks. These findings were later replicated using a more advanced method of fMRI analysis (Rapp, Leube, Erb, Grodd, & Kircher, 2007).

In addition, Stringaris, Medford, Giampietro, Brammer, and David (2007) also found that the right hemisphere is not specifically involved in metaphor comprehension. The authors presented participants with three types of sentences: metaphorical (e.g., some surgeons are butchers), literal (e.g., some surgeons are fathers), or non-meaningful (e.g., some surgeons are shelves). In this German-language study, participants were required to press one button if the sentence made sense and another if it did not. The left thalamus was activated specifically by metaphorical sentences. This finding was made more interesting by the fact that, behaviourally speaking (i.e., reaction time measures), there was no difference between responses to metaphorical or literal sentences. Additionally, the left inferior frontal gyrus was activated when participants responded to both metaphorical sentences and non-meaningful sentences, but not to literal sentences. This suggests that even when behavioural measures show that people process metaphorical and literal sentences in similar ways, they may be using different neurological systems to arrive at these responses.

Shibata, Abe, Terao, and Miyamoto (2007) extended these findings with similar results in a Japanese-language study. That is, participants were presented with three types of sentences in the form “an X is a Y” that were either metaphorically meaningful, literally meaningful, or non-meaningful. They were asked to press one of two buttons to indicate whether or not the sentence makes sense. Contrast measures demonstrated that the left medial frontal cortex, the left superior frontal cortex, and the left inferior frontal cortex showed higher activation when participants responded to metaphorical sentences than literal sentences. When participants responded to literal sentences, more activation was seen in the precuneus, and the right middle and superior frontal cortex.

Eviatar and Just (2006) provided further support that left-hemisphere network may be implicated in metaphoric processing, but with some right hemisphere involvement. In this fMRI Hebrew-language study, brain activation patterns of 16 healthy participants were measured while they read brief three-sentence stories that concluded with either a literal, metaphoric, or ironic (sarcastic) sentence. When compared to reading literal sentences, reading the metaphorical sentences resulted in activation of the left inferior frontal gyrus and bilateral inferior temporal cortices. Reading ironic (sarcastic) statements resulted in activation of the superior and middle temporal gyri as compared to reading literal statements, with metaphorical statements resulting in intermediate activation of these regions.

On the other hand, using the Principal Components Analysis technique for fMRI data, Mashal, Faust, and Hendler (2005) found a link between right hemisphere networks and comprehension of metaphors. In this Hebrew-language study, 15 healthy volunteers were recruited. While in the scanner, three types of word-pairs were presented: conventional metaphors (e.g., sweet dreams), novel metaphorical expressions (e.g., wisdom dust), literal expressions (e.g., dog bite), and unrelated word-pairs (e.g., fuel rectangle). Participants were asked to silently decide if the words are metaphorically related, literally related, or unrelated. It was found that a unique network, consisting of the right homologue of Wernicke's area, right and left premotor areas, right and left insula and Broca's area, was recruited for the processing of novel metaphors but not conventional metaphors. However, in an fMRI study involving Mandarin Chinese conventional versus unfamiliar metaphors, contrary to expectations, increased activation in the right-hemisphere occurred for familiar but not unfamiliar metaphors or literal sentences (Ahrens, Liu, Lee, Gong, Fang, & Hsu, 2007). These studies, however, involved different processes in that participants in the Ahrens et al. study simply passively read metaphorical sentences rather than being asked to make a decision about the relation of the words in a word pair.  In fact, Mashal and Faust (2010) showed that presentation style (i.e., word pairs vs. sentences vs. paragraphs) can affect brain activation patterns in processing metaphors. That is, it may be the case that there is an interaction between presentation style and metaphoricity in these studies. The authors presented participants with four-line metaphorical texts taken from Hebrew-language poetry as well as constructed literal counterparts (e.g., "And for a sick sun fields were cushioned/And it feels soft/Its yellow tongue will elongate/Against the river's scales" vs. "And for a sick child pillows were padded/And he feels soft/His red tongue will elongate/In front of the doctor's eyes"). To ensure participants paid attention while reading these sentences, participants were presented with a target word after reading each sentence and were asked to indicate whether or not the word was in the text. However, the authors were only interested in brain activation patterns that occurred while participants were reading these texts. It was found that both metaphorical and literal texts resulted in activation in the left and right posterior and anterior superior temporal gyri.

Contrary to the authors' expectations, the metaphorical texts resulted in significantly lower activation in the anterior superior temporal gyri than literal texts. Although the authors introduced a task to ensure participants were paying attention, the task did not require participants to pay attention to the meaning of the text. Rather, it only required that participants scan the words and recognize a target word later on. This, as opposed to presentation style, may also have influenced the lack of involvement of the frontal lobes while reading metaphorical text.

Schmidt and Seger (2009) attempted to parse out the effects of figurativeness, familiarity, and difficulty on the recruitment of neural systems involved in language in the right versus left hemispheres. In this study, participants were presented with four types of sentences while in the scanner: literal sentences, familiar and easy to understand metaphors, unfamiliar and easy to understand metaphors, and unfamiliar and difficult to understand metaphors. Participants were required to read each sentence and press the response key as soon as they had understood it. Overall, metaphors recruited the right insula, left temporal lobe, and right inferior frontal gyrus more so than literal sentences. Unfamiliar metaphors recruited the right middle frontal gyrus less so than familiar metaphors. Difficult metaphors showed higher activation in the left inferior frontal gyrus as compared to easy metaphors, which recruited the left middle frontal gyrus. This study highlighted the fact the figurativeness, familiarity, and difficulty all play a role in how and where metaphors are processed within the brain.

Overall, fMRI studies confirm the role of left-hemisphere fronto-temporal networks in language processing as a whole. The right-hemisphere appears to be less involved than would be expected based on lesion studies when functional brain imaging techniques are used in healthy adults. That said, the type of metaphorical processing involved in these studies is quite restricted given that the participants have to be in the scanner at the time, and responses are limited to pressing one of two buttons. Further, some studies involved passively reading metaphorical sentences while others required decision making about the items being read. Additionally, the procedures used to evaluate metaphorical processing varied greatly between these studies. For example, some studies only included a novel or familiar metaphor, and most did not require an individual familiarity rating by participants.

***Transcranial Magnetic Stimulation.*** Pobric, Mashal, Faust, and Lavidor (2008) attempted to establish causal relationships between local brain activity in the right hemisphere and metaphorical comprehension. They also attempted to shed a light on the difference in brain activation by familiar versus novel metaphors. The authors used repetitive transcranial magnetic stimulation (rTMS) to examine the role of the right hemisphere in processing novel and familiar metaphorical expressions taken from poetry. In this Hebrew-language study, participants were presented with four types of word pairs: literal, conventional metaphoric, novel metaphoric, and unrelated. Then they were asked to indicate if the words go together. It was found that rTMS of the right posterior superior temporal sulcus disrupted processing of novel but not conventional metaphors or literal word pairs. On the other hand, rTMS over the left inferior frontal gyrus selectively impaired processing of literal word pairs and conventional but not novel metaphors. These findings are best explained using the graded-saliency hypothesis. That is, more salient metaphors are more likely to be processed in the left hemisphere, whereas more novel ones are processed in the right hemisphere. In other words, the right hemisphere is important in integrating the meanings of two seemingly unrelated concepts; and once this is integrated, processing is delegated to the left hemisphere.

**Evidence from cognitive science.** In order to discern differential hemispheric involvement in metaphorical processing, cognitive studies have typically used the semantic priming paradigm with lexical decision tasks. That is, words are presented to the right-visual-field (left-hemisphere) or to the left-visual-field (left-hemisphere). Two types of priming effects could occur (Neely, 1977). Facilitation occurs when the recognition of a target word following a semantically related prime word is faster and more accurate. Inhibition occurs when the recognition of a target word following an unrelated prime is slowed down.

Anaki, Faust, & Kravetz (1998) used the semantic priming paradigm in metaphorical (stinging-insult) versus literal (stinging-mosquito) word associates that were presented to either the left or right visual fields. In this Hebrew-language study, metaphorically related words were facilitated in the left-visual-field and literally related words were facilitated in the right-visual field. These results support the idea that metaphoric comprehension relies more on the right-hemisphere than literal word comprehension. Another finding of this study was that this effect was pronounced when stimulus onset was long but not when it was short. This was taken to imply that there is a slower decay of metaphorical meanings in the right hemisphere relative to the left-hemisphere; and therefore that it is involved in more effortful or elaborated stages of metaphorical comprehension.

In an extension of this study, Faust and Weisper (2000) investigated hemispheric differences in comprehending metaphoric word meanings in the context of a sentence.

Participants were presented with incomplete priming sentences followed by metaphorically true, literally true, or false target words. They were asked to decide whether or not the sentence is literally true. On this task, metaphorical sentences were slower and less accurately responded to regardless of visual field. Therefore, when context is provided, the role of the right hemisphere appears to be reduced. In order to further explain these results, Kacinik and Chiarello (2005) conducted an experiment with two conditions, one with single words and one with contextual sentences. It was found that the right-hemisphere was activated with contextually-irrelevant words, whereas left-hemisphere activation was more dependent on context.

Given what is posited by the graded-saliency hypothesis and what is known from brain imaging studies, it can be posited that context provides familiarity, and that when metaphors are familiar, they are more likely to be processed by the left hemisphere. Using divided visual field experiments, Schmidt, DeBuse, and Seger (2007) presented metaphorical and literal sentences with varying familiarity. Familiarity was assumed to be equivalent to distance in semantic relationships (i.e., unfamiliar sentences contain distant semantic relationships and familiar sentences contain close semantic relationships). It was found that participants showed a right hemisphere advantage for unfamiliar sentences and a left hemisphere advantage for familiar sentences regardless of metaphoricity.

**Evidence from studies of artificial intelligence.** Kintsch (2000) provided a computational model of model comprehension that is based on Gluckberg's class-inclusion theory (previously discussed). Recalling the metaphor "my lawyer is a shark," Glucksberg has shown that people automatically understand that what is being referred to is the super-ordinate category of predatory creatures. Kintsch's model aimed to address how people know to assign a particular super-ordinate category rather than the category of fish for example. The model is based on an algorithm that uses latent semantic analysis to produce interpretations similar to those that people would produce. The algorithm uses vectors in semantic space. That is, a vector of the topic is merged with selected features of the vehicle vector. It is then compared with known landmarks in the semantic space.

For example, the vectors for "lawyer" and "my lawyer is a shark" map on closely with the landmarks "justice," "crime," and "viciousness" and are less related with the landmarks "shark" and "fish." Comparatively, the vectors for "lawyer" and "my lawyer is young" map on closely with the landmarks "jury," "crime," and "age." This model also accounts for the non-reversibility of metaphors. That is, "my surgeon is a butcher" and "my butcher is a surgeon" produce different vectors and align differently to different landmarks. Interestingly, this model would suggest that literal comprehension and metaphorical comprehension are only different in terms of the semantic distances involved in the vectors.

Wallington, Agerri, Barnden, Lee, and Rumbell (2011) have recently developed a computer system able to ascribe positive or negative affect to limited types of metaphorical expressions. Namely, the system is able to decipher metaphors in which a person is stated to be something non-human such as an animal, supernatural being, or object. The system does this by recognizing such utterances as metaphors, and then analysing them to determine the meaning of their (typically affective) content.

The authors provide examples and the course of their processing. Consider the statement "Lisa is an angel." Firstly, the metaphor detector recognizes the "X is a Y" signal and recognizes that Lisa is a name of a person and “angel” is a noun. Based on Glucksberg’s theory of class-inclusion discussed above, the metaphor analyzer finds that “angel” fits the class of supernatural being. It also finds that angel can also belong to the category of person. It then would look at words linking “angel” and “person” and finds eight positivity-indicating words and 0 negativity-indicating words. The metaphor is then labelled as having a positive polarity. The system would then conclude that the metaphor “Lisa is an angel” means that Lisa is being labelled as a positive supernatural being.

It is apparent that at present, such systems only represent a shallow type of metaphorical processing. As it stands, such systems are able to recognize metaphors and identify whether or not they are associated with negative or positive characteristics. Perhaps one limitation of these systemsis the sequential approach used to identify the metaphors. As previously described, most contemporary theories of metaphorical processing in humans have rejected the sequential approach and are in favour of direct parallel processing approaches.

## Metaphorical Processing Across the Lifespan

**Early childhood.** Children have a propensity to attribute affective properties to visually perceived objects (Nathan & Hass, 1970). For example, children are likely to attribute a smiling face to cars. Such actions are called physiognomic attributions. These types of attributions were shown to begin around age three and continue to develop throughout childhood (Seitz & Beilin, 1987). That is, children as young as three attributed physiognomic properties to pictures of inanimate objects, and older children were able to do this more often. Additionally, physiognomic attributions were positively correlated with IQ measures.

In Dent-Reed and Szokolsky's (1993) extended definition of metaphors, children's play actions can sometimes be metaphorical. For example, when making a teddy bear dance, the child is likening the teddy bear to a human. Children would also understand if an adult puts a small doll in a life-size shoe, and moves the shoe while making a motor noise, that the shoe is meant to be a vehicle. Similarly, a child may wear a cup on their head as a hat. These action metaphors are understood even before children have a full grasp of language. These instances are examples of ways children can symbolically represent objects and actions that were previously only known to them through direct sensory-motor interactions (Winner, McCarthy, Kleinman, & Gardner, 1979). These action metaphors may then act as precursors of psychological-physical metaphors that involve attributing physiological characteristics to psychological aspects of objects or individuals (e.g., person X is cold). Alternatively, these may represent mistaken use of words or objects (overextensions), which adults in turn mistakenly classify as metaphorical (See Winner, 1979). Such studies have shown that a basic competence in understanding figurative language is present even at the pre-school years, but that these abilities continue to develop through early adulthood (e.g., Billow, 1975; Cometa & Eson, 1978; Douglas & Peel, 1979; Pollio & Pollio, 1974).

**Pre-adolescence.** Studies indicate that the pre-adolescent years appear to mark a period of abrupt acceleration in acquiring these skills, thought to coincide with Piaget's formal operations stage of cognitive development (Piaget, 1972). For example, Billow (1975) studied metaphor comprehension in boys between the ages of five and 13 years, and the relationship with performance on Piaget-type cognitive tasks. He found that different aspects of metaphor comprehension (as measured by asking these children to orally explain a list of metaphors) were related to concrete operational mechanisms and formal operational mechanisms respectively.

Furthermore, developmental studies appear to show that mental imagery is an important part of comprehension of figurative language. Nippold and Duthie (2003) compared school-age children's (mean age: 12.3 years) and adults' (mean age: 27 years) understanding of idioms as it relates to their ability to form mental images. Participants were presented with a number of figurative sentences and were asked to describe in writing their own mental images for each expression. They were then presented with a multiple-choice task to measure their comprehension. It was found that school-age children tended to describe images that were less sophisticated, more concrete, and less comprehensively descriptive of the expressions than those of adults. Although this study shows that the formation of mental images may be important in understanding metaphors, it is also possible that adults are better able to describe these images in writing than school-age children. Nippold and Martin (1989) found that interpretation of figurative language (idioms) was significantly correlated with specific measures of literacy in adolescents.

**Metaphorical Processing and Cognitive Aging.** It is well known that vocabulary knowledge continues to improve with age, showing little decline well into the last years of life (Verhaeghen, 2003). However, despite what was previously assumed in the literature, the format of testing recently has been shown to influence differences in performance between age groups (Bowles & Salthouse, 2008). That is, although older adults' vocabulary abilities are generally better than younger adults overall, younger adults perform better on free expression of definitions than synonym multiple choice, whereas older adults tend to perform equally well in both formats. Therefore, the difference favouring older adults is less pronounced for free expression than multiple choice. Presumably, this pattern results from the fact that expressive vocabulary taps reasoning and memory more than multiple-choice vocabulary, and reasoning and memory are areas in which younger adults on average surpass older adults (Burke, MacKay, & James, 2000). When it comes to literal reading comprehension, older adults are known to have more trouble inhibiting irrelevant information than younger adults (Hasher & Zacks, 1988). This ability to suppress intrusive thoughts, behaviours, or material is in turn is thought to be associated with working memory capacity (Rosen & Engle, 1998). Working memory capacity, in turn, is a complex concept and is thought to depend on a combination of storage capacity, processing efficiency, and ability to coordinate simultaneous activities (Salthouse, 1990). Coincidentally, Broadbent (1971) used the metaphor of a desktop to describe working memory. That is, working memory functions as the space for carrying out one's cognitive "work" and for keeping items recently used in order to carry out this work, just as a desktop is used for both carrying out ones work (e.g., writing) and storing needed items (e.g., papers, books, bills, receipts, etc.). Given such theories of cognitive aging, older adults are predicted to show reductions in performance on cognitive tasks because they have less of the relevant information available. This becomes troublesome when a large chunk of information must be integrated or evaluated before reaching a decision. Whether or not these changes are related to difficulties with metaphorical processing remains uncertain.

Newsome and Glucksberg (2002) compared metaphor comprehension in older and younger adults using a timed property-verification task. In this priming task, participants were asked to indicate if sentences made sense or not. The sentences were metaphorical (e.g., my father's dead-end job is a jail) or literal (e.g., his jacket was corduroy), and were either sensible or insensible (e.g., corduroy swims in the lake). On this task, there was no difference between older and younger adults in that both groups benefited from metaphor-relevant primes and were able to filter out metaphor-irrelevant primes.

However, when it comes to proverb comprehension, it has been shown that this ability varies with age (Nippold, Uhden, & Schwarz, 1997). The ability to explain proverbs improves markedly during adolescence and into early adulthood, plateaus during the 20s, remains stable into the 50s, and begins to decline in the 60s reaching statistical significance during the 70s (Nippold et al., 1997). In a German-language study, Uekermann, Thoma, and Daum (2008) showed that the proverb comprehension reductions in older adulthood appear to be related to reduced executive functioning skills, namely in working memory. This study required participants to choose one of four explanations for each proverb.

For example, the alternative interpretations for the proverb "all that glitters is not gold" were: (1) abstract meaningful (things are often not what they seem to be), (2) abstract-meaningless (life is not only about becoming rich, because that alone does not make anyone happy), (3) concrete-meaningful (metals which are less valuable than gold may also glitter... thus, glitter alone is no indicator of high value), and (4) concrete-meaningless (gold is not the most valuable of all metals). In this study, abstract meaningful responses were correct, whereas the next three options represented different error types. Older adults chose fewer correct responses than younger adults, and were more likely to choose the concrete-meaningful responses. Regression analyses showed that working memory measures and years of education were the best predictors of correct responses.

When it comes to idioms and metonyms, Qualls and Harris (2003) showed that when the effects of reading comprehension and working memory are co-varied, older adults outperformed younger adults on the comprehension of idioms and metonyms but not metaphors in an exclusively African American sample. These findings suggest that working memory is an important aspect of understanding figurative language, and that different types of figurative language are differentially influenced by age.

Monetta, Ouellet-Plamondon, and Joanette (2007) compared older (between 50 and 65 years old) and younger adults (between 20 and 30 years old). Participants were required to perform a version of the metaphor-triad task described earlier (Brownell et al., 1990) with and without any interference (counting backwards). The main finding of this study was that older adults had more difficulty than younger adults on this task in both conditions. On the interference condition, the younger adults showed a decline in performance as compared to the non-interference condition, whereas the older adults did not show this decline. It was suggested that older adults may have had working memory constraints without the interference, and as such there was no difference between the interference and no interference conditions due to a floor effect.

Mashal, Gavrieli, and Kave (2011) found that older adults were less likely than younger adults to identify metaphorical word pairs as plausible; however, they were more likely to rate metaphorical expression as familiar (as opposed to novel) than younger adults. This suggests an inverse relationship between familiarity ratings and ability to see a similarity between two words that are metaphorically related. In this Hebrew-language study, examples of conventional metaphors included "sweet smile" and "stock crash;" examples of novel metaphors included "pure hand" and "diamond eyes;" examples of literal expressions included "police officer" and "movie ticket;" and examples of unrelated word pairs included "cheek brains" and "splendor dog."

# CHAPTER 2

## The Present Study

The body of research on metaphor comprehension as it relates to cognitive aging is sparse. As previously reviewed, most of the work on figurative language has focused on proverb interpretation (Douglas & Peel, 1979; Drury et al., 1998; Gallagher et al., 2000; Gibbs & Beitl, 1995; Goldstein, 1959; Gorham, 1956; Iakimova et al., 2006; Martin & McDonald, 2003; g, 1989; Nippold & Duthie, 2003; Nippold & Martin, 1989; Uekermann et al., 2008), or very brief metaphors or word pairs (Ahrens et al., 2007; Amanzio, et al., 2008; Anaki et al., 1998; Blasko & Connine, 1993; Bottini et al., 1994; Brownell et al., 1990; Cometa & Eson, 1978; Coulson & Van Petten, 2002; Eviator & Just, 2006; Faust & Weisper, 2000; Gernsbacher et al., 2001; Giora et al., 2012; Gold & Faust, 2010; Kircher et al., 2007; Lee & Dapretto, 2006; & Rapp et al., 2007). Further, the interacting effects of format of presentation (free expression versus multiple-choice) and cognitive aging have not been studied.

In the present study, the first goal was to assess the sensitivity of a newly-constructed task of metaphorical processing (Iskandar & Baird, 2013) to the effects of aging. A second goal was to examine the validity of the measure by determining whether there were expected associations between metaphorical processing andperformance on neuropsychological tasks that load highly on working memory and other executive functions.

In order to accomplish these goals, a study was conducted by Iskandar and Baird (2013), in which a series of high-imagery metaphors was selected from a list of normed metaphors (Katz, Paivio, Marschark, & Clark,1988) and presented to university students, who were asked to write down a good explanation of each metaphor. These students also completed a series of neuropsychological tests: Auditory Consonant Trigrams, Sentence Repetition, and Digit Span. The purposes of this study were to see whether university students would provide answers naturally (without prompting) that could be classified into four categories--*abstract-complete (AC)*, *abstract-partial (AP)*, *concrete (CT)*, and *unrelated/other (OT)*, to develop a scoring system to be used for the main investigation, and to use these naturally-occurring responses to create a multiple choice formatted task with an exemplar of each response type as a potential choice. Correlation analyses were run in order to find associations between the category of the participants' responses and performance on the neuropsychological measures with the hypothesis that measures of working memory would predict performance on the initial free writing test for student participants. In the present study the performance of older and younger adults was compared on both formats of the Metaphor Interpretation Test, with exploration of interactions between test format and age group. Given that all metaphors were chosen to be high in imagery, a measure of visual-spatial abstract thinking as well as another measure of verbal abstract thinking was administered. Further, to evaluate the effects of premorbid verbal intelligence, the North American Adult Reading Test (NAART35) was administered.

The following directionalhypotheses were examined:

1. (a) Older adults were expected to provide more concrete answers than younger adults (i.e., they will provide a greater number of CT answers than younger adults on free response and choose a greater number of CT answers on multiple choice).

(b) Younger adults were expected to provide more abstract answers than older adults (i.e., they will provide a greater number of AC responses and choose a greater number of AC responses on multiple choice). This hypothesis is based on results of studies of proverb comprehension, which have shown that older adults' free written responses (Nippold, Uhden, & Schwartz, 1997) and multiple choice responses (Uekermann, Thoma, & Daum, 2008) tend to be more concrete than younger adults'.

(c) Based on work by Bowles and Salthouse (2008) examining the effects of age on performance on vocabulary tests in various formats, younger adults were expected to perform better (i.e., provide more abstract complete [AC] responses) on the free response version than older adults, whereas the difference was expected to be less pronounced on the multiple choice version. Current research has yet to explain the reason for more pronounced age effects on free response compared to multiple-choice vocabulary tests, but this finding may stem from greater demands on reasoning and memory skills in the free response than in the multiple-choice format.

2. (a) Based on previous work (Iskandar & Baird, 2013) it was expected that working memory (i.e., the Digit Span forward score , Digit Span backward score, and Sentence Repetition total score) would be associated with greater abstract and lower concrete responding on the Metaphor Interpretation Test and (b) that performance on the multiple choice format would be positively correlated with performance in the free writing format

(i.e., number of AC free response will be correlated with number of AC responses chosen on multiple choice, etc.)

The following exploratory hypotheses were examined:

3. In order to examine a wider spectrum of the abilities associated with performance on the Metaphor Interpretation Test (i.e., number of AC responses and CT responses), correlations with measures of working memory, verbal and visual-spatial abstract thinking, processing speed, reading ability, and cognitive flexibility were examined. In order to further investigate these associations, multiple regression analyses were performed to see which scores best predicted the number of AC responses and number of CT responses. Auxiliary analyses were also conducted for number of AP responses and number of OT responses in order to explore whether these scores also could be predicted by neuropsychological measures.

4. (a) Based on the suggestion that working memory differences account for differences in figurative language between older and younger adults (Qualls & Harris. 2003), it was predicted that co-varying on the Sentence Repetition total score (the working memory measure with the strongest correlation with AC in previous work (Iskandar & Baird, 2013) would eliminate the age difference in number of AC responses. (b) Based on the theory of cognitive reserve (for critical review of this concept, see Stern, 2002), it was predicted that older adults who performed well on measures of estimated crystallized verbal intellectual abilities likely would not show the differences in AC responses that are expected with age (i.e., a lower number of AC responses than in younger adults). That is, these age differences might not be apparent until scores on the metaphor interpretation

test were statistically adjusted for crystallized verbal abilities by using the NAART total score as a covariate.

5. Although familiarity was not associated with performance in previous work (Iskandar & Baird, 2013), it is possible that there is an age interaction between familiarity (with the metaphors) and performance. This would be in keeping with the graded-saliency hypothesis (Giora, 1997) and studies showing that metaphors rated as more familiar are processed quicker (e.g., Blasko & Connine, 1993). In order to explore this possibility, interactions between familiarity and age group were examined as a possible explanation of any difference in number of AC responses provided.

# CHAPTER 3

# Methods

## Participants

A sample of 80 participants was collected. Forty older adults (50- to 74-years old and 40 younger adults (16- to 38- years old) were included in the study (See Table 1 for demographic details).  Of the 40 older adults, 34 were biological parents, 3 were biological grandparents, 2 were biological aunts, and 1 was an unrelated friend. Ethics approval was granted by the University of Windsor Research Ethics Board, and informed consent was obtained from all participants before testing.

Table 1

*Sample Demographics*

| Measures | Older Adults | Younger Adults |
|---|---|---|
| Age | 56.55 (6.55) | 23.23 (6.18) |
| Education | 15.22 (2.91) | 14.40 (2.15) |

| | | |
|---|---|---|
| % Female | 77.5 | 82.5 |
| Estimated FSIQ | 104.93 (9.32) | 104.50 (7.46) |

Note. For Age, Education, and Estimated Full Scale IQ (FSIQ), means are provided with standard deviations in parentheses. IQ was estimated using an abbreviated version of the North American Adult Reading Test.

This sampling of young-old participants (over 50) was thought to be important in showing the sensitivity of the Metaphor Interpretation Test to early cognitive changes with age. Participants were recruited for this project through the University of Windsor Research Participant Pool. The recruitment advertisement asked students to bring a relative or a friend over the age of 50 years. Students received bonus point credits towards a participating course of their choosing, and the members of the older adult group were entered to win one of four $20 gift cards. Student participants and a relative or acquaintance over 50 years old were interviewed by a research assistant and the author respectively in separate rooms of the Centre for the Study of Cognition and Function across Adulthood, a research laboratory located at the University of Windsor. Participants were asked about their primary language (language used most often in the last four years for speaking, reading, and writing), years of education, and age, as well as about any history of psychiatric illness, neurological illness, and head trauma. Participants with a significant history of psychiatric illness, neurological illness, or head trauma known to affect cognitive functioning were excluded (see Appendix B for interview form). Participants who reported that English was not their primary language in reading and writing and those who had completed less than four years of education solely in English also were excluded. The Montreal Cognitive Assessment (see Materials and Procedures) was administered to the older adult group to screen out for dementia or mild cognitive impairment with a cut off score of 24/30 (McLennan, Mathias, Brennan, & Stewart, 2011). If the nominated older adult did not meet criteria for the study, the student was nonetheless awarded partial credit. The selection criteria resulted in 5 pairs ($n$ =10) being excluded from the study.

### Materials and Procedure

Eligible participant pairs were tested in adjacent rooms at the same time by the author and a research assistant. Each participant completed the Metaphor Interpretation Test first (free response then multiple choice) and then they were asked to complete a number of tasks as described below in a randomized order.  A list of the variables to be analysed is provided in Table 2.

**Metaphor Interpretation Test.** Twenty  metaphors were used in the original version of this measure, as described in Iskandar & Baird (2013). All items were taken with permission from Katz et al. (1988). To develop the measure for the present study, an item analysis was conducted of the data gathered from undergraduates and summarized in Iskandar & Baird..  This analysis revealed that three metaphors (babies are angels; a skyscraper is the giraffe of buildings; divorce is the earthquake of the family) had elicited no concrete answers in that study and that almost all participants had givenabstract complete responses. Consequently, these three metaphors were not included in the Metaphor Interpretation Test in the present study.

As described in Iskandar & Baird (2013), participants in the present study were asked to rate “how familiar is this metaphor?” on a five point scale: (1) not at all familiar, (2) somewhat familiar, (3) quite familiar, (4) highly familiar, and (5) very highly familiar.

Then, participants were instructed to "Please explain what you think the metaphor means. Write down a good explanation of the metaphor." The scoring system developed in Iskandar & Baird was slightly altered in some cases to better reflect the criteria below.

The following general criteria for scoring were used:

- An *Abstract Complete (AC)* response provides a full explanation of the metaphor, using a super-ordinate category that is pertinent for both the vehicle and topic of the metaphor.
- An *Abstract Partial (AP)* response provides an abstract explanation that is incomplete; or uses a super-ordinate category that is correct but less pertinent to both the topic and the vehicle
- A *Concrete (CT)* response provides an explanation that is indicative of concrete thinking (e.g., concentrates on physical similarities when a pertinent functional similarity is present; it provides a literally true statement that does not explain the similarity).
- *An Other/Unrelated (OT)* response provides a clearly wrong explanation, but not evidently due to concreteness.

Keeping a separate tally of the frequency with which a given participant made each type of response allowed for a clearer interpretation of the type of error or response style a participant (and potentially, a patient in a clinical setting) is likely to have. Specific criteria for scoring can be found in Appendix A.For example, a participant might give 13 AC responses, 2 AP, 1 CT, and 1 OT responses. The number of each type of response served as a dependent measure in one or more of the analyses concerning the association of neuropsychological test scores with performance on the Metaphor Interpretation Test. Following scoring, an item difficulty index (as described in Hambleton, Swaminathan, &

Rogers, 1991) was calculated for each metaphor based on the proportion of participants who made an AC response as compared to other response types (see Iskandar & Baird, 2013).

A research assistant was trained to score the metaphors using previous samples. A random sampling of twenty protocols from the present study was scored by this second rater to ensure inter-rater reliability for all response types. Based on previous studies (e.g., Nippold, Uhden, & Schwarz, 1997), an inter-rater correlation co-efficient of 0.90 was considered sufficient. Examination showed that the scoring criteria met this standard. The intraclass correlation coefficient (ICC) was 0.97 (95% CI 0.91–0.99) for AC responses, 0.94 (95% CI 0.84–0.98) for AP responses, 0.95 (95% CI 0.88–0.98) for CT responses, and 0.89 (95% CI 0.71–0.95) for OT responses.

Based on responses from the Iskandar & Baird (2013) study, a multiple choice format of the metaphor interpretation task was constructed. This format included one example of each response type for each metaphor as an alternative. The response types were presented in random order for each multiple choice question. That is, each question had one AC, one AP, one OT, and one CT response as choices. The instructions for this were "Here are some metaphors. Each one has four different possible meanings below it. For each metaphor, read all possible meanings and circle the one that best explains the metaphor.." For example, the following item was presented:

"Education is a lantern" means:

a) Education can illuminate one's life.

b) When you learn, things become clear.

c) You have to work hard in school to light up the lantern.

d) Education continues forever, and you are always learning.

**Working Memory: Digit Span (from the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III); Wechsler, 1997).** To evaluate short-term memory and attention span, digit span forward of the WAIS-III was administered. This involved asking participants to repeat a series of digits, increasing by one digit every two trials. The digit span forward task mainly involves the phonological loop, which is responsible for maintaining a string of verbal items in a given temporal order. Digit span backward was also administered. This task involves asking participants to repeat digits in the reverse order of presentation. This places a higher demand on working memory by involving the central executive. Both aspects of this task are affected somewhat by cognitive aging (Wechsler, 1997), but substantially more by education (Ardilla & Rosselli, 1989; Ostroski-Solis & Lozano, 2006). Practice effects on these tasks are negligible and there is high test re-test reliability (McCaffery, Duff, & Westervelt, 2000).

**Sentence Repetition Test (Spreen & Benton 1977 [in Strauss, Sherman, & Spreen, 2006]).** Sentence repetition was used to evaluate immediate memory for sentences of increasing length (Strauss et al., 2006). This measure involves both linguistic knowledge and working memory, specifically measuring the maximum amount of meaningful verbal information that one can hold in memory. According to Meyer, Volker, & Diep (2000), this test is highly correlated with digit span forward (Pearson $r$ = .75), with digit span backward (Pearson $r$ =.66), and with Full Scale IQ (Pearson $r$ = .62). Age has been found to affect performance in some studies (Spreen and Benton, 1977) but not others (Vargo & Black, 1984). Gender has been found not to affect performance, whereas education and IQ do (Vargo & Black, 1984). This test has been found to have an acceptable test-retest reliability of .71 in children with mixed diagnoses (Brow, Rourke, & Cicchetti, 1989) and of .84 in patients with chronic schizophrenia (Klonoff, Fibiger, & Hutton, 1970). In relation to other measures, it is reported that sentence repetition correlates with Digit Span Forward at $r = .75$, and Digit Span Backward at $r = .66$ (Meyers et al., 2000).

**Estimated verbal intelligence.** The North American Adult Reading Test (NAART35) is a measure of premorbid cognitive ability that is often used to estimate lifelong verbal IQ (Strauss et al., 2006). This test consists of 35 irregularly spelled words that participants are asked to read aloud. The words are scored for accuracy, with both Canadian and American pronunciations counted as correct. This test has been shown to have high validity and reliability across the lifespan (Uttl, 2002). NAART35 scores increase with age across the lifespan and with years of education, but they are unrelated to gender. The NAART35 is a short version of the full NAART, which consists of 61 items. The NAART35 and full NAART have been found to be equally precise and valid in predicting VIQ (Uttl, 2002).

**Abstract Thinking: WASI-2 Matrix Reasoning.** On this task, participants are required to view an incomplete visual matrix or series pattern and select the response option that completes the matrix or series (Wechsler, 2008). In addition to being a measure of visual-spatial abstract thinking, this measure places a high load on working memory (Lichtenberger & Kaufman, 2009). Performance on this task is known to steeply decline with age (Elias et al., 2011, Wechsler, 2008). This test is based on and is strongly correlated ($r = .80$) with Raven's Coloured Progressive Matrices (Wechsler, 1997), which in turn is associated with measures of working memory (Salthouse, 1993). It is also associated with the Halstead Category test and measures of verbal fluency (Dugbartey et al., 1999). The Matrix Reasoning subtest is known to have high reliability across different age groups (average $r = .90$; Tulsky, 2003), and performance is highly related to education (Elias et al., 2011). Similar findings are seen in Raven's Coloured Progressive Matrices with large education effects (Smits, Smit, van den Heuvel, & Jonker, 1997) and moderate reliability (Salthouse, 1993).

**Processing Speed and Cognitive Switching: Trail Making Test (Trails A & B; Reitan, 1958).** The Trail Making Test is a measure of attention, speed, and cognitive flexibility (Strauss et al., 2006). This test involves two separate tasks measuring somewhat different abilities. In the first task, the participant is asked to connect 25 encircled numbers randomly arranged on a page in order (Part A). In the second task, the participant is required to alternate between 25 numbers and letters in order (Part B). As such, the second task is considered more effortful, requiring more executive control than the first task. Correlations between the two tasks have been found to range from $r = .31$ to $r = .60$ (Strauss et al., 2006).

Hester, Kinsella, Ong, and McGregor (2005) have shown that age and years of education significantly impact performance on this test. Performance on both parts of this test declines with age. According to Hester et al., gender has a very small effect on performance. Steinberg, Bieliauskas, Smith, and Ivnik (2005) showed that years of education are not as closely related to test performance as general intellectual functioning. That is, test performance on Part A was more highly correlated with FSIQ (Pearson's $r = .368$) than education (Pearson's $r = .174$). Similarly, Part B performance was also more highly correlated with FSIQ (Pearson's $r = .495$) than education

(Pearson's $r$ = .242). In relation to other measures, the Trail Making Test Part B has been found to be sensitive to measures of cognitive flexibility more so than ability to maintain set (Kortte, Horner, & Windham, 2002). That is, on the Wisconsin Card Sorting Test, percent of perseverative responses as opposed to failure to maintain set predicted performance on Trail Making Tests Part B.

**Cognitive Screening: Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005).** The MoCA is a 10-minute cognitive screening tool covering broad cognitive domains including: short-term memory recall, visual spatial abilities, executive functions, attention/concentration, language and orientation. More specifically, this screening tool includes two learning trials and delayed recall of five nouns, clock drawing, a three-dimensional cube copy, phonemic fluency, verbal abstraction task, target detection using tapping, serial subtraction, confrontation naming, repetition, and orientation to time and place. According to Nasreddine et al., the MoCA has a high test-retest reliability ($r$ = .92, p <.001), and good internal consistency (Cronbach alpha = 0.83). Education was found to affect performance, and it is recommended that 1 point is added for those with 12 or less years of education to correct for education effects. The authors recommended a cut-off score of 26/30 for the detection of mild cognitive impairment. However, more recent studies (e.g., et al., 2011) have shown that using a cut-off score of < 24/30 improves the specificity of the task (fewer false positives) without compromising the sensitivity of the task to identifying patients with mild cognitive impairment.

Table 2

*Tests and Test Scores*

| Test | Scores Used |
|---|---|
| Metaphor Interpretation Test | Free response AC |
| | Free response AP |
| | Free response CT |
| | Free response OT |
| | Multiple Choice AC |
| | Multiple Choice AP |
| | Multiple Choice CT |
| | Multiple Choice OT |
| Digit Span Test | Total Score |
| | Total Digit Span Forward |
| | Longest Digit Span Forward |
| | Total Digit Span Backward |
| | Longest Digit Span Backward |
| Sentence Repetition | Total Correct |
| NAART35 | Total Correct |
| Trail Making Test | Part A Time |
| | Part A Errors |
| | Part B Time |
| | Part B Errors |
| WASI-2 | Matrix Reasoning Total Score |
| | Similarities Total Score |

*Note.* All scores are raw scores. AC: Abstract Complete; AP: Abstract Partial; CT: Concrete; OT: Other; NAART35: North American Adult Reading Test (35-item); WASI-2: Wechsler Abbreviated Scale of Intelligence ($2^{nd}$ ed.).

**Statistical Analysis**

All variables were examined and there were no missing data. The assumptions of the statistical analyses including linearity, independence, homoscedasticity, and normality were tested. Raw scores were used in all analyses, and data were analyzed using SPSS for Windows 17.0 (SPSS Inc., Chicago, IL, USA). For all analyses a two-tailed *p*-value of <.05 was considered statistically significant. All effect size magnitude interpretations were based on Cohen (1988).

# CHAPTER 4

## Results

### Preliminary Analyses

Preliminary analyses involved ascertaining age group differences on standardized neuropsychological measures and associations in performance between younger and older adults who were biologically related or friends**.** In order to see whether participants showed the age group differences seen in the neuropsychological literature, age differences in performance on the neuropsychological measures also were examined using ANOVAs. Based on the literature reviewed above (Hasher & Zachs, 1988; Salthouse, 1990, 1993), it was expected that there would be age differences favouring younger adults on raw scores of working memory tests (Digit Span forward and backward, Sentence Repetition), processing speed (Trail Making Test: Part A), cognitive flexibility (Trail Making Test: Part B), visual-spatial abstract reasoning (Matrix Reasoning subtest), and verbal abstract reasoning (Similarities subtest). Age differences favouring older adults were expected for the raw scores on the North American Adult Reading Test.

As expected based on the aging literature, there were age differences favouring younger adults (See Table 3) on raw scores of the Sentence Repetition Test, the Trail Making Test: Part B, the Matrix Reasoning subtest, and the Similarities subtest. Results indicated that, on the neuropsychological measures sampled, the two groups performed as would be expected based on age-norms with the following exceptions. Contrary to expectation, older adults performed as well as (not better than) younger adults in terms of raw scores on the North American Adult Reading Test. Additionally, younger adults' performance was not significantly better than older adults on Trail Making Test: A or Digit Span Backwards. Age-corrected T scores for all measures were within the average range (T-score range = 48 to 52) for both older and younger adult sample. Therefore, there appeared to be no underlying differences in ability level between the two age groups

Table 3

*Neuropsychological Test and Metaphor Interpretation Test Age Group Differences*

| | Younger Adults ($n$ = 40) | | Older Adults ($n$ = 40) | | |
|---|---|---|---|---|---|
| Measure | *M* | *SD* | *M* | *SD* | Cohen's *d* |
| Digit Span Forward | 10.80 | 1.94 | 9.92 | 2.23 | 0.42 |
| Digit Span Backward | 6.90 | 2.23 | 6.90 | 2.20 | 0 |
| Matrix Reasoning* | 21.18 | 3.38 | 19.08 | 4.59 | 0.52 |
| Similarities* | 32.65 | 3.66 | 30.78 | 4.29 | 0.47 |
| Trail Making Test A^ | 23.83 | 9.80 | 27.1 | 9.09 | -0.35 |
| Trail Making Test B*^ | 54.51 | 21.00 | 69.18 | 36.78 | -0.49 |
| Sentence Repetition* | 15.20 | 2.21 | 14.13 | 1.84 | 0.52 |
| NAART-35 | 17.33 | 6.54 | 18.15 | 7.75 | -0.11 |
| MIT: FR AC | 8.15 | 2.97 | 7.4 | 2.80 | 0.26 |
| MIT: FR AP | 5.38 | 1.81 | 4.53 | 2.08 | 0.33 |
| MIT: FR CT* | 1.00 | 0.99 | 2.35 | 1.56 | -1.03 |
| MIT: FR OT | 2.48 | 2.30 | 2.73 | 2.06 | -0.11 |
| MIT: MC AC* | 12.13 | 2.20 | 10.98 | 2.25 | 0.52 |
| MIT: MC AP | 2.90 | 1.88 | 2.95 | 1.34 | -0.03 |
| MIT: MC CT* | 1.15 | 0.92 | 1.93 | 1.43 | -0.78 |
| MIT: MC OT | 0.78 | 0.92 | 1.15 | 1.08 | -0.37 |

*Note.* MIT: Metaphor Interpretation Test; MC: FR: Free Response; Multiple Choice; AC: Abstract Complete; AP: Abstract Partial; CT: Concrete; OT: Other. **All significant differences favoured younger adults p* < .05. ^Lower scores represent quicker performance in seconds.

**Hypothesis 1: Age differences on the Metaphor Interpretation Test**

It was expected that older adults would provide more CT answers but fewer abstract answers than younger adults, and that these differences would be greater on the free response version of the test than the multiple choice version. To evaluate the different parts of this hypothesis, repeated measures ANOVAs were conducted in order to examine age group differences in performance on the Metaphor Interpretation Test and interactions with test format. Age differences in AC, AP, CT, and OT responses were examined for the free response and multiple choice formats (with age group as the independent variable, scores as dependent variables, and the free response vs. multiple choice score as the within-subject repeated measure).

As expected, older adults gave more concrete answers than younger adults, $F$ (1, 78) = 25.61, $p$ < .001, Cohen's $d$ = -.84. Younger adults tended to provide more abstract complete responses, although this effect was not as strong, $F$ (1, 78) = 3.951, $p$ = .050, Cohen's $d$ = .37. Furthermore, it was confirmed that older and younger adults did not differ in their propensity to provide abstract partial responses, $F$ (1, 78) = 1.81, $p$ = .183, Cohen's $d$ = .22 or other unrelated responses, $F$ (1, 78) = 1.01, $p$ = .317, Cohen's $d$ = -.19. It was found that participants were less likely to come up with abstract complete responses in the Free Response than in the Multiple Choice format, $F$ (1, 78) = 138.35, $p$

<.001. However, contrary to expectations, there was no interaction between age group and test format type, $F$ (1, 78) = .388, $p$ = .535 (see Figure 1).

Overall, participants were no more likely to produce concrete answers on the Free Response format than to choose concrete answers on the multiple choice format, $F$ (1, 78) = .539, $p$ = .465. Moreover, the interaction between age group and test format type was not significant, $F$ (1, 78) = 2.356, $p$ = .129 (see Figure 2).

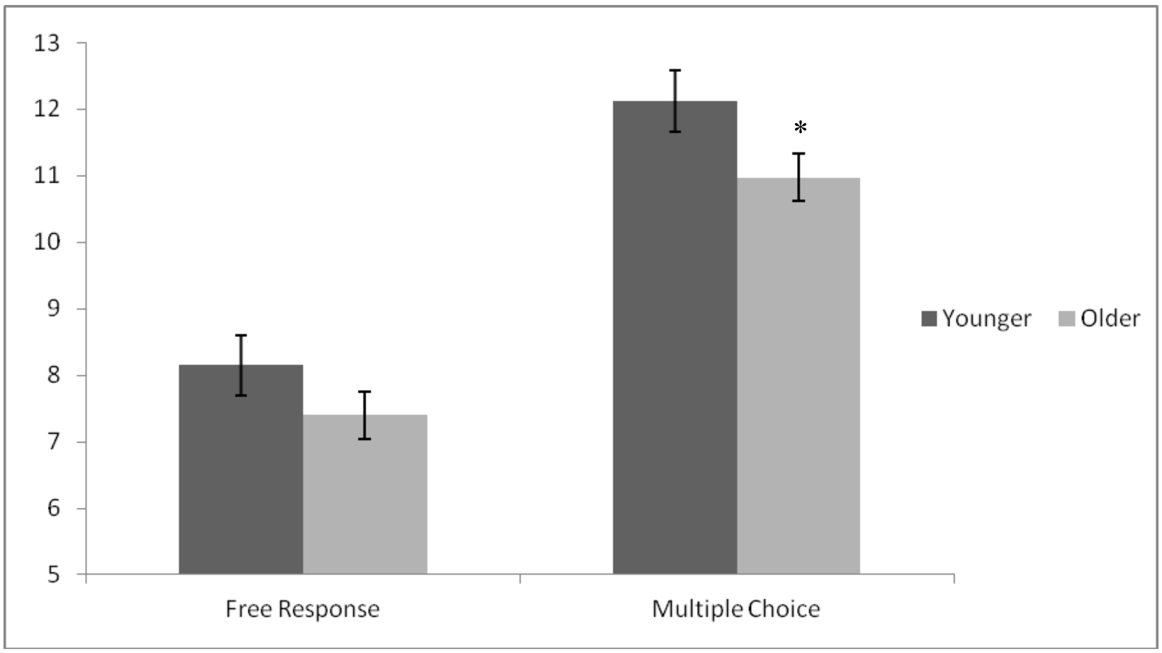


*Figure 1.* Number of Abstract Complete answers provided by younger and older adults in free response versus multiple choice formats.

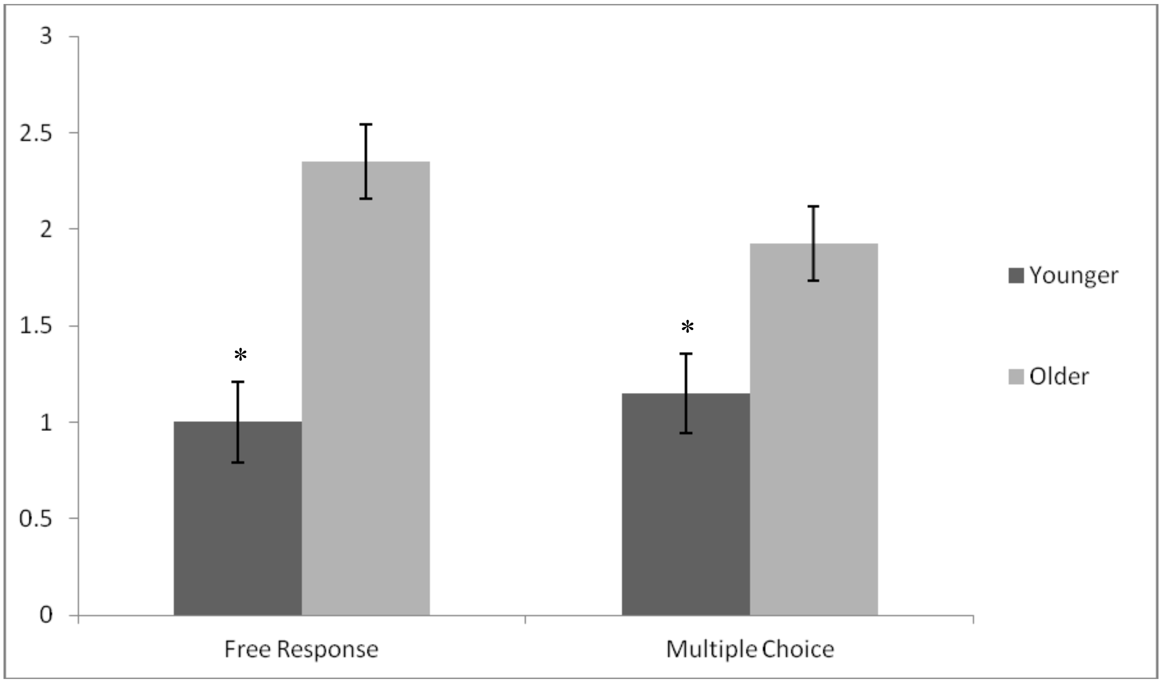


*Figure 2.* Number of Concrete answers provided by younger and older adults in free response versus multiple choice formats.

**Hypothesis 2: Correlational Analyses**

Based on Iskandar & Baird (2013), it was expected that tasks emphasizing working memory (the Digit Span scores and Sentence Repetition total score) would be associated with performance on the Metaphor Interpretation Test. It was also expected that scores on the multiple choice version of the test would be correlated with those on the free response version.

Two-tailed Pearson correlations were computed in order to examine the relations between these neuropsychological measures and the relations between the neuropsychological measures and the metaphor interpretation task (listed in Table 2 above). These correlations were examined separately for the two age-groups in order to see if there was a difference in these associations with age.

The expected findings were shown to some extent for older adults (see Table 4), and to a lesser extent for younger adults (see Table 5). That is, in older adults, significant correlations were seen between the Sentence Repetition score and free AC, AP, and OT responses as well as multiple choice AC, CT, and OT responses. Additionally, significant correlations were seen between the Digit Span Backward score and free AC, CT, and OT responses and multiple choice OT responses. In younger adults a significant correlation between the Sentence Repetition score and free CT responses was found.

Table 4

*Correlations of Metaphor Interpretation Test Responses with Neuropsychological Measures in Older Adults (N = 40)*

| | FR: AC | FR: AP | FR: CT | FR: OT | MC: AC | MC: AP | MC: CT | MC: OT |
|---|---|---|---|---|---|---|---|---|
| Matrix Reasoning | .455** | .122 | -.272 | -.534** | .383* | .034 | -.399* | -.309 |
| Similarities | -.375* | .227 | -.263 | -.537** | .337* | .025 | -.372* | -.237 |
| Digit Span Forward | .251 | -.058 | .015 | -.294 | .158 | .102 | -.193 | -.198 |
| Digit Span Backward | .559* | -.062 | -.347* | -.559** | .124 | .085 | .086 | -.480** |
| Trail Making A | -.100 | -.023 | -.194 | .110 | .295 | -.273 | -.074 | -.177 |
| Trail Making B | -.402* | .099 | .032 | -.374* | .034 | -.179 | -.136 | .332* |
| Sentence Repetition | .711** | -.326* | -.287 | -.375* | .453* | -.060 | -.316* | -.450* |
| NAART35 | .472** | .024 | .066 | -.262 | .293 | .066 | -.142 | -.508* |

*Note.* FR: Free Response format; MC: Multiple choice format; AC: Abstract Complete; AP: Abstract Partial; CT: Concrete; OT: Other. *$p$ <.05, **$p$ <.01

Table 5

*Correlations of MIT Response Types with Neuropsychological Measures in Younger Adults (N = 40)*

| | FR: AC | FR: AP | FR: CT | FR: OT | MC: AC | MC: AP | MC: CT | MC: OT |
|---|---|---|---|---|---|---|---|---|
| Matrix Reasoning | .148 | .044 | -.092 | -.186 | .263 | -.094 | -.025 | -.424** |
| Similarities | .147 | .230 | -.043 | -.351* | .006 | .013 | .031 | -.016 |
| Digit Span Forward | .095 | -.103 | -.107 | .005 | -.066 | .072 | .103 | -.012 |
| Digit Span Backward | .014 | .041 | -.175 | .025 | .024 | -.064 | .182 | -.111 |
| Trail Making A | -.240 | .290 | .058 | .056 | -.094 | -.026 | .241 | .081 |
| Trail Making B | -.272 | -.031 | .355* | .219 | -.078 | -.102 | .001 | .435** |
| Sentence Repetition | .210 | .128 | -.388* | -.206 | -.021 | .110 | .023 | -.141 |
| NAART35 | .245 | -.113 | -.342* | -.080 | -.212 | .245 | .158 | -.047 |

*Note.* FR: Free Response format; MC: Multiple choice format; AC: Abstract Complete; AP: Abstract Partial; CT: Concrete; OT: Other. *$p$ <.05, **$p$ <.01

Performance on the multiple choice format was consistently significantly positively correlated with performance in the free writing format in both age groups for the AC response score only. For both older and younger adults (see Table 6 and Table 7, respectively), there was a correlation between AC responses provided in free recall and on multiple choice. However, this finding did not extend to the other types of responses, because participants were likely to choose a different type of response on multiple choice (i.e., switch to a more complete response or abstract response) if they provided an AP, CT, or OT response on free response. One exception to this was for OT responses in older adults. That is, older adults who gave OT free responses were also likely to choose OT responses on multiple choice.

Table 6

*Correlations of MIT Response Types in Older Adults (N = 40)*

| | MC: AC | MC: AP | MC: CT | MC: OT | FR: AC | FR: AP | FR: CT | FR: OT |
|---|---|---|---|---|---|---|---|---|
| MC: AC | 1 | -.529** | -.603** | -.624** | .360* | .063 | -.275 | -.344* |
| MC: AP | | 1 | -.175 | .094 | .040 | .111 | -.102 | -.089 |
| MC: CT | | | 1 | .140 | -.177 | -.081 | .195 | .174 |
| MC: OT | | | | 1 | -.566** | -.163 | .441** | .597** |
| FR: AC | | | | | 1 | -.408** | -.555** | -.527* |
| FR: AP | | | | | | 1 | -.114 | -.367* |
| FR: CT | | | | | | | 1 | .110 |
| FR: OT | | | | | | | | 1 |

*Note.* MC: Multiple choice format; FR: Free Response format; AC: Abstract Complete; AP: Abstract Partial; CT: Concrete; OT: Other. *$p$ <.05, **$p$ <.01

Table 7.

*Correlations of MIT Response Types in Younger Adults (N = 40)*

| | MC: AC | MC: AP | MC: CT | MC: OT | FR: AC | FR: AP | FR: CT | FR: OT |
|---|---|---|---|---|---|---|---|---|
| MC: AC | 1 | -.866** | -.288 | -.328 | .422** | -.148 | -.035 | -.413** |
| MC: AP | | 1 | -.006 | .031 | -.333* | .094 | .028 | .344* |
| MC: CT | | | 1 | -.232 | .029 | -.004 | -.085 | .002 |
| MC: OT | | | | 1 | -.298 | .114 | .000 | .295 |
| FR: AC | | | | | 1 | -.518** | -.403** | -.710** |

| | | | |
|---|---|---|---|
| FR: AP | 1 | -.043 | -.137* |
| FR: CT | | 1 | .057 |
| FR: OT | | | 1 |

*Note.* MC: Multiple choice format; FR: Free Response format; AC: Abstract Complete; AP: Abstract Partial; CT: Concrete; OT: Other. *$p < .05$, **$p < .01$

**Hypothesis 3: Regression Analyses**

In order to examine a wider spectrum of the abilities associated with performance on the Metaphor Interpretation Test (i.e., number of AC responses and CT responses), correlations between these scores and measures of basic short-term memory span, meaningful short-term memory span, executive working memory, verbal and visual-spatial abstract thinking, processing speed, cognitive flexibility, and reading ability were computed. These abilities were operationalized as Forward Digit Span total, Sentence Repetition total, Backward Digit Span total, Similarities, Matrix Reasoning, Trail Making Test A, Trail Making Test B, and the North American Adult Reading Test, respectively. Auxiliary analyses were also conducted for number of AP responses and number of OT responses with the expectation that these types of responses would not be strongly associated with the neuropsychological measures.

Multiple regression analyses were performed using the *enter method* with number of AC responses, number of AP responses, number of CT responses, and number of OT responses as the dependent variables and all the neuropsychological test variables that showed a significant bivariate association for that specific age group (two-tailed at $p<.05$) with each response type score on the Metaphor Interpretation Test (e.g., the neuropsychological test scores that were significantly associated with the number of AC responses in multiple choice were included in that particular regression). Separate regression analyses for older and younger adults were conducted because older and younger adults were expected to perform differently on the Metaphor Interpretation Test and the neuropsychological measures. Additionally, including both age groups in the same analyses would violate the independence of observations assumption of regression analysis, because older adults were family members or friends of the younger adults. These analyses were done separately for the Metaphor Interpretation Task–Free-response performance and the Metaphor Interpretation Test–Multiple-choice performance.

For younger adults, regression analyses were performed for two Free Response types and one Multiple Choice response type. The free response types were CT responses and OT responses. The regression models were significant for both response types: $R^2$= .289, $F$ (3, 36) = 3.561, $p$ = .007 and $R^2$= .123, $F$ (1, 38) = 5.354, $p$ = .026 respectively (see Table 8). The regression model for the multiple choice OT response type was also significant $R^2$= .287, $F$ (2, 37) = 7.231, $p$ = .002 (see Table 9).

Table 8

*Regression Analyses for Variables Predicting Free Responses in Younger Adults (N = 40)*

*Concrete Response Types*

| Measures | B | *B* | *T-Score* | *P-value* |
|---|---|---|---|---|
| Trail Making Test B | .012 | .252 | 1.707 | .097 |
| Sentence Repetition | -.143 | -.323 | -2.198 | .035 |
| NAART35 | -.031 | -.206 | -.206 | .173 |

*Other/Unrelated Response Types*

| | | | | |
|---|---|---|---|---|
| Similarities | -.221 | -.351 | -2.314 | .026 |

Table 9

*Regression Analysis for Variables Predicting Multiple Choice Responses in Younger Adults (N = 40)*

*Other/Unrelated Response Types*

| Measures | B | *B* | *T-Score* | *P-value* |
|---|---|---|---|---|
| Trail Making B | .015 | .343 | 2.334 | .025 |
| Matrix Reasoning | -.086 | -.325 | -2.212 | .033 |

No regression models were analyzed for Multiple Choice – Abstract complete, Abstract Partial, or Concrete responses because no predictors were significantly correlated with these types of responses. Similarly, no regression models were analyzed for Free Response – Abstract Complete or Abstract Partial responses.

For older adults, regression models for all response types were conducted, with the exception of those for Multiple Choice – AP responses, because no predictors were significantly correlated with this type of response. All regression models tested were statistically significant. That is, the regression model significantly predicted Free Responses that were Abstract Complete [$R^2$= .699, $F$ (6, 33) = 12.358, $p$ = < .001], Abstract Partial [$R^2$= .106, $F$ (1, 38) = 4.521, $p$ = .040], Concrete [$R^2$= .120, $F$ (3, 36) = 5.203, $p$ = .028], and Unrelated/Other [$R^2$= .500, $F$ (5, 34) = 6.807, $p$ < .001, see Table 10]; and Multiple Choice responses that were Abstract Complete [$R^2$= .288, $F$ (3, 36) = 4.863, $p$ = .006], Concrete [$R^2$= .230, $F$ (3, 36) = 3.577, $p$ = .023], and Unrelated/Other [$R^2$= .391, $F$ (4, 35) = 5.458, $p$ = .002, see Table 11]

Table 10

*Regression Analyses for Variables Predicting Free Responses in Older Adults (N = 40)*

*Abstract Complete Response Type*

| Measures | B | *B* | *T-Score* | *P-value* |
|---|---|---|---|---|
| Sentence Repetition | .932 | .614 | 5.311 | <.001 |
| Digit Span Backward | .523 | .412 | 2.941 | .006 |
| Trail Making Test B | .003 | .038 | .311 | .758 |
| NAART35 | -.012 | -.032 | -.256 | .800 |
| Matrix Reasoning | .068 | .111 | .879 | .386 |
| Similarities | .017 | .026 | .212 | .833 |

*Abstract Partial Response Type*

| | | | | |
|---|---|---|---|---|
| Sentence Repetition | -.367 | -.326 | -2.126 | .040 |

*Concrete Response Type*

| | | | | |
|---|---|---|---|---|
| Digit Span Backward | -.246 | -.347 | -2.281 | .028 |

*Other Response Type*

| | | | | |
|---|---|---|---|---|
| Digit Span Backward | -.287 | -.307 | -1.954 | .059 |
| Matrix Reasoning | -.086 | -.191 | -1.230 | .227 |
| Similarities | -.123 | -.256 | -1.684 | .101 |
| Trail Making Test B | .003 | .054 | .363 | .719 |
| Sentence Repetition | -.205 | -.183 | -1.401 | .170 |

Table 11

*Regression Analysis for Variables Predicting Multiple Choice Responses in Older Adults (N = 40)*

*Abstract Complete Response Type*

| Measures | B | *B* | *T-Score* | *P-value* |
|---|---|---|---|---|
| Matrix Reasoning | .093 | .190 | 1.094 | .281 |
| Similarities | .080 | .152 | .897 | .375 |
| Sentence Repetition | .443 | .363 | 2.458 | .019 |

| | | | | |
|---|---|---|---|---|
| *Concrete Response Type* | | | | |
| Similarities | -.068 | -.202 | -1.146 | .260 |
| Matrix Reasoning | -.071 | -.226 | -1.250 | .220 |
| Sentence Repetition | -.159 | -.204 | -1.328 | .192 |
| *Other Response Type* | | | | |
| Sentence Repetition | -.164 | -.281 | -1.815 | .078 |
| Digit Span Backward | -.144 | -.296 | -1.660 | .106 |
| Trail Making Test B | .001 | .024 | .149 | .883 |
| NAART35 | -.032 | -.226 | -1.325 | .194 |

**Hypothesis 4: Covariance Analyses**

It was predicted that (a) co-varying on the Sentence Repetition total score would eliminate any age group difference in number of AC responses and CT responses; and (b) co-varying with measures of estimated crystallized verbal intellectual abilities would increase the effect size in group differences between older and younger adults in AC responses and in CT responses. That is, that these difference may not be apparent until a measure of these abilities (NAART total score) is used as a covariate; because older adults with higher estimated verbal IQ would have theoretically have reserve that allows them to compensate for cognitive changes that would otherwise lead to more concrete thinking.

Covariance analyses were conducted in order to attempt to explain the potential differences in metaphorical interpretation. Co-varying on Sentence Repetition Total scores (with test format as a repeated measure) was expected to eliminate the age-related differences in metaphorical interpretation, whereas co-varying on the NAART total score was expected to augment these differences. As expected, co-varying on the Sentence Repetition total score eliminated the difference in AC responses between younger and older adults, $F$ (1, 78) = 1.226, $p$ = .272, suggesting that short-term memory span mediates the relationship between age group and abstract response production on the Metaphor Interpretation Test. There was also a response type by Sentence Repetition total interaction, whereby co-varying on sentence repetition eliminated the age difference in the free response but not the multiple choice format, $F$ (1, 78) = 6.566, $p$ = .012 (see Figure 3 as compared to Figure 1).

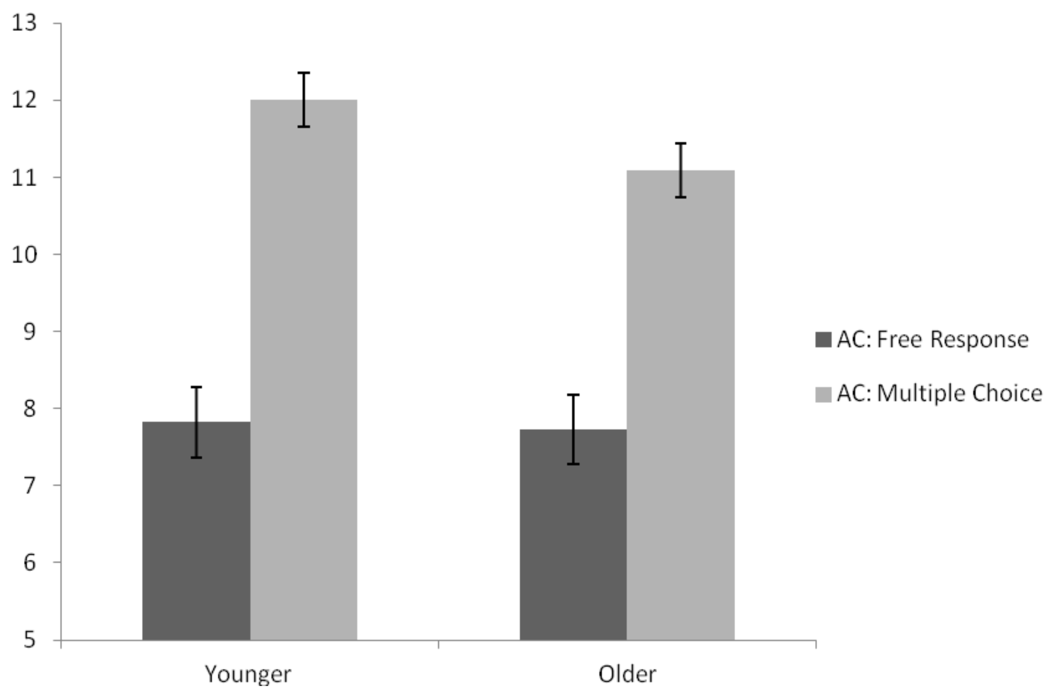


*Figure 3.* Number of Abstract Complete answers provided by younger and older adults in free response versus multiple choice formats with Sentence Repetition Total score co-varied.

Supporting the second part of this hypothesis, co-varying with NAART35 score resulted in a medium effect of age on AC response production, $F$ (1, 78) = 4.674, $p$ =

.034, $\eta^2$ = .06. The effect size without using the NAART35 as a covariate was small, $\eta^2$ = .02. There was also a response format by NAART35 score interaction, whereby NAART35 score augmented age group differences in the free response but not the multiple choice format, $F$ (1, 78) = 6.293, $p$ = .014. Figure 4 shows this effect by comparing low (below average) and high (above average) scorers in the younger and older age groups.

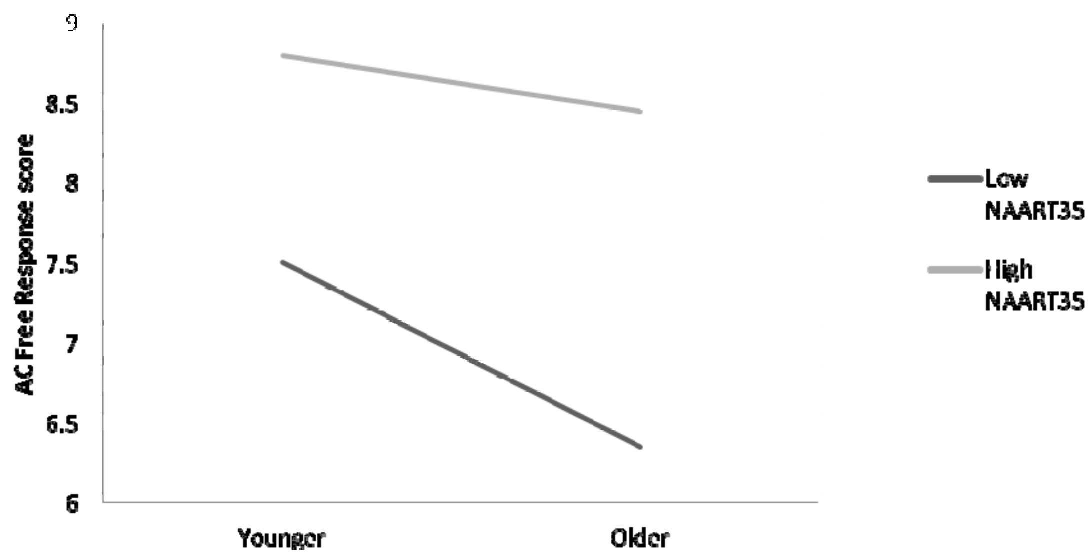


*Figure 4.* The effect of estimated premorbid verbal IQ (estimated by NAART35) on production of abstract complete responses on the MIT- free response.

### Hypothesis 5: Effects of Perceived Familiarity

Although familiarity was not associated with performance in Iskandar & Baird(2013), it was thought that an age interaction between familiarity and performance was possible. In order to explore this possibility, interactions between familiarity score and age were examined when age group differences in number of AC responses were observed. To do so, familiarity scores were used to divide the participants into a high familiarity group (those reporting above average familiarity with the metaphors) and a low familiarity group (those reporting below average familiarity with the metaphors). Within-subject repeated measures ANOVAs were conducted with age (older versus younger) and familiarity (high versus low) as the IVs and the number of AC responses as the dependent variable.

There was no difference between average reported perceived familiarity (on a 1 to 5 scale) between the older adult and younger adult groups, $F$ (1, 78) = .712, $p$ = .401.

It was found that familiarity did not significantly affect number of AC responses on the Metaphor Interpretation Test, $F$ (1, 78) = 2.254, $p$ = .137, and there was no interaction between age group and familiarity, $F$ (1, 78) = 0.111, $p$ = .740 (see Figure 5).

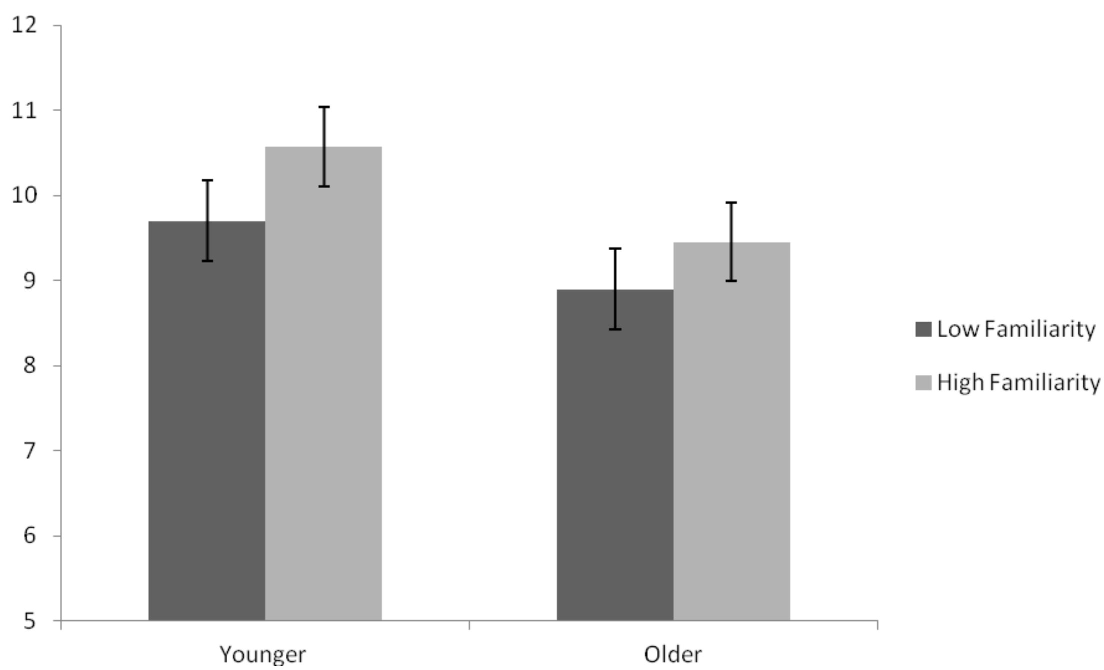


*Figure 5.* The effect of perceived familiarity on abstract complete response production or selection (based on an aggregate of free response and multiple choice responses).

# CHAPTER 5

## Discussion

In this study, the Metaphor Interpretation Test (Iskandar & Baird, 2013), a test of abstract thinking and figurative language focusing on people's understanding of metaphors, was further refined and evaluated. The first part of the test requires free responses explaining what metaphors mean, and the second part of the test requires participants to choose the best response amongst four options for each metaphor. This test, along with a number of neuropsychological measures, was administered to a group of younger adults and a group of older adults. The following research questions were addressed: whether older adults produced more concrete responses and fewer abstract responses than younger adults; whether older adults benefitted from the multiple choice format more  than younger adults; whether different neuropsychological measures predicted performance on the Metaphor Interpretation Test for older as compared to younger adults; whether age group differences in working memory capacity underlay the difference in abstract response production in older versus younger adults; whether older adults with higher crystallized verbal intelligence (and therefore more cognitive  reserve) showed a  curtailed age-related tendency towards producing more concrete responses; and whether perceived familiarity with the metaphors influences performance on the task and had a different effect for an older versus a younger age group

Results indicated that older adults were more likely than younger adults to give concrete responses in a free response format and to choose concrete responses in a multiple-choice format. Older adults also chose fewer abstract complete responses on multiple choice and freely provided fewer abstract complete responses than younger adults.

Contrary to expectations, older and younger adults benefitted equally from the multiple choice format as compared to the free response format. Performance on free response versus multiple choice formats was predicted by different neuropsychological measures, and it is likely that the two formats of the test require somewhat different cognitive processes despite the fact that both technically are measures of metaphor interpretation. In a way, this is not surprising, because the free response measure requires participants to mentally search for and retrieve a correct response, while the multiple choice measure only requires an evaluation of different responses (i.e., the participant only needs to recognize the response that they know is the best interpretation, rather than come up with it spontaneously). Measures of working memory, verbal and visual-spatial abstract thinking, reading ability, and cognitive flexibility were associated with the Metaphor Interpretation Test scores. Simple processing speed, however, appeared to clearly rely on a different domain of cognition unrelated to the thinking process required in producing abstract responses.

There were more statistically significant bivariate correlations between neuropsychological and Metaphor Interpretation Test measures in older versus younger adults. As such older adults' performance on the Metaphor Interpretation Test was more often predicted by neuropsychological measures than younger adults' performance. That is, significant regression models were identified for free response AC, AP, CT, and OT responses as well as multiple choice AC, CT, and OT responses. Similar to previous findings with younger adults (Iskandar & Baird, 2013), short-term memory span for meaningful language, or working memory storage, was a reliable predictor of AC responses in an older adult sample. This finding was not replicated for younger adults in this study, possibly because of the exclusion of three metaphors that were in the previous study (making this version of the Metaphor Interpretation Test less sensitive for younger adults). Additionally, in older adults, the executive aspects of working memory were also a significant predictor of performance, with lower scores predicting more concrete responses.

For younger adults, regression models significantly predicted free response CT and OT responses, and multiple choice OT responses. In younger adults, lower performance on mental flexibility predicted OT responses on multiple choice, lower working memory storage predicted CT responses on free response, and lower verbal abstraction abilities predicted OT responses on free response.

As hypothesized, short-term memory span for meaningful language appeared to influence the difference between younger and older adults' performance on the Metaphor Interpretation Test. Co-varying on a measure of sentence repetition eliminated the difference between younger and older adults in AC responses. Additionally, it was shown that age group differences in performance on the Metaphor Interpretation Test were also related to a measure of crystallized verbal ability expected to increase throughout adulthood (NAART35). Older adults did not rate the metaphors in the Metaphor Interpretation Test as more familiar than younger adults,. Perceived familiarity did not result in greater numbers of AC responses on the Metaphor Interpretation Test.

As can be seen in Table 1, age group differences were found on a variety of cognitive abilities sampled including visual abstract problem solving (Matrix Reasoning);

verbal problem solving (Similarities); attention switching (Trail Making Test B); and short-term memory span, also referred to as *storage* component of working memory, for meaningful language (Sentence Repetition). Amongst this sample, there were no age-related differences in short-term memory span for numbers (Digit Span Forward); mental manipulations, also referred to as the *executive* component of working memory (Digit Span Backward), processing speed (Trail Making Test A), or estimated premorbid verbal intelligence (NAART35).

Overall the sample collected performed as expected based on age norms. That is, the younger adults in this study performed almost identically to adults aged 20-24 on Digit Span Total raw score, and the older adults performed almost identically to adults aged 66-64 in normative samples gathered for the WAIS-III manual (Wechsler, 2008). The age differences noted on Matrix Reasoning and Similarities are also typical given age-based norms from the WASI-2 manual (Wechsler, 2012). High scores on Matrix Reasoning indicate well developed visual-spatial abstract reasoning; and although lower scores indicate rigid thinking, they may also reflect poor concentration (Groth-Marnat, 2003) or lowered working memory capacity (Salthouse, 1993). Similarly, high scores on Similarities indicate well developed verbal abstract reasoning and concept formation, and although lower scores may indicate concreteness, they may also indicate poor verbal fluency (Groth-Marnat, 2003) or difficulties in retrieval of verbal information from long-term memory (Lichtenberger & Kauffman, 2013).

The Metaphor Interpretation Test was developed to provide a purer measure of concrete versus abstract thinking by separating retrieval difficulties from general inability to abstractly interpret information (by comparing scores on free response and multiple choice formats). It also more clearly separates concreteness from general comprehension difficulties. By using the scoring system for free response, general comprehension difficulties would be coded as OT as compared to concreteness difficulties that would be coded as CT.  On the multiple choice version, concreteness is easily identified by participants' choice of concrete options.

On the Trail Making Test A, a processing speed measure, there surprisingly was no difference between the younger and older adults. The older adults in the present study outperformed those in the most recent normative studies of this test (Hester, Kinsella, Ong, & McGregor, 2005; Tombaugh, 2004). However, the older adult group in Hester et al. was considerably older than in this group (minimum age 60 years); and a comparable age-group from Tombaugh's study had considerably fewer years of education ($M = 13.59$ years) as compared to the average older adult ($M = 15.22$ years) in the present study. Formal educational attainment plays a role in processing speed, especially for adults over 54 years (Tombaugh, 2003). For example, lower educated adults aged 18-24 performed comparably on Trail Making Test A to higher educated adults in the 70-74 age range (Tombaugh). On the other hand, there was a significant difference on Trail Making Test B, a measure of cognitive flexibility and set shifting, as expected based on age-norms. This suggests that processing speed measures that involve cognitive flexibility are more sensitive to age-related changes than simple processing speed measures.

On Sentence Repetition, a measure of short-term memory span for meaningful language, there was a clear effect of age on performance favouring younger adults. This was in line with the original scoring of the test (see Gilbert, 1941), as well as the Spreen and Benton (1977) version, which allotted +1 extra points for adults between 35 and 44 years old and +2 extra points for adults between 45 and 64 years old; but not with other studies showing no age difference (Vargo & Black, 1984; Meyers, Volkert, & Diep, 2000). Meyers et al. attributed these discrepant findings to differences in administration procedure, such as reading the stimuli rather than presenting them on tape. However, in the present study, stimuli were also read out and an age difference was still found. It is possible that the speed with which we read the material better reflected that used in the original study, whereas it was slower (presumably for both younger and older adults) in the other studies in order to accommodate for theoretical age-effects on processing speed. There was no age-group difference in the raw scores on the NAART35, which measures estimated verbal intelligence. The mean scores of both the younger adult and older adult group represented average verbal intelligence.

Perhaps most importantly for the purposes of this study, it was found that the biggest age group related effect sizes were for the number of concrete answers provided on the free response version of the test and chosen on the multiple choice version of the test (see Table 1). Older adults were also less likely to choose an abstract complete response in the multiple-choice format than were younger adults. These findings replicate those from a German language study on proverb comprehension using a multiple choice format test (Uekermann et al., 2008), and an English language study using a free response format test (Nippold et al., 1997). In fact, these findings also suggest that metaphor interpretation may be more sensitive to age-effects than proverb tests in that these differences (older adults producing and choosing more concrete responses than younger adults) are very much apparent at a young-old age (*M* age = 56.44). In the study by Uekermann et al. differences in proverb interpretation were not found in adults 40-59 years of age, but were only detected at ages 60+ (*M* age = 68.17). Similarly, in Nippold et al.'s study, differences did not reach statistical significance before age 70 years.

Given the finding that co-varying with short-term memory span for meaningful information eliminated the age difference in performance, it appears that the ability to interpret metaphors is lowered with age as a result of a reduced working memory storage, or ability to hold, information. From a cognitive psychology perspective, it is well established that short-term memory span for meaningful information (or working memory capacity for language) can constrain comprehension of complex language (Just & Carpenter, 1992). When syntax is ambiguous, which was the case in many of the novel metaphors used in the Metaphor Interpretation Test, having a larger storage capacity for information permits one to maintain several different interpretations in mind. Hasher and Zacks (1988) refer to ambiguous syntactic structures as having high demands on working memory and thus as more likely affected by age.

Another difference between younger and older adults is that concreteness in younger adults is consistently predicted by lower short-term memory span, or the storage component of working memory; whereas in older adults, concreteness in predicted by lower mental manipulation abilities, or the executive component of working memory as well short-term memory span. This finding may be related to the compensation hypothesis of neurocognitive aging. Simply stated, when older adults find a task more difficult, they are more likely to recruit different cognitive networks in order to come up with a response (for a review of this hypothesis, see Reuter-Lorenz & Cappell, 2008). This hypothesis has been shown to be especially relevant in working memory tasks. That is, the higher working memory loading, the more likely it is for older adults to show greater activation in different brain networks (prefrontal, parietal, medial, and occipital) than younger adults as well as more bilateral activation as compared to left-lateralized activation in younger adults (Schneider-Garces et al., 2010). The fact that working memory is not easily localized mirrors the fMRI findings on figurative language reviewed in the introduction. In the present study, the compensation hypothesis can also explain why more regression models were significant for older adults than younger adults overall.

Unlike short-term memory span for meaningful verbal information, which was lower in older compared to younger adults, verbal intelligence as estimated by the NAART35 was not statistically significant across groups. Verbal intelligence was strongly associatedwith free response production of abstract complete responses in older adults and weakly associated in younger adults. Based on theories of cognitive reserve, it was predicted and found that co-varying with estimated verbal intelligence augmented the difference between younger and older adults in free production of abstract complete responses. This suggested that adults with greater intellectual resources (cognitive reserve) do not show the same age-related declines as those with lower premorbid abilities. These findings are encouraging in that they highlight that age-related cognitive decline is not necessarily a universal or pervasive process. That is, there is great intraindividual variability within older adults (for review of this literature, see Hultsch, Strauss, Hunter, MacDonald, & Stuart, 2008) in terms of their cognitive abilities as well as how they perceive themselves as they age. Secondly, these findings allow for the idea that these changes may be preventable or reversible. They may be preventable in the sense that adults who incorporate lifelong learning into their daily lives will likely have a greater verbal knowledge reserve which can continue to grow or at least stabilize with age (for theoretical overview see Sternberg, 2008). There are also differences in how older adults adapt to cognitive declines. Plasticity theories predict that adaptation to atrophy in prefrontal regions may involve network restructuring that can lead to equivalent functional performance in day-to-day life (for review of this literature, see Greenwood, 2007).

In terms of familiarity, older adults did not report being more familiar with the metaphors than younger adults unlike what was shown in the proverbs study by Uekermann et al. (2008). [This suggests that the metaphors in this study were novel (average ratings were 2.6 on a 5-point scale)] and performance on the Metaphor Interpretation Test is less likely to be a measure of crystallized knowledge. Furthermore, the finding that younger adults provided more abstract responses than older adults despite no difference in familiarity suggests that there is more to metaphor interpretation than salience.

Results of the present study suggest that alternating attention, as measured by Trail Making Test B, plays a role in choosing the best metaphor interpretation when four alternatives must be considered, and more specifically in the avoidance of choosing a clearly incorrect (unrelated/other) interpretation on multiple-choice (see Tables 7 and 9). This suggests that when individuals encounter a metaphor that they do not immediately understand, the ability to alternate attention is important in switching or shifting one's focus from a seemingly correct interpretation that is actually neither literally or figuratively true to one that is more appropriate. These findings add a level of complexity not addressed in Iskandar & Baird (2013), which suggested that the computational model of language processing can be applied to the understanding of metaphors. The computational model and other theories of figurative language comprehension have focused on the processes involved in the correct interpretation of metaphors. An incorporation of error analysis can shift this focus to understanding erroneous interpretation of metaphors and the breakdowns in cognitive processes that can lead to this (such as faltering alternating attention). Given the results of the present study, it is posited that if literal and figurative processing occur in parallel networks, a process responsible for switching attention between the two levels of interpretation is necessary for prevention of erroneous/unrelated responses.

Further research questions in this area remain unanswered. For example, in this study, the same sample received the multiple choice format following the free response. Although this was necessary in order to compare the formats of testing within subjects, future research may use different samples to evaluate the multiple choice format as a stand-alone measure. In addition, neuroimaging, which was not a part of this study, is an area for future research. That is, although behavioural data can provide clues as to the neurocognitive processes involved, a modification of this study for fMRI would more clearly delineate the functional neuroanatomy involved in the abstract interpretation, concrete interpretation, and other/unrelated interpretation of the Metaphor Interpretation Test items.

Future studies may also involve assessing language skills in a functional manner. That is, although older adults provided less abstract and more concrete interpretations, it is not necessarily the case that these difficulties arise for them in daily life. Correlating performance on the Metaphor Interpretation Test with interpretation of figurative language from a news article or a conversation would add further credence to its ecological validity.

Due to the cross-sectional nature of this study, age-related results may be better framed as age group differences because there may be  cohort effects that may have interfered with performance in addition to age-related changes. However, by recruiting mainly biological relatives in the older and younger groups, who also had similar levels of education, I may have reduced some of the social, cultural, and economicdifferences that may be confounded with age differencesin typical cross-sectional studies.

There are many potential applications of this project. In addition to highlighting age-differences, the Metaphor Interpretation Test theoretically can be applied to help with the differential diagnosis and treatment planning of a number of clinical presentations. In having both free response and multiple choice components and a scoring system that clearly differentiates different response types, it can be posited that this test can differentiate abstract from concrete thinking, and concrete thinking from retrieval or expressive difficulties. That is, in future research, the scores can potentially differentiate among the following profiles: good expressive abilities with abstract thinking, good expressive abilities with concrete thinking, poor expressive abilities with abstract thinking, and poor expressive abilities with concrete thinking.

Theoretically, these profiles may be linked to different clinical disorders. For example, in Alzheimer's disease, delayed memory is the best predictor of early stages, whereas examining lexical-semantic processing is important in determining whether progression to later stages has occurred (Welsh, Butters, Hughes, Mohs, & Heyman, 1992). Therefore, one might expect good expressive abilities with abstract thinking at the early stages; poor expressive ability, or retrieval, with abstract thinking intact at the moderate stages; and poor expressive ability with concrete thinking at the later stages. In an Italian language test of metaphors, Papagno (2001) found no differences between healthy older adults and those with early stage Alzheimer's disease. On the other hand, mental rigidity and inflexibility with language disorder is a hallmark of frontotemporal dementia (the Lund and Manchester groups (1994). Therefore, as opposed to early stage Alzheimer's, patients with frontotemporal dementia are expected to show poor expressive ability with concrete thinking. Patients with Parkinson's disease are thought to have difficulties in working memory storage (short-term memory span), as well as planning and allocation of attentional resources (Dubois & Pillon, 1996). Therefore, these patients are expected to have difficulty generating abstract complete responses. In fact, Monetta & Pell (2007) showed that patients with Parkinson's disease with a working memory storage impairment had difficulty understanding metaphors whereas those with intact working memory storage did not.

Potentially, the use of the Metaphor Interpretation Test also can be extended to developmental neuropsychological disorders. For example, in Down syndrome, a neuropsychological profile showing motor, language (morpho-syntax), verbal short-term memory span, and explicit long-term memory impairments, with relative preservation of implicit long-term memory is seen (Vicari, 2006). In an Italian language case study, Papagno and Vallar (2001) showed that a woman with Down syndrome performed within normal limits on a task of literal language comprehension but within the impaired range on a task of metaphor comprehension. Theoretically, such patients are expected to produce poor expression with concrete thinking on the Metaphor Interpretation Test. In autism, neuropsychological impairments include motor imitation, divided attention, and response to emotional stimuli (Dawson, Meltzoff, Osterling, & Rinaldi, 1998). In high functioning autism, patients are expected to show normal expression with concrete thinking.

Children with language based learning disabilities tend to be a heterogeneous group with phonological awareness being the only ability that is reliably impaired (Fletcher et al., 1994). However, several studies have shown some degree of impairment in figurative language in this population (e.g., Jones & Stone, 1989; Lee & Kamhi, 1990; Nippold & Fey, 1983). Due to the heterogeneous nature of learning disabilities, there is little theoretical basis for predicting the pattern of impairment on the Metaphor Interpretation Test; however, knowing the profile may be helpful on a case by case basis. Future research may also show a pattern for a particular learning disability type or subtype.

The Metaphor Interpretation Test also may be useful in psychiatric disorders. In schizophrenia, the neuropsychological profile is characterized by generalized thought disorder with severe impairments in episodic memory and executive control processes (Reichenberg & Harvey, 2007). In a French language study of free response metaphor interpretation, patients with schizophrenia made more errors (not differentiated) than patients with depression (Iakimova et al., 2006). Given this it would be expected that patients with schizophrenia are more likely to produce and choose unrelated/other responses on the Metaphor Interpretation Test. Overall, the Metaphor Interpretation Test provides a measure of a specific type of figurative language, with two formats, and a comprehensive scoring system allowing for varied, practical, and theoretically informed future applications.

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## Appendix A

**General Scoring Guidelines**

*AC (Abstract Complete)* – provides a full explanation of the metaphor, using a super-ordinate category that is pertinent for both the vehicle and topic of the metaphor.

*AP (Abstract Partial)* **–** provides an abstract explanation that is incomplete; or uses a super-ordinate category that is correct but less pertinent to both the topic and the vehicle

*CT (Concrete)* – provides a response that is indicative of concrete thinking (e.g., concentrates on physical similarities when a pertinent functional similarity is present; provides a literally true statement that does not explain the similarity).

*OT (Other)* **–** Clearly wrong responses, but not evidently due to concreteness

If more than one response is given, use the full response if it is part of the same idea/explanation and use the last response if it is a new idea/explanation.

### 1. The mind is a sponge

*AC* **–** the mind *absorbs/ /soaks up/takes in/sucks in* information/knowledge/facts

– "can absorb a lot of information"
– "the mind can soak in a lot if information"
– "mind is able to absorb a variety of things and remember them when needed.

*AP* **–** answer does not fully explain the relationship between the two elements; does not use above keywords; retains; holds

– "the mind can hold as much information as you feed it
– "there is great retention of knowledge in our mind"

*CT*– interprets metaphor literally

– "the mind has holes"
– "the mind can be subjected to pressure and capable of changing size or shape"

OT – misinterprets the metaphor, but not due to concreteness

– "the mind is interesting"
– "nothing sticks when learning or trying to remember"

### 2. Faithful love is a tree standing through the stormiest hour

*AC*– mentions *withstands/overcomes/work through/lasts through/make it through/conquers/remains/stand against/endures* difficult situations

– "faithful love is love that endures everything and doesn't leave you or is very strong when difficulties come"

– “faithful love remains through good and bad”
– “faithful love is one that can withstand anything that comes its way”

*AP* – answer does not fully explain the metaphor, does not use above key words
– “faithful love is a strong kind of love”
– “still in love even through hard times”
– “it will still be there when the storm is over (a fight)”

*CT*– interprets metaphor literally
– “Love is like a tree which provides shelter”
– “it is at a standstill”
– “it has roots deep in the ground”

*OT* – misinterprets the metaphor, but not due to concreteness
– “love can be tough, just as a storm can be on a tree”
– “faithful love is very difficult to achieve”

**3. A butterfly is a winged rainbow**

*AC* –mentions *colourful*
– “filled with colours”
– “a butterfly is colourful”
– “a butterfly is as beautiful and colourful as a rainbow, but it also flies”

*AP* – mentions only a secondary property – *beautiful*; *rare*
– “both beautiful”
– “butterflies are a beautiful part of nature”

*CT* – literally true statement, incorrect interpretation.
– “both are in the sky”
– “both hard to catch (or impossible)”

*OT* – irrelevant explanations
– “a rainbow has the ability to come from something smaller as a butterfly appears from a cocoon from a caterpillar”
– “life is about growing and trying new things”
– “creations”

**4. A rabbit's fur in winter is a soldier's army green uniform in a jungle**

*AC* – mentions *camouflage*; *blending* into the environment; *hide* from predators
–“needed to survive, used as camouflage”
– “a rabbit’s fur helps it blend into the environment”
– “the rabbit’s fur camouflages it to match the colour of the snow to hide it from predators”

*AP* – mentions protection (but not from weather)
– "both protect and serve their purpose in times of need"
– "protection from danger"
–"the colour of a rabbit's fur can be used to protect it from predators"

*CT* – mentions a similarity, without mention of purpose; mentions a concrete purpose; describes a concrete feature of only one of the items.
– "keeps you warm"
– "a rabbit's fur in winter is green"
– "a rabbit's fur in the winter is its protection from the cold"

*OT* – irrelevant
– "it's meant for conventional use"
– "people should suffer for one another"
– "a rabbit's fur is as natural to him as a uniform is to a soldier."

**6. The stars are signposts**

*AC* – mentions *guide, point/lead/show the way, provide direction*; you can *navigate* using them
– "the stars are useful in helping guide someone along the way or through a path"
– "the stars can be used for navigation"
– "we can navigate ourselves by the stars"

*AP* – shows abstraction but unclear or does not use above keywords, uses above keywords incorrectly
– "stars are like a map to the sky"
– "the stars are arranged in a way that can help us find where we are."
– "stars are directions"

*CT* – mentions a literally true but irrelevant fact, mentions astrology/signs/omens
– "looks like stop signs and other signs"
– "they guide through darkness"
–"stars are signs that the universe is huge"

*OT* – irrelevant statement
– "a guide is close by"
– "the gateway to great things like the universe or discovering self"

**7. A tree is an umbrella**

*AC* – mentions *shields, guards, covers, protects from* the rain/sun*; provides shade, shelter, protection*
– "a tree provides shelter from the rain"

– “a tree will protect someone/thing from rain or sun”
– “a tree covers you from the rain”

*AP* – mentions a secondary function: provides *shadow, blocks things, canopy, keep you out*; uses keyword unclearly
– “a tree provides shadow to the people in the sunlight”
– “tree is like an umbrella, you go under a tree when it’s raining or when it’s really sunny”
– “it can keep the rain away”

*CT* – concentrates on the shape/look
– “many things have the same shape”
– “a tree looks like an umbrella”
– “a tree is long like an umbrella and has an opening at the top of it. It is also circular looking at the top”

*OT* – irrelevant non-concrete statement
– “all branches working together in a cohesive process”

**8. Snow is winter's robes**

*AC* – mention *covers/blankets/coats/dresses*
– “snow covers the ground like a robe covers a person”
– “snow coats the ground in the winter like a robe coats a person”
– “snow blankets the earth in winter as a person putting a robe on”

*AP* – mentions *protection*; an abstract interpretation that doesn’t use above keywords (or uses them as a noun).
– “plants need protection from the harsh cold of winter and snow provides a robe of warmth to the plants/ecosystem like a person in a cold home”
– “snow is the outer later. If winter was a person, that person would be draped with snow”
– “winter wears snow. It’s found all over the rolling hills and streets, flowing like a robe”

*CT* – a literally true but incorrect interpretation, a literal reiteration of the metaphor
– “snow is accompanied by winter”
– “indication of winter season”
– “snow keeps winter warm”

*OT* – mentions irrelevant function
– “they are both soft”
– “snow is the shield against winter’s cold temperatures”
– “white snow is wet”

**9. Love is a flower**

*AC* – mentions *blooms*/*grows*/*blossoms*

– “like a flower, love takes time to grow and bloom between two people”
– “love starts small and grows”
– “love needs nurturance and care for it to grow”

*AP* – mentions a non-functional property, does not include above keywords.

– “love is beautiful”
– “love the emotion is beautiful as a glower created in nature”
– “love is delicate and beautiful like a flower, and love needs to be taken care of by putting in time, like a flower needs”

*CT* – a literally true statement that inaccurately explains the metaphor; mentions a property of flowers not applicable to love (fragrant)

– “you give flowers to someone you love”
– “it is nice and smells good”
– “it is beautiful, loses petals.”

*OT* – unclear meaning

– “picked to find the right one”
– “if you take care and pay attention if not it dies”

**10. Genes are blueprints**

*AC*– mentions that they *dictate/determine/lay out/map out* how something will turn out

–“blueprints are required in building any structure; they tell exactly how the structure will look like before it’s done. Genes also serve as the substance that determines how a living thing will look or turn out.”
– “genes determine an individual’s make up physically, mentally, etc.”
– “they determine what the person will be like”

*AP*– mentions that they *make up;* they are maps; does not use above keywords

– “genes make up the body”
– “they identify traits of the person”
– “they tell us about where we come from”

*CT* – a literal interpretation of blueprints

–“genes are like the blueprints for a building, then you can design and decorate.”
– “it shows how to build something”
– “genes are designed by an architect”

*OT*– an inaccurate statement; a descriptor that only applies to genes or blueprints; hereditary

– “genes don’t predict everything”
– “genes are stronger”
– “genes can tell you what’s wrong.. problems you have”

**11. The stars are fireflies**

*AC* – mentions that they *light up* /*blink/flicker/twinkle/sparkle/give off light* (*verb) at night
– “they twinkle in the night sky”
– “stars twinkle and shine in the dark”
– “both sparkle in the dark”

*AP* – mentions they are *bright,* uses *light* (*noun), mentions a function of stars that is less specific than above keywords, mentions a more permanent state (e.g. *shine, glow)*
– “the stars are bright in the night like fireflies”
– “the stars shine in the dark”
– “in the dark, fireflies are nothing but little specks of light... just like stars”

*CT* – a literally true statement that does not specifically address the similarity in the metaphor, focus on size
– “when you put a fire they look like stars. You see them everywhere”
– “stars look tiny”

*OT* – irrelevant
– “grasp attention”
– “happiness is attainable”

**12. A pimple is the skin's volcano**

*AC* – mentions *erupts*/*explodes/bursts/ruptures/blasts/emits*
– “a pimple is a skin’s volcano because it is a mound that contains a substance that will burst out just like a volcano contains lava and it is also a mound on the earth”
– “a pimple is an eruption waiting to happen”
– “a pimple is ready to erupt puss like a volcano and lava”

*AP* – mentions that pimples are unwanted/disruptive/problematic, *comes out,* correct but without above keywords
– “a pimple happens when something bad needs to go out”
– “a pimple is a disaster to the skin”
– “a pimple emits substance from the skin as volcano emits magma from the earth core”

*CT* – shows evidence of concrete thinking (focus on shape/colour without containing substance/potential for eruption), use explosion/eruption incorrectly, a literally true but unrelated property of pimples

– “a pimple looks like a volcano”
– “a pimple can cause people to explode”
– “can stand out on the skin like a volcano does in a geographic region”

*OT* – unrelated
– “no matter how small something is, it is still important”
-- “pimples are normal”
– “a sign of something wrong in the skin”

**13. Hard work is a ladder**

*AC* – mentions that hard work *improves/lifts up/moves up;* can get you to *higher levels/places/to the top/*
– “the harder you work, the higher you go”
– “with hard work you improve upward”
– “hard work will eventually lead to the top”

*AP* – abstract statement that does not fully explain the metaphor or is overly specific; does not use keywords above but describes getting somewhere better, *success*
– “success is given to those who work hard”
– “the harder you work, the higher you get on the payscale”
– “hard work is a way to succeed”

*CT* – interprets the metaphor literally; literally true statement, but inaccurate interpretation
– “hard work takes climbing many rungs (or overcoming many steps in life)”
– “as a ladder, you start very easily and as you climb you get tired and it’s harder”
– “work gets harder and harder each step one takes in their career”

*OT* – irrelevant explanations
– “the more you work, the more you want to work”
– “you need to keep persevering in life”
– “hard work isn’t easy. It’s a process and needs perseverance.”

**14. Education is a lantern**

*AC*– mentions that education *sheds light/brightens/illuminates/enlightens/shines/lights up* the way/path/future/life/mind
– “education can light up your life”
– “education sheds light to your path, guides you and opens up many options for you”
– “education can illuminate one’s life”

*AP* – abstract statement that does not fully explain the metaphor; does not use keywords above; *guides*

– “being educated is to not be in the dark about certain things”
– “when you learn, things become clear”
– “education guides us towards a better life”

*CT* **–** interprets the metaphor literally; literally true statement, but inaccurate interpretation
– “won’t be scared of being alone”
– “education is light that enables you see clearly in the dark”
– “you have to light up the lantern, you have to work hard in school to light up the lantern”

*OT* **–** irrelevant explanations
– “can be used or not, it’s up to you”
– “only those who wield the lantern will be shown the way ahead”
– “education continues forever and you are always learning”

**15. An autumn’s storm is the funeral song of a dying year**

*AC* – mentions *signals/signifies/indicates/marks/represents/reflects/symbolizes* the *end* of the year/summer is *over*; *shows* that the year is coming to an *end/over*
– “autumn signifies the end of a year, so the noises made in autumn can represent its death”
–“an autumn’s storm is the event that marks the near end of the year”
– “autumn marks the end (funeral) of the summer; the year is getting closer to being over (dying) just like a funeral marks the ends of life.”

*AP* – mentions end of the year without above keyword; mentions that it signals something but not the end of the year
– “autumn is the end of the year”
– “autumn is the last season before winter... winter is the dead season”
– “the year is almost over”

*CT*– a literally true fact that is related to the metaphor, but incorrect
– “a funeral consists of many tears”
– “the end of fall heading into winter can be very depressing”
– “an autumn’s storm removes all leaves from the trees”

*OT* – a unrelated response, incorrect interpretation
– “killing something so beautiful”
– “this is when the world starts anew”
– “the season of acceptance and letting go”

**16. A judge is a balance**

*AC* – mentions that a judge */considers/weighs/measures/mediates/determines/sees/evaluates* all/both/two views/ sides *(*of the story/argument*)*/the evidence before coming to a decision;

– "a balance measures the weight of two objects to see which side weighs more or falls even between, a judge must consider both sides of a story to see which side is weaker and which has more weight"

– "a judge must weigh two opposing views in court and decide which one is correct and which is not (to decide who is guilty)

– "a judge's role is to weigh what information is given to him/her and to provide an objective ruling"

*AP* – abstract statement that does not fully explain the metaphor; does not use keywords above; a judge *decides*; mentions a primary shared property: *unbiased/neutral/objective/fair/not predisposed to one side*

– "a judge is fair and unbiased or neutral"

– "a balance and a judge are not (supposed to be) predisposed to one side or the other"

– "a judge decides who gives the best argument"

*CT* – interprets the metaphor literally

– "a judge creates balance"

– "the judge tries to balance good and bad somewhere in the middle"

– "a judge is a balance between what is fair and what is just"

*OT* – irrelevant explanations

– "a judge sustains"

– "a judge must keep things equal"

– "knows good and evil"

**17. Alcohol is a crutch**

*AC* – mentions that alcohol can be something you *lean/latch/depend/rely on.*

– "alcohol doesn't fix problems, but it's something to lean on"

– "some people use alcohol to deal with their problems and rely on it to function"

– "alcohol is like a crutch in the sense that some will lean on it and depend on it to help support them when times become difficult"

*AP* – abstract statement that does not fully explain the metaphor; does not use keywords above. Mentions another valid reason people use alcohol to cope

– "this refers to how some use alcohol to overcome hardship in life"

– "this is saying that alcohol is used by some for help; it can give them help in times of need"

– "people use alcohol to handle difficult or stressful situations, to perform or cope."

*CT* – interprets the metaphor literally; literally true statement, but inaccurate interpretation

- – “alcohol makes you fall”
- – “alcohol make you dizzy and unstable. Can handicap temporarily”
- – “comparing alcohol to a disability”

*OT* – irrelevant explanations, harmful effects of alcohol

- – “alcohol can hurt you a lot if you allow it to”
- – “alcohol can cause hurt in people and damage lives. Alcohol can bring people to their worst”
- – “bad”

## Appendix B

## Demographics Questionnaire

1. What is your primary language (language you are most proficient in/use most often) for:
    a. Reading/Writing: _________________
    b. Speaking: _____________

2. How many years of education have you accumulated (e.g., high school diploma = 12 years)? ____

3. What is your age? ___

4. Have you been diagnosed with a psychiatric illness (e.g., Schizophrenia, Bipolar Disorder)? ____

5. Have you been diagnosed with a neurological illness (e.g., Multiple Sclerosis, Stroke)? ____

6. Have you experienced a brain injury? ____

7. What is your relationship to your co-participant? _____

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