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Testing a Structural Equation Model of Language-based Cognitive Fitness

Elizabeth Ann Moxley-Paquette
Walden University

Walden University

College of Social and Behavioral Sciences

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Elizabeth Moxley-Paquette

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Chief Academic Officer

Eric Riedel, Ph.D.

Walden University

2013

Abstract

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Elizabeth Moxley-Paquette

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MBA, University of Toronto, 1991

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Abstract

The normative development of language is often taken for granted, yet problems with language development can result in stress for the individual and family. A challenge with these language development problems lies within the contemporary education system, which assumes that children have appropriate skills when they begin school. The purpose of the study was to test a theoretical model of language readiness known as language-based cognitive fitness, which includes measures associated with structural concepts of language involving receptive language, expressive language, spontaneous narrative speech, and writing fluency. The sample included children from a private school who received an extensive battery of tests at admission and annually thereafter. Scores from a variety of cognitive measures were used in a structural equation modeling framework to test the model. Results demonstrated language-based cognitive fitness to be an interplay of verbal reasoning abilities, visual synthesis, and active analysis broadly representing receptive language, expressive language, spontaneous narrative expression, and writing fluency. Verbal reasoning, visual synthesis, and active analysis explained 91% of the variance in achievement. Implications for positive social change include an improved understanding for those who work with children's language development, specifically of the language structures responsible for language deficits and how these relate to overall cognitive fitness; interventions can be provided to help children more quickly make up language deficits.

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Dedication

I dedicate this study to those who have given me the gift of insight, the courage to innovate, and the fortitude to make it happen: To Edith Marilyn (Wasdell) Moxley who inspired insight through her acts of humanitarianism and wisdom; mom emmulated compassion. To Ernest Vincent Moxley who inspired conviction to do the right thing regardless of trials and tribulations; dad exuded relentless tenacity. To Vincent Moxley-Paquette who awakened a mother's greatest fears, deepened her resilience, and inspired the creation of a school with neuroscience as its fulcrum. To William Moxley-Paquette who reframed the challenge, provided deeper insight into auditory processing, and raised the bar for innovation in education. To each student in this school who has provided the gift of insight, new benchmarks for innovation, and the greatest gifts to staff and parents – personal achievement in abilities and academics!

Together we dedicate this project to the wellbeing of all young people in the hopes that it will breathe insight into psychologists, educators, and those in a position to make adjustments to the education system so that every child has the opportunity to build their human potential.

Acknowledgments

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All parents and students who have attended our school provided support for this project through their attendance, participation in the testing processes, feedback, yearend reviews, and case study diaries. These parents and students are who this study is all about.

I would also like to acknowledge Michael Charron from Pearson Corp. who assisted in the test selection process, adding valuable perspective. I thank Pearson for their corporate generosity making it easier to fund the purchase of needed test protocols and for the interest shown in the results of this study.

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Chapter 1: Introduction

Language is fundamental to education because it is the major form of "knowledge representation and is the principal medium for instruction" (Cowan et al., 2005, p. 732). Diagnosed language disorders include dyslexia, which has a prevalence range of 5% to 7% of school age children (Schulte-Körne et al., 2010) and has been reported as high as 10% (Kujala & Näätänen, 2001). Other language-related issues include expressive language disorder, which occurs in 3-7% of children (APA, 2000); central auditory processing disorder (CAPD), which occurs in 5-10% of school-age children; specific phonological disorders, which affect 2% of school age children (APA, 2000); mixed expressive-receptive language disorder, which affects 3% of school age children (APA, 2000); and variations of verbal/graphomotor language expression disorders, which affect 6% of school aged children (APA, 2000). Children with delays in language processing and acquisition are at risk for learning difficulties broadly across academic subjects including reading and mathematics (Cowan et al., 2005). A disorder of language has profoundly negative implications for psychosocial development of affected children and youth, including early school dropout or psychiatric disorders as a consequence of chronic school failure (Schulte-Körne et al., 2010; Schulte-Körne & Bruder 2011). Researchers have demonstrated that language disabilities persist into adulthood for 40-50% of those affected (Schulte-Körne et al., 2010).

The links between language challenge, chronic school failure, and mental health issues have been broadly documented (Cowan et al., 2005; Hannaford, 1995; Nicolson & Fawcett, 2011; Schulte-Körne et al., 2010; Semrud-Clikeman, 2010). For example Cowan et al. (2005) demonstrated that children with specific language impairment (SLI) are at risk for difficulties with numbers and that phonological processing is implicated in difficulties in both reading and math. Semrud-Clikeman (2010) highlighted the comorbidity of attention deficit hyperactivity disorder (ADHD) in 20% to 50% of children with reading difficulties; this complicates the prognosis for language challenged children in school.

Language challenges have been showed to be related to school failure; nearly a third of students with language challenges did not complete high school in 2003-04 in Ontario (Ontario Ministry of Education [OME], 2005). The costs of students' dropping out of high school include loss of lifetime income earning capacity of more than $100,000 compared to those who complete high school; an average public cost of providing social assistance estimated at over $4,000 per year per student who drops out; being overly represented in the prison population; and fewer years of a reasonable quality of life (OME, 2005). There is a strong association between education and health across a range of illnesses, including cancer and diabetes (OME, 2005). Combining morbidity and mortality costs, there is an estimated cost to a student who drops out of more than $8,000 per year (OME, 2005). Further, chronic experience of school failure can lead to mental health problems, with anxiety and depression significantly and negatively altering effectiveness in the workplace as adults (Currie & Stabile, 2009).

In this study, I introduce the term *language-based cognitive fitness*. Cognition is defined broadly in the literature to include skills in nonverbal reasoning, language comprehension, short term and working memory, transcoding and number combinations/calculations, and motor skills (Cowan et al., 2005), as well as skills including solving novel problems, modifying behavior in light of new information, generating strategies, and sequencing complex actions (Elliott, 2003; Salthouse, 2005). Performance on cognitive tasks depends on coordinated distributed brain activity and how well basic "cognitive mechanisms can be recruited in goal oriented behavior" (Turken et al., 2008, p. 1034).

Cognitive performance depends on cognitive fitness. Similar to physical fitness, cognitive fitness is expressed in the literature as the state of one's ability to carry out cognitive tasks with vigor and alertness, to learn, and to adapt efficiently to all circumstances (Gläscher, et al. 2009, 2010; Jung & Haier, 2007; Oberauer et al., 2003; Salthouse, 2005; Shelton, et al. 2010). The importance of cognitive fitness to the *development of language* has been broadly supported by foundational and theoretical researchers including Goldstein (1936, 1946), Goldstein and Scheere (1941), Hannaford (1995), Head (1920, 1923), Luria (1973), and Vygotsky (1962), as well as more contemporary neurobiological researchers (Damasio, 1989; Kemp & Tenenbaum, 2009;

Semrud-Clikeman, 2010; Tranel, Rudrauf, Vianna, & Damasio, 2008; Wasserman & Young, 2010).

Language-based cognitive challenges can inhibit learning, particularly in mainstream classroom learning environments (Cowan et al., 2005). Given the implications of language challenges for mental, physical, and psychological health, efforts to better elucidate the underlying constructs representing both process and structure of language and their interactions are important.

Overview of Chapter

Chapter 1 includes information which provides the background for understanding language-based cognitive fitness, the research problem addressed in this study, and the research questions and hypotheses. The theoretical and conceptual frameworks supporting this study are described. The choices for study design and methodology are defended and the nature of study is delineated. Key definitions are described in addition to assumptions, study scope and delimitations, and study limitations. This chapter ends with reflections on the study's significance and social implications of the research.

Problem Statement

Development of language depends on interconnections with other neurocognitive systems such those represented in the Boca's, Wernicke's, parietal, and cerebellum regions (Catani, 2009). However, much of the current understanding of the anatomy of language is based upon researchers examining parts, or subsystems, of the language system. In particular, Boca's (1861), Wernicke's (1874), and Geshchwind (1965) studied the components and complexities of language; their theorizing has resulted in increased knowledge of the subsystems involved in language involving the Boca's, Wernicke's, and parietal regions of the brain. But language subsystems reach beyond these brain structures (Gläscher et al., 2009, Gläscher et al., 2010; Kemp and Tenenbaum, 2009; Moore, 2007; Price, 2012). Moore (2007) posited that research localized to these subsystems is due, at least in part, to reductionist approaches to language-based research. The result is fragmented understanding and knowledge of components of language specific to disciplines that include acoustics, phonetics, phonology, cognitive neuroscience, neural imaging, machine learning, and natural language processing. Such reductionist approaches are indicative of a gap in research. A holistic model that represents the structure of language is missing.

Purpose of the Study

The purposes of this quantitative, correlation study are to (a) test a model of language-based cognitive fitness that contains four key constructs hypothesized to impact language-based cognitive fitness, and (b) to demonstrate whether certain groups of test scores best discriminate cognitive ability.

Research Questions and Hypotheses

Two primary research questions were addressed in the study. The first question involves testing whether there is evidence for a theoretical model of language-based cognitive fitness using cognitive test data from a private school. The second involves understanding whether there are combinations of test scores that best discriminate among differing levels of cognitive ability in children. From these two questions, two research hypotheses were examined:

H_1: There is statistical evidence, through various measures of structural fit associated with structural equation modeling, for a four-component model of language-based cognitive fitness that includes information from 17 cognitive test scores that are available for analysis

H_2: There are linear combinations of the independent variables (represented by the cognitive test results from children) that best discriminate cognitive ability using discriminant analysis.

Theoretical and Conceptual Framework for the Study

The model for language-based cognitive fitness comprises four components (receptive language, expressive language, spontaneous narrative language, and writing fluency) that support the overall structure. Receptive language involves auditory perception (Bishop, 2007; Garrido, et al., 2009c; Kujala, et al., 2007; Näätänen, 2000;

Näätänen et al., 2007; Pulvermüller, et al., 2008; Sussman, 2007; van Zuijen et al., 2006), word meaning (Otis & Lennon, 2002; Munroe & Sherman, 1966; Price, 2012; Wechsler, 2004; Woodcock, 1999), and understanding of whole word expressions (Tranel, et al., 2008; Korvost, Roelofs, & Levelt, 2007; Meeuwissen, Roelofs, & Levelt, 2004, 2005). The theories of Luria (1973), Goldstein (1936, 1946), and Head (1920, 1923) support the receptive language aspect of structure. Expressive language involves the ability to repeat what is heard (Kuhl, 2004; Zhang et al., 2005, 2009), name objects (Acres, Taylor, Moss, Stamatakis, & Tyler, 2009; Allen, Bruss, & Damasio, 2004; Damasio et al., 2002), and retrieve words (Price, 2012; Tranel, Adolphs, Damasio, and Damasio, 2001). Spontaneous narrative language involves speech fluency (Buchsbaum et al., 2011) and writing (graphomotor) fluency involves written expression (De Smet et al., 2011; Luria, 1973; Mariën, Verhoeven, Brouns, De Witte, Dobbeleir, and De Deyn, 2007; Nicolson & Fawcett, 2011).

This language-based cognitive fitness model posits receptive language as the foundation required to support expressive language abilities. Receptive and expressive language abilities support spontaneous narrative language (speech fluency); these three abilities support the development of writing (graphomotor) fluency within a hierarchical structure (Luria, 1973). Together, the four components represent a model for language-based cognitive fitness.

The critical points of interest for language-based cognitive fitness include process characteristics such as the ability to (a) hear and decode sounds, (b) understand what the sounds mean, (c) put the sounds together creating word sound patterns (words), (d) develop word sound patterns into whole expressions, and (e) express that language understanding in written form. The taxonomical or structural model represents the ideal characteristics for language-based cognitive fitness. A child demonstrating language-based cognitive fitness provides a strong foundation for learning within a conventional educational environment. Modeling these attributes is akin to establishing a score card for desired standards for characteristics of language-based cognitive fitness. A more detailed analysis of and theoretical justification for the model is presented in Chapter 2.

Nature of the Study

This correlation study included a validation study, exploratory factor analysis, confirmatory factor analysis (CFA) within structural equation modeling (SEM), and discriminant factor analysis (DFA). The validation study was required to establish the initial validity of 16 of the test measures included in the model that have received scant support in the published literature. Exploratory factor analysis was used to provide initial evidence for contruct validity of the four key concepts of the taxonomical structure. The goal of the analysis was to examine the relationships among latent factors representing the four key aspects of language structure (receptive language, expressive language, spontaneous narrative expression, and writing (graphomotor) fluency. Finally, discriminant analysis was used to determine whether there were linear combinations of test scores that best discriminate children of varying cognitive abilities.

The target population consisted of students between the ages six and 19 attending private schools. Participants for this study were recruited from a K-12 private school that has collected neurocognitive and achievement measurements for each student from 2005 to 2012. The test battery has been administered by the school's educators to students as part of normal administrative processes designed to actively monitor academic progress and to provide students with direct interventions based on the results of those tests. Test scores demonstrate that academic ability for grade level varies.

Definitions

In this study there are four components representing independent variables, three dependent variables, and one covariate.

Receptive Language: Receptive language is defined as processes in the brain involved with receiving and interpreting incoming information beginning with sounds, words, and broader relational understanding using words (Catani, 2009; Luria, 1973; Näätänen, 2007; Näätänen et al., 2011; Price, 2012; Schröger, 2007). An individual receives, decodes, and understands information, begining with auditory perception and ending with word/phrase/passage meaning (stages one, two, and three of language development). This latent factor was operationalized by 12 tests that included Wepman Auditory Discrimination Test, the GDRAAT short term Auditory, Visual, and Form memory, the GDRAAT Vocabulary and Paragraph Comprehension. These tests and others are more fully described in Chapter3.

Expressive Language: Expressive language is defined as an expression of processes which establish readiness for verbal articulation (Luria, 1973). The individual needs to be able to repeat what is heard (Kuhl, 2004; Luria, 1973; Zhang et al., 2005, 2009), name objects (Luria, 1973), and retrieve words representing objects and concepts (Price, 2012; Tranel, Adolphs, Damasio & Damasio, 2001). This latent variable was operationalized by the Gibson Auditory Analysis (blending and segmenting) and Thurston's Closure Speed tests.

Spontaneous Narrative Language: Spontaneous narrative language is defined as an expression of processes that support organized and logical speech (Luria, 1973). The individual needs to be able to convert inner thoughts, dependent upon receptive language and expressive language, into connected verbal speech (Buchsbaum et al., 2011; Price, 2012). Reading comprehension and social comprehension measures specifically measuring the verbalization of inner speech were used to operationalize the latent variable and are further described in Chapter 3.

Writing Fluency: Writing fluency is defined as the ability to write quickly and with ease; this is also called graphomotor automaticity (Luria, 1973). The individual needs to be able to sequence motor hand strokes (Barkley, 1997) leveraging connections between the pre-motor and cerebellum brain regions **(**De Smet et al., 2011; Mariën et al., 2007; Nicolson & Fawcett, 2011). This latent variable was operationalized by the GDRAAT Coding subtest specifically measuring speed of copying that is described in Chapter 3.

Achievement: Achievement is a combined measure of reading and mathematical performance. Achievement was operationalized by measuring an individual's performance in reading and mathematics. Achievement in reading was measured by the individual's total score in the Woodcock Reading Mastery Test (WRMT-R); measuring pre-reading, basic reading, and comprehension skills. Achievement in mathematics was measured by the individual's total score in the Key Math Test (KMT); measuring 13 strands of mathematics skills across basic concepts, operations, and applications.

Cognitive Ability: Cognitive ability was operationalized for this study in terms of three categories (challenged, average, and gifted). Consistent with Connelly (2000), Klein & Mannuzza (2000), Lancee (2003), and Woodcock (1998), a challenged student was defined as a student presenting with an overall standard score of 85 or less (minus one standard deviation from 100) based on both the Woodcock Reading Mastery Test and the Key Math Test protocols. An average student was defined as a student presenting with overall standard scores between 86 and 115, or within a one standard deviation range from 100 either positive or negative, based on both the Woodcock Reading Mastery Test and the Key Math Test protocols. A gifted student was defined to present with overall standard scores in excess of 115 or more than one standard deviation from 100, based on both the Woodcock Reading Mastery Test and Key Math Test protocols.

Assumptions

There are several assumptions regarding the database, specific test instruments, process sequencing, and study design that are associated with the study.

First, there was an assumption that the database is a good source of data for this study. The database has been populated since 2005 with the beginning of the use of tests for the purpose of understanding the cognitive profile of each student and how student profiles develop over time. The database included test data for the duration of students' attendance at the school. Tests were administered by teachers trained in using standard protocols as directed by each test when the student first joins and then at the end of each school year thereafter. Thus, it is assumed that tests were administered in a reliable manner and that the test scores are accurate reflections of student ability and skill.

Second, the assumption was that the test instruments used are measuring the intended theoretical constructs of the model. There may be other more closely aligned test measures for the theoretical constructs in the proposed model. The study will provide some evidence (predictive and construct validity) as to whether this assumption holds true. A validation study was conducted to provide support for concurrent validity of some measures used in the four components model.

Third, there was an assumption that the proposed model inherently reflects the actual processes and process sequencing of language development that ultimately produces the ideal language-based cognitive fitness. While this study does acknowledge the role of process development (Luria, 1973; Hannaford, 1998), its main focus is on the taxonomy or structure of the final and ideal model of language-based cognitive fitness. As a result, there is a fourth assumption that the study can establish the extent to which measures are correlated; but, causation cannot be determined. With correlation there is always a risk that the order in time is not correct. Further work using the available longitudinal data would be needed to validate the developmental process of language.

Scope and Delimitations

This study focused on building a model of language by establishing taxonomic constructs critical to understanding the logic and the structure of language (Kemp & Tenenbaum, 2009). A model was built that reflects structural components involved in processes supporting stages of language development. A model was established and tested for fit with data. Steps were taken to determine if there were specific profiles within the sample. This study did not directly focus on the process of language acquisition except in its support role of taxonomic constructs.

Limitations

The potential threats to internal validity for this study were associated with instrumentation (Cresswell, 2009; Stanley & Campbell, 1969). Applied to this study, there were two areas of concern specific to instrumentation: changes in scorers and the measures available. First, while it is possible that changes in scorers used may produce changes in obtained measurements, the examiners were well instructed on test administration and followed protocols provided. Second, in this study, the secondary data were composed of test scores resulting from valid and reliable measures as well as unvalidated measures. For those measures that had received little attention in the empirical literature, steps were taken to test construct validity through a small validation study (described in more detail in Chapter 3).

Potential threats to external validity included threats to representativeness, or generalizability (Cresswell, 2009; Stanley & Campbell, 1969). Bias in the study results can occur from the selection of participants. The school population was a naturally formed group and was considered a form of selection bias which could potentially predispose certain outcomes specific to individuals more likely to be affiliated with families who want private education (Cresswell, 2009; Stanley & Campbell, 1969).

It is also recognized that even with an extensive literature review, the specification of a hypothesized model is complicated by the vagueness of theoretical literature, the potentially infinite number of possible causal determinants, and the general complexity inherent in social science (Mertler & Vannatta, 2010). Rather than being discouraged by the potential extensive list of sources for invalidity of a proposed model, Campbell and Stanley (1969) proposed instead the researcher chose to be vigilant for and cognizant of design flaws, the analysis guided by increased awareness in study design, and increased accuracy in interpretation.

Significance and Social Implications

This research study will provide a theoretical frame of reference for understanding the key constructs, components, and moderating variables involved in language-based cognitive fitness. The practical application of this study is an improved understanding of why some children have difficulty acquiring their native language and to give specific insight as to why there may be difficulty. Such insight can fuel future work in the development of interventions that enable progression of a child's development towards increased language competence.

The model that results from this research may also contribute to the modeling of the process of language development. Bayesian analysis in particular is well suited to cross-time analysis associated with understanding processes, but a specific a priori model from which to model a time path for predictive coding, adjustment, and modification is required (Baldeweg, 2007; Friston, 2005; Garrido et al., 2009c; Kemp & Tenenbaum, 2009). This study could provide a specific a priori model for such research.

Summary

Chapter one provided background explaining the gap in knowledge surrounding language-based cognitive fitness, its supporting problem statement, study purpose, and research questions and hypotheses. The theoretical and conceptual frameworks were introduced along with study design and methodology. Key definitions were described in addition to assumptions, scope delimitations, and study limitations. This chapter ended with reflections on the social implications derived from this study. Chapter 2 contains the literature review, including the theoretical sources from which the conceptual framework emerged. Chapter 3 then describes the methodology of the study. Chapter 4 reports study results. Chapter 5 interprets the findings and explores implications for social change.

Chapter 2: Literature Review

Language is a highly complex facility and a uniquely human characteristic that allows people to encode, synthesize, and communicate thoughts and experiences through arbitrary symbols (words) to which they give meaning (Catani, 2009). In some children the ability to encode, process, and communicate via language does not develop in the way that it should (Hannaford, 1995), leaving these individuals vulnerable in the educational system that assumes a basic entry level of language-based cognitive fitness: an ability to receive and express in one's native language (Hannaford, 1995; Kuhl, 2010). This is an urgent matter for the contemporary education system, a system which assumes that children entering school have the capacity to learn using language.

Organization of the Chapter

This chapter contains a detailed literature review of process and structures important for language-based cognitive fitness. The review includes research from the neuroscience literature in the areas of neurophysiology, cognition, cognitive measurement, and brain imaging. To support a clear and concise argument, this chapter is broken into three separate but integrated parts. Part 1 introduces the work of Luria (1973) and foundational theoretical literature defining the process of language acquisition. Part 1 elucidates the five stages of temporal developmental processes leading to mastery of language. The five stages are acoustic hearing to decode as well as development of auditory and visual perception (Stage 1); acoustic hearing to understand

and development of radical symbolization (Stage 2); understanding the meaning of whole expressions and the development of spatial organization and perception (Stage 3); spontaneous narrative speech (Stage 4); and graphomotor (writing) fluency (Stage 5).

In Part 2, the aforementioned developmental processes are incorporated into a taxonomical structure with four components. This taxonomical structure is the end goal, or ideal outcome, of emerging developmental processes; it is what the structure of language should be when all developmental processes have happened as idealized. An analogy is found in horse management. The International Friesian Horse Society has developed a linear score sheet depicting the perfect Friesian horse. On this scale, there are 45 characteristics (for example, head, neck size, neck angle, and so on) which are defined in ideal terms. Judges rate horses relative to the ideal. However, the developmental trajectory of the horse is critical in achieving or approximating the ideal. In language-based cognitive fitness, one is concerned with understanding the developmental trajectory (processes) as well as the ideal profile (structure) that is based on the developmental trajectory. These processes and structures and the ways both are interrelated are described in the following sections.

The critical points of interest for language-based cognitive fitness include process characteristics such as the ability to hear sounds, decode those sounds, understand what the sounds mean, put the sounds together creating word sound patterns, develop word sound patterns into whole expressions, and express that language understanding in written form. The taxonomical or structural model represents the ideal characteristics for language-based cognitive fitness that provides strength for learning within our conventional educational environment and is akin to establishing a score card for desired standards for characteristics of language-based cognitive fitness.

Researchers have established that both process and structure are important for full understanding of the nature of language; having the right structure is not sufficient for building a model (Kemp & Tenanbaum, 2009). The model is the end goal, but the process is also critical for building an understanding of how one arrives at this ideal state (Kemp & Tenanbaum, 2009). Individuals develop at rates dependent on interactions among genetic and environmental influences; therefore, the taxonomy (structure) serves as a benchmark for an ideal profile from which to measure progression within the developmental process.

In Part 3, a conceptual model for language-based cognitive fitness is introduced. The concepts associated with process and taxonomy development are organized into a conceptual framework describing language-based cognitive fitness. This analysis contains theorized relationships among concepts; the testing of this model will be described in more detail in Chapter 3.

The Literature Review Strategy

Numerous primary sources were reviewed. The initial research focused on the seminal work of Luria (1973) and his neurocognitive perspective of language, other experts cited by Luria, and researchers directly influenced by Luria; the former include Goldstein (1936, 1946) and Head (1920, 1923) who described the role of symbolic thinking and abstract attitude in language); Tsvetkova (1969) and Vygotsky (1962) for the importance of inner speech and predicative structure; and Goldstein and Scheere (1941), Head (1923), and Vygotsky (1962) for the role of concrete and abstract thinking in language. Those influenced by Luria whose research was principally about language include Fuster (for speech and memory, including the role of prefrontal function); Baddeley (for phonetic processing called phonological loop; attention; visual processing of space, or visuospatial sketchpad; and episodic (short term) memory as it relates to language); Barkley (for working memory, reconstitution (synthesis) of information, and how people translate mental language to written language); Bronowski (for stages of language synthesis, attention, and working memory in language); and Hannaford (for the educator's perspective on developmental and biological views of language). Current research in neural imaging (Allen, Bruss, & Damasio, 2004) continues to mention the work of Luria within the context of brain physiology; however, the link to language is less apparent in the literature. Research has continued to focus on specific aspects of language verses a more comprehensive model of language.

EBSCO (Academic Search Complete/Premier, including PsycINFO, SocINDEX, PsycARTICLES, and PsycEXTRA), ProQuest Central, and Science Direct sources were the primary databases used for the literature search. This literature search included subject-based searches specific to *auditory processing*, *mismatch negativity (MMN), visual processing, visual mismatch negativity (MMN), reasoning, memory, working memory, motor processing, word naming, motor apraxia, dyslexia, specific language impairment, expressive language, expressive language and repetition, expressive language and naming, expressive language and word retrieval, cognition and language, and structural equation modeling.*

Theoretical Foundation

Part 1: The Process of Language Acquisition

Luria (1973) noted the importance of reviewing language acquisition from both developmental *process* and *taxonomic* (structural) perspectives. Research by Luria (1973), along with the educational perspective of Hannaford (1995), provided a model for understanding the process of language acquisition. The process of language acquisition has five iterative dynamic stages, including the *phasic or acoustic aspects* stage of language (hearing language, or the conversion of isolated useful sounds into discrete units of language called phonemes), *radical symbolization* (the seeing of images and concepts converted into verbal equivalents; this is supported by the learning of meanings [lexical-morphological] of base grammatical units such as the form of language and its use for purpose of expressing ideas), *spatial organization of perception* and movement (through the use of prepositions, word order, verbs, etc. for creating understanding of relationships), and *predicative coding* into connected narrative speech (which is the coding of inner thoughts and images into organized speech first verbally. The final and 5th stage, *graphomotor fluency*, involves the activity of handwriting.

The first stage of the process of acquiring language is the "phasic or acoustic aspect" (Luria, 1973, p. 138). This phasic or acoustic aspect involves auditory (what is referred to as *hearing*) analysis of the flow of speech and the subsequent conversion of this information into phonemes, the smallest units of sounds that are unique and distinguished in meaning for one's native language from other sounds. Phoneme capture is based on the ability to isolate useful sounds supporting discrimination of meaning within a given language (Luria, 1973). In essence, the individual is hearing sounds and distinguishing their meaningful differences. Luria posited that these articulatory cues are required precursors for the ability to later pronounce required phonemes (single sounds, such as the hard sound of *g*), graphemes (sound blends, such as *fr*, the combining of two letters), and articulemes (root words and affixes, which are added to existing root words to form new words, such as the word group *pre* that is added to the beginning of words).

Should there be difficulty in isolating articulatory cues, an individual misses key sounds important for acquiring native language and therefore has difficulty processing the differences between what is heard from hearing required for interpretation of language. This is what Luria (1973) called *acoustic-agnosia aphasia*. Acoustic-agnosia aphasia is the inability to hear sounds through the use of senses (Luria, 1973). An example of acoustic-agnosia aphasia occurs when a child cannot hear *th* but instead hears *f*; the result is that the child will hear the word *the* as *fe*. Luria (1973) provided an example of the loss of ability to discriminate sounds in an adult who has damage to secondary zones in the left temporal brain region. This person cannot distinguish between the phonemes *g* and *k*. If the person hears the word *golos* (which means *voice* in Russian) instead of *kolos* (which mean *ear of corn* in Russian), he or she will not be able to grasp word meaning and words of his or her native tongue will begin to resemble words in a foreign language (p. 139). The symptoms of acoustic-agnosia aphasia include an inability to retain even a short series of sounds, syllables, or words in memory, resulting in the individual confusing sound or word order or the loss of some of the sounds heard from short term memory (Luria, 1973).

Hannaford (1995) posited the need for ability to hear in this way to discriminate rhythm and tone, to form words, and to hear the full tone range including the higher harmonics that occur in normal speech; these were deemed to be critical for language development. Hannaford found that when these capabilities were impaired, language acquisition suffered. Ear infections in the first years of life increase risk for the inability to discriminate sounds because complex tones are missed. The result is greater risk of later insensitivity for hearing specific sound discriminations that can lead to speech understanding difficulties (Hannaford, 1995).

Stage 2 involves lexical semantic organization of speech. Luria (1973, p. 307) described this as “the mastery of the lexical code [patterns of word forms] – morphological code [patterns of morphemes] of the language to enable images or concepts to be converted into their verbal equivalents”. Luria referred to this process as the “radical symbolization” (p. 307) of speech involving object categorization. Object categorization is the creation of patterns of letters into meaningful words and then patterns of words into meaningful categories. First links are created between sounds, their letters, patterns of letters, and associating these letter patterns with images through a process called *visual-auditory learning* (Bronowski, 1977; Hannaford, 1995; Luria, 1973). Visual-auditory learning is the process of attaching letter patterns to visual images that give meaning to words. Word patterns are then organized into relationships, or categories based on a theme or meaning. Categorical meaning can be organized based on morphological (word form) or semantic (word meaning) criteria (Luria, 1973). For example, one could form a category of nouns using the morphological (patterns of word form) code ending words in *cy*: constan*cy*, legitima*cy*, pira*cy* or hesitan*cy*; or ending in -*ness*: strange*ness*, happi*ness*, forgive*ness*, or eager*ness*). Categorical meaning using semantics (word meaning) would group words supporting a theme; one example would be the semantic category *public institutions* that include the words hospital, school, police station, and so forth.

Hannaford (1995) posited that as phonemic awareness is acquired (Stage 1), children develop an understanding of how objects and people relate through naming and categorizing them (usually by ages 15 months to 4 years). Naming and categorizing objects, people, and how objects and people relate marks the beginning of a child's development of a lexical-semantic organization of speech. As a children's ability to categorize and name objects strengthens, broader word-object representations can be understood which results in formation of increasingly complex categories. For example, the use of the word *table* at first has its own unitary *category* but over time this word can become expanded to include different kinds of tables including other square tables, rectangular tables, round tables, and triangular tables. Over time, the category of *tables* expands to include tables to be categorized by their usefulness (for example, counter tops used as tables). Finally, the concept of *table* expands to include abstract concepts such as *tabling an idea*. The ability to *see* categories (relationships between objects and people) provides a semantic base that allows for the continuous building of categorical understanding through language over time (Hannaford, 1995, p.89).

Hannaford (1995) associated this increasing capacity in seeing relationships among categories with the development of the limbic system, a group of brain structures that are activated by motivated behavior searching out relationships. Hannaford (1995) specifically tied this process of increasing capacity to see relationships to the enlargement of Boca's area and the Wernicke's area of the left neocortex after age four. The development of Boca's area for motor coordination for lips and mouth ensures the ability to produce clear speech (Hannaford, 1995; Luria, 1973). The enlargement of Wernicke's area of the left neocortex assists in recall, recognition, and interpretation of words supporting language comprehension. The enlargement also allows for increased capacity for reasoning and for moving from concrete (literal) to abstract (relational) conceptual understanding (Hannaford, 1995; Luria, 1973). Once language comprehension is in place, the child processes thought by speaking to him or herself until about age seven (Luria, 1973; Hannaford, 1995; Vygotsky, 1962). At first this verbalized thought would be characterized as *stream-of-consciousness* ideas openly shared but not necessarily representing organized thinking (Hannaford, 1995). With practice discourse becomes more organized.

This growing categorical understanding, or the *seeing* of relationships learned through socialization, was first introduced by Vygotsky (1929, 1962). Vygotsky posited that children start to practice the behaviors once practiced on them by adults and that the child's logic develops with increasing social interaction that expands as a result of the child's range of experience and vocabulary; such socialization was important for acculturation (cultural teaching) of individuals and increasing their understanding of concepts through language (Vygotsky, 1929, 1962, 1966). Luria (1973) and Vygotsky

(1929) both acknowledged the role of active socialization for developing individual's growing understanding of concepts beyond concrete (literal) understanding to abstract (relational) understanding.

Goldstein (1936, 1946) , Goldstein and Scheere (1941), and Hanfmann, Rickers-Ovsiankina and Goldstein (1944) demonstrated the differences between concrete and abstract thinking by showing that patients with brain injuries (particularly left temporal injuries including the impact of the Wernicke's center) lost the quality of being able to abstract. Patients could perform well if a task could be performed in a concrete (literal) way, but could not perform if abstract thinking was required. For the injured patient *words had lost their symbolic meaning* and the patient understood the word in a way other than what was meant (Goldstein, 1944; Head, 1921, 1923) preventing the extension of thought beyond concrete thinking to abstract understanding of words and phrases necessary for making broader associations, categorizing, and generalizing.

Head (1920, 1923) also believed that in addition to language being important to the act of speaking and writing, language was involved in the simple act of imitating movement. If one person faces the other, any attempt to repeat the actions of the other required interpretation of the visual gesture. The act of interpretation was believed to involve inner speech requiring both concrete understanding of the gesture specific to what body parts are engaged and abstract interpretation skills specific to whether they need to move left because the other person's hand moved to their right. Both the concrete (literal) specific understanding of what an *eye* or *ear* is, and the abstract (relational) understanding of *right* versus *left* needed to be translated into inner speech and incorporated in the act of imitation (Head, 1920; 1923).

Hence, stage two lexical-semantic organization (radical symbolization) of speech involves creating verbal-visual objects through the process of visual-auditory learning and then through the development of categorical meaning. Categorical meaning starts from the attachment of an image to letter patterns creating meaningful words (visual-auditory learning); then, these first simple words start to be clustered into simple categories and grow in complexity over time as language grows from concrete to abstract concepts supporting a growing relational approach in understanding. Social intervention and inculcation guides the understanding of concrete and abstract concepts. The degree to which an individual is able to *see* (understand) abstract relationships is determined by command of language. Loss of the ability to see categorical relationships can limit an individual to concrete (literal) thinking and inability to *see* (understand) symbolic meaning. This need to be able to *see* relationships is required for inner speech even in the act of imitation.

Stage three involves spatial organization. Spatial organization is described as the critical filter for *understanding* phrase and sentence syntax (the words and the way we put words together) represented in language through prepositions, word order, word endings, word prefixes, and logical grammatical structure (Hannaford, 1995; Luria, 1973). Prepositions, word order, word endings, word prefixes, and logical grammatical structure create *spatial organization* of information, *relational understanding*, and therefore *perception*. The way words are put together in a sentence serves to organize relational aspects of the phrase. For example, in the sentence, *The boy that is chasing the clown is mad*, the conjured image is of an angry boy chasing a clown. We see a visual and have extracted a single main idea representing the relationship. This represents spatial organization of a perception. One's perception is determined by the ability to *see and understand* primary relationships among words in phrases, relationships among words in sentences, and relationships among sentences in paragraphs. Spatial organization of perception is critical for comprehension of main ideas that demonstrate language-based reasoning (Bronowski, 1977; Goldstein, 1944, Hannaford, 1995; Head, 1923; Luria, 1973, Vygotsky, 1962).

Stage four involves the organization of these inner thoughts and images into verbalized sentences or expressions. It is described as *spontaneous narrative speech* (Luria, 1973; Vygotsky, 1962). This fourth stage is a step beyond radical symbolization (stage 2) and spatial organization of perception (stage 3) and involves the recoding of thoughts into formal speech. This step is more formally called *predicative coding*. It requires acoustic differentiation, mastery of word meaning and patterns of word formation, relational understanding of words, phrases, paragraphs with both concrete and abstract qualities, *seeing* main idea, now requiring higher order processes of intention to make the act of predicative coding happen (Luria, 1973).

Both the ability to recode thoughts into formal speech and intention to act are necessary to execute spontaneous narrative speech (Luria, 1973; Vygotsky, 1934, 1956). Even if there is intention to speak, there can still be difficulty in executing sentence syntax (structure specific to the words and the way words are put together). This is because despite intention, if the ability to recode thoughts into the elements of the sentence is absent internally, the formulation of a sentence is prevented. Should this be the case, providing external aides to provide the missing structure will help. For example, Luria (1973) used a simple test to understand the source of why a patient could not formulate the simple sentence such as, *I like walking*. Placing cards corresponding to each sentence element in front of the patient helped the patient to form the linear structure of the sentence. Early experimental work by Tsvetkova (1969) demonstrated support for Luria's claim. An electromyographic recording (EMG, a method measuring muscle activation (NIH, n.d.)), from lips and tongue during direct attempts to formulate expressions without supports revealed no special impulses for such patients, but when the Lurian cards (aids) were used to help the person create sentence structure, distinct electromyographic impulses from the lips, tongue, and larynx appeared. This discovery supported not only the value of external supports in helping a patient to articulate an intention (Tsvetkova, 1969), it also provided evidence that both intention and ability to form internal linear schemata of words (predicative [syntactic] coding) are required for verbal articulation.

Hannaford (1995) also posited movement to be a vital part of language. Verbal motor movement of the face is supported by the temporal mandibular joint (TMJ) which houses both sensory and motor neurons prime for activating facial muscles. Predicative (syntactic) coding, which involves preparing the construction of a verbal response, occurs in a partnership between sensory and motor neurons that control the expression of our eyes and the movement of our tongue, mouth, and jaw necessary for enunciation (Hannaford, 1995).

Hence spontaneous narrative speech (verbal articulation) associated with Stage 4 involves the organization of thoughts, images, and their relationships into verbal expressions (Luria, 1973; Vygotsky, 1962). Articulate speaking requires intention to make this cumulative act of predicative coding happen (Luria, 1973). External aids for syntactic structure and motor movement through verbalizing were identified as successful strategies for those patients who struggled with verbal articulation (Luria, 1973; Tsvetkova, 1969).

Stage 5 involves language acquisition in the form of graphomotor (handwriting) fluency. Handwriting fluency is a function of language-based cognition and acquisition. Graphomotor fluency is the ability to write fluently without effort (Luria, 1973). Graphomotor fluency was linked to the frontal lobe via Broca’s area (Hannaford, 1995;

Luria, 1973). Broca's area was viewed as central for development of inner speech enabling a person to process information internally at a much faster rate than verbalization would allow (Hannaford, 1995). Given Broca's area is the hub for inner thinking and motor-automaticity (automatic motor movement), motor movement and thinking were necessarily involved in information processing. Head (1920, p.111) supported the interconnection of language and graphomotor fluency identifying agraphia as not just the loss of the ability to write but often accompanied with the loss of some other language function, particularly evident when the power of naming objects was impaired. Specifically, a patient suffering with difficulty in writing down the time as part of the CLOX Drawing test often also fails to set the hands correctly to verbal or printed command due to difficulty with ability in translating symbols (representing relationships) into written language form.

Summary of Processes of Language Acquisition

Viewing language acquisition from a developmental perspective highlights language acquisition as a progressive and staged hierarchical process (Hannaford, 1995; Luria, 1973). It begins with acquisition of phonemic awareness (stage 1) with its core ability to perceive, segment, blend, and use phonemes and graphemes. This is followed by the development of visual-auditory memory (stage 2) that allows a word to take on pictorial meaning (semantics), word pattern understanding and recognition (lexical & morphological patterns), and the growing ability to categorize and see broader and broader relationships (spatial/abstract/symbolic thinking) for words, which Luria (1973) called radical symbolization. Stage 3 involves *spatial organization* of information, *relational understanding*, and therefore *perception* by the way words are put together. Finally, there comes the ability to articulate word movements (stage 4) via the enlargement of Broca's (motor planning) area for internal then external speech articulation, and later (graphomotor fluency) written expression (stage 5). As a result of progression through these stages language competence also involves a relational (qualitative) shift in process from concrete thought to abstract thought processes (Goldstein, 1936, 1943, 1944; Goldstein & Scheere, 1941; Head, 1920, 1923; Luria, 1973) with greater functional, hierarchical, interconnectedness (Vygotsky, 1962).

More current research supports this model of language development. Studying children with cochlear implants has provided a unique opportunity to study the nature of the dependency of language development on a child's ability to hear and differentiate sounds. Coene, Schauwers, Gillis, Rooryck, and Govaerts (2012) found in their research with cochlear-implanted children that language development is positively related to the age at which children have access to hearing language and therefore acoustic awareness (stage 1) with later access to language associated with slower than normal language learning. Coene et al. (2011) provided evidence that prosodic awareness (sound intonation patterns of just noticeable differences in language) normally established by age 5 can still be developed in cochlear-implanted children up to age 13 once hearing is established. Bevilacqua et al. (2011) found the age of cochlear implant surgery to be a determining factor for the ease of acquisition and development of basic auditory skills. Most and Michaelis (2011) found auditory hearing to be important to learn and perceive abstract emotional concepts. Hearing impaired children performed lower in ability to perceive happiness, sadness, and fear in auditory and auditory-visual conditions establishing that emotional perception and enhanced socialization is linked to the ability to receive auditory information. This research demonstrates the use of cochlear-implants to be important to the timing and quality of language acquisition and that normal language acquisition begins with language-based auditory perception (stage 1 of the 5 stage developmental process).

Active temporal processes represent critical developmental stages in acquiring language and support an individual's growth towards language-based cognitive fitness. Lurian era research also supports the inclusion of these developmental processes within an end goal taxonomic structure of four components including receptive language, expressive language, spontaneous narrative (speech) language, and writing (graphomotor) fluency. Next, each of these four structural components is reviewed and aligned with the developmental processes described above. In addition, the most current research supporting the taxonomic structure is reviewed.

Part 2: Taxonomy of a Cognitively Fit (healthy) Language System

Taxonomy refers to structure. The taxonomy of language refers to language abilities represented by structures or components. Luria (1973) proposed four structures that are interconnected and hierarchical components; these are receptive language, expressive language, spontaneous narrative (speech fluency) expression, and writing (graphomotor) fluency components.

The next four sections will address each of the structural (taxonomic) components: First, the elements supporting receptive language (the first component), including both *decoding* auditory (and visual) information and *understanding* that information, are described. Decoding is supported by acoustic and visual feature perception and memory trace formation. Understanding information is supported by a more complex set of processes involving broader cognition and involves *visual-auditory pairing* (commencing with letter to sound correspondence for acoustic interpretation) to create visual meaning (interpretation) for letters and then for letter patterns that comprise words, creating word *objects* and then, *word categorization* that enables growth of vocabulary and broader word comprehension. Next, understanding must be extended to *meaning of whole expressions* (for example, beyond word pairs to phrases, sentences, paragraphs, and passages) that enable broader comprehension of language. Within the concept of understanding *whole expressions* there are three subcomponents: *working memory* required to hold and coordinate information; *reasoning* (which Luria (1973) referred to as *simultaneous synthesis*) involving the formation of schemas or perceptions based on comprehending logical-grammatical relationships; and, *active analysis* (Bronowski, 1977) for *intentional* analysis and reconstitution (bringing the information back to a main idea).

Next, the elements supporting *expressive language* (the second component) are described. These include repetition, object naming, and word retrieval. Following this is a description of *spontaneous narrative speech* (the third component) in which the person has the ability to spontaneously verbalize. Included is a review of the research on recoding of inner thoughts into connected narrative (verbal) speech (predicative structure) as well as the role of intention. Finally, *writing* (graphomotor) *fluency* (the fourth component) is described with focus on the role of language in motor automaticity.

Component 1: Receptive Language

Receptive language includes processes in the brain involved with receiving and interpreting incoming information. Such brain processes include the perception of auditory information for the purpose of understanding meaning. The individual needs to first *hear* the words in order to *decode* language sounds (which involves auditory perception of sounds (stage 1 of language acquisition), which then allows one to *hear* and then to *understand* or recode for language meaning. This recognition (perception) of sounds required to *decode* assumes auditory and visual memory trace formation. *Understanding* information is supported by a more complex set of processes involving broader cognition. Luria (1973) wrote that language understanding is comprised of a number of components beginning with the visual-auditory pairing (learning) of words and images for word understanding, word categorization (stage 2 of language acquisition), followed by understanding the meaning of whole expressions (phrases, sentences, groups of sentences, and passages).

Word learning requires perception, memory trace formation, and sound analysis pairing sound and images to create meaningful words. Words are then organized into categories based on a central theme or meaning. As categorization of words increases in complexity, the individual moves beyond literal (concrete) understanding to relational (abstract) understanding (stage 3 of language acquisition). Functions necessary for relational (abstract) understanding involved in the concept of symbolic thinking (Goldstein & Scheere, 1941; Head, 1923; Vygotsky, 1962) at the next level of understanding include *auditory working memory*, which involves holding of information for coordinated review/processing (Oberauer et al.,2003), *reasoning*, which involves deductive and inductive reasoning supporting quality of reasoning, and *active analysis* which involves *intentional* acts of reasoning for purpose of reconstitution (Bronowski, 1977) requiring supervision of cognitive processes and actions including their selective activation and suppression (Oberauer et al., 2003). Thus, receptive language as a structural component involves the first three developmental stages of language processing (Luria, 1973).

Decoding. *Decoding* involves auditory perception of sounds and recognition of these sounds through *memory trace formation.* Auditory perception is the core ability to perceive, segment, blend, and use phonemes and graphemes and remember them (Luria, 1973). Auditory trace formation is the core ability to create and hold memories, referred to as short term memory (Luria, 1973). Both auditory perception and auditory memory trace formation are measured using a measurement technique called mismatch negativity (MMN).

Mismatch negativity (MMN) is the difference in brain response between standard sounds and deviations from the standard sounds. More specifically, MMN is defined as a neurophysiological brain event response potential (ERP) to violations of an expected (standard) sound; such violations reflect the brain's ability to make automatic comparisons of an auditory nature (Garrido, et al., 2009; Kujala, et al., 2007; Näätänen, 2000; Näätänen et al., 2007; Pulvermüller, et al., 2008; Sussman, 2007; van Zuijen et al., 2006). ERP measurement is used to index automatic acoustic change detection in the brain which has been found to be a sensitive indicator of long term memory for native language sounds for phonemes and syllables (Shtyrov, 2007). At the genetic level, MMN is attributed to the N-Methyl-D-Aspartate (NMDA) receptor system necessary for establishing memory traces at the cellular level and, therefore, includes establishing phonemes and phonemic awareness, syntactic awareness, and grammatical processing memories (Pulvermüller, et al., 2008; Pulvermüller & Shtyrov, 2003) supporting language-based cognition (Näätänen, 2007; Näätänen et al., 2011). Psychometrically, auditory perception is measured by tests of same-difference detection and short term memory for auditory, visual, and form stimuli created to capture the individual's ability to detect differences and hold them in short term memory (Munroe & Sherman, 1966; Otis & Lennon, 2002; Price, 2012; Wepman & Reynolds, 1973).

The importance of this research is its support for Luria's (1973) view that phonological memory (the ability to hear, distinguish between closely sounding phonemes, and form lasting memory traces) is necessary to support auditory analysis and for language learning. This research underscores the importance of auditory perception and auditory *trace formation* (memory creation) and establishes its biological base. This research also supports Luria's (1973) concept of *law of strength* (automatic memory recall) for phonetic association as the base upon which letter patterns, words, and word patterns are built. Current research has increased the specificity of knowledge associated with the taxonomy and processes of auditory perception for the isolation of precise sounds, phonemes, graphemes important to learning one's native language (Catani, 2009; Price, 2012).

Understanding. *Understanding* information is supported by a more complex set of processes involving broader cognition. Understanding language involves *radical symbolization* involving *visual-auditory pairing* (commencing with letter to sound correspondence and the pairing of visual images to the sounds) to create meaning for letters and then for letter patterns that comprise meaningful words. This is followed by *word categorization* (the grouping of words on the basis of common semantic or morphological themes) that represents the individual's broadening word comprehension. Then, meaning must be extended to *whole expressions* (for example, beyond word pairs to phrases, sentences, paragraphs, and passages) that enable broader comprehension of language. Meaning of whole expressions is derived from understanding phrase and sentence predicative structure and the ability to categorize and see broader relationships involving spatial, abstract, and symbolic thinking abilities that create meaning (perception, stage 3). Meaning of whole expressions involves the use of *working memory*, *reasoning*, and *active analysis*. Working memory is required to hold information for review. Working memory supports reasoning (deductive and inductive reasoning) and its quality (Luria, 1973). While deductive and inductive reasoning and its quality is about the formation of schemas or perceptions as a result of understanding logical and grammatical relationships (Luria, 1973), understanding requires active analysis which is the *intentional* analysis and reconstitution of information into a main idea (Bronowski, 1977).

Radical symbolization. *Radical symbolization* involves visual-auditory pairing and word categorization. *Visual-auditory pairing* is the pairing of visuals (images) and sounds to create meaning for letter patterns that comprise words. W*ord categorization* involves the grouping of words on the basis of common semantic or morphological themes, developing broader word comprehension.

Visual-Auditory Pairing. Research supports the importance of visual-auditory paring that involves strong visual and auditory perception. Visual-auditory pairing is necessary for language comprehension (Luria, 1973; Näätänen et al., 2007). Research demonstrates that the way we learn language is by taking letter patterns that a person internally *hears* (the auditory component), converting it to an internal visual letter pattern and then pairing that pattern with an image. The resulting pairing is then imprinted on the brain as a meaningful memory (that is, as a word). Thus, visual-auditory pairing is a word learning process commencing with perception, memory trace formation of letter patterns and images, paired, giving meaning to words (Luria, 1973; Näätänen et al., 2007).

Visual auditory pairing requires strong visual perceptual skills to distinguish features of an object and to retain these features in memory. This is measured currently through neurophysiological and psychometric means (involving both audible and visual cues). Visual perception can also be measured using mismatch negativity (MMN). Just as MMN is defined as a neurophysiological brain event-response-potential (ERP) to violations of an expected (standard) sound supporting the brain's ability to make automatic comparisons of an auditory nature, visual MMN (vMMN) is defined as an ERP to deviations from an expected visual object (Garrido, et al., 2009; Kujala, et al., 2001b, 2007; Näätänen, 2000, 2007; Näätänen et al., 2011; Pulvermüller, et al., 2008; Sussman, 2007; van Zuijen et al., 2006; Winkler, 2007).

This pairing of visual images to letter patterns and sounds of those letter patterns is labeled *visual-auditory learning*; this is supported by vMMN-MMN memory trace formation. Both MMN and vMMN encode the features of the stimuli presented and combine these audible and visual features into relationship-based objects forming perceptions (Winkler & Czigler, 2011). Discriminating perception involves the ability to detect and create associative memory traces that are categorized into separate perceived objects. This categorization allows for the establishment of categorical boundaries (Winkler & Czigler, 2011) as well as visual boundaries (Clifford et al., 2010); these boundaries are language dependent (Thierry et al., 2009). Psychometrically, visual-auditory learning is measured by testing memory for remembering presented symbol and rebus (image) pairs that are new to the individual (Woodcock, 1999).

Word categorization develops from word understanding (Luria, 1973; Otis-Lennon, 1936, 2002; Woodcock, 1999) and ability to grasp interword similarity and associations (Price, 2012). Word categorization is measured by testing vocabulary understanding and through word association tests, both of which require word understanding and mastery of word pairing, synonyms, antonyms, and analogies (Otis & Lennon, 2002; Munroe & Sherman, 1966; Price, 2012; Wechsler, 2004; Woodcock, 1999). The research supports the validity of the connection between word categorization and various word mastery tasks; the research on vMMN and MMN provide increased clarity around the supporting biological mechanisms.

Meaning of whole expressions. Receptive language involves receiving articulatory cues and organizing them into letter patterns (words) that are given meaning through visual-auditory pairing. Beyond the understanding of words and word categories, part of the development of language involves the ability to understand the meaning of whole (speech) expressions (phrases, sentences, paragraphs, and passages). Sentence meaning is more than the sum of its words (Price, 2012). Whole expressions require more complex cerebral coordination than that required for simple decoding of word meaning (Luria, 1973). Luria (1973) posited that there were three principal components involved in this process that included *working memory*; *reasoning* represented by logical and grammatical relationships defining the formation of logical schemas and therefore perceptions, and *active analysis* which is the active organizing and planning of inner speech with the goal to understand main idea (Bronowski,1977):

Working Memory. Working memory provides the capacity to organize auditory-visual trace formations (that is, memories of objects) into broader categories. Working memory is the active tracking and organizing of thoughts (Luria, 1973); it is a term adopted within the field of cognitive psychology to cover systems involved with temporary manipulation of information (Baddeley, Gathercole, & Papagno, 1998; Baddeley, 2006). Both Luria (1973) and Baddeley (2006) viewed working memory as integral to the process of reasoning. Luria (1973) wrote about working memory − the complex process of receipt and coding of information and fitting information into categories − as the essential link between short term memory and long term memory. Baddeley (2006) viewed working memory to specifically involve a phonological loop, a visual sketchpad, an episodic buffer, and the central executive brain function. Both models provide an integrated view of working memory and its contribution to the individual's ability to reason as important for understanding the complex nature of how we think through language.

This relationship between working memory and reasoning ability has also been posited by several early researchers who viewed working memory as a critical support structure for reasoning. Barkley (1997) posited working memory to be "essential for the orderly execution of novel, complex behaviors;" (p. 62). Bronowski (1977) viewed working memory as essential for *reflection* allowing "different lines of action [to be] played through and tested, . . . [which] could only happen if there was a delay between the arrival of the stimulus and the response – requiring some biological mechanisms to produce delay and allow the 'memory space'" (p. 113). Fuster (1967) posited working memory as essential for sequential comparative thinking. Vygotsky (1962, 1966) positioned working memory as the facility giving capacity for an inner discussion of alternatives prior to a response unique to human thought and speech. Working memory requires not only the ability to visualize relationships but to hold, manipulate, compare, and sequence such relationships in inner speech.

Current research also recognizes working memory and reasoning as having an integrated relationship; however, what has been debated is the neurobiological structure of memory. In particular, there has been argument about whether working memory is a construct separate from reasoning (with reasoning viewed as a critical measure of general intelligence, or *g*) or whether working memory is subsumed within reasoning (Ackerman, Beier, & Boyle, 2005; Buehner, Krumm, Ziegler, & Pluecken, 2006; Colom, Jung, & Haier, 2007; Colom, Rebollo, Palacios, Espinosa, & Kyllonen (2004); Gläscher, et al. 2009, 2010; Jung & Haier, 2007; Kane et al., 2005; Salthouse, 2005; Shelton, et al. 2010; Oberauer et al., 2003). Evidence suggests that working memory has four distinct neural correlates, with two related to reasoning and two related to executive functioning branching beyond reasoning.

Buehner et al. (2006) demonstrated that working memory can be divided into four functions. Two working memory functions involve the capacity to process and hold information specific to a given problem and to coordinate information. Two additional functions are aligned more to frontal lobe duties specific to the capacity to supervise the thinking process and maintain sustained attention, both traditionally thought to be in the executive function domain. This research was important for improving the specificity of the variables measured for working memory and reasoning demonstrating that reasoning and working memory are equally important and distinct yet interrelated concepts. The expression of working memory is the processing of information within a given situation (context) and the coordination of the activity for processing information in the first place (Buehner et al., 2006).

Other researchers also characterize working memory as a critical and special construct framing the boundaries of reasoning (Constantinidis & Procyk, 2004; Kyllonen & Christal, 1990; Shelton, Elliott, Matthews, Hill & Gouvier, 2010). Constantinidis and Procyk (2004) viewed reasoning to be subordinate to working memory, demonstrating in experiments with rhesus monkeys that the prefrontal cortex (associated with reasoning) is only one of a broad number of interconnected brain areas associated with working memory. Kyllonen & Christal (1990) posit that reasoning is little more than working memory capacity. Shelton et al. (2010) explains that working memory is "special" (p.813) in its prediction of fluid reasoning, because strong working memory allows individuals to better constrain their search strategy and more effectively retrieve items from secondary memory.

Reasoning. Reasoning (Luria's (1973) concept of simultaneous synthesis) is *the sense of understanding* derived from logical-grammatical relationships that allow the individual to *see* (visualize) relationships between objects and concepts and to form schemas supporting an individual's perceptions (Luria, 1973). Growth of the ability to reason is a necessary prerequisite for the development of categorical thinking and abstraction (Luria, 1973). As language matures, there is a qualitative shift in reasoning, from literal, concrete understanding to abstract, conceptual understanding (Goldstein, 1944; Head, 1920, 1923). The following sections include descriptions of deductive and inductive reasoning, foundational for developing *quality of reasoning.*

Deductive reasoning is the simplest form of reasoning. Deductive reasoning was defined by Grafman and Goel (2002) as "the cognitive activity of drawing inferences from given information" (p.875). It is about seeing relationships and evaluating relationships for their validity. Through the use of positron emission tomography (PET), Grafman and Goel demonstrated that the left prefrontal cortex in the left hemisphere was very important for deductive reasoning; the more anterior the activation, the more likely it was that there was a semantic (language meaning) component required to solve the problem. Their findings suggested support for a dual-mechanism theory of deductive reasoning; the use of semantic content engaged the language system (left hemisphere) and the absence of semantic content engaged the visuospatial system (right hemisphere) for the identical reasoning task.

Inductive reasoning is a higher order of reasoning, more complex than deductive reasoning to model, because inductive reasoning requires an individual to arrive at conclusions based on evidence that is likely but not certain (Kemp & Tenenbaum, 2009). Kemp and Tenenbaum (2009) argued that inductive reasoning could be conceptualized by choosing a model to form the argument. They referenced the use of Heit's (1998) memory-based inference Bayesian model, a model previously used for modeling machine learning (Haussler, Kearns, & Schapire, 1994), concept learning (Shepard, 1987; Tenenbaum & Griffiths, 2001), and further used to conceptualize inductive reasoning in humans (Heit, 1998).

Grafman and Goel (2002) and Kemp and Tenenbaum (2009) both advocated that reasoning was not a single-function cognitive process; reasoning should be viewed as a process that utilizes multiple cognitive abilities dependent on what type of reasoning (inductive vs. deductive) was being demanded by the individual's circumstances. The importance of this research is the theoretical recognition of modeling complexity in reasoning, with more sophisticated reasoning requiring multiple abstract (vs. simple and more concrete) paths of thinking given the individual is now contemplating options and uncertain outcomes. The ability to reason across deductive and inductive modes of reasoning has implications for an individual's quality of reasoning.

Quality of reasoning. As proposed by Luria (1973), Goldstein (1943, 1944), and Head (1923), quality of reasoning can be characterized as the capacity for insight into relationships and is dependent upon the individual's capacity for deductive and inductive reasoning. Limited insight is more associated with less sophisticated, direct, linear, and inflexible thinking, and deeper insight tends to be associated with more sophisticated, abstract, fluid thinking. Wasserman and Young (2010) agreed and proposed that there is a continuum of quality, dependent on an individual's ability to recognize (*differences)* "sameness" and "differentness" (Wasserman & Young, 2010, p. 1); this mechanism akin to stage 1 abilities represented in research on how vMMN-MMN differences create auditory and visual objects. Stage 2 and 3 abilities then transform these perceived objects into patterns from which the individual can derive meaning, such as reading the pattern of hands on an analogue clock.

The CLOX Drawing Test (Tranel et al., 2009) is one example of a test designed to measure the comprehension of spatial patterns at the neurocognitive level. This process of recognizing differences, creating auditory and visual objects, and transforming objects into patterns, and then subsequently deriving language-based meaning from these patterns, are all necessary contributors to the act of reasoning. Tranel et al. (2008) research using the clock as a tool to understand an individual's competency for reasoning supported the work of Korvost, Roelofs, and Levelt (2007) and the work of Meeuwissen, Roelofs, and Levelt (2004, 2005) who measured language-based reasoning through measuring an individual's ability to tell time. This research supports reasoning as the act of actively seeing relationships and transforming visual information into language meaning (comprehension).

Psychometric measurement tools for reasoning include a wide variety of tests that measure an individual's ability to reason at various levels of sophistication. These tests include those used to assess understanding direct and indirect wording in paragraphs for paragraph and passage understanding (Woodcock,1999); tests to assess understanding of paragraphs (RFU) requiring extrapolation of answers not contained in the paragraph (Scientific Research Associates, 1963); and tests that measure an individual's ability to see visual patterns and relationships (for example, the Clox Drawing Test by Royall, Cordes, & Polk (1998); the Visual Logic and Planning test by Gibson (2002); and Raven's Matrices by Raven (1998); assess deductive and, deductive and inductive reasoning with verbal and nonverbal stimuli by Munzert (1980); detecting likeness and differences by Otis & Lennon (2002); seeing whole and parts as assessed in Block Design by Wechsler (2004) and visual processing by Gibson (2002). Overall research on deductive, inductive, and quality of reasoning demonstrates the interdependence of language ability and quality of reasoning. As the ability to see relationships increases with broadening categorization that includes abstract concepts, the understanding necessary for higher quality reasoning improves.

Active analysis. Active analysis is defined as "optimal cortical tone" (p.287) involving "total vigilance" (p.287) when coding and categorizing information (Luria, 1973). Active analysis is a frontal lobe attribute (Luria, 1973). There is historical support for active analysis as vigilant reasoning including Bronowski's (1977) concept of reconstitution (active analysis and synthesis), Fuster's (1995) concept of temporal comparative analysis (active comparison), and Vygotsky's (1962) concept of inner speech (active internal dialogue).

Research continues to support Luria's (1973) view of frontal lobe involvement in active analysis as *purposeful behavior*. Oberauer et al. (2003, 2005) demonstrated active analysis to involve *purposeful* supervision and *purposeful* attention. Korvorst, Roelofs, and Levelt (2007) demonstrated *active analysis* as purposeful tracking, analysis, and *intentional* reconstitution of information. Speech comprehension requires active analysis to find a concept from many possibilities using particular search criteria (Price, 2012). Active, purposeful, intentional analysis is a necessary component for reasoning, since reasoning requires an individual to conceptually transform information as part of its process. Active analysis therefore extends reasoning to specifically include intention, a frontal lobe function.

Summary of literature on receptive language. Researchers have produced an enriched understanding of the neurophysiological and neurocognitive components associated with receptive language involving auditory perception (stage 1 sound and phoneme perception and their memory trace formation), word understanding (stage 2 radical symbolization via auditory-visual learning and categorization of words) and relational understanding of and between words (stage 3). Language understanding then grows beyond the understanding of words and phrases to the understanding of whole expressions (stage 3).

Researchers have provided support for Luria's (1973) view that phonological memory, the ability to hear and then distinguish between closely sounding phonemes, is foundational for language learning (stage 1). More specifically, current researchers support the use of MMN to understand auditory perception and the isolation of precise sounds, phonemes, and graphemes important to learning one's native language. Auditory perception further supports speech discrimination skills, memory trace formation, precise articulation, fluid switching of articulemes, and ability to abstract and understand precise word meaning and word categories.

At minimum, visual perception and auditory perception combine neuro–physically into a cohesive vMMN-MMN-based perception object (stage 2). It is the perception of same-different that is critical to creating memory traces. It is both MMN and vMMN mechanisms that encode the combination of features of the stimuli presented audibly and/or visually into relationship-based objects (Winkler & Czigler, 2011). Researchers support visual-auditory learning involves the ability to create associative memory traces that are categorized into separate perceived objects; thus, categorical boundaries shed (Winkler & Czigler, 2011) and visual boundaries (Clifford et al., 2010) are established, and these boundaries are language dependent (Thierry et al., 2009). Hence Luria's (1973) concept of *radical symbolization* in the form of visual-auditory learning has been substantiated with research, and research has added increasing clarity to the mechanisms and structure of radical symbolization.

Researchers also support the Lurian view that understanding whole expressions (stage 3) involves three principal mechanisms: *working memory* (the active processing of thoughts), *reasoning* (the formation of logical schemas and therefore perceptions), and, *active analysis* (the act of intentional understanding for main ideas; also referred to as reconstitution/analysis and re-synthesis (Bronowski, 1977)).

There exists some debate about working memory. Buehner et al. (2006) supported the Oberauer et al. (2003) model demonstrating there was significant shared variance between reasoning and memory but that these are distinct constructs; the link between the two is based on the need to communicate and coordinate activity supporting neural efficiency. Working memory is a partner with reasoning, yet working memory has its own identity. By some accounts (Ackerman et al., 2005) working memory is subsumed within reasoning. Still other researchers, such as Constantinidis and Procyk (2004), viewed reasoning to be subordinate to working memory. Working memory is the predominant predictor of fluid intelligence, which in turn determines reasoning ability. In addition to the research implicating reasoning and working memory as a tightly bound partnership, the broader research on the topic of reasoning unveiled reasoning characterized as a complicated multimodal taxonomic construct. Structurally, reasoning could be segmented into deductive reasoning and inductive reasoning. Deductive reasoning is the understanding of relationships from given information and evaluating those relationships for validity (Grafman & Goel, 2002). Kemp and Tenenbaum (2009) characterized the ability to make inductive inferences as the ability to go beyond the available data; this requiring one to arrive at conclusions given evidence that is likely but not certain. Contemporary researchers also substantiate the principles of reasoning as the ability to see relationships with the *quality of reasoning* determined by an individual's ability to see sameness and differentness (Wasserman and Young, 2010), concrete relations, and symbolic or representational relationships at the abstract level (Tranel, et al., 2009; Korvost, Roelofs, & Levelt, 2007; Meeuwissen, Roelofs, & Levelt, 2004, 2005); this predicted by Luria (1973), Goldstein (1936, 1946), Goldstein and Scheere (1941), and Head (1920, 1923).

Active analysis was reviewed as the third key mechanism of understanding phrases, sentences, paragraphs, and passages within the theme of receptive language. Active analysis is a process involving whole cerebral organization relating to language (left temporal or left parieto-temporo-occipital regions) where intention was recoded into a verbal form (Luria, 1973). Active analysis requires frontal lobe active searching behavior and stable intention, the formation of a schema and supporting actions, and the checking of progress against the plan (Luria, 1973). Luria (1973) and Vygotsky (1962) viewed active analysis as time sensitive comparative analysis using "inner speech" (p. 181). This view of active analysis, as a requirement of reasoning (Luria's (1973) concept of simultaneous synthesis for the formation of schema), requires support from the frontal lobe via intention and attention (Korvorst, Roelofs, & Levelt, 2007; Semrud-Clikeman, 2005).

The second component of language-based cognitive fitness, expressive language, is described in the next section. Expression language comprises a set of competencies that build on the receptive language foundation.

Component 2: Expressive Language

Expressive language is the second structural component involving the retrieval of information and the most basic ability to verbalize. Luria (1973) described expressive speech as a*ctivity of* and *preparation for* the act of predicative coding (the recoding of inner thoughts) into connected narrative (verbal speech), characterized as early stage 4. Three skills are identified as important to expressive language. The first skill is *repetition* which is the act of repeating back words heard exactly as they were heard. The importance of auditory perception (phonemic awareness and memory trace formation in stage 1), precise articulation, verbal flexibility applying articulemes, and the ability to abstract and inhibit irrelevant alternatives (word substitutions) are identified as important attributes for repetitive speech (Luria, 1973). The second skill is *object naming.* The third skill is *word retrieval*. Object naming and word retrieval require accurate visual perception and ability to distinguish acoustic features automatically drawing upon on all skills from stage 1 (acoustic discrimination), stage 2 (radical symbolization), and stage 3 (spatial organization/perception of receptive language) (Luria, 1973).

Repetition. Repetition is part of stage 4 and involves an individual's ability to repeat back exactly what has been heard. Researchers support the proposition that the act of repetition requires a series of key abilities including auditory perception and auditory sound discrimination for native language phonemes (Kuhl, 2004; Zhang et al., 2005, 2009), repeated exposure to these sounds in order to solidify memory traces (Saffran et al., 1996), and social interaction including exposure to a mother's more elongated and expressive speech to her infant (also called *motherese*) (Kuhl, 2010).

In addition to the enabling value of motherese, social interaction was posited to also play a constraining or "gating" role (Kuhl, 2012, p.715) limiting the readily perceived phonetic sounds to those important for an individual's native language (Kuhl, 2010). When learning elementary units of language, *gating* encourages the inhibition of irrelevant alternatives (Kuhl, 2010). The importance of this research is the role motherese plays with initial development of language perception (recall Luria's law of strength for remembering phonemes, graphemes, and articulemes). The results of this research is consistent with vMMN-MMN research specific to setting boundaries for objects, establishing distinctions, and allowing the development of categorization skills (Kuhl et al., 2006; Teinonen et al., 2009).

Attention is a critical aspect for language repetition and learning (Conboy et al., 2008b; Kuhl et al., 2008; Meltzoff et al., 2009). Conboy et al. (2008b) in particular demonstrated that infants who shifted their gaze more often between looking at the tutor's eyes and the object being introduced during the Spanish exposure sessions showed greater neural MMN discrimination in response to Spanish phonetic contrasts. In fact, the more social the infant, the greater the infant's ability to learn phonetic sounds and words. Zhang et al. (2005) demonstrated that hearing native language becomes easier and more efficient with continued exposure through repetition. Zhang et al. (2009) demonstrated that neural efficiency for language could be trained through repetition, particularly under more social conditions. Conboy and Kuhl (2010) demonstrated language learning to be adaptable, as it was noted that infants' adaptable babbling is designed to practice prosodic patterns of sounds heard across different languages.

In summary, research shows that the simple act of repetition is supported by a complex process involving auditory perception abilities such as auditory (phonetic) discrimination (stage 1); the goal is to be able to hear accurately in order to repeat sounds correctly. The need for accurate auditory perception for precise repetition of articulemes (Luria, 1973) has been supported by Zhang et al. (2009) who showed that neural efficiency for language can be trained through repetition, particularly under more social conditions, and that infant babbling is adaptive and necessary to build precision with prosodic patterns of sounds heard across different languages (Conboy & Kuhl, 2010).

Research also supports Luria's (1973) view that repetition requires ability to inhibit irrelevant alternatives. Social interaction was posited by Kuhl (2010) to be the source of "gating" (p.715) native sounds allowing the learning of elementary units of language while encouraging the inhibition of irrelevant alternatives.

Repetitive speech therefore requires accurate auditory perception, practice, an ability to adapt to prosodic nuances, and the inhibition of alternatives (stage one). The goal for the individual is to be able to hear accurately in order to repeat effortlessly without undue extraneous interference. Repetition is one building block of expressive language and it supports the second and third abilities, *object naming* and *word retrieval.*

Object naming. Object naming is part of stage four and involves object recognition (vMMN-MMN trace memory formation) and word retrieval skills (that is, memory retention for object-word associations); accurate visual perception; the ability to distinguish acoustic and visual features automatically (stage one); and the ability to learn word meaning through visual-auditory pairing and word categorization (stage two) (Luria, 1973). Object naming is a more complex level of processing than repetition. Object naming also involves processing visual and auditory features of objects that represent concrete things (stage three) (Luria, 1973). However, Luria posited that task difficulty increases because when an individual is naming objects there is no acoustic model of the word audibly or visually (sound-letter pattern) provided to assist the individual in the recollection process. Current research places brain functioning for word naming in multiple left hemisphere locations including the temporal, occipital, and parietal brain regions; the exact location is dependent upon the type of word naming required (Acres, Taylor, Moss, Stamatakis, & Tyler, 2009; Allen, Bruss, & Damasio, 2004; Damasio et al., 2002).

The research of Allen et al. (2004), Damasio et al. (2002), and Acres et al. (2009) suggest that models of naming emphasize left perisylvian structures and extend to reflect a larger network including the left inferior and anterior temporal lobe. These studies highlight the importance of anterior and inferior temporal lobe regions in conceptual knowledge processing, thus supporting Luria's (1973) visual-auditory connection. This research also demonstrates the distributed nature and complexity of object name recall.

Word retrieval. While naming was intended by Luria (1973) to focus on the act of seeing an object and being able to name it, word retrieval extends beyond naming to include both concrete (object naming) and abstract (concept naming). The literature supports the existence of multiple functional systems operating in the left hemisphere that support word retrieval. Tranel, Adolphs, Damasio, and Damasio (2001) proposed that the retrieval of knowledge and words involves the use of "flexible-route" or "preferred-system" arrangements (p. 667). The preferred system for *concrete words* involves the ventral occipital-temporal and anterolateral temporal cortices that excel at processing knowledge for concrete entities. This ventral system processes feature-related information (shape, colour, and texture) critical for the neural encoding of concrete entities. The preferred system for *action words* involves the networks in the dorsal component of temporo-occipital and parietal cortices and in the ventrolateral premotor/prefrontal region for processing concepts of actions and their corresponding words (Tranel et al., 2001). Word retrieval is also complicated by the need to select words from competing possibilities, suppression of unintended words, and the linking of semantics to articulation (Price, 2012). Thus, the act of word retrieval demands resources of the brain dependent on the nature of the word use, competing possibilities, and intended use; concrete (literal) words use different retrieval routes compared to those having abstract meanings.

Summary of expressive language. Expressive language is founded upon receptive language. For expressive language (early stage four), repetitive speech, word naming, and word retrieval are important. Recent literature suggests the existence of multiple functional systems operating in the left hemisphere to support word naming and word retrieval (Tranel et al., 2001). Tranel et al. (2001) suggested the existence of “flexible-route” or “preferred-system” arrangements (p. 667). Psychometric tests available to test object naming and word retrieval, include word list recall (Wechsler, 2009), Closure Speed (Thurstone & Jeffrey, 1984), Visual-Auditory Learning subtest of the Woodcock Johnson Reading Mastery protocol (Woodcock, 1999); word comprehension involving antonyms, synonyms, and analogies (Woodcock, 1999); and repetition measured via blending and segmenting tasks in the Auditory Analysis subtest of the Gibson Cognitive Test Battery (Gibson, 1999).

In summary, research provides support for the importance of Luria’s (1973) concepts of repetition and object naming for the expression of language. There is evidence to support the inclusion of word retrieval as part of the complete support system needed for expressive language. Component 3 involves abilities required for verbal articulation of a broader nature which involves spontaneous narrative expression (the act of speaking effortlessly).

Component 3: Spontaneous Narrative Language

Spontaneous narrative (speech fluency) language is the third structural component and involves the act of spontaneous verbal articulation (speaking effortlessly). The frontal lobe initiates the process of spontaneous narrative language given an individual's intention to speak and capacity for motor coordination to support the act of speaking (Luria, 1973). This ability to spontaneously verbalize involves conversion of inner thoughts into connected narrative (verbal) speech (stage four). Conversion of inner thoughts requires accurate visual perception and an ability to distinguish acoustic features automatically in order to retrieve and name, drawing on all skills from receptive language – component one and expressive language – component two (Luria, 1973).

Conduction aphasia is defined as difficulty with verbal articulation that is spontaneous and particularly demonstrated in conversation (Buchsbaum et al., 2011). Brain imaging research on conduction aphasia implicates the left temporoparietal zones (Buchsbaum, et al., 2011). They demonstrated, through analysis of *f*MRI imaging data from five working memory studies completed within the last five years, that conduction aphasia was not a white matter disconnection issue but instead a sensory integration challenge localized in the cortical sylvian parietal temporal (SPT) zone and/or a challenge in the posterior lateral superior temporal gyrus (STG) and posterior superior temporal sulcus (STS). Because the SPT zone includes cortex on the posterior plenum temporale considered to be part of the auditory processing region, Buchsbaum et al. (2011) proposed phonological short term memory as a spontaneously emergent property from sensorimotor interaction mediated by the SPT sensory-motor circuit; in contrast to previously accepted models as exampled by Baddeley's concept of a phonological memory buffer within the phonological loop (Buchsbaum et al., 2011)

This view of the SPT area rooted in both auditory processing and expressive language has received broader research support on several fronts. SPT involvement has been implicated in audible verbalizing and lip reading (Okada &Hickok, 2009); as a loci for memory of sound sequences, words, and word meaning (semantics) for repetition (Baldo, Klostermann & Dronkers, 2008); and as an area shared by the processes of auditory short-term memory and speech comprehension (Leff et al., 2009).

Price (2012) found support in brain imaging research for both a covert (silent) planning for the production of speech sounds (which include the selection of motor commands from alternatives, the sequencing of motor plans, orofacial motor planning, and auditory expectation), and overt articulation which is the actual motor execution, timing of output, and breathing control. Price (2012) also referenced research pointing to the importance of auditory and motor feedback which depends upon auditory processing, auditory imagery, and auditory expectation.

Psychometric measurement of spontaneous narrative language involves tests using stimuli that require organizing and planning of thoughts that are verbally articulated. Test protocols include instruments probing an individual's ability to see main idea with both verbal stimuli (Science Research Associates, 1958), and nonverbal stimuli (for example, Thematic Apperception Test; Murray 1935).

Summary of literature on spontaneous narrative language. Research supports the quality of spontaneous narrative speech to be dependent upon auditory perception (stage one), radical symbolization for word understanding and categorization (stage two), growing spatial organization/perception (stage three) supporting naming and word-finding/retrieval (early stage four). Verbal conduction is now more broadly accepted as the result of a sensory-motor system that leverages auditory processing with phonological short-term memory as an emergent property. Psychometric measurement is more *free form* (verbal responses demonstrating inner speech organizing and planning) and requires interpretation by the examiner.

Component 4: Writing Fluency

Writing fluency, also referred to as graphomotor automaticity, is the fourth component of language-based cognitive fitness and it involves the ability to write with ease. Writing fluency has been identified as a critical component of language (Barkley, 1997; Fuster, 1995). Early literature defined writing fluency to incorporate the premotor and motor cortex of the brain in preparation for motor expression and that the act of handwriting could not be separated from language. Fuster (1995) specifically identified the premotor and motor cortex to act in collaboration with memory neurons intermingled with sensory cells formally linking memory to motor preparation. Barkley (1997) also proposed handwriting as "complex motor sequencing" (p. 83) of hand strokes commencing with lines, curves, circles, and then developing greater complexity as language develops. Early research therefore viewed auditory memory formation, phonetic knowledge, motor preparation, and motor practice as key aspects of writing fluency.

Luria (1973) further connected writing issues with the most basic of language-based abilities associated with Stage one phasic/acoustic hearing. Luria (1973) posited the source of writing challenges to result from the disturbance of phonemic (phasic/acoustic) hearing. He found the loss of the ability to write was characteristic of patients with lesions of the left temporal lobe, the brain region important for phasic/acoustic hearing. Luria (1973) posited that phonemic skills were necessary for translating words heard into written words. Luria, Simernitskaya and Tubylevich, (1970) positioned handwriting of words to be the result of a process requiring: the individual's ability to acoustically hear, enabling the accurate reception of phonemes, graphemes, and articulemes (stage one); allowing translation of sound into meaningful words (stage two); formulating inner speech (stage three); condensing this inner speech into predicative (syntax) structure (stage four); and readying the hand for action involving collaboration between the premotor cortex and motor cortex (stage five). Luria, Simernitskaya and Tubylevich (1970) posited the writing of words to form a process “requiring precise acoustic analysis into a motor automatism [a physical reflex or involuntary activity of the body]” (p. 140). Literature supports the integral role of language in writing based expression. Dysfunctional writing (graphomotor) skill is identified as apraxic agraphia or dysgraphia involving damage to the processing components required in the programming of skilled movements for writing (De Smet, Engelborghs, Paquier, De Dey, & Mariën, 2011).

Apraxic agraphia is a disorder of the writing movements necessary to produce letters (De Smet et al., 2011). De Smet et al. (2011) and Mariën, Verhoeven, Brouns, De Witte, Dobbeleir , and De Deyn (2007) hypothesized that apraxic agraphia results from damage to the cerebellar-encephalic projections connecting the cerebellum to the prefrontal and parietal areas important for the process of writing. Nicolson and Fawcett (2011) supported the language-motor connection and more formally demonstrated an overlap of dyslexia (language) and dysgraphia (motor) on the basis of common underlying learning problems with the learning of procedure (for automaticity).

Developmental dyslexia (language difficulties) was proposed to arise from impaired performance in the procedural learning system for language involving the prefrontal cortex, Boca’s area, the parietal cortex, and sub-cortical structures including the basal ganglia and cerebellum (Nicolson & Fawcett, 2011). Dysgraphia (handwriting difficulties) was proposed to arise from impaired performance on the procedural learning system involving the pre-motor regions and its connections with the cerebellum **(**De Smet et al., 2011; Mariën et al., 2007; Nicolson & Fawcett, 2011).

Dysgraphic individuals also presented with significant issues specific to difficulties with naming, memory, attention, visuo-spatial planning, and executive functions; this suggests that perception (receptive language) and the act of writing are coupled and tied to executive functions of attention and motor planning **(**De Smet et al., 2011). Tranel et al. (2001) supported the interdependency of motor planning and reasoning. Hauk et al. (2004) demonstrated this interdependency of motor and language functions by revealing that even with passive reading of action words referring to face, arm or leg actions (for example, “lick”, “pick”, “kick”), language areas along the motor strip adjacent and/or overlapping those neurons responsible for the execution of the movements were also activated. Pulvermüller et al. (2005) demonstrated that activation of the arm using transcranial magnetic stimulation (TMS) led to faster naming of arm-related words. Research by Bak and Hodges (2004), Grossman et al. (2008), and Bak and Chadran (in press) supports the connections between motor skill and language and suggests that they are wired together.

Psychometric measurement of graphomotor skills range from speed of copying by Munroe & Sherman (1966), coding in the Wechsler Intelligence Scale for Children (WISC, 2004), and essay composition in the Wechsler Individual Aptitude Test (WIAT-

III, 2009). Psychometric measurement of graphomotor fluency targets the measurement of automaticity of handwriting and essay composition.

Summary of writing fluency. Researchers tie language very closely to writing fluency (motor automatism); this is consistent with Luria's (1973) hypotheses associating writing automaticity with auditory perception. The neural network for written language planning now extends beyond the parietal and frontal lobes to include the cerebellum (De Smet et al., 2011; Mariën, et al., 2007). Nicolson and Fawcett (2011) proposed difficulty in learning due to an impaired performance with the individual's procedural learning system common to both dyslexia and dysgraphia.

Summary of Part 1 and Part 2

The review of literature first focused on describing the ideal structure (similar to the linear score sheet analogy for judging Friesian horses) for language-based cognitive fitness. Researchers have provided support for the Kemp and Tenenbaum (2009) view that both process and structure are important for full understanding of the nature of language. The initial focus was on the process of language acquisition involving five stages of increasing competence. Then, the structures were described. Process and structure are closely related, and development of both process and structure are necessary for cognitive fitness. There are several themes that evolved from this review.

First, there are hierarchical and interdependent relationships within processes (stages one through five), structures (components), and between processes and structures. The five stages of process are necessary for the evolution of taxonomic structure; the presence or absence of the processes impacts the growth of language-based cognitive fitness and achievement of the final ideal structure. Equally, the degree to which an individual is able to emulate the ideal characteristics for language-based cognitive fitness, akin to establishing *a score card for* desired standards for characteristics of language-based cognitive fitness, is an expression of the strength of processes supporting the taxonomical structure. Hence, multiple factors and factor interdependencies work together to determine language-based cognitive fitness.

Second, the researchers expressed broad support for the Luria (1973) model of brain functionality using more advanced measurement tools, such as *f*MRI. The more advanced measurement tools are discovering source processes with greater detail, such as the research supporting MMN and vMMN as a basis for perceiving and creating memory traces for auditory and visual objects (Garrido, et al., 2009; Kujala, et al., 2007; Näätänen, 2000; Näätänen et al., 2007; Pulvermüller, et al., 2008; Sussman, 2007; van Zuijen et al., 2006).

Third, researchers supported Vygotsky's (1962) views on the role of human socialization in language development; a perspective not embraced broadly until more recently. The role of biological abilities (auditory processing) is viewed as critical for opening the opportunity for development of social ability; while, social interaction is critical for channeling this development. For example, the use of cochlear implants in children delayed in language and social development gave these children access to hearing sounds ─ enabling auditory awareness, and opening the door to building auditory processing abilities ─ to enable more normal language and social awareness (seeing emotions and their meaning) development (Bevilacqua et al., 2011; Coene et al., 2011; Most & Michaelis, 2011). Other researchers reporting on the process by which infants begin to gate native sounds and start to drive categorization also uncovered the importance of the role of social interaction in molding word categories (Kuhl et al., 2006; Teinonen et al., 2009). Collectively both biological ability and social interaction interact to develop language-based cognitive fitness consistent with Vygotsky's views.

Researchers demonstrated that language-based cognitive fitness is expressed through components and processes that build on each other in a hierarchical design. These hierarchical relationships are highly complex and interrelated. The nature of these relationships is more recently understood in more refined terms given advanced technologies available. Theoretical and empirical researchers reviewed in this study contributed knowledge for the development of an empirical model grounded in theory. A conceptual model will be presented in Part three.

Part 3: A Conceptual Model for Language-based Cognitive Fitness

Part 3 contains a conceptual model for language-based cognitive fitness. Researchers have provided overall support for a model that describes language-based cognitive fitness. Based on the cumulative evidence, the following model is one way of expressing the process and taxonomy of language. Research questions that naturally flow from the model are presented.

The Language-based Cognitive Fitness Model

The model for language-based cognitive fitness incorporates four key constructs: Receptive Language (auditory perception and word meaning); expressive language (repetition and word retrieval); spontaneous narrative (speech fluency) language; and writing (graphomotor) fluency. Receptive language is the foundation supporting expressive language abilities. Receptive and expressive language abilities support spontaneous narrative language (speech fluency); these three abilities support the development of writing (graphomotor) fluency within a hierarchical structure.

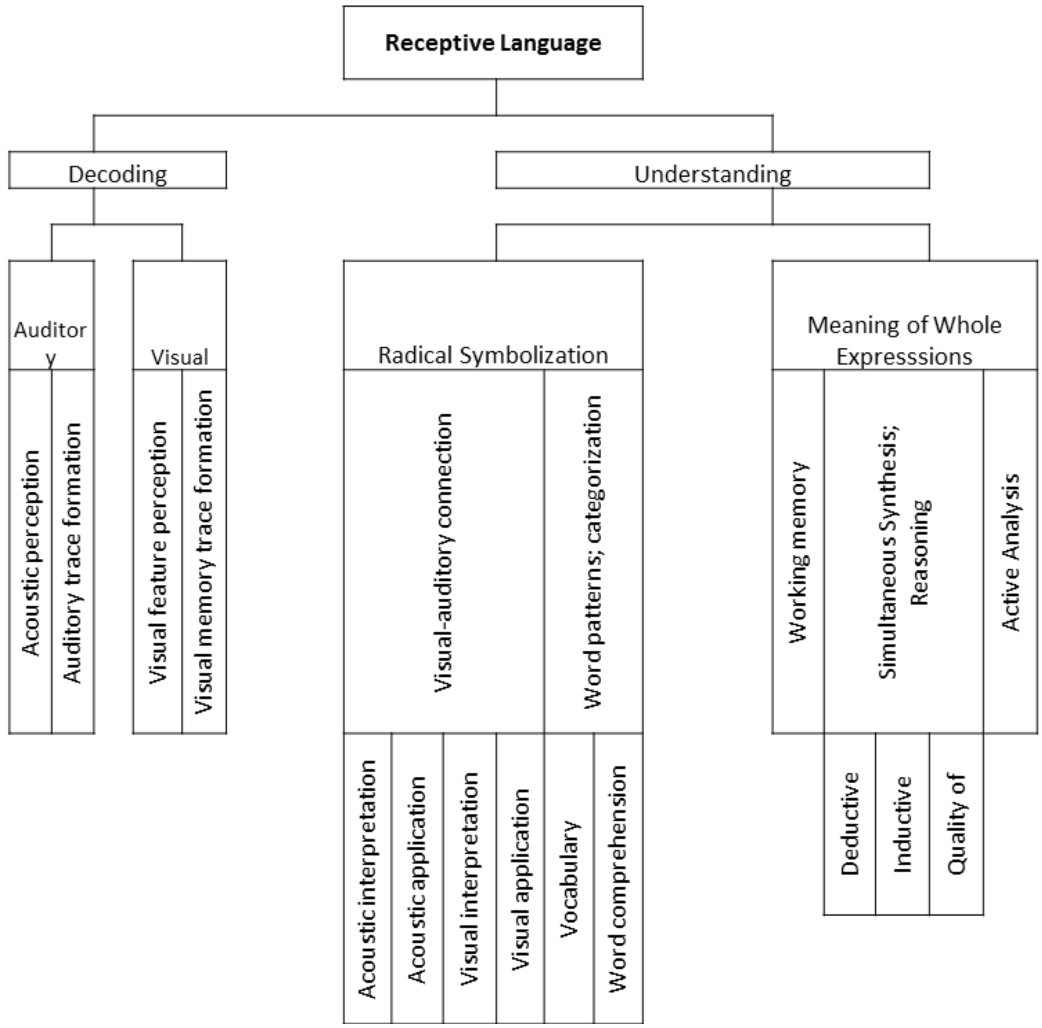


Figure 1. The theoretically supported model for Receptive Language derived from the literature review.

Receptive language involves both *decoding* auditory information and *understanding* that information. Decoding and understanding information is supported by a more complex set of processes involving broader cognition and involves radical symbolization supported by *visual-auditory pairing* (commencing with letter to sound correspondence) to create meaning for letters and then for letter patterns that comprise words, and *word categorization* (broadening vocabulary and word meaning). Then, meaning is extended to *whole expressions* (for example, beyond word pairs to phrases, sentences, paragraphs, and passages) that enable broader comprehension of language. Within the concept of understanding *whole expressions* there are three subcomponents: *working memory*, required to hold and coordinate information for *reasoning* involving the formation of schemas or perceptions; and, *active analysis*, the intentional analysis, synthesis, and reconstitution of information.

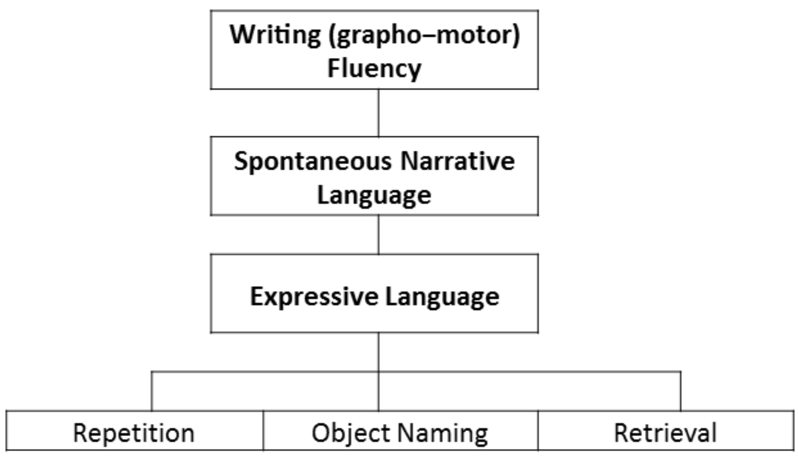


Figure 2. The theoretically supported model for Expressive Language, Spontaneous Narrative Language, and Writing (graphomotor) Fluency

Expressive language includes repetition, word naming, and word retrieval. Spontaneous narrative (speech fluency) language involves the ability to organize and plan predicative structure verbally representing one's inner speech. Writing (graphomotor) fluency focuses on the role of language and the ability to automatically write and express one's thoughts on paper.

Literature Review Related to Key Variables and Concepts

Language-based cognitive fitness is the result of a highly complex series of relationships between processes and taxonomical structure. Both construct hierarchy (structure) and their core processes (stages) are candidates for statistical testing (Cowan, et al, 2005; Kemp & Tenenbaum, 2009). This section reviews past studies that justify the constructs of interest and chosen methodology, describes the problems and strengths in these approaches, justifies the rationale for selection of the variables and concepts, and highlights any controversies or research gaps.

A Review of Related Constructs and Research Methodology

Modeling frameworks initially reviewed for consideration when building a model for language-based cognitive fitness included models of general cognitive fitness with focus on executive function (associated with reasoning), working memory, and processing interrelationships (Ackerman et al., 2005; Buehner, Krumm, Ziegler, & Pluecken, 2006; Colom, Rebollo, Palacios, Espinosa, & Kyllonen, 2004; Gläscher, et al. 2009, 2010; Jung & Haier, 2007; Kane, Hambrick, Tuholski, Wilhelm, Payne, & Engle, 2004; Salthouse, 2005; Shelton, et al. 2010; Oberauer et al., 2003). These models used cognitive testing and statistical analysis (confirmatory factor analysis; SEM) to better understand the complexity of intelligence and create simplified models of cognitive fitness that include aspects of language (Buchsbaum, et al., 2011; Buehner et al., 2006; Gläscher, et al. 2009, 2010; Salthouse, 2005; Tranel et al., 2009).

Other process models reviewed that leveraged predictive coding theories for memory and general intelligence which assumed the brain follows a Bayesian-based model in a hierarchical setting (Friston & Kiebel, 2009; Garrido et al., 2009; Yuille & Kersten, 2006; Winkler & Czigler, 2011), were also considered. These models were rich in their use of a priori structures providing strong structural guidelines for model building.

Strengths, Weaknesses, and Literature Gaps in Modeling

Few researchers (exceptions include Gläscher et al., 2009, 2010; Kemp & Tenenbaum, 2009; Moore, 2007; Price, 2012) have expressed concern about the lack of language-based models. Moore (2007) posited that part of the reasoning for a lack of modeling was that knowledge was fragmented across a wide range of disciplines attached to language, with language disciplines broadly including acoustics, phonetics, phonology, cognitive neuroscience, neural imaging, machine learning, and natural language processing. Moore (2007) explained this fragmented research approach to be consistent with Descartes scientific reductionist principles (that understanding can be reduced to mechanisms at the component parts); what are needed are models that connect individual variables in meaningful ways. Review of the research suggest the need to understand processes and structures related to cognitive fitness in a more holistic (that is, model-based) fashion.

Some researchers have provided insight into modeling processes associated with general intelligence, executive functioning (reasoning), and working memory; techniques which can also be applied to language modeling using techniques and methodologies specific to conventional stochastic (structural equation modeling) or structured Bayesian model (Gläscher, et al. 2009, 2010; Kemp & Tenenbaum, 2009). Bayesian modeling techniques have been used in computer simulations of language acquisition; these models are limited in scope (Byoung-Tak & Chan-Hoon, 2008; Fazeli & Bahrami, 2009). Fazeli and Bahrami (2009) modeled language acquisition using computational approaches and computer simulations applying Hebbian cell assembly concepts; these are used to model neural network architecture and to re-enact memory trace formation and learning through association. Although promising, their work was restricted to syllable learning. Other simulation work by Byoung-Tak and Chan-Hoon (2008) used the "mental chemistry" (p. 134) cognitive model and "molecular self-assembly" (p. 134) technology in biochemistry to model sentence completion demonstrating how individuals develop predicative sentence structures.

Other research has sought to define specific aspects of language. Vogt and Haasdijk (2010) modeled social learning of language and skills. Moore (2007) sought to explain the motivation for human spoken language by modeling behavioral mechanisms underlying language processing. Specifically, the drivers of spoken language included the individual's needs, their want to sense, their want to know, and their want to imagine. Ottem (2002) used the Illinois Test of Psycholinguistic Abilities (ITPA) protocol for validating language impairment, concluding that language impairment was due to constraints on an individual's information processing effort. Woodrow (2006) developed a model of language learning with motivation, self-efficacy, anxiety, and language learning strategies as key model constructs. Van der Velde (2005) defined a model of constraints similar to Khul's (2010) concept of gating native sounds as key to guiding an individual's development of language.

Results from a number of studies using structural equation modeling of psychometric data have been validated using brain imaging techniques; this has provided additional insight on how testing might improve. For instance, the Wechsler Adult Intelligence Scales (WAIS) is used as an indicator of intelligence and considered to be the standard for measuring broad intelligence, including language. Brain imaging studies by Gläscher et al. (2009, 2010) demonstrated the responses on the WAIS did activate some language centers (for example Boca's area which is important for motor coordination) but not others (for example, Wernicke's area which is important to semantics which is necessary for verbal comprehension). Instead of activating Wernicke's area important to word meaning and word categorization, the WAIS Verbal

Comprehension Index tapped in on Brodmann's Area 10 viewed to be a brain center more specialized in higher abstract thinking.

Other researchers validating cognitive testing as sensitive and predictive of brain injury and brain fitness via brain imaging studies include Damasio et al. (2004) for naming and concrete vs. abstract thinking; Gläscher et al. (2009, 2010) for broad intelligence factors; Jung and Haier (2007) for intelligence and reasoning; and, Tranel et al. (2009) for understanding the neural correlates of reasoning using the CLOX Drawing Test. Available Bayesian model types provide statistical means to produce models that increase understanding of how individuals learn; Haussler, Kearns, & Schapire (1994) for machine learning, Shepard (1987) for modeling concept learning, and Heit (1998) for inductive reasoning. Other than the reviews provided by Price (2012) and Catani (2009) available frameworks for modeling language are designed for measuring broader intelligence, include aspects of language. Researchers have not developed and tested language-centric models of cognitive fitness; this provides an opportunity to build on this knowledge by developing appropriate, theory-based models.

The specific cognitive measures representing the independent and dependent variables will be defined in chapter three.

Overall Chapter 2 Summary and Conclusions

There are several themes in the literature reviewed involving model design, methods of inquiry, and research gaps. First, the integration of both taxonomic and process based research methods are viewed as critical to understanding the logic of language acquisition and the modeling of the structure of language (Kemp & Tenenbaum, 2009). Researcher publications primarily from 2005 to 2011 supported models representing aspects of intelligence that assumed language to be included (Shelton, et al. 2010; Oberauer et al., 2003; Gläscher, et al. 2009, 2010; Jung & Haier, 2007; Salthouse, 2005). The purpose of the present study is to build a model that reflects taxonomy (structural components) and that includes processes (that is, stages of language development).

Second, consistent with research in the realm of intelligence modeling (Gläscher et al., 2009, 2010; Kemp & Tenenbaum, 2009; Salthouse, 2009), quantitative methods of inquiry are chosen to be used to test the four component taxonomic model defining language-based cognitive fitness. Factor analysis, structural equation modeling, and discriminant analysis tools are appropriate to be chosen as the core statistical tools for this study. Exploratory modeling is appropriate for this study and has been used in other explorations. For example Burkholder and Harlow (2003) explored longitudinal models of factors correlated with HIV risk behavior, Buehner et al. (2006) explored the relationship between working memory and reasoning, and Salthouse (2005) explored factors involved in executive functioning. The details of this modeling will be explored in chapter three.

Third, the primary gap (in scholarship) of interest in this study is the lack of a model that addresses the neurobiological basis of language as its central focus with an examination of the model components' relationships to achievement in reading and mathematics. Available theoretical models incorporate aspects of language (Byoung-Tak & Chan-Hoon, 2008; Fazeli & Bahrami, 2009; Gläscher, et al. 2009, 2010; Kemp & Tenenbaum, 2009) but focus more broadly on measuring executive functioning, reasoning and/or intelligence, and working memory.

Therefore, there are two primary questions addressed in the present study described below. The strategies for analysis of each are described in more detail in chapter three: First, using structural equation modeling, does an empirical model of language-based cognitive fitness, based on a model derived from the theoretical and applied literature, fit the data? Second, can children of differing cognitive abilities (below grade achievement, normal achievement, and gifted achievement) be discriminated based on their scores on variables associated with a language-based cognitive fitness model? Based on review of the literature, three potential model scenarios are supported; each will be tested, and the tests will be described in more detail in chapter three.

Theoretical Models

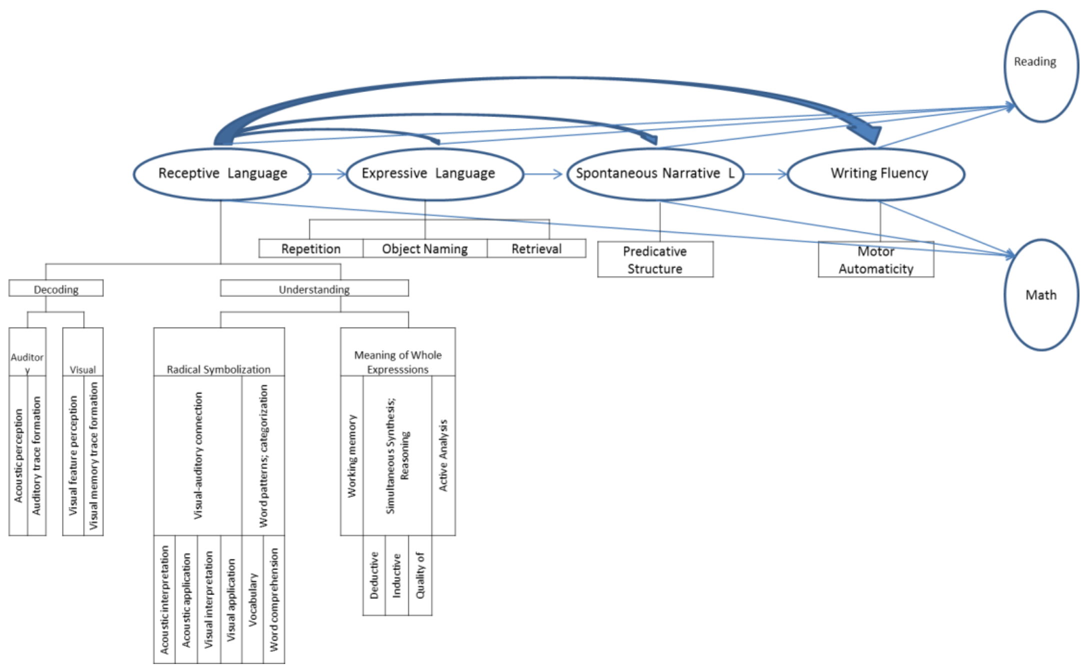


Figure 3. The theoretically supported four components model for Language-based Cognitive Fitness

The four components model includes Receptive Language, Expressive Language, Spontaneous Narrative (speech) Language (verbal fluency), and Written (graphomotor) Fluency as key constructs. Results of research position receptive language as the foundational structure supporting all other structures. Receptive Language is a necessary component supporting Expressive Language. Receptive Language and Expressive Language support Spontaneous Narrative Language. Receptive Language, Expressive Language, and Spontaneous Narrative (speech fluency) Language support Writing (graphomotor) Fluency. It is expected that these four components have a direct impact on an individual's performance in reading and mathematics achievement tests. Cowan et al. (2005) demonstrated children with language impairment are at greater risk of developing reading difficulties, difficulties in mathematics, and therefore at risk for broad learning difficulties that would be expressed in achievement tests such as reading and mathematics.

This conceptual model provides the basis for several predictions that could potentially be tested in future research. One of these, for example, if MMN and vMMN within Receptive Language are faulty, then expressions of fault lead to faulty phoneme awareness impacting speech discrimination (the hearing of some native language sounds), resulting in faulty auditory and visual object memory trace formation. This in turn would result in faulty sound analysis and its application in word attack (the sounding out of words phonetically), resulting in delayed word identification, slow learning of word meaning, word categorization, and broader language meaning and understanding. Hence, there would not be a foundation for building strong abilities in repetition, object naming, or word retrieval affecting vocabulary learning (expressive language). Without word meaning, word categorization, broader language meaning and understanding, and the ability to repeat what is heard, name objects, and retrieve words, there is nothing to support organizing and planning of thoughts into predicative (sentence) structure for verbal articulation. Without these former abilities writing (graphomotor) fluency has no basis for expression.

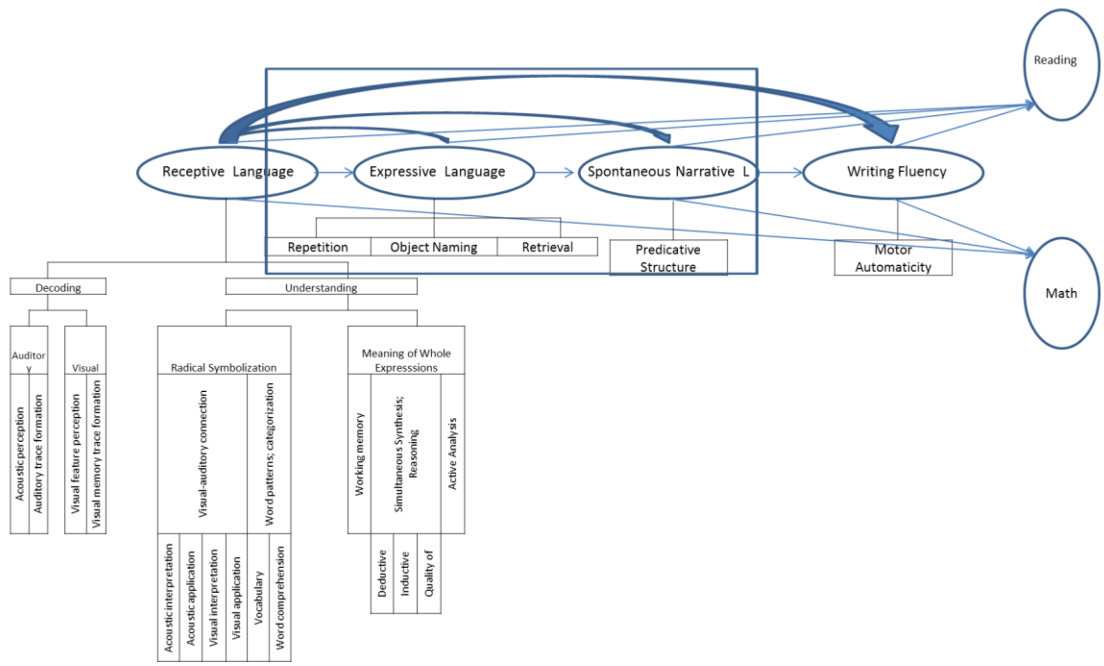


Figure 4. The three components model of Language-base Cognitive Fitness

There is the potential for a three component model with Receptive Language; Expressive Language and Spontaneous Narrative (speech fluency) Language combined together; and, Writing (graphomotor) Fluency. Researchers have identified repetition, object naming and retrieval as an expression of Expressive Language, but there may not be enough power (statistically) in the difference between (verbal) repetition, object naming, word retrieval, and spontaneous narrative (verbal) language. In addition to word naming and word retrieval necessary for fluent verbal articulation, stage four processes involve the coding of thoughts into formal speech (more formally called predicative coding). It is possible that both Expressive Language and Spontaneous Narrative (speech fluency) Language (Luria, 1973) are a singular construct. Hence a three component model possibility needs to be addressed in this study.

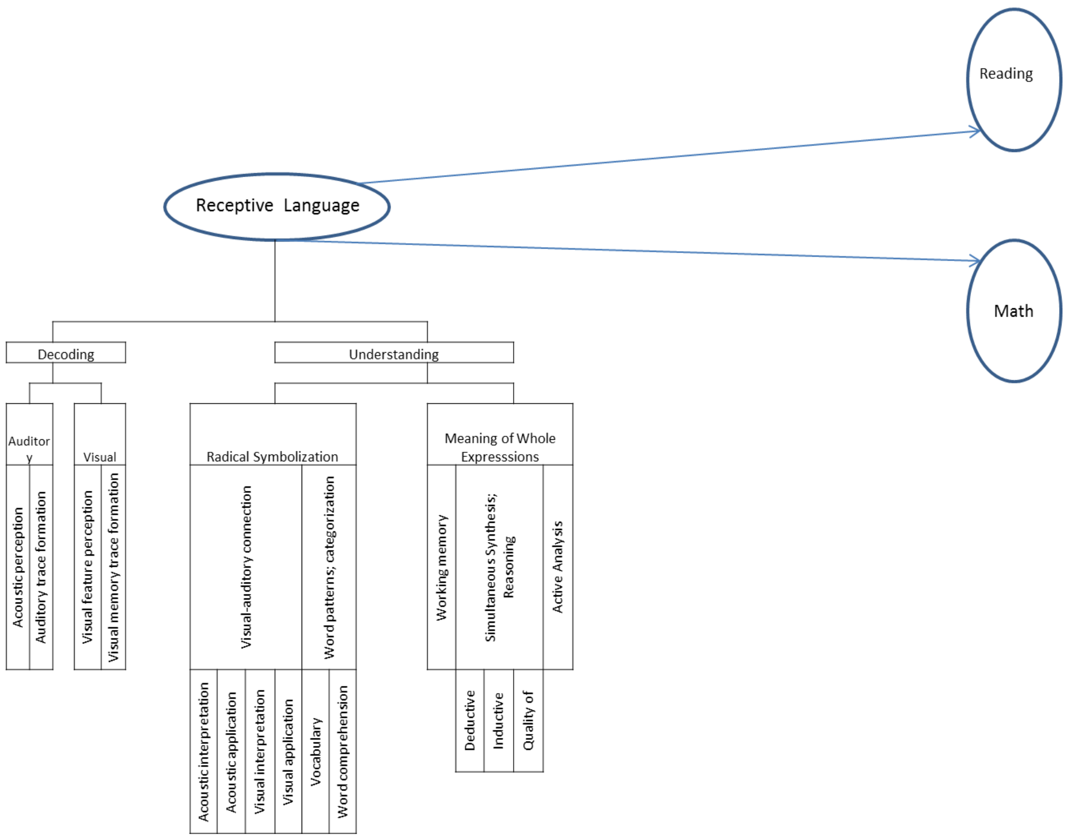


Figure 5. The singular component model of Language-base Cognitive Fitness

Although the results of a literature search support the full four component model there is a possibility for a single component model. Researchers (Garrido, et al., 2009; Kujala, et al., 2007; Näätänen, 2000; Näätänen et al., 2007; Pulvermüller, et al., 2008;

Sussman, 2007; van Zuijen et al., 2006) defined receptive language as the prime component. Further, researchers presented a disproportionate number of attributes aligned with receptive language relative to other components. Researchers' support of receptive language processes and structure as critical to the success of subsequent components places significant emphasis on receptive language as the foundation for language-based cognitive fitness.

These three models have research support. Procedures to test the three models and make comparisons among models for empirical fit are described in more detail in chapter three.

Research Contribution

This research is designed to provide a theoretical frame of reference for understanding the key constructs, components, and moderating variables for language-based cognitive fitness. The practical application of this study is an improved understanding specific to why some children have difficulty acquiring their native language, and how to assess and respond to the nature of their difficulty. Once a model is established future work can also consider Bayesian analysis given there will be an a specific a priori model from which to model a time path for predictive coding, adjustment, and modification (Baldeweg, 2006; Friston, 2005; Garrido et al., 2009; Kemp and Tenenbaum, 2009) for language-based cognitive fitness.

Conclusion

A conceptual framework for modeling language-based cognitive fitness has been designed from the theory that and will be tested as part of the study. This model links receptive language, expressive language, spontaneous narrative language, and writing fluency components. The model(s) will be tested using factor analysis, structural equation modeling, and discriminant analysis. A language-based cognitive fitness model has the potential to increase theoretical knowledge and enable clinicians and educators to infer predictive relationships between cognitive variables and language-based cognitive performance. Understanding these predictive relationships builds on the base of scholarly theory and allows clinicians to more effectively isolate language-based challenges and advise parents and educators. Chapter three provides a detailed overview of the research design for this study and operationalizes the theoretical model developed in chapter two.

Chapter 3: Research Method

Introduction

The purpose of this research was to define and test a model of language-based cognitive fitness derived from the literature. The seminal work of Luria (1973) focusing on the developmental process and technical (taxonomic) structure of language was used to provide the foundation for the theoretical model. Chapter 3 includes a description of the methodology. This chapter is divided into four parts. Part 1 introduces the study variables and includes a defense of and rationale for the research design, the connection of study design to the research questions; and, defines the target population, sample, and sampling procedures. Part 2 is dedicated to the operationalization of the study variables for each of the four model components: receptive language, expressive language, spontaneous narrative language, and writing (graphomotor) fluency. Information is provided for what each variable measures, support for variable validity and reliability, how the associated test is administered, and how the test is scored. Part 3 provides description of the plans for data analysis. Part 4 provides description of threats to study validity as well as ethical considerations.

Part 1: Research Design and Rationale

Study Variables

Key study variables included independent variables: receptive language involving the decoding of incoming language and its understanding; expressive language involving repetition, naming, and word retrieval; spontaneous narrative expression pertaining to spontaneous verbal expression in proper predicative structure; and writing (graphomotor) fluency pertaining to ease of writing. Achievement measures for reading mastery and mathematics served as the dependent variables. Cognitive profile (challenged, average, or gifted) was a third dependent variable and investigated through discriminant analysis. Age was treated as a covariate in all analyses.

Research Design

This study was correlational design. Correlational design is an appropriate selection for defining a model of language-based cognitive fitness examining the association of multiple continuous observed dependent and independent variables. Structural equation modeling (SEM) is an advanced statistical modeling technique suitable for exploratory testing of proposed models as well as for confirmatory analysis; SEM is widely used in modeling research (Burkholder, 2003; Gläscher, et al. 2009, 2010; Jung & Haier, 2007; Oberauer et al., 2003; Salthouse, 2005; Shelton, et al. 2010;

Salthouse, 2005). It combines techniques associated with regression and confirmatory factor analysis.

SEM is one technique used in causal modeling; such modeling is used to examine whether a pattern of intercorrelations among variables fits the researcher's underlying theory. This process allows researchers to identify potential causal connections among the variables (Mertler & Vannatta, 2010). Model specification is the most important and preliminary step in the process. The specification of the model is the formal declaration of the researcher's beliefs about the causal structure of the model (Mertler & Vannatta, 2010). Yet, it is recognized that even with an extensive literature review, the specification of a hypothesized model is complicated by the vagueness of theoretical literature, the potentially infinite number of possible causal determinants, and the general complexity inherent in social science (Mertler & Vannatta, 2010).

Discriminant analysis was used to determine whether the total sample population was heterogeneous or marked by differences that can distinguish specific populations (Mertler & Vannatta, 2010). Similar to factors in factor analysis, discriminant analysis produced uncorrelated linear combinations of independent variables representing different characteristics defining subgroups on a dependent variable (Mertler & Vannatta, 2010).

Connection of Study Design to the Research Questions

The research questions were driven by a review of neurocognitive research contributing to the understanding of language-based cognitive fitness. Language-based cognitive fitness was found to involve reception and expression of language as a multifaceted, interrelated, and multilevel taxonomic model supported by specific language acquisition processes (Allen, Bruss, & Damasio, 2004; Buehner et al., 2006; Colom, Jung, & Haier, 2007; Cowan et al., 2005; Gläscher, Rudraulf, et al., 2010; Gläscher, Tranel, et al., 2005; Hannaford, 1995; Jung & Haier, 2007; Levine, 2002; Luria, 1973; Menzinich, 2001; Neubauer & Fink, 2009; Oberauer, et al., 2003; Inhelder & Piaget, 1958; Piaget, 1926; Salthouse, 2005; Semrud-Clikeman, 2005; Turken et al., 2005; Vygotsky, 1929). The goal of this study was to empirically test models of language-based cognitive fitness with an existing data set. The working model integrated abilities associated with language process into four taxonomical structures.

The review of neurocognitive research indicated that modeling techniques have been used by researchers to understand language and cognition. For example, Vogt and Haasdijk (2010) modeled social learning of language and skills. Other researchers testing models included Moore (2007) who sought to explain the motivation for human spoken language by modeling behavioral mechanisms underlying language processing, Ottem (2002) who used the Illinois Test of Psycholinguistic Abilities (ITPA) protocol for validating language impairment concluding that language impairment was due to constraints on an individual's information processing effort, Woodrow (2006) who developed a model of language learning with motivation, self-efficacy, anxiety, and language learning strategies as key model constructs; and, van der Velde (2005) who defined a model of constraints consistent with Khul's (2010) concept of gating native sounds as key to guiding an individual's development of language.

The study design supported two primary questions: First, using structural equation modeling does an empirical model of language-based cognitive fitness based on a model derived from the theoretical and applied literature, fit the data? Second, can children of differing cognitive abilities (normal achievement, below grade achievement, and gifted achievement) be discriminated based on their scores on variables associated with a language-based cognitive fitness model?

This design choice was also consistent with research designs needed to advance knowledge in the field of cognition. Researchers have modeled isolated components of language consistent with a reductionist approach using the scientific model (Moore, 2007). Yet, there was a need and an opportunity to understand how these numerous components could act together to form language-based cognition. One of the purposes of this study was to connect these isolated pockets of research into a unified model.

Target Population, Sample, and Sampling Procedures

The target population for this study included students attending private schools between the ages of 6 and 19 years who represent the spectrum of challenged, average, and gifted achievement for their ages. The participants providing data were from a K-12 private school. Ethnic and religious backgrounds of students included North American, Caucasian, European, African-Canadian, Indian, Trinidadian, Israeli, Muslim, Hindu, Catholic, and Protestant.

Testing for ability and achievement is required for all students attending this school at point of entry and at the end of each academic year. The purpose of this testing is to establish entry levels of academic achievement and neurocognitive profiles of strengths and weaknesses; this allows for tailored academic programming fit to the needs of individual students. Testing then occurs at the end of each academic year to track progress yearly on the same dimensions. All tests are administered by the school's educators to students as part of normal administrative process. Parents are informed in person of the test results and provided a proposed action plan for responding to test results that include programming to build both brain fitness and academic progress. The students receive feedback on their performance so they understand why specific brain-based fitness and academic programs are important for their development. The school teachers receive the test results so intervention requirements are specifically understood and academic accommodations can be planned. At the end of each year students incorporate their test results into a reflective essay designed to help students understand their progress over the year. Data from all students at this private school were considered for inclusion in the study; approximately 178 students have attended the school on a full time basis.

Sample Size Analysis

SEM uses covariance matrices in modeling which requires larger sample size (Tabachnick & Fidell, 2007). Cases for lower sample sizes include models in which parameter estimates are expected to be strong and for which reliable data are available; these models can have as few as 60 participants (Bentler & Yuan, 1999). G*Power 3.1.4 was used to determine sample size. An effect size of 0.3 was used, degrees of freedom = 16 (17 variables -1), and a $\beta/\alpha = 1$. With these three values, a total sample size of 140 was required to achieve a power of at least .80 with a critical value for χ^2=20.62 (Faul, Erdfelder, Lang, & Buchner, 2007). Post hoc power achieved for an effect size of 0.3, a sample size of 161, and three factor variables (two degrees of freedom) equated to .94.

Procedures for Recruitment and Data Collection

Secondary data was made available by the private school using an excel spreadsheet containing scores on the 17 independent and two dependent variables and alternate measures (as defined in table 3.1) for 16 variables from the verification study of up to 30 students; age was included as a covariate. Informed consent of the original data collection has been included as part of the school's administrative procedures. Permission to use this data for the purposes of research was obtained by the school as part of the yearly student registration process. Data are collected when the student first registers and at the end of each academic year while attending the school.

Part 2: Operationalization of Study Variables

In this section the measures used to operationalize manifest indicators of the four principle latent variables – receptive language, expressive language, spontaneous narrative language, and writing fluency – are described. Key information provided for each measure includes:

a) The name of the instrument;.
b) The ability or attribute measured by the instrument;
c) Validity and reliability information; and
d) Score calculation and its meaning (in most cases the raw score is used and transformed into a percentage correct to standardize measures among variables; the exceptions are the Reading For Understanding (RFU) and Reading Comprehension SMaRts (RC SMaRts) tests for which a level and percentage correct are assigned).

In terms of validity, the emphasis on concurrent validity refers to the extent the test is testing what is wanted to be measured as already measured by other tests.

Correlation with other tests is used as a marker for this purpose. Moderate correlations are expected when there are differences in item format and specific content (Connolly, 2000). Reliability measures refer to the consistency of scores obtained from repeated testing of a student with a same or similar test (Connolly, 2000). Some evidence was found in the technical manuals of tests, while other evidence was found because there was use of the test protocol in other publications. Where evidence was found through other publications and these publications did not reference specific validity and reliablity metrics it was not assumed that the researcher's use of the protocol had been validated.

Operationalization of Constructs

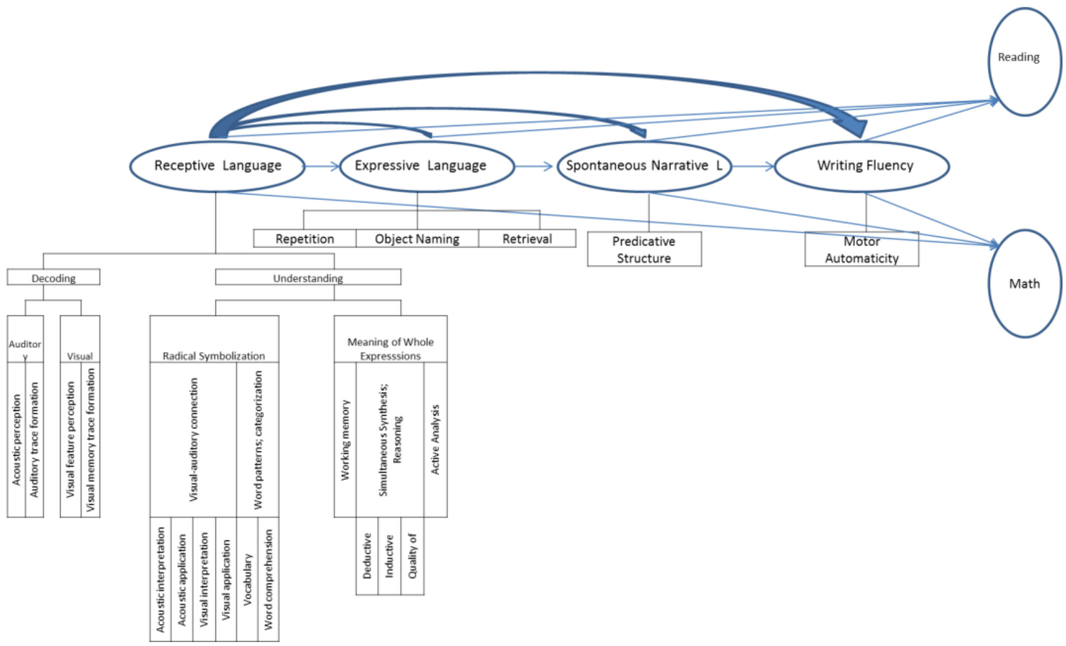
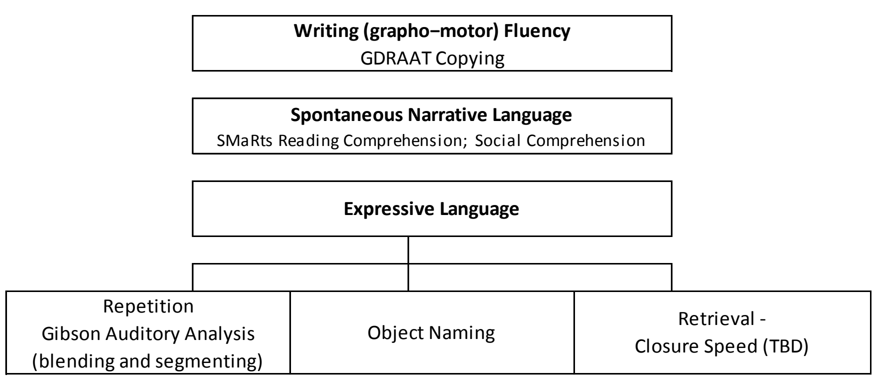


Figure 6. The Four Component Model of Language-based Cognitive Fitness without variable measures



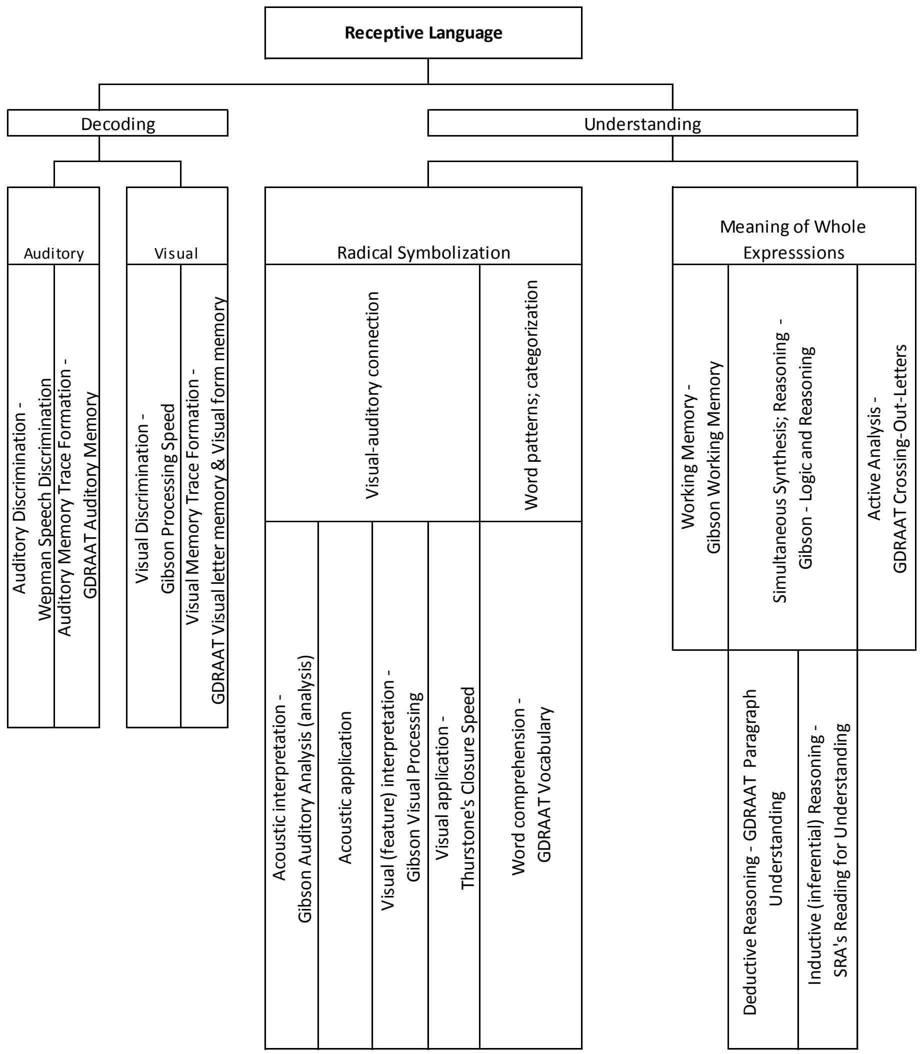


Figure 7. The Four Component Hierarchical Model of Language-based Cognitive Fitness with variable measures

Receptive Language: Decoding (Four Measures)

Wepman Auditory Discrimination Test. The *Wepman Auditory Discrimination* Test (ADT) measures an individual's ability to hear same or different sounds. It is a valid and reliable screening test for auditory sound discrimination. Criterion-based validity metrics range from .74, p<.001 when correlated with the Schlanger and Galanowsky (1966) Nonsense Syllable Sound Discrimination test, to .87, p<.001 when correlated with Kimmell and Wahl (1969) Screening Test of Auditory Processes (Wepman, 1977). Test retest reliability is reported by Wepman (1977) to range across ages between .88 through .96. The Wepman Auditory Discrimination Test (ADT) is used as a test for the assessment of children's ability to discriminate between commonly used phonemes in the English language (Pannbacker & Middleton, 2004). Weiner (1967) theorizes that test items contain sounds more severely affected individuals misarticulate making the test item errors relevant to that individual's misarticulation. The test was administered using a pre-recorded list of 40 word pairs presenting two separate sound blends in sequence; the individual being tested determined if the sound blends were same or different (Wepman & Reynolds, 1973). The total score calculated was the number correct pairs of the 40 word pairs presented; transformed to a percent correct. Higher scores represented higher ability.

GDRAAT *Auditory Letter Memory* subtest. The Group Diagnostic Reading Aptitude and Achievement Tests (GDRAAT) Auditory Letter Memory subtest (Munroe

& Sherman, 1966) is used to measure auditory-based short term memory formation and recall. The GDRAAT battery is used as a screening device to assess reading achievement and aptitude. While this psychometric tool has been used by Lancee (2003, 2005) to validate advances in reading by students in a specific school board as a result of cognitive interventions there was limited proof of predictive validity. Given this measure was unvalidated additional procedures were used to provide evidence for validity of the measures (described later in this chapter). A series of cards read with random letters increased from two to seven over a series of 16 cards. For each card read the student was asked to write the letters in the order presented. The score was calculated by computing the number of correct recalls (out of a possible 16 total cards); transformed to a percent correct. Higher scores represented higher ability.

Gibson Cognitive Test Battery (GCTB) Processing subtest. The *Gibson Processing* subtest of the Gibson Cognitive Test Battery is designed to measure an individual's ability to search for matches of target symbols drawing upon short-term memory and visual discrimination abilities (Gibson, 1999). The Gibson Cognitive Test Battery (GCTB) is a screening device used to assess aptitude within the Processing and Cognitive Enhancement (PACE) program, a broadly available commercial intervention for children with reading difficulties. Publications in support of its validity and reliability were limited to commercial claims (http://www.processingskills.com/ps/02_step2.htm). Given these measures were unvalidated additional procedures were used to provide evidence for validity of the measures (described later in this chapter). The maximum score was 35. One point was assigned for every correctly labelled puzzle piece; the number correct transformed to a percent correct. Higher scores represented higher ability.

GDRAAT *Visual Letter Memory Test*. The GDRAAT Visual Letter Memory test is designed to measure an individual's ability to hold letters in a sequence given requiring short term memory formation and recall. While this psychometric tool has been used by Lancee (2003, 2005) to validate advances in reading by students in a specific school board as a result of cognitive interventions there was limited proof of predictive validity. Given this measure was unvalidated additional procedures were used to provide evidence for validity of the measures (described later in this chapter). A series of cards held up for five seconds presented random letters increasing from two to seven over a series of 18 cards. The individual observed the letters and once the card was placed down by the test administrator the examinee wrote out the letters in the order presented on the card. The score calculated was the number correct of 18 cards presented transformed to a percent correct. Higher scores represented higher ability.

GDRAAT *Visual Form Memory Test*. The GDRAAT Visual Form Memory test is designed to measure ability to hold rebuses (forms such as ◊, ⌂, Ọ that have no inherent meaning) in a sequence given and requiring short term memory formation and recall for forms. While this psychometric tool has been used by Lancee (2003, 2005) to validate advances in reading by students in a specific school board as a result of cognitive interventions there was limited proof of predictive validity. Given this measure was unvalidated additional procedures were used to provide evidence for validity of the measures (described later in this chapter). For the GDRAAT Visual Form Memory test a card was held up for 10 seconds that presented four random forms; the forms used increased in complexity over a series of four cards. The individual observed the forms and once the card was placed down by the examiner the individual was requested to write out the forms in the order presented. The score calculated was the number correct of 16 forms presented. Both scores for letter memory and form memory were added together and converted to an overall percent correct figure. Higher scores represented higher ability.

Receptive Language: Understanding – Radical Symbolization (Four Measures)

Understanding. There were four measures used to operationalize subcomponents of an individual's *understanding* involved in receptive language. The first measures were associated with visual-auditory connection (the creation of word meaning; the first step of radical symbolization) and the final measure was associated with broadened understanding of word patterns and categorization (the second part of radical symbolization).

Gibson Auditory Analysis (analysis subtest). Gibson's Auditory Analysis analysis subtest of the Gibson Cognitive Test Battery (GCTB) measures the individual's ability to *hear and analyze* speech sound within a spoken pattern (Gibson, 1999). The Gibson Test battery is a screening device used to assess aptitude in the Processing and Cognitive Enhancement (PACE) program; broadly available as a commercial intervention for children with reading difficulties (http://www.processingskills.com/ps/02_step2.htm). Given the limited research support for validity of the Gibson's Auditory Analysis additional procedures were used to provide evidence for validity of the measures (described later in this chapter). For the GCTB Auditory Analysis (analysis) subtest 10 auditory instructions were given sequentially; for instance, say /hot/ without the /h/ or say /plan/ without the /l/. The score calculated was the number correct of 10 auditory requests presented and transformed to percent correct. Higher scores represented higher ability.

Gibson Cognitive Test Battery (GCTB) Visual Processing. The GCTB Visual Processing subtest measures the ability to picture, manipulate, organize, comprehend, and think with visual information (Gibson, 1999). The GCTB is a screening device used to assess aptitude within the Processing and Cognitive Enhancement (PACE) program broadly available as a commercial intervention for children with reading difficulties (http://www.processingskills.com/ps/02_step2.htm). Given the limited research support additional procedures were used to provide evidence for validity of the measures (described later in this chapter). The examinee was presented with a series of puzzles on the left hand side of the page and the same puzzles dissembled to the right of each; the examinee identified and numbered the pieces within a two minute time limit. There were eight puzzles of increasing complexity presented for the examinee to identify and number. The score calculated was the number correct of 32 puzzle pieces presented transformed to percent correct. Higher scores represented higher ability.

Thurstone Closure Speed Test (TCST). The Thurstone Closure Speed Test (TCST) measures an individual's ability to visualize parts and wholes of pictures, to construct a gestalt from visual features, and *cloze* in on the name of an object (Thurstone & Jeffrey, 1984). Closure Speed presupposes ability with visual processing. Researchers such as Crawford (1981) have used the TCST to measure the relationship between hypnotic susceptibility and scores on gestalt closure tasks. While this psychometric tool has been used by Crawford (1981) there was limited proof of predictive validity. Given this measure was unvalidated additional procedures were used to provide evidence for validity of the measures (described later in this chapter). The examinee was presented with a series of incomplete pictures and requested to identify them within a three minute time limit. There were 24 incomplete pictures presented for the examinee to identify. The score calculated was the number correct of 24 auditory requests presented transformed to percent correct. Higher scores represented higher ability.

GDRAAT Vocabulary. The GDRAAT Vocabulary subtest measures the individual's word knowledge and ability to understand word relationships demonstrated by correct pairing of words. While this psychometric tool has been used by Lancee

(2003, 2005) to validate advances in reading by students as a result of cognitive interventions, there was limited proof of predictive validity. Given this measure was unvalidated, additional procedures were used to provide evidence for validity of the measures (described later in this chapter). In the GDRAAT Vocabulary subtest the examinee was verbally presented with word pairs from which the most correct word pair was selected. During the GDRAAT Vocabulary subtest the examiner read 28 sets of three word pairs (for example, /*ball rolls*/ /*ball bats*/ /*ball jumps*/*)* with the individual identifying the pair that made the most sense. The correctly identified word pairs were tallied and transformed into percent correct. Higher scores represented higher ability.

Receptive Language: Understanding – Meaning of Whole Expressions (Four Measures)

Beyond radical symbolization of individual words and word pairs an understanding of whole expressions is important. Once words have meaning in the context of word pairs then an understanding of the meaning of phrases, paragraphs, and passages is possible that involve increasingly abstract concepts. The foundational abilities needed to support understanding of whole expressions and more abstract (symbolic) thinking include *working memory* (involving the holding of information for review), *reasoning* (Luria's simultaneous synthesis) involving the formation of schemas or propositions, and *active analysis* (Luria, 1973) involving *intentional* acts of reasoning for purpose of reconstitution (Bronowski, 1977).

Meaning of Whole Expressions - Working Memory. The Gibson Working Memory subtest measures the ability to store, retain, and retrieve information using auditory and visual stimuli (Gibson, 1999). The Gibson test battery is a screening device used to assess aptitude within the Processing and Cognitive Enhancement (PACE) program broadly available as a commercial intervention for children with reading difficulties (http://www.processingskills.com/ps/02_step2.htm). Given the limited research support, additional procedures were used to provide evidence for validity of the measures (described later in this chapter). The Gibson Working Memory subtest presented 12 verbal and visual stimuli by the examiner. For example, the examiner presented "The ball picture" or say "Steve went to the store with his father to buy a red flashlight". Two questions would follow about the picture and the statement. This process would continue as more information was given. The individual was asked questions on any of the information presented. The combined points were tallied and converted to percentage correct. Higher scores represented higher ability.

Meaning of Whole Expressions – Reasoning. Reasoning is measured in this study using four measures including the GDRAAT Paragraph Understanding, WRMT-R Passage Comprehension, Reading for Understanding (RFU), and the Munzert IQ Test.

GDRAAT Paragraph Understanding. The GDRAAT Paragraph Understanding test measures more literal understanding of paragraph content. While this psychometric tool has been used by Lancee (2003, 2005) to validate advances in reading by students as a result of cognitive interventions there was limited proof of predictive validity. Given this measure was unvalidated, additional procedures were used to provide evidence for validity of the measures (described later in this chapter). The examinee was presented with a series of paragraphs; each paragraph increasing in level of reading difficulty . The individual was instructed to read the question, read the paragraph, re-read the question, then choose the answer from the multiple choice set of answer options. The individual was given five minutes to complete as many questions as possible. The number correct were tallied and converted to percent correct. Higher scores represented higher ability.

Reading for Understanding. The Reading for Understanding (RFU) test measures inferential understanding of paragraph content (Kemp, 1982). This measure was unvalidated and additional procedures were used to provide evidence for validity of the measures (described later in this chapter). The examinee was presented with a series of 10 paragraphs per grade level with each set of 10 paragraphs increasing in content difficulty. The individual was instructed to read the question, read the paragraph, re-read the question, then choose the answer from the multiple choice set of answer options. The questions in this test were inferential; an individual needed to surmise the answer. The individual was not given a time limit. The number correct were tallied and converted to percent correct for each level. Higher scores represented higher ability.

Visual Logic and Reasoning. The GCTB Logic and Reasoning subtest measures the ability to reason and solve spatially defined problems which require high level conceptual abilities using visual stimuli (Gibson, 1999). The Gibson test battery is a screening device used to assess aptitude within the Processing and Cognitive Enhancement (PACE) program broadly available as a commercial intervention for children with reading difficulties (http://www.processingskills.com/ps/02_step2.htm). Given the limited research support, additional procedures were used to provide evidence for validity of the measures (described later in this chapter). The Gibson Logic and Reasoning subtest presented 17 visual stimuli by the examiner. For example, the examiner presented a series of matrices with missing information. The examinee would pick options from offered options to complete the matrix. The combined points were tallied and converted to percentage correct. Higher scores represented higher ability.

GDRAAT Crossing-Out-Letters. The GDRAAT Crossing-Out-Letters test measures the individual's ability to selectively attend to task, discriminate the target symbol, and check for accuracy. While this psychometric tool has been used by Lancee (2003, 2005) to validate advances in reading by students as a result of cognitive interventions there was limited proof of predictive validity. Given this measure was unvalidated, additional procedures were used to provide evidence for validity of the measures (described later in this chapter). The individual was required to find the letter /*a*/ in every other word in a passage of nonsense words and to strike out all instances as quickly as possible within a 90 second time limit. The number of correct answers was tallied and transformed into a percent correct. Higher scores represented higher ability.

Expressive Language (Two Measures)

Expressive language is the second component of the four component model of language-based cognitive fitness. Expressive language involved coding of inner thoughts into verbal speech and involves three abilities: repeating back words exactly as heard, object naming, and name retrieval.

Gibson Auditory Analysis (blending and segmenting). The Gibson Auditory Analysis blending and segmenting subtests measure the ability to repeat back exactly what has been heard (Gibson, 1999). The Gibson test battery is a screening device used to assess aptitude within the Processing and Cognitive Enhancement (PACE) program broadly available as a commercial intervention for children with reading difficulties (http://www.processingskills.com/ps/02_step2.htm). Given the limited research support additional procedures were used to provide evidence for validity of the measures (described later in this chapter). The Gibson Auditory Analysis blending subtest presented 10 regular and nonsense words verbally by the examiner. For example, if the examiner said /d/ – /a/ the individual would be required to repeat back the blended sound /da/. For the Gibson Auditory Analysis segmenting subtest eight regular and nonsense words were verbalized by the examiner and the individual was requested to segment the words into their sounds with each sound awarded a point. The combined points were tallied and converted to percentage correct. Higher scores represented higher ability.

Thurstone Closure Speed Test (TCST). Closure Speed is being used for measuring applied visual decoding. The Thurstone Closure Speed Test (TCST) measures an individual's ability to visualize parts and wholes of pictures, to construct images, and, to apply visual features to close in on object names (Thurstone & Jeffrey, 1984). Closure Speed presupposes ability with visual processing. Researchers such as Crawford (1981) have used the TCST to measure the relationship between hypnotic susceptibility and scores on gestalt closure tasks. Given the limited research support additional procedures were used to provide evidence for validity of the measures (described later in this chapter). The examinee was presented with a series of incomplete pictures and requested to identify them within a three minute time limit. There were 24 incomplete pictures presented for the examinee to rapidly name. The score calculated was the number correct of 24 auditory requests presented, which was then transformed to percentage correct. Higher scores represented higher ability.

Spontaneous Narrative (speech fluency) Language (Two Measures)

Spontaneous narrative (speech fluency) language is the third component of the four component model involving the ability to organize and plan thoughts into predicative structure and with ease of expression (Buchsbaum et al., 2011). Two measures were used to assess speech fluency.

Reading Comprehension SMaRts (RC SMaRts) Test. The RC SMaRts Test is designed to measure the individual's ability to synthesize a main idea from a paragraph and organize and plan a verbal response. The RC SMaRts Test is a locally developed test and thus did not have reliability and validity support from the literature. Procedures described in the analysis section were used to ascertain validity. Paragraphs referenced to grade level were presented to the individual both visually (a paper document to be read) and audibly (listening to recordings). The individual read along as s/he listened to the paragraph being read. The examiner then prompted the individual to articulate the main idea. The examiner wrote out verbatim what was expressed by the examinee. The results were scored based on criterion answers with each of the 10 paragraphs in each grade level marked out of 10. Each grade level was summarized to a number out of 100 and expressed as a percentage. Higher scores represented higher ability.

Social SMaRts Test. The Social SMaRts Test was developed to measure verbal production of social awareness. Social SMaRts tests the individual's ability to critically evaluate a picture of a social situation, plan a response, organize inner speech, and then verbalize this response. Because the Social SMaRts test is an in house developed test and not demonstrated in the literature as valid and reliable there were procedures used (described in the analysis section) to add evidence for validity. Each response was graded out of 10 using a scoring template. The story was marked based on its connection to the clues, emotions, and its realistic plausibility. The individual was presented with 10 still pictures, one at a time, and was instructed to take time to look for clues and when ready requested to describe what was happening in the picture. Each story was graded out of 10. A cumulative score from the 10 pictures was converted to percent correct. Higher scores represented higher ability.

Writing Fluency

GDRAAT Copying Test. The GDRAAT Copying Test measures an individual's ease of handwriting. While this psychometric tool has been used by Lancee (2003, 2005) to validate advances in reading by students as a result of cognitive interventions, there was limited proof of predictive validity. Given this, additional procedures were used to provide evidence for validity of the measures (described later in this chapter). The individual was given a paragraph and requested to copy it as fast as s/he can within a one and one half minute time limit. The number correct of 59 words written was calculated and then transformed to percent correct. Higher scores represented higher ability.

Dependent Variables

One dependent variable was created to represent achievement from two dependent measures: The two primary dependent measures express classroom achievement in both reading and mathematics. The two dependent measures express classroom achievement in both reading and mathematics. The Woodcock Reading Mastery (WRMT-R) and Key Math (KMT-R) test protocols are widely accepted in psychoeducational circles with strong proof of validity (Murray-Ward, 2012) and reliability (Beck, 2012). The number of correct answers was calculated and then transformed to percent correct. Higher scores represent higher ability. These two composite measures were combined by averaging the resulting total scores.

WRMT-R is an individually administered test that is recognized for its psychometric qualities and its broad testing range for ages 5.6 years to college years (Prasse, Siewert, & Breen, 1983). The strengths of the WRMT-R are its uses for reading assessment and placement (Caskey, 1986; Prasse, Siewert, & Breen, 1983; Woodcock, 1998). The validity of WRMT-R has been demonstrated; significant correlations with the Woodcock Johnson have ranged from .88 to.91. Total test reliability coefficients ranged from .86 to .97 for people in the age range of first grade adulthood (Woodcock, 1998). The individual was presented with various subtests for letter, word, passage reading, and comprehension. The total number of correct answers was tallied and converted to percent correct. Higher scores represented higher ability.

The KeyMath Test-Revised (KMT-R) Diagnostic Inventory of Essential Mathematics test instrument is a test battery designed to measure mathematics achievement across 13 dimensions of mathematics and is widely used for educational and research purposes (Connolly, 2000). The content of Key Math is based on the recommendations of the National Council of Teachers for Mathematics (NCTM) and viewed by the psychometric community as having strong validity and reliability (Beck, 2012; Finley, 2012). The KMT-R diagnostic assessment is an individually administered test that can inform the design of individual student intervention programs and monitor performance over time for grade K to nine (Beck, 2012). Correlation between KeyMath Test-R (KMT-R) and Comprehensive Tests of Basic Skills (CTBS) was .66 in one study (Connolly, 2000) and .76 between KeyMath Test-R (KMT-R) and the Iowa Tests of Basic Skills (ITBS); split half reliability correlations range from .91 to.98 for fall testing and from .95 to .99 for spring testing (Connolly, 2000). The individual was presented with visual and verbal questions and instructed to answer. The total number of correct responses was tallied and converted to percent correct. Higher scores represented higher ability.

The third dependent variable was cognitive profile. Discriminant analysis was the statistical technique used to determine the existence of more than one population profile. The process employed is described in the data analysis plan.

Validity Variables

A validation study was designed to provide further evidence of concurrent validity of test measures in the main study that were not validated in the research community. Working with representatives of Pearson (www.psychcorp.ca), a list was established of other test instruments available that would fit the needs of this study for those measures with limited or no verification of validity. The variables for the validation study were drawn from the Weschler Intelligence Test for Children (WISC-IV) and the Kauffman ABC (KABC-II) test batteries designed to measure aspects of intelligence age three-18; the NEPSY-II, which was designed to study the neurological development of individuals age three to age 16; the Process Assessment of the Learner (PAL-II), which was designed as a reading and writing diagnostic assessment tool used with children between 6 and 12 years; and the Weschler Individual Aptitude Test (WIAT-II), which was designed to measure aspects of language for between the ages of 4 and 50 years. These test protocols all had strong validity and reliability metrics and as such were appropriate for use. The specific subtests have been chosen based on fit to desired measure; and, to provide a test for proof of concurrent validity of test measures used by the school that are not proven to be valid or reliable.

Table 1

Alternate Measures for Unvalidated Measures within the Four Component Model

Concept	Measure	New Measure(s)
1.Auditory memory trace formation	GDRAAT ST Memory (auditory)	WISC Digit Span Forward (auditory)
2.Visual feature perception	Gibson Processing Speed	WISC Symbol Search
3.Visual memory trace formation	GDRAAT ST Visual Letter and Form Memory (combined)	NEPSY-II Memory for Designs/delayed NEPSY-II Design Copying
4.Auditory acoustic interpretation	Gibson Auditory Analysis (analysis)	PAL-II Phonological Coding; rimes
5.Visual (feature) interpretation	Gibson – Visual Processing	WISC Block Design NEPSY-II Geometric Puzzles
6.Application of visual (featural) information	Closure Speed (Gestalt)	WISC Picture Completion NEPSY-II Picture

7.Word Relationships	GDRAAT – Vocabulary	Puzzles KABC-II Gestalt Closure WISC-IV Picture Concepts PAL-II Are They Related?
8. Whole Expressions: Working Memory	Gibson – Working Memory	WISC-IV – Letter Number Sequencing
9.Whole Expressions: Reasoning (deductive)	GDRAAT – Paragraph Understanding	WIAT-III Reading Comprehension (literal indicators)
10. Whole Expressions: Reasoning (inferential)	SRA - Reading For Understanding	WISC-IV Word Reasoning
11. Whole Expressions: Reasoning	Gibson – Logic and Reasoning	WISC IV – Matrix Reasoning
12. Whole Expressions: Active Analysis	GDRAAT Crossing-Out-Letters	WISC-IV Cancellation WISC-IV Coding
13. Expressive Language: Repetition	Gibson - Auditory Analysis – blending and segmenting	NEPSY-II Repetition of nonsense words;
14. Spontaneous Narrative Expression: Main Idea	RC SMaRts	WISC IV - Similarities WIAT-III; Written Expression (Sentence Combination applied by someone scribing)
15. Spontaneous Narrative Expression: Social	Social SMaRts	WISC IV - Comprehension NEPSY-II Social Perception (Affect Recognition and Theory of Mind)
16. Writing Fluency	GDRAAT – Copying	PAL-II Copy B at the 90 sec interval

Note. Only measures that will be validated are reported in the table.

Alternate Measures for Receptive Language (Measures one to 12)

Auditory memory trace formation. The GDRAAT Short Term Auditory memory subtest was correlated to WISC's Digital Span Forward (auditory) subtest. The WISC Digit Span Forward has been validated against the Wechsler Individual Achievement Test (WIAT-II) (validity coefficient equal to .45), and test retest-reliability coefficients of .85 have been found (WISC-IV, 2003). Both tests required the individual to listen to a list of letters and immediately recall them. The number of letters to be recalled by the individual increases with each stimulus presented. The number correct of responses were tallied and transformed to percent correct. Higher scores represent higher ability.

Visual discrimination. Gibson's (GCTB) Processing Speed subtest requires the individual to distinguish two of the same in a line-up of letters and numbers. The alternate test was the WISC Symbol Search subtest. The WISC Symbol Search subtest was correlated with the Wechsler Individual Achievement Test (WIAT-II) (r = .28); test-retest coefficients of .77 determined (WISC-IV, 2003). The WISC Symbol Search subtest required the individual to distinguish target symbols within a series of symbols tapping in on cognitive flexibility, visual discrimination, and concentration (Pearson, 2003). The number correct of responses were tallied and transformed to percent correct. Higher scores represented higher ability.

Visual memory trace formation. The GDRAAT Short Term Memory for letter and form subtests require the individual to observe and then recall a series of letters and forms presented visually. Alternate tests involved the NEPSY-II Memory for Designs with/without Delay and NEPSY-II Design Copying.

Validity and reliability of the NEPSY-II Memory for Designs with/without Delay subtest is supported by correlation metrics .20 with the WISC-IV Picture Concepts subtest; test-retest reliability was found to be .60 (NEPSY-II, 2007). The NEPSY-II Memory for Designs/Delayed is designed to assess spatial memory for novel visual material. The individual is shown a grid with four to ten designs on a page which is then removed from view; the individual selects the designs from a set of cards placing the cards on a grid reproducing the original grid pattern. The number correct of responses are tallied and transformed to percent correct. Higher scores represent higher ability.

Validity and reliability of the NEPSY-II Design Copying subtest has been supported. This test was correlated with the WISC-IV Block Design subtest; test-retest reliability coefficient was .74 (NEPSY-II, 2007). The NEPSY-II Design Copying is designed to assess motor and visual-perceptual abilities specific to copying. The individual copies figures presented. The number correct of responses are tallied and transformed to percent correct. Higher scores represent higher ability.

Acoustic interpretation. Acoustic interpretation is measured by the Gibson Auditory Analysis subtest and used in the study to measure the individual's ability to analyse speech sound within a given spoken pattern. The Gibson (GCBT) Auditory Analysis subtest requires the individuals to remove parts of a word; reconstructing the word. The alternate test is the PAL-II Phonological Coding subtests for Rimes. Validity and reliability of the PAL-II Phonological Coding subtest is supported by correlation with the NEPSY-II Phonological Processing subtests; test retest reliability metrics equate to .77-.85 (PAL-II, 2007). The PAL-II Phonological Coding subtests require repetition and reconstruction of nonsense words according to directions given. The number of correct responses are tallied and transformed to percent correct. Higher scores represent higher ability.

Visual interpretation. Visual *interpretation* is measured by the Gibson (GCTB) Visual Processing subtest and used in the study to measure the individual's ability to picture, manipulate, organize, comprehend, and think with visual information, known as visual perception and organization. Puzzles are disassembled and puzzles parts need to be labelled. Alternate tests include the WISC Block Design and the NEPSY-II Geometric Puzzles.

The WISC-IV Block Design subtest results was found to be correlated ($r = .59$) with the NEPSY-II Block Construction Test; test retest reliability metrics reported equate to .77-.84 (WISC-IV, 2003). The WISC Block Design requires the individual to construct a series of puzzle designs. The number correct of questions given to the individual are tallied and transformed to percent correct. Higher scores represent higher ability.

Validity and reliability of the NEPSY-II Geometric Puzzles subtest is supported by research showing correlations with the WISC-IV Block Design Test; test retest reliability metrics reported equate to .77-.84 (NEPSY-II, 2007). The NEPSY-II Geometric Puzzle subtest requires the individual to match two shapes outside a grid with shapes inside the grid. The number correct of questions given to the individual are tallied and transformed to percent correct. Higher scores represent higher ability.

Visual application. Alternate tests for Thurston's Closure Speed include the WISC-IV Picture Completion subtest, the NEPSY-II Picture Puzzles subtest, and the KABC-II Gestalt Closure subtest. Validity and reliability of the WISC-IV Picture Completion subtest is supported by correlation with the WIAT-II Reading Comprehension subtest; test retest reliability coefficient equal to .82 has been reported (WISC-IV, 2003). The WISC Picture Completion subtest requires the individual to identify the missing aspect of the picture. The number correct of questions given to the individual will be tallied and transformed to percent correct. Higher scores represent higher ability.

The NEPSY-II Picture Puzzles subtest has been shown to be correlated with the WISC-IV Block Design subtest; test-retest reliability was reported to be .89 (NEPSY-II, 2007). The NEPSY-II Picture Puzzles subtest divides a photo into a grid, places the smaller pieces beside the grid requiring the individual to identify the location of the pieces on the large picture. The number correct of questions given to the individual will be tallied and transformed to percent correct. Higher scores represent higher ability.

The KABC-II Gestalt Closure subtest was shown to be correlated with the WISC Perceptual Reasoning Index; test-retest reliability was reported to be .74 for ages three to 18 years (KABC-II, 2004). The KABC-II Gestalt Closure subtest measures the individual`s ability to fill in gaps of a partially completed inkblot drawing and names (or describes) the object of action depicted in the drawing. The number correct of questions given to the individual will be tallied and transformed to percent correct. Higher scores represent higher ability.

Word categorization. Alternate tests include the WISC-IV Picture Concepts and the PAL-II Morphological *Are they Related*? subtests. The WISC-IV Picture Concepts subtest is correlated with the WIAT-II total achievement; test-retest reliability was reported to be .62 (WISC-IV, 2003). The WISC Picture Concepts subtest requires the individual to find a similar theme within two or three rows of pictures, measuring abstract categorical thinking. The number correct of questions given to the individual will be tallied and transformed to percent correct. Higher scores represent higher ability.

Validity and reliability of the PAL-II Morphological *Are they related*? subtest has been found to be correlated with the NEPSY-II Phonological Processing subtest; the test retest reliability coefficient was reported to be .88 (PAL-II, 2007). This subtest requires the individual to determine if a word pair is related or not. In each test the number correct of questions given to the individual is tallied and transformed to percent correct. The number correct of questions given to the individual will be tallied and transformed to percent correct. Higher scores represent higher ability.

Inductive reasoning. Inductive reasoning is measured by the Scientific Research Associates (SRA) Reading for Understanding (RFU) test. The individual reads the paragraph and answers inferential questions. For example a paragraph could read: /The door was locked and I wanted to open it. So I would need a,…. [a door knob], [a hinge], [a key]/. An alternate test for the SRA RFU is the WISC Word Reasoning subtest. Validity and reliability of the WISC-IV Word Reasoning subtest has been demonstrated in the research. Correlations of .53 with the WIAT-II Reading Comprehension subtest have been found; test-retest reliability coefficients have ranged from .76 to .88 (WISC-IV, 2003). The WISC Word Reasoning subtest presents clues to the individual in a riddle format requiring the individual to infer what the word might be. The number of correct responses are tallied and transformed to percent correct. Higher scores represent higher ability.

Deductive and inductive reasoning can also be measured by the Gibson Logic and Reasoning subtest. The Gibson Logic and Reasoning subtest requires an individual to pick and answer from options that complete a matrix. An alternate test for the Gibson Logic and Reasoning subtest is the WISC Matrix Reasoning Test. Validity and reliability of the WISC-IV Matrix Reasoning subtest has been supported; correlations of .59 have been determined with the WIAT-III Math Reasoning subtest. Test-retest reliability coefficients ranging from .77 to .92 have been found (WISC-IV, 2003). The WISC-IV Matrix Reasoning subtest requires the individual to pick an answer from options to fill in a missing piece of the matrix.

Active analysis. Active analysis is the purposeful active sustained attention, active monitoring of progress, and active self-correction associated with executive functioning. In this study active analysis is measured by the GDRAAT Crossing-out-letters requiring the individual to search for the letter /a/ in nonsense words, stroke it out, and proceed as quickly as possible. Alternate tests include the WISC Cancellation and the WISC Coding subtests.

Validity and reliability of the WISC-IV Cancellation subtest has been supported in the literature; correlations with the WIAT-III Reading Comprehension subtest of .18 have been found. Test-retest reliability coefficients range from .71 to .86 (WISC-IV, 2003). The WISC Cancellation subtest requires the individual to draw a line through a pre-identified stimulus under time pressure. The number of correct responses are tallied and transformed to percent correct. Validity and reliability of the WISC-IV Coding subtest has also been supported through correlation with the WIAT-III Written Expression subtest. Test-retest reliability coefficients of .87 have been demonstrated (WISC-IV, 2003). The WISC Coding subtest presents a *key* for associating shapes with numbers; and, the individual is required to mark down the shape that is associated with a number for series of numbers and under time pressure. The number of correct responses are tallied and transformed to percent correct. Higher scores represent higher ability.

Alternate Measures for Expressive Language (Measure 13)

Repetition. Repetition is the individual's ability to repeat back exactly what has been heard. In this study repetition is measured by the Gibson (GCTB) Auditory Analysis subtest and specifically blending and segmenting subtests. The alternate test (though in a slightly different format) is the NEPSY-II Repetition of Nonsense Words. Validity and reliability of the NEPSY-II Repetition of Nonsense Words subtest has been demonstrated through its correlation with the WISC-IV Letter-Number Sequencing (working memory) subtest. Test-retest reliability has been reported to be .80 (NEPSY-II, 2007). The NEPSY-II Repetition of Nonsense Words subtest requires the individual to repeat nonsense words verbally presented. The number of correct responses are tallied and transformed to percent correct. Higher scores represent higher ability.

Alternate Measures for Spontaneous Narrative (speech) Language (Measures 14 and 15)

Reading comprehension (RC SMaRts). Alternate tests (though in a different format) included the WISC-IV Similarities subtest and the WIAT-III Written Expression Sentence Combination subtest. Validity and reliability of the WISC Similarities subtest was demonstrated through its correlation with the WIAT-II Word Reasoning. Test-retest reliability coefficient was reported to be .83 (WISC-IV, 2003). The WISC Similarities subtest is designed to measure verbal reasoning and concept formation, measure the ability to distinguish between nonessential and essential features, and measure verbal expression. The individual was required to explain the source of the similarity between two items on a list given. The number of correct responses were tallied and transformed to percent correct. Higher scores represented higher ability.

Validity and reliability of the WIAT-III Written Expression Sentence Combination subtest also had support in the research literature through its correlation with the Wechsler Fundamentals Test. Reliability coefficients ranged between .83 and .96 across grades pre-kindergarten to 12 (WIAT-III, 2009). The WIAT-III Written Expression Sentence Combination subtest required the individual to combine (synthesize) two sentences into one sentence measuring ability to distinguish between nonessential and essential features and synthesizing information. The number of correct responses were tallied and transformed to percent correct. Higher scores represented higher ability.

Social comprehension (Social SMaRts). Alternate tests (though in a different format) include the NEPSY-II Social Perception Affect Recognition and Theory of Mind subtests, and the WISC Comprehension Test. Validity and reliability of the NEPSY-II Social Perception Affect Recognition and Theory of Mind subtests have been demonstrated through a correlation with the WISC-IV Comprehension subtest. Test-retest reliability coefficient of .58 was demonstrated (NEPSY-II, 2007). The NEPSY-II

Social Perception subtest measures the individual's ability to recognize affect from photos of faces. The NEPSY-II Theory of Mind subtests measure the individual's ability to infer beliefs, emotions, imagination, desires, deception, and intentions, in social context. The number of correct responses were tallied and transformed to percent correct. Higher scores represented higher ability.

Validity and reliability of the WISC-IV Comprehension subtest has been supported through its correlation with the WIAT-III Listening Comprehension subtest. Test-retest reliability coefficients range from .78 to .86 (WISC-IV, 2003). The WISC-IV Comprehension subtest measures the individual's knowledge of appropriate response to social situations and general cultural knowledge. The number of correct responses are tallied and transformed to percent correct. Higher scores represent higher ability.

Alternate Measures for Writing (Graphomotor) Fluency (Measure 16)

An alternate test is the PAL-II Handwriting Copy B (Paragraph Copying) subtests. Validity and reliability of the PAL-II Handwriting Copy B (Paragraph Copying) subtest has been supported by correlation with the NEPSY-II Design Copying subtest; test retest reliability metrics equating to .82 (PAL-II, 2007). Both tests required the individual to copy by printing out the sentence or paragraph under time constraints. PAL-II Copy B was measured at 90 seconds.

Covariate

Age was included as a covariate in this study consistent with other studies of cognition (Buehner, Krumm, Ziegler, & Pluecken, 2006; Salthouse, 2005).

Part 3: Data Analysis Plan

Research Questions and Analysis Phase Description

Research Question #1. Using structural equation modeling can an empirical model be designed that has good fit to the data that shows the constructs related to each other as theoretically expected?

Research Question #2. Can children of differing cognitive abilities (below grade (or challenged) achievement, within normal grade achievement, and gifted achievement) be discriminated among the variables associated with a language-based cognitive fitness model?

There were six phases to data analysis. These included: (a) Phase I, a validation study to provide evidence of validity for variables not demonstrated to be valid in the literature; (b) Phase II, data cleaning, screening, and preparation; (c) Phase III, exploratory factor analysis to determine the most parsimonious underlying structure of the constructs comprising the cognitive based language fitness model; (d) Phase IV, testing variations of the structural model of the four component proposed model; and (e)

Phase V, the use of discriminant analysis to determine whether children of differing cognitive abilities (normal achievement, below grade achievement, and gifted achievement) can be discriminated among the variables associated with a language-based cognitive fitness model:

Phase I: Validation Study

Variables involved in the validation study included 16 measures identified in Table 1. Thirty students between the ages 6 and 19 years enrolled with the private school were tested October and November 2012 with additional tests for purpose of establishing base-line measures for new tests the school was considering to include in their year end psychoeducational test battery. The testing included measures from The Weschler Intelligence Test for Children (WISC-IV), NEPSY-II a comprehensive instrument used to assess neuropsychological development, Kauffman Assessment Battery for Children (KABC-), the Weschler Individual Achievement Test (WIAT-III), and Process Assessment of the Learner Second Edition (PAL-II). Test scores from these valid and reliable test instruments deemed by research to be similar to the study variables were made available for this study. The objective of this step in analysis was to determine if there were statistically positive relationships between newly available valid and reliable measures and the study database measures for those variables with questionable (or no) evidence demonstrating validity or reliability. The tests were administered according to test protocol guidelines. Raw scores were used and transformed into percent correct.

Correlations between the variable of concern or interest and the alternate variables were completed and these results reported in chapter four. It was expected that there would be appropriate levels of correlation providing initial evidence supporting validity of the variables of concern.

Phase II: Data Cleaning and Preparation

The second step in data analysis was to examine the data and prepare it for use in factor analysis (FA), structural equation modeling (SEM), and discriminant analysis (DA). First, data accuracy was checked by examining descriptive statistics to ensure no cases had values outside the range of possible values. Missing data was examined for amount and pattern and potential effects on the results since nonrandom missing data can create problems with generalizability of the results (Tabachnick & Fidell, 2007). Extreme values (outliers) were identifed using the Mahalanobis distance (a chi-square statistic with degrees of freedom equal to the number of variables in the analysis) and then examined for data entry error, instrumentation error, or whether the subject was just different from the rest of the sample (Tabachnick & Fidell, 2007). There was no need to transform data to reduce the relative impact of legitimate extreme cases (Tabachnick & Fidell, 2007). If there were missing data options for missing data estimation included the deletion of the cases or variables that have created the problem, estimation of the missing value using prior knowledge or a well-educated estimation given other data for a given student, or, using the SPSS AMOS 19 software missing data imputation option

(Tabachnick & Fidell, 2007). Tabachnick and Fidell (2007) suggested that if missing values were estimated the SEM analysis should be conducted twice; the main analysis with missing values and repeat with imputed values. If the results were similar then there would be added confidence with the outcome, but if the results were dissimilar then one set of results would need to be chosen for better fit to real world representation. There was no need to estimate for missing data and no need to conduct SEM twice.

Normality, linearity, and heteroscedasticity of the variables were evaluated. The data was expected to be normally distributed demonstrating a linear relationship between standardized residual values and the predicted residual values on a given variable. Heterogeneity (variability) of scores for each continuous variable were expected to be roughly the same as assessed by Box's M test for equality of variance-covanriance matrices (Tabachnick & Fidell, 2007).

Phase III: Exploratory Factor Analysis

Next, an exploratory factor analysis was used to determine the most statistically parsimonious underlying structure that explained the 17 independent variables. Given this was an exploratory procedure the number of components retained for the model was determined using Kaiser's rule (factors retained for eigenvalues >1), a scree plot (a visual representation, in graphical form, of the Eigenvalues), and review of the number of factors needed to account for near 70% of total variability. While the use of Promax rotation with Kaiser Normalization was supported by theory (based on there being interrelationships), instead Varimax rotation was used to force orthogonality in order to better crystalize factor groupings (Mertler &Vannatta, 2010). Cronbach's alpha was used to measure the internal consistency of the factors with a goal of greater than 70% consistency of variables within a given factor. Parsimony was the overall goal (Horn, 1965; Mertler & Vannatta, 2010). A refined set of variables was then explored via SEM.

Phase IV: CFA using SEM Analysis

SEM analysis began using a model with fewer variables that represented broader measures. The study gradually incorporated the full four component model with all variable measures for the structural model. The relational model had Achievement as the dependent variable. Achievement was a variable created by averaging the WDCKtotal and KMtotal measurements (Burkholder & Harlow, 2003). Practical considerations included constraining those variables contained within the same test instrument and those tests administered in the same test session.

SPSS AMOS 21 was used to test structural equation models. AMOS provides a number of fit statistics that provide insight into overall fit between the model and theory. Structural equation modeling allows examination of intercorrelations among variables and whether they support fit to an underlying theory; this allowing identification of potential causal connections among the variables (Mertler & Vannatta, 2010; Tabachnick & Fiddell, 2007). The model fit indices of structural equation models were used to test which of the competing models had the best fit to the data (Tabachnick & Fiddell, 2007).

Model adequacy was determined by model fit. One component of a good model is the fit between the sample covariance matrix and the estimated population covariance matrix (Tabachnick & Fiddell, 2007). Because the goal was to develop a model that fits the data a nonsignificant chi square statistic (χ^2) was desired (Tabachnick & Fidel, 2007). An additional rule of thumb was the ratio of the χ^2 to the degrees of freedom;to be less than two for a good-fitting model (Tabachnick & Fidel, 2007).

Tabachnick and Fidel (2007) proposed that although the choice of indices to report is a matter of personal preference they identified the comparative fit index (CFI) and the root mean square error of approximation (RMSEA) as the most used indices. The CFI employs a noncentral χ^2 distribution with noncentrality parameters (Tabachnick & Fidel, 2007). A CFI greater than .95 is indicative of good-fitting models (Tabachnick & Fidel, 2007). The RMSEA estimates the lack of fit in a model compared to a perfect model (Tabachnick & Fidel, 2007). A RMSEA of .06 or less indicates a good-fitting model and values larger than .10 indicate a poor-fitting model (Tabachnick & Fidel, 2007).

For this study, the chi square test($\chi^2 < 2$), RMSEA ($< .10$) and CFI ($> .95$) fit indicators were used to assess model fit. Schreiber et al. (2006) proposed that after examination of parameter estimates, fit indexes, and residuals, there could be reason to conduct analysis of modified models to create a better fit or more parsimonious model. The modifications completed should make theoretical sense. These modifications would then need to be reported including the modification test used (e.g chi-square, Lagrange, or Wald), why it was used, and whether the modification made theoretical sense (Schreiber et al., 2006). In addition, if a model had been modified and reanalyzed evidence that the modified model was statistically superior to the original model with a chi-square test needed to be provided (Schreiber et al., 2006). This study followed these suggestions.

Because there is no empircal test to help a researcher understand the degree to which his/her model is reflective of reality I focused attention on the credibility, reasonableness, and utility of the proposed models. A model is credible when it is plausible to those expert in the field. The model is reasonable if it is in keeping with the context of the current research literature. The model has practical application if it is useful in predicting future events.

Part three of chapter two defined three plausible models as a result of a comprehensive literature review of foundational theories and current brain imaging research. It was expected one of these models or a modified version would be practical for predicting future events; demonstrating important indicators of language-based cognitive fitness helpful for assessment and design of interventions in aid of developing language-based cognitive fitness.

Phase V – Discriminant Analysis

Discriminant analysis addresses the second research question and used to test whether children of differing cognitive abilities (below grade achievement, normal achievement, and gifted achievement) can be discriminated among the variables associated with a language-based cognitive fitness model. Discriminant analysis involved four steps: (a) statistics describing group differences, (b) tests of significance and strength of relationship for each discriminant function, (c) discriminant function coefficients, and (d) group classification: First, an eigenvalue and percentage of variance explained were provided for each discriminant function. Second, a canonical correlation value measuring the correlations between the discriminant scores and *the levels of the dependent variable (DV)* were reported. A high canonical correlation value demonstrates a function that discriminates (classifies) well between subjects (Mertler & Vannatta, 2010). Third, a test of significance of each of the discriminant functions was done using Wilks' Lambda (Λ) and this significance tested using a chi-square criterion (Mertler & Vannatta, 2010). I looked for a significant chi-square indicating the function discriminates well, based on the levels of the DV. The question to be answered here was whether there was statistical support for classifying students according to different cognitive profiles.

Threats to Validity and Ethical Procedures

Threats to Validity

The potential threats to internal validity for this study were associated with answering the question whether there is a statistically valid model (Stanley & Campbell, 1969). There were three potential areas of concern (Cresswell, 2009; Stanley & Campbell, 1969): First, changes in examiners may produce changes in obtained measurements. Second, biases in the selection of participants may limit generalizability of results. And third, the specific instrumentation used to measure constructs may not be perfect representations (Cresswell, 2009; Stanley & Campbell, 1969). Specifically:

The impact of the first concern was expected to be minimal as examiners followed the test protocols as defined by their authors. It was recognized the sample used in this study was based on the convenience of a pre-existing database.

The second concern was valid. The school is a naturally formed group that could potentially predispose certain outcomes specific to individuals more likely to be affiliated with families who want private education.

The third concern was also valid. The secondary data is composed of test results using both valid and reliable variable measures and unvalidated inhouse developed and commercially developed tests hence steps will be taken to test construct validity.

The potential threats to external validity were threats to representativeness, or generalizability (Cresswell, 2009; Stanley & Campbell, 1969). The convenience of the sample being a naturally formed group is a form of selection bias which could potentially predispose certain outcomes specific to individuals more likely to be affiliated with families who want private education (Cresswell, 2009; Stanley & Campbell, 1969). As this is the case I appropriately restricted claims about the results and suggested additional studies (Cresswell, 2009; Stanley & Campbell, 1969).

Finally, it was recognized that even with an extensive literature review the specification of a hypothesized model is complicated by the vagueness of theoretical literature, the potentially infinite number of possible causal determinants, and the general complexity inherent in social science (Mertler & Vannatta, 2010). But, rather than being discouraged by the potential extensive list of sources for invalidity the emphasis of the study design was in keeping with Campbell and Stanley (1969) who pointed out the need to be cognizant of design flaws for purpose of increased awareness in study design and for increased accuracy in interpretation.

Ethical procedures

Protection of the participants was ensured by removing any identification information from the secondary data. The researcher could not link the data with the individual students. Students involved were not subjected to any additional testing that would not already be part of the normal educational process within the private school.

All information was kept secure on the researcher's computer to protect participant information.

Summary

This chapter defended the research design and rationale. Chapter three included a discussion on modeling and research methodologies specific to this study. This study was a correlational design appropriate for defining a model of language-based cognitive fitness using multiple continuous observed dependent and independent variables. SEM was the advanced modeling technique used given it is suitable for testing the proposed models, for exploratory modelling, and it has been widely used in modeling research (Burkholder, 2003; Salthouse, 2005; Shelton, et al. 2010; Oberauer et al., 2003; Gläscher, et al. 2009, 2010; Jung & Haier, 2007; Salthouse, 2005). Since the specific goal of the analysis was to test associations defining a theoretical model of language-based cognitive fitness structural equation modeling (SEM) was the recommended statistical technique for this kind of application (Tabachnick & Fiddell, 2007).

Part one introduced the study variables, included a defense of the research design and rationale, established the operational measures for variables to be included in the model, provided a connection of study design to the research questions and, defined the target population, sample, and sampling procedures. Part two was dedicated to the operationalization of the study variables for each of the four model components: receptive language, expressive language, spontaneous narrative language, and writing (graphomotor) fluency. Information was provided for what each variable measures, variable validity and reliability, how the associated test was administered, and how the test will be scored. Part three provided a description of the plans for data analysis. Part four provided a description of threats to study validity as well as ethical considerations. Chapter 4 will report on the results of the analysis.

Chapter 4: Results

Introduction

Chapter 4 includes results of the study. The chapter begins with the results of the validation study completed to provide support for the validity of 16 subtests used in the study that did not have sufficient published evidence of instrument validity. Data collection parameters and a description of the process of data screening and preparation are then presented. This is followed by the results of testing H_1 using exploratory factor analysis (EFA) to explore structural relationships among the tests and structural equation modeling (SEM) to confirm the hypothesized model. The testing of H_2 using discriminant analysis (DA) to determine whether there is evidence of linear combinations of the independent variables that best discriminate language-based cognitive ability is then reported. Answers to the research questions are then summarized.

Purpose and Problem

The purpose of the study was to develop and test a structural model of language. The review of the literature demonstrated fragmented understanding and knowledge of the components of language and their relationships. A holistic model that represents the structure of language is missing.

Research Questions

There were two primary research questions addressed in the study. The first question involves testing whether there was evidence for a theoretical model of language-based cognitive fitness using cognitive test data from a private school. The second involves understanding whether there are combinations of test scores that best discriminate among differing levels of cognitive ability in children.

Validation Study

A validation study was conducted to determine the validity of measures used in the study that that did not have sufficient published evidence of instrument validity. The results demonstrate statistically strong positive correlations; this supports use of each of the 16 variables selected for analysis. Table 2 summarizes the correlations among unvalidated and validated tests.

Table 2.

Correlations Between Tests in the Validation Study

Unvalidated Test Description	Validated Test Description	Correlation
GDRAAT Short Term Memory (Auditory)	WISC-IV Digit Span Forward	0.727**
Gibson Processing Speed	WISC-IV Symbol Search	.396*

GDRAAT Short Term Memory (Letter and Form subtests combined)	NEPSY-II Memory for Design Delayed	.685**
	WISC-IV Letter Number Sequence	.799**
Gibson - Auditory Analysis	PAL-II Rimes	.596**
Gibson - Visual Processing	WISC-IV Block Design	.604**
	NEPSY-II Geometric Puzzles	.399*
Closure Speed (Gestalt)	WISC-IV Picture Completion	.830**
	NEPSY-II Picture Puzzles	.665**
	KABC-II Gestalt	0.240
GDRAATVocabulary	WISC-IV Vocabulary	.785**
	WISC-IVPicture Concepts	.671**
	PAL-II Are They Related?	.538**
Gibson Working Memory	WISC-IV Letter Number Sequence	.730**
GDRAAT - Paragraph Understanding	WIAT-III Reading Comprehension	.689**
SRA Reading for Understanding	WISC-IV Word Reasoning	.549**
Gibson Logic & Reasoning	WISC-IV Matrix Reasoning	.718**
GDRAAT Crossing-out-letters	WISC-IV Coding	0.236
	WISC-IV Cancellation	0.149

Gibson Auditory Analysis (blending and segmenting combined)	NEPSY-II Nonsense Word Repetition	0.246
	WISC-IV Letter Number Sequence	.522**
SMaRts Reading Comprehension for Main Idea Test	WISC-IV Similarities	.653**
	WIAT-III Sentence Combination	.395*
SMaRts Social Comprehension Test	WISC-IV Comprehension	.614**
	NEPSY-II Affect Recognition	0.213
	NEPSY-II Theory of Mind (visual)	.483*
	NEPSY-II Theory of Mind (concept)	0.349
GDRAAT Copying (90 seconds)	PAL-II Copying (90 second limit)	.658**

Note.
Test Names: GDRAAT (Group Diagnostic Reading and Aptitude Test); RFU (Scientific Research Association's Reading For Understanding test); SMaRts Reading Comprehension for Main Idea Test); SMaRts Social Comprehension Test; WISC-IV – Weschler Intelligence Scale for Children, 4th Edition; WIAT-III – Weschler Individual Achievement Test, 3rd Edition; NEPSY-II – The NEPSY Test Protocol, 2nd Edition; PAL-II – Process Assessment of the Learner, 2nd Edition

Data Screening and Preparation

Archival data from the school included 184 cases. A total of nine students were removed from the data base prior to data screening and cleaning. Three students did not meet the age criterion for the study (two were under the age of 6 years and one person was over age 19), and six students were unable to complete testing due to severe language deficits. Thus, 175 cases were available for statistical screening.

An examination for univariate outliers was conducted. Skewness and kurtosis were within acceptable range for 16 of the 17 variables (within plus or minus 2.0; Mertler & Vannatta, 2010). Distribution of the scores on the Wepman Auditory Analysis exceeded this range. Prior to considering any transformation of data, an examination of multivariate outliers took place. Results of the Mahalanobis distance test for multivariate outliers resulted in removal of an additional 14 cases exceeding the critical chi-square statistic; this resulted in 161 cases for analysis. A second examination of univariate properties for each of the variables demonstrated that all variables had acceptable skewness and kurtosis.

Table 3

Table of Descriptives for Independent and Dependent Variables

Descriptive Statistics

	N	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
MSParaU	161	0.49	0.21	0.02	0.19	-0.13	0.38
MSCopying90	161	0.42	0.22	0.31	0.19	-0.55	0.38
MSAudM	161	0.53	0.19	0.52	0.19	-0.15	0.38
RFU	161	0.51	0.21	-0.25	0.19	0.67	0.38
GAAan	161	0.82	0.22	-1.24	0.19	0.61	0.38
GAAbs	161	0.82	0.17	-1.12	0.19	1.81	0.38
Closure	161	0.43	0.21	-0.12	0.19	-0.49	0.38
GVisProc	161	0.67	0.20	-0.21	0.19	-0.55	0.38
GVisLogic	161	0.56	0.20	-0.23	0.19	-0.44	0.38
SocSMaRts	161	0.59	0.24	-0.31	0.19	-0.75	0.38
MSxoltrs	161	0.55	0.20	0.07	0.19	-0.42	0.38
Achievement	161	0.60	0.17	-0.11	0.19	-0.78	0.38
Valid N (listwise)	161						

Note: MSParaU = paragraph understanding; MSCopying90 = Copying; MSAudM = Short term auditory memory; RFU = Reading for Understanding; GAAan = Gibson Auditory Analysis (analysis); Closure = Closure Speed; GVisProc = Gibson Visual Processing; GVisLogic = Gibson Logic and Reasoning; SocSMaRts = Social Comprehension; MSxoltrs = GDRAAT Crossing-Out-Letters; Achievement = the average of Woodcock and KeyMath percentages

Multivariate normality, linearity and homogeneity of variance were examined for the 161 cases. Examination of scatterplots for independent variables demonstrated shapes close to elliptical providing evidence for multivariate normality and linearity of variable combinations. Examination of standardized residuals to predicted values (residual plots) demonstrated a central even dispersion; therefore, plots suggested that the homogeneity of variance-covariance matrices was met. All 161 cases had complete data on all study variables.

Study Results

Demographics

The target population for this study included students attending private schools between the ages of 6 and 19 years who represent the spectrum of challenged, average, and gifted achievement for their ages. The participants providing data are from a K-12 private school. Participant ages range from 6 to 19 years (*M* = 12.3, *SD* = 2.7). Males represent 68% of the students. Forty-three percent of all students (*N* = 69) have a challenged cognitive profile, 45.3% (*N*=73) have an average profile, and 11.8% (*N*=19) have a gifted cognitive profile.

Results of Tests of the Study Hypotheses: Hypothesis 1

H_1: There is statistical evidence, through various measures of structural fit associated with structural equation modeling, for a four-component model of language-based cognitive fitness that includes information from 17 cognitive test scores that are available for analysis

H_0: Support is not found, through various measures of structural fit associated with structural equation modeling, for a four-component model of language-based cognitive fitness.

Support for the null hypothesis was demonstrated in a three step process using exploratory factor analysis (EFA), confirmatory factor analysis (CFA) using structural equation modeling, and regression also using structural equation modeling.

Results of the Exploratory Factor Analysis (EFA)

EFA with varimax rotation (chosen to try to get as much unique variance represented in the factors as possible) was conducted to determine if there was an underlying structure represented by the 18 tests. The tests included the GDRAAT Paragraph Understanding, GDRAAT Short Term Memory (auditory); SRA Reading for Understanding; GDRAAT Copying; Gibson Auditory Analysis (blending and segmenting combined); Gibson Auditory Analysis (analysis); Gibson Visual Logic and Reasoning; SMaRts Social Comprehension Test; GDRAAT Crossing out letters; Gibson Working

Memory; SMaRts Reading Comprehension for Main Idea Test; GDRAAT Short Term Memory (Letter-Form combined); Gibson Processing speed; GDRAAT Vocabulary; Wepman Auditory Discrimination; Closure Speed; and Gibson Visual Processing. After rotation, the first component accounted for 51.5% of the variance in the items, the second 9.1%, the third accounted for 7.9%. Examination of the results showed that six variables were loaded across multiple factors (this was defined as factor loadings within .2 across factors). These items were removed; removed items included the Gibson Working Memory, SMaRts Reading Comprehension for Main Idea Test, GDRAAT Short Term Memory (Letter-Form combined), Gibson Processing speed, Wepman, and GDRAAT Vocabulary. The EFA was performed again on the remaining 11 items. Table 4 shows the results of the final factor structure; the three factors explain 68.5% of variance in the items.

Table 4

Three Factor Solution Results from Exploratory Factor Analysis of 11 Items

	Factor Loading		
	Factor 1	Factor 2	Factor 3
MSParaU GDRAAT Paragraph Understanding (represents deductive reasoning)	**.83**	.32	
MSAudM GDRAAT Short Term Memory (auditory)	**.80**	.23	
RFU SRA **Reading for Understanding** (represents inferential reasoning)	**.77**	.37	.11

MSCopying90 GDRAAT Copying Test (represents writing fluency)	**.74**	.28	.25
GAAan Gibson Auditory Analysis (analysis of sounds)	**.68**	.27	.16
GAAbs Gibson Auditory Analysis (blends and segmentation)	**.62**	.17	
Closure Speed Visual Interpretation and application (gestalt)	.13	**.85**	.13
GVisProc Gibson Visual Processing (seeing whole and parts)	.39	**.72**	
GVisLogic Gibson Logic and Reasoning (discerning patterns)	.34	**.71**	
SocSMaRts SMaRts Social Comprehension (synthesis of social situations)	.42	**.65**	.16
MSxoltrs GDRAAT Crossing out Letters (active analysis)	.18	.14	**.97**

The first factor, *verbal reasoning ability*, comprises (6) items related to the ability to verbally reason capturing aspects of auditory processing for blending and segmenting of sounds(a=.51, p =.000 , short term auditory memory (a=.76, $p < .000$), auditory analysis (a =.70, $p < .000$), deductive reasoning (a=.86, $p < .000$), extrapolative reasoning (a=.83, $p < .000$), and writing fluency (a = .78, $p < .000$). The second factor, *Visual Synthesis*, comprises (4) items related to synthesize visual concepts including visual processing of whole and parts (a=.77, p < .000), gestalt closure (a=.54, $p < .000$), visual logic and reasoning (a =.74, $p < .000$), and social comprehension using visual stimuli (a=.48, $p < .000$. The third factor, *Active Analysis*, is a single variable Crossing-

Out-Letters and is a measure that measures the individual's ability to selectively attend to task, discriminate the target symbol, and check for accuracy, on a timed basis. Cronbach's alpha was used to measure the internal consistency of the factors. For *Verbal Reasoning Abilities*, Cronbach's alpha was .89, and for *Visual Synthesis,* it was .82; values above .70 are typically considered acceptable.

Results of the Structural Model using Confirmatory Factor Analysis

The factors structure resulting from EFA was tested using CFA (maximum likelihood). The structural model demonstrated good overall fit to the data, χ^2 (34) = 63.57, p = .002, CMIN/DF = 1.87, CFI = .97, and RMSEA = .07. The error terms for variables were constrained for test measures that were from the same test battery and those administered in the same testing session (Burkholder, 2003) and based on theoretical support (Byrne, 2010). Results of the CFA confirmed the structure of the EFA:

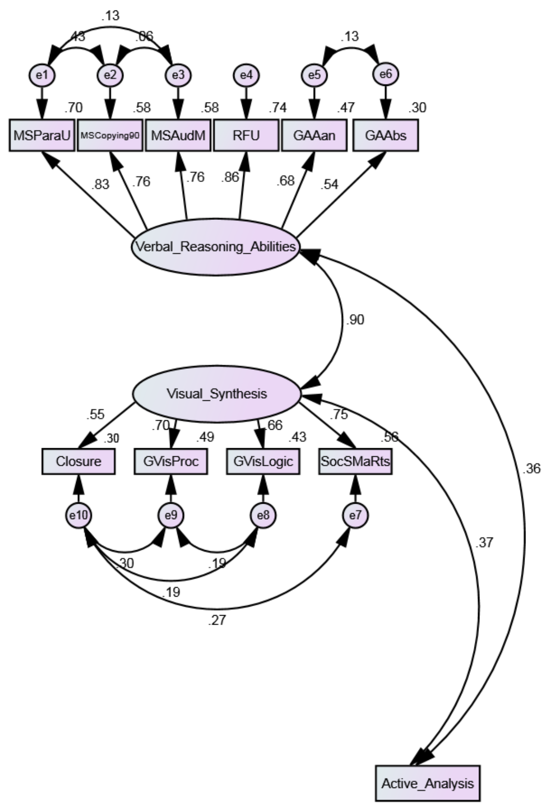


Figure 8. The Structural Model for Language-based Cognitive Fitness

Note – the squares represent the 11 test items; the ovals represent the factors one and two with multiple variables; the rectangle represents factor three represented by one variable; the circles represent the error terms; the arcs represent covariances between variables and between factors; the arrows represent pathways of influence; and, the numbers over the pathways represent the strength of the path relationship.

Results of the Structural Equation Model with the Dependent Variable Achievement

The relational model introduced *achievement* as the dependent variable. The initial model that included age resulted in a satisfactory fit to the data, χ^2 (53) = 157.36, p =.000, CMIN/DF = 2.97, CFI = .92, RMSEA = .11; however, age was not statistically related to the dependent variable. Removal of age resulted in a model that resulted in a better fit to the data, χ^2 (42) = 82.97, p =.000, CMIN/DF = 1.98, CFI = .97, RMSEA = .08. Figure 9 shows the final model.

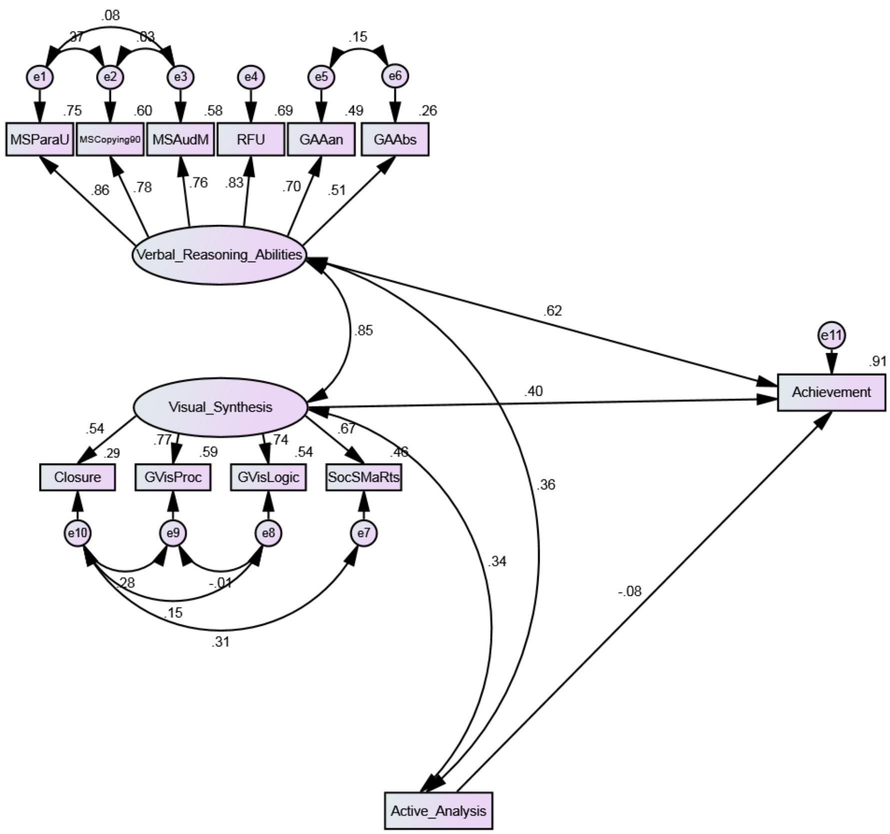


Figure 9. The Relational Model for Language-based Cognitive Fitness

This final model did not support the alternative H_1. Rather the best model fit resulted from three latent factors (*Verbal Reasoning Abilities, Visual Synthesis, and active analysis*) directly related to the dependent variable. The relationship between

Verbal Reasoning Abilities and *achievement* was strong and positive (α = .62, *p < .000*). *Visual Synthesis* had a moderate positive significant relationship with *achievement* (α=.40, *p* =.000. *Active analysis* had a small negative but significant relationship with *achievement* (α = -.08, *p* = .021). Predictors of *achievement* explained 91% of the variance of the model. The resulting model will be discussed more fully in Chapter 5.

Results of Tests of the Study Hypotheses: Hypothesis 2

H_2: There are linear combinations of the independent variables (represented by the cognitive test results from children) that best discriminate cognitive ability using discriminant analysis.

H_0: There are no linear combinations of the independent variables (represented by the cognitive test results from children) that best discriminate cognitive ability using discriminant analysis.

A stepwise discriminant analysis was conducted to determine the extent to which *Verbal Reasoning Abilities*, *Visual Synthesis*, and *active analysis* predict language-based cognitive profiles (challenged, average, and gifted). Cronbach's alpha was used to measure the internal consistency of the factors. For *Verbal Reasoning Abilities,* Cronbach's alpha is .89, and for *Visual Synthesis*, it is .82; values above .70 are typically considered acceptable. The tests of equality-of-group-means demonstrated that *Verbal Reasoning Abilities* and *Visual Synthesis* had significant group differences. The Box's M

Test indicated homogeneity of covariance could be assumed (*p* =.825). The analysis generated one statistically significant function, $\Lambda = .82$, χ^2 (2, 161) = 17.17, $p < .000$ with 17.9% of the function variability explained by cognitive profile. *Verbal Reasoning Abilities* was the only factor included in the model; *Visual Synthesis* and *active analysis* were excluded.

Table 5 presents the standardized function coefficients and correlation coefficients. Classification results revealed the discriminant classified cases with 58.4% overall accuracy. Accuracy for each group was 62.3% for the challenged cognitive profile, 69.9% for the average cognitive profile, and 0% for the gifted cognitive profile. The cross-validated results supported original accuracy levels with 62.3% correctly classified overall. Group means for the function indicated: a challenged language-based cognitive profile had a *Verbal Reasoning Abilities* function mean of .52, those who presented with an average language-based cognitive profile had a function mean of .63, those who presented with a gifted cognitive profile had a mean of .72. These results provide statistical support for classifying students according to their language-based cognitive profile based on *Verbal Reasoning Abilities* only. The results suggest that individuals who present as cognitively gifted have the strongest verbal language abilities and individuals who present as cognitively challenged have a relative deficit in verbal abilities. The results also suggest that while those with gifted cognitive profiles achieve the highest scores in *Verbal Reasoning Abilities* characteristics other than those in *Verbal Reasoning Abilities* predict the gifted profile.

Table 5.

Correlation Coefficients and Standardized Function Coefficients for Cognitive Profile

	Correlation Coefficients with Discriminant Function	Standardized Function Coefficients
Verbal_Reasoning_Abilities	1.00	1.00
Visual_Synthesis	0.65	
Active_Analysis	0.36	

Summary

The results demonstrate partial support for the study hypotheses. A three-factor model predicting achievement emerged (the three latent factors are *Verbal Reasoning Abilities*, *Visual Synthesis*, and *Active Analysis*). Results of the second hypothesis supported that each of the factors does discriminate between cognitive profiles but only *Verbal Reasoning Abilities* was statistically significant for prediction. The results will be examined further in Chapter 5. The results will be integrated into what we know about cognitive fitness and potential further directions for research in this area.

Chapter 5: Discussion, Recommendations, and Conclusions

Introduction

The purpose of this study was to develop a model representing the structure of language with the goal of providing a framework for the fragmented understanding and knowledge of components of language. Understanding language structure involves knowledge from a broad array of disciplines including acoustics, phonetics, phonology, cognitive neuroscience, neural imaging, machine learning, and natural language processing. This research provided an opportunity to test a specific model of language structure. What emerged were three superordinate constructs that predict reading and mathematics achievement but do not provide evidence for a clear hierarchical structure. Finally, while the model produced three components and each component was able to differentiate between challenged, average, and gifted students, only *verbal reasoning abilities* was statistically significant. This chapter will reflect on what these outcomes mean, whether the models are really different; and, if so how so, and what does this say.

Analysis of Findings

Three key insights emerged through analysis of the study findings. First, there is some evidence of validity of the 16 test measures that had not been previously validated in the literature. Second, the emergent model is not a hierarchical model, but all four components of the theoretical model are embedded in the empirical model. Also, CFA confirms a strong relationship of the structural model with *achievement*. Third, discriminant analysis demonstrated that the linear combination of three factors predict achievement of students in the sample. Each of these findings is described below.

Validation Study

Most test measures had a strong positive correlation with validated tests; this provided initial empirical evidence of validity. However, the tests did not always align as expected. For example, the GDRAAT Crossing-Out-Letters, which was used in the study to measure the individual's ability to selectively attend to task, discriminate the target symbol, and check for accuracy (under time constraints), did not correlate as expected with the WISC Coding or the WISC Cancellation tests. Rather, the test corrrelated with tests measuring higher order cognitive abilites; these tests included WISC Arithmetic, WISC Matrix Reasoning, and WISC Letter Number Sequencing. This unexpected correlation may be indicative of some additional executive function abilities associated with auditory working memory and coordination within context that are captured by the GDRAAT consistent with the findings of Buehner et al. (2006). In addition, the Gibson Auditory Analysis (blending and segmenting) was not correlated with NEPSY Repetition of Nonsense Words; rather, it was correlated with the WISC Letter Number Sequencing which measures working memory, a precursor ability for word repetition specific to sound sequencing. These results indicate that there is a need to find a better measure of word repetition. The alternative measure to GAAbs for repetition could be the NEPSY Repetition of Nonsense Words.

Overall, the results of the validation study support the validity of the tests used in the local private school as proxies for concepts included in the theorized model. Validation provides evidence that the tests are measuring similar concepts to those in the more widely published tests.

The Empirical Model

The empirical model presented some thought provoking results: First, the emergent model is not a hierarchical model, though variables from all four components from the theoretical model are embedded in the empirical model. Second, the CFA confirms a strong relationship of the structural model with *achievemen*t:

Not a hierarchical model. The empirical model is an interactive model that represents superordinate and overlapping domains comprising verbal reasoning, visual synthesis, and active analysis components; this is somewhat different than the hierarchical model represented by a linear sequence of receptive, expressive, narrative, and writing fluency components. The model reflects interplay among abilities (Buehner et al., 2005); it also reflects connectionism rather than localizationism (Catani, 2009). Additionally, the model potentially reflects a distributed pattern of activation across process structures rather than a pure hierarchical structure (Price, 2012).

The empirical model differentiates latent factors into verbal, visual, and frontal (analysis) components, not inconsistent with the same research supporting the theoretical (hierarchical) model if one is able to look at the research from a different lens. For example, the theoretical model demonstrates the need for verbal and visual aspects but grouped under decoding and radical symbolization as the primary themes. The empirical model shifts the perspective to instead demonstrate a more primary differentiation based on verbal, visual and analysis (frontal) abilities as the key themes. This “different lens” is plausible and evident in the literature when we look more carefully at the research on mismatch negativity (MMN-vMMN) specific to neurophysiological brain event response potentials (ERPs) supporting the process of conjoining auditory and visual memory representations into object files (auditory and visual features are combined into one object) if they are matched within a temporal window (Garrido et al., 2009; Kujala et al., 2007; Näätänen, 2000; Näätänen, 2007; Näätänen et al., 2011; Pulvermüller et al., 2008; Pulvermüller & Shtyrov, 2003; Sussman, 2007; van Zuijen et al., 2006; Winkler & Czigler, 2011); these object files then separated into categories (Winkler & Czigler, 2011). This research demonstrates the need for overlap in verbal and visual abilities for foundational language development, reflecting connectionism (vs. localization) and shared abilities that are common to multiple neural systems. Research similarly supports active analysis to be characterized by shared abilities common to multiple neural systems: including frontal lobe functions for motor coordination (Buehner et al., 2006; Shalom & Poeppel, 2008) and auditory analysis and inductive reasoning functions consistent with the language processing role of the frontal lobe involving the integration of auditory information (Kotz & Schwartze, 2010). Hence, there is reasonable empirical evidence (given the EFA and CFA results), supported by the literature, that *Verbal Reasoning Abilities, Visual Synthesis*, and *Active Analysis* reflect distinct yet overlapping domains, and these interconnecting verbal, visual, and frontal abilities provide a common base across multiple neural systems.

The emergent model highlights the importance of superordinate predictors for reading and mathematics achievement; and, the use of an empirical, data-driven approach, agnostic with respect to the language modules in the classic and generally accepted Broca-Wernicke-Lichtheim language model (Shalom & Poeppel, 2008). This empirical language-based cognitive fitness model draws from MMN-vMMN (Garrido et al., 2009; Kujala et al., 2007; Näätänen, 2000; Näätänen, 2007); Näätänen et al., 2011; Pulvermüller et al., 2008; Pulvermüller & Shtyrov, 2003; Sussman, 2007; van Zuijen et al., 2006; Winkler & Czigler, 2011), the interplay of cognitive abilities (Buehner et al., 2006), functional language organization (Shalom & Poeppel, 2008), and the physical anatomy of language using neuroimaging techniques (Catani, 2009; Price, 2012). The model provides a visual explanation of why researchers and practitioners should not look at isolated components when modeling language; language demands a distributed set of abilities with each participating in multiple functions (Price, 2012). Finally the model positions language to be more integrated with cognitive abilities traditionally viewed as correlates for general intelligence, traditionally separately measured from language (Buehner et al., 2006).

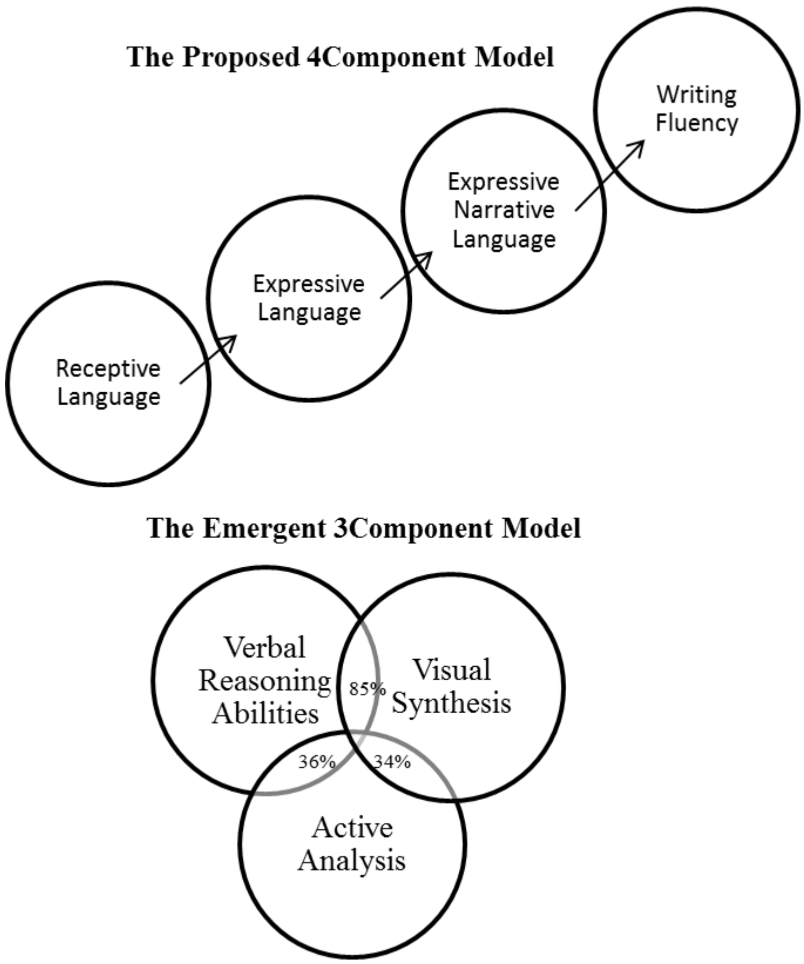


Figure 10. Relationship Between the Theorized Four Component Model and the Empirical Model.

This figure demonstrates the emergent model to be a recombination of variables representing all four components of the proposed model separated into two main components and then a single third component. *Verbal Reasoning Abilities* include auditory-based receptive language (auditory short term memory, auditory analysis, deductive and inductive verbal reasoning), expressive language (repetition), and writing fluency components. *Visual Synthesis* includes visual-based receptive language (visual processing, visual logic & reasoning), expressive language components (object naming), and spontaneous narrative expression components (reasoning using nonverbal social stimuli). *Active analysis* includes one variable associated with selective attention to task, discrimination of target symbol, and monitoring for accuracy using active memory and basic motor coordination.

Very strong correlation between *Verbal Reasoning Abilities* and *Visual Synthesis* (r = .85) might lead one to think they are really one and the same construct. The full model including *verbal reasoning ability*, *Visual Synthesis*, *active analysis*, mapped to *achievement* provides a strong model fit to data that has a broad reach across cognitive domains important for predicting language-based cognitive fitness measured by *achievement*. Within this model there is overlap, but this overlap is differentiated by auditory and visual themes supported by research that demonstrates that auditory and visual memory traces are integrated at a very early decoding stage of language (Garrido, et al., 2009; Kujala, et al., 2007). Hence, rather than *Verbal Reasoning Abilities* and *Visual Synthesis* being one and the same construct they are separate, yet dependent on a set of cognitive resources that combine in early stages of language development resulting in their development being highly correlated.

The relationship between active analysis and achievement represented a negative correlation. Oberauer et al. (2003) found a negative correlation between supervision (a frontal lobe function) and reasoning; this is consistent with findings in the present study and suggests a general but weak inhibitory mechanism.

Discriminant Analysis

Discriminant analysis demonstrated that the linear combination of three factors could differentiate among challenged, average, and gifted profiles. Individuals who presented as cognitively gifted have the strongest *Verbal Reasoning Abilities*. This outcome is consistent with expected outcomes from research on the relationship between MMN-vMMN ERP differences and dyslexia by Kujala and Näätänen (2001) and developmental implications of the timing of maturation of auditory evoked potentials for temporal encoding of auditory information (Wang, Datta, and Sussman, 2005) that demonstrate support for there being structural differences in performance of verbal abilities due to differences in underlying verbal abilities.

Limitations

This discussion of limitations will include issues relating to instrumentation (internal validity) and generalizability of the findings (external validity).

Internal Validity

The primary potential threat to internal validity was instrumentation (Cresswell, 2009; Stanley & Campbell, 1969). Data are secondary and include scores from both valid and reliable tests as well as those that do not have published reliability and validity. This was the rationale for including a validity study to assess validity of these specific tests not having demonstrated validy. All 16 measures that did not have published reliability correlated positively and strongly with subtests of larger instruments that have enjoyed more extensive published reliabilty and validty (for example, the WISC-IV, NEPSY-II, WIAT-III, KABC-II, and PAL-II). While this is an important step toward establishing initial evidence for validity, more extensive testing for reliability and validity is required.

Internal validity can also be impacted by possible limitations in what the instruments of this study actually measure; the measures available for use measure multiple constructs making it difficult to isolate finer aspects of language-based cognitive fitness. It is possible that test measures validated with neuroimaging measurement techniques will be more able to accurately distinguish among the theoretical structures than what are currently available. For example, neuroimaging measurement tools are discovering source language processes with greater detail and increased specificity. One example is the mismatch negativity measures for both auditory and visual stimuli (MMN and vMMN). To measure one's ability to perceive and create memory traces for conjoined auditory and visual objects; Garrido, et al., 2009; Kujala, et al., 2007; Näätänen, 2000; Näätänen et al., 2007; Pulvermüller, et al., 2008; Sussman, 2007; van Zuijen et al., 2006) specific . sine-wave amplitudes for sounds could be used to assess speech discrimination and auditory-visual trace formation abilities as part of language-based cognitive testing protocols; this consistent with research methods used with infants as early as six months of age to identify risk for delayed language development (Kujala & Näätänen, 2001).

Finally, data are cross-sectional in nature. An examination of a hierarchical structures theorized in Chapter 2 may be better addressed with analysis of longitudinal data. There could be time-based relationships among variables that might explain a more hierarchical structure based on developmental trajectories of specific abilities.

External Validity

Potential threats to external validity include threats to representativeness, or generalizability (Cresswell, 2009; Stanley & Campbell, 1969). Parents chose to have their children attend a private school. The sample may not be representative of all school-age children; children in the study had a higher percentage of challenged academic ability profiles (43% challenged compared to only 12% gifted) than would be expected in the general population. However it is also possible that the range of abilities demonstrated in this study might be more reflective of the population of K-12 children in general if schools in general conducted more extensive testing as completed by the private school involved in this study. Discriminant analysis did demonstrate that there were predictable structural differences between challenged, average, and gifted student profiles with achievement and that challenged and average profiles could be predicted from combinations of the three domains. This means that although the sample may have been more heavily weighted to challenged profiles than the general population, specific characteristics, such as *Verbal Reasoning Abilities*, can accurately predict ability. However, a larger sample size randomly drawn from the population would provide a validation test to address the limitation of sample size and generalizability.

Implications

Implications for Research

Research in the future needs to be longitudinal. The results of this cross-section study reflect language as a superordinate collection of verbal, visual, and analysis components rather than a hierarchical model represented by a linear sequence of receptive, expressive, narrative, and writing fluency components. The concept of visual-auditory conjoining (the foundation for building vocabulary), creating associative memory traces that are categorized into separate perceived objects with categorical boundaries (Winkler & Czigler, 2011) and with visual boundaries (Clifford et al., 2010) that are language dependent (Thierry et al., 2009), is supported. Future research could use longitudinal data to further clarify the model. Bayesian analyses in this case would be appropriate given this modeling technique is well suited to cross-time analysis associated with understanding processes given the a priori theorized model (Baldeweg, 2007; Friston, 2005; Garrido et al., 2009c; Kemp & Tenenbaum, 2009) this study has provided.

Future research could also involve tracking the paths of language development of children. For example, MMN measures of sine-wave amplitudes for sounds can be used in infants as early as six months of age to identify risk for delayed language development (Kujala & Näätänen, 2001). Tracking could provide further data to inform interventions focused on improving language development.

More investigation is required to better understand the components of *active analysis*. This factor appears to represent a frontal lobe regulation function involved in language-based cognition; however, among the tests available in the database, only one test (Crossing-Out-Letters) emerged from principle components analysis as associated with *active analysis*. Buehner et al. (2006) identified components within the frontal lobe function include *supervision* and *coordination* of information during processing (in addition to sustained attention and speed) as participants of frontal lobe functions. The validation study showed active analysis to be associated with tests (for example, WISC-IV Arithmetic, Matrix Reasoning, and Letter Number Sequencing) normally associated with frontal lobe functions that require coordination and supervision in addition to attention and speed. Thus, further research could explore further variables that make up active analysis would result in increased understanding of the nature of the language-frontal lobe regulation link.

Implications for Practice

Practical implications include the need to reconsider test battery choices for screening students for language-based disorders and an opportunity to reflect on the value of the study results for predicting classroom achievement within public educational settings. The emergent model included a reduced number of variables with representation from all four components of the theoretical model. The results of the principle components analysis suggest significant redundancy among tests. Thus, there may be an opportunity to reduce the overall number of tests used with students to key tests that assess competencies in verbal, visual, and active analysis areas of language. In fact, discriminant analysis results provide support for the prioritization of the six subtests collected into *Verbal Reasoning Abilities* as the most critical tests to differentiate students needing interventions.

The practical implications of a reduced number of subtests is a reduced time requirement for testing students; this is a shorter battery of tests, practical to administer, and likely to take 30 to 40 minutes. Practical implications of these results also include the opportunity to create *report card* templates for judging language-based cognitive fitness and then the use of these templates to track response to interventions. The report card would give the school psychologist a template for understanding a student’s profile, the specific areas of concern, and insight for how to intervene to enhance a student's prediction of achievement. The school could monitor the impact of interventions on achievement and plan a course of treatment to optimize a student's future language-based cognitive fitness as demonstrated through achievement.

Finally, the validation study provided important support for 16 test measures requiring more evidence of construct validity. This study provided important initial evidence supporting the use of these test measures for psycho-educational purposes. Equally important (referencing appendix 1) are the implications of the emergent model for existing test protocols given the results from the validation study. If the emergent model were to be applied there would be a redistribution of measures across traditional factors for validated test protocols such as the Weschler Intelligence Scale for Children (WISC-IV, 2003): Given the validation study correlations the emergent model would redistribute the Weschler WISC-IV Coding (processing), WISC-IV Letter Number Sequencing (working memory), WISC-IV Word Reasoning (verbal comprehension), and WISC-IV Digit Span Forward (working memory), add PAL Rimes (auditory analysis), and WIAT Reading Comprehension (inductive reasoning) tests – all under the umbrella for *Verbal Reasoning Abilities*. Given the validation study correlations the emergent model would pull WISC-IV Matrix Reasoning and WISC Similarities (abstract logic and reasoning), WISC-IV Comprehension (abstract social reasoning and social pragmatics), WISC-IV Picture Completion (object recognition), and WISC-IV Block Design (visual processing) tests – all under the umbrella for *Visual Synthesis*. Finally, given the validation study correlations the emergent model would draw in the WISC-IV Arithmetic (working memory), WISC-IV Matrix Reasoning (perceptual reasoning), and WISC-IV Letter Number Sequencing (working memory) under the umbrella for *active analysis*.

Given this redistribution of variables into two factors (*Verbal Reasoning Abilities* and *Visual Synthesis*) and the new *active analysis* factor not correlating with WISC processing measures as expected, the emergent model challenges the iconic model of intelligence that separates intelligence into silos: these being verbal, perceptual, working memory, and processing abilities as presented by Weschler (2003). The emergent model of language-based cognitive fitness is represented by a pattern of verbal, visual, and analysis abilities that interplay with each other. This outcome is consistent with the results of a review of neuroimaging studies by Price (2012) that suggest distributed processing, for example, phonological processing that draws upon auditory processing, and articulation, is represented by a distributed pattern of activation over many different brain functional areas and each functional area participates in multiple processes.

Implications for Social Change

This research study provided both theoretical and practical implications for positive social change. First the study provided a theoretical frame of reference for understanding the key constructs, components, and moderating variables involved in language-based cognitive fitness. Second, the practical implication of this study is an improved understanding of why some children have difficulty acquiring their native language leading to specific insight as to why there may be difficulty. Such insight can fuel future work in the development of interventions that enable progression of a child's development towards increased language competence.

The model that resulted from this research will also contribute to the modeling of the process of language development helpful to professionals (educators, educational psychologists, cognitive scientists) who in turn can impact the social course of individuals and educational systems. Bayesian analysis in particular is well suited to cross-time analysis associated with understanding processes but a specific a priori model from which to model a time path for predictive coding, adjustment, and modification is required (Baldeweg, 2007; Friston, 2005; Garrido et al., 2009c; Kemp & Tenenbaum, 2009). This study provides a specific a priori model for such research which could have very positive social implications for understanding the process of interaction between variables and latent factors and therefore positively impact both the development of proactive and response-based interventions to ensure more children develop language-based cognitive fitness earlier in their developmental lifespan.

Positive social change is also inherent in the results from the validation study. Initial evidence for the validation of test measures for two in house developed tests important for measuring inner speech and spontaneous narrative expression, for tests created by Gibson for the PACE Program, and for the GDRAAT test protocol developed by Munroe and Sherman (1966), has been provided. Not only did this validation study add to the theoretical knowledge base, the practical social implications are also important for potential future uses of the tests that were in question. Social implications extend from this evidence of validity to include positive signals to the users of these test measures that these tests are measuring what is expected and to encourage the developers to take next steps to further validate and standardize these tests.

Finally, the steps of this model building process reduced the original 17 measured variables down to 11 measured variables. The positive social implication is that fewer measures than first anticipated are needed to crystalize key statistical differences and that the private school can with clear conscience reduce the number of tests used to measure a student's language-based cognitive fitness. Furthermore, given the discriminant analysis results there is also room to focus first on a basic screening test that just addresses *Verbal Reasoning Abilities* before additional testing of *Visual Synthesis* if screening is to be used to determine base line risk for language fitness. The positive social implication is less testing for more insight with confidence in the screening process.

Collectively the above implications provide solid footing to make positive social change beginning with how government and schools look at all students. The emergent model provides the seeds of insight into what predicts language-based cognitive fitness that is represented by reading and mathematics achievement. Not only can these insights give value to educational practitioners including educational psychologists, teachers, and education administration, it has potential to reframe how the educational system supports student development. This model could stimulate adaptive education models assisting all students towards achieving their personal potential, optimizing their experience in education.

Conclusions

The purpose of the study was to test a theoretical model of language readiness, noted as language-based cognitive fitness, which included measures associated with structural concepts of language involving receptive language, expressive language, spontaneous narrative speech, and writing fluency. The sample included students from a private school who received an extensive battery of tests at admission and annually thereafter. Scores from a variety of cognitive measures were used in a structural equation modeling framework to test the model.

Language-based cognitive fitness was found to involve reception and expression of language as a multifaceted, interrelated taxonomic model supported by specific language processes. The results of the validation study, the EFA, the CFA (SEM), and DFA support the model of language-based cognitive fitness to be founded upon a verbal and visual backbone with a third frontal lobe influence. Attributes associated with expressive language were present but aligned with both *Verbal Reasoning Abilities* and *Visual Synthesis*. Spontaneous narrative expression was present but was aligned with *Visual Synthesis* while the act of writing fluency (graphomotor) was aligned to *Verbal*

Reasoning Abilities. More investigation of factor three active analysis is suggested given study outcomes.

Theoretical implications include additions to the knowledge base specific to language-based models and the initial steps to validating a broader set of measurement instruments and the repackaging of measures across factors of existing valid test protocols. Practical implications include the increased credibility of in house and lesser known tests for use in the field, and a clearer more parsimonious test battery for screening students for potential problems in language-based cognition. Both theoretical and practical benefits derived from this study's results pave the way to clearer response options for identifying and responding to a given student's specific needs. Educational psychologists have a tool that strongly predicts reading and mathematics achievement clearly tied back to specific characteristics of verbal reasoning ability, simultaneous synthesis, and active analysis.

Implications for positive social change include an improved understanding of the language structures responsible for language deficits and how these relate to overall language-based cognitive fitness so interventions can be provided to help children more quickly make up language deficits to the benefit of our educational system and society in general. Rather than development of language taken for granted early screening and responses to problems with language development will result in less stress for the individual and family; and more proactivity in that the contemporary education system ensuring children have appropriate skills as they begin school.

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Appendix A: Validation Study Results

Appendix A

The table demonstrates the alignment between the 4Component proposed model unvalidated test measures and valid test measures. All tests that are relevant to each other that have underlying common variance that is significant are listed. These valid tests demonstrate complementary themes and will be used by the private school to determine a future test battery for student evaluation.

Correlations between Unvalidated tests paired with appropriate Validated tests

Concept	Unvalidated Test	Measure	Valid Test	Corr	*p*	N = 26[1]
Auditory Memory trace formation	GDRAAT ST Memory (auditory)	GAudM	**WISC DSf**	0.73**	0.000	
			WiscLtrNbrS	0.58**	0.002	
Visual feature perception	G Processing Speed	Gpspeed	**WiscSymbS**	.40*	0.045	
			WiscPicCompt	.61**	0.001	
			WiscBlkD	.58**	0.002	
Visual Memory trace	GDRAAT ST Memory (ltr & form	MSVisLtrFm	**NepsyMfDDt**	.69**	0.000	

formation	combined)					
			WiscLtrNbrS	.80**	0.000	
Auditory acoustic interpretation	Gibson - Auditory Analysis	GAAan	**PalRimes**	.60**	0.003	N = 23
Visual (feature) interpretation	Gibson - Visual Processing	GVisProc	**WiscBlkD**	.60**	0.00	
			NepsyGeoPzl	.40*	0.04	
Application of visual (feature) information	Closure Speed (Gestalt)	Closure	**WiscPicCmpt**	.83**	0.00	
			NepsyPicPzl	.67**	0.00	
			KabcGestalt	0.24	0.24	
Word relationships	GDRAATVocabulary	MSVocab	**WiscVocab**	.79**	0.00	
			WiscPicCon	.67**	0.00	
			PalRelated	.54**	0.01	N = 23
			WiscSimilar	.48**	0.01	
			WiscWrdR	.72**	0.00	
Whole expressions - Wkg Memory	Gibson Wkg Memory	GWkgM	**WiscLtrNbrS**	.73**	0.00	
			WiscMtxR	.52**	0.01	
			KabcRiddles	.65**	0.00	
			WiscWrdR	.64**	0.00	
Whole expressions - deductive reasoning	GDRAAT - Paragraph Understanding	MSParaU	**WiatRC**	.69**	0.00	

Whole expressions - inferential reasoning	SRA - Reading for Understanding - RFU	RFU	**WiatRC**	.67**	0.00	
			WiscWrdR	.55**	0.00	
Whole expressions - Reasoning	Gibson Logic & Reasoning	GVisLogic	**WiscSimilar**	.50**	0.01	
			WiscMtxR	.72**	0.00	
Whole expressions - Active analysis	GDRAAT Crossing-out-letters	Msxoltrs	**WiscCoding**	0.24	0.25	
			WiscCancel	0.15	0.47	
			WiscArith	.52**	0.01	
			WiscMtxR	.50**	0.01	
			WiscLtrNSeq	.44*	0.02	
Expressive Language - Repetition	Gibson - Auditory Analysis - blending and segmenting	GAAbs	**NepsyRepWrd**	0.25	0.23	
			WiscDSF	.41*	0.04	
			WiscLtrNSeq	.52**	0.01	
			WiscMtxR	.43*	0.02	
			WiscCompr	.46*	0.02	
Spontaneous narrative expression: Main idea	RCSMaRts	RCSMaRts	**WiscSimilar**	.65**	0.00	
			WiatSentence	.40*	0.00	
			WiatRCgrd	.58*	0.00	

Spontaneous narrative expression: Nonverbal main idea	Social SMaRts	SocSMaRts	**WiscCompr**	.61**	0.00	
			NepsyAffectRec	0.21	0.30	
			NepsyTofMindv	.48*	0.01	
			NepsyTofMindc	0.35	0.08	
Writing fluency	MSCopying90	MSCopying90	**PalCopy90**	.66**	0.00	N = 23
			WiscCoding	.55**	0.00	
FN[1] There were 27 participants in the verification study; 1 participant was removed given this case was an outlier during data screening; N=23 is identified for 3 subtests.						

Curriculum Vitae

Elizabeth holds an Honours B.A. (psychology & economics), an MA (economics), an MBA with the University of Toronto, and a PhD in Business Strategy with the University Of Bradford, England. In her first doctoral endeavor Elizabeth established a framework (report card) for managers to assess their firm's state of competitive responsiveness within a global market based on econometrically testing Porter's Theory of Country Competitive Advantage using 35 countries and 5 years of data.

Elizabeth is a former faculty member with the Athabasca University internet-based Executive MBA program, and has developed courses on Information Technology and Management; delivered this course and several others including Economics & Ethics. Elizabeth has developed and taught similar courses at the Schulich School of Business (York University's MBA programme). Elizabeth has also taught introductory economics (micro and macro), and Information Technology Strategy to MBA students at the University of Toronto; and, she has taught at Atkinson College York University with a focus on Marketing Strategy.

Over the last 12 years Elizabeth has extended her educational expertise into childhood and high school education starting a private school, developing the Wasdell SMaRts® brain-fitness programs, and integrating these within the fabric of a full academic school program actively leveraging neuroscience principles of learning into the classroom. The goal is to develop all students to their full human potential.