

THE RELATIONSHIP OF LANGUAGE AND PERFORMANCE
ON THE REPEATABLE BATTERY FOR THE ASSESSMENT OF
NEUROPSYCHOLOGICAL STATUS (RBANS)

A DISSERTATION

SUBMITTED TO THE GRADUATE SCHOOL

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE

DOCTOR OF PHILOSOPHY

BY

ADELE ANN LARSSON

DISSERTATION ADVISOR: DR. ANDREW DAVIS

BALL STATE UNIVERSITY

MUNCIE, INDIANA

DECEMBER 2018

ACKNOWLEDGEMENTS

Throughout this graduate school journey, numerous individuals have provided me essential support and guidance, both professionally and personally. First, thank you to my dissertation committee chair, Dr. Andrew Davis. The opportunity to learn from you and be advised by you has been instrumental in the progress toward my goal of becoming a neuropsychologist. Thank you for your tireless support, patience, and guidance through the program and dissertation process.

I would also like to thank the current and past members of my dissertation committee, those who have been there from the beginning and those who have stepped in at critical times to ensure my progress through the graduate program has been possible. Thank you to Dr. Holmes Finch, Dr. Maria Hernández-Finch, Dr. Thomas Holtgraves, Dr. Julie Griffith, Dr. Jeanne McMillan, Dr. Barry Wagner, and Dr. Karen Thatcher. Also, thank you Dr. Janay Sander, Dr. Katie Maki, and all other Department of Educational Psychology faculty members who assisted throughout my graduate program. Please know how much I appreciate your time, efforts, and guidance. I have been so very fortunate to have worked with all of you.

Thank you to my Ball State family as well. Thank you to my cohort-mates who supported me through those early stages in the program and provided as inspiration in these latter stages. Also, thank you to my fellow graduate students, especially Dr. Rita Nogin, for always showing me the light at the end of the tunnel. Thank you to the administrative members of the Department of Educational Psychology for your willingness to help with any and all scheduling, paperwork, and enrollment needs throughout the years. Thank you to the members of the Department of Speech Pathology and Audiology for your flexibility in allowing me enroll in courses, efforts to relate material to the field of psychology, and endless encouragement. Without the motivation,

support, feedback, and learning opportunities from each and every one of you, this would not have been possible.

Words cannot describe how thankful and grateful I am to my truly wonderful partner, Jared. Your endless patience, undying understanding, key house-spouse skills, and amazing puppy-wrangling abilities provided me the environment to be able to continue this graduate school journey. Thank you for valuing my education, at times above all else, and for keeping your promise to my mother. Please know how loved you are.

Finally, none of this would be possible without the values and standards instilled in me by my family. The importance of education within our family drove me to academic success from preschool through college, and your insistence to follow my academic-dreams drove me to attend graduate school and pursue this doctoral degree. Your constant understanding throughout these past six years has been invaluable to reaching this point, even when you weren't quite sure how to describe what I have studied to others. Perhaps most importantly, this dissertation is dedicated to my mother, Barbara. This would not have been possible without encouragement to follow my heart and your belief I could succeed. The significance you have always placed on my education has been my biggest motivation in continuing this journey. I would not be at this stage in my academic career without you.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS.....	ii
LIST OF TABLES.....	vii
LIST OF FIGURES	ix
CHAPTER I. INTRODUCTION.....	1
Overview.....	1
Language Abilities and Their Importance in Neuropsychology.....	2
Assessment of Receptive and Expressive Language	4
Assessment of Neurocognitive Domains in the Current Study	6
Rationale of the Current Study	8
Significance of the Study	9
Research Questions.....	10
CHAPTER II. REVIEW OF THE LITERATURE.....	13
Language.....	13
Linguistic Levels of Language.....	13
Language as a Neuropsychological Construct.....	16
Neuropsychological Assessment of Neurocognitive Domains.....	20
Attention	22
Visuospatial/Construction.....	29

Memory.....	34
Language.....	41
Summary.....	47
CHAPTER III. METHODOLOGY	49
Research Questions.....	49
Procedures.....	52
Participant Demographics.....	53
Instrumentation	54
Demographics Questionnaire.....	54
Boston Naming Test	55
Delis-Kaplan Executive Functioning Scale	56
Repeatable Battery for the Assessment of Neuropsychological Status	58
Statistical Procedures and Data Analysis.....	64
CHAPTER IV. RESULTS.....	66
Results and Analyses	66
Descriptive Statistics of Measures Used.....	66
Research Question 1 and Canonical Correlation	70
Research Question 2 and Canonical Correlation	72
Research Question 3 and Correlation Analysis	74
Statistical Assumptions.....	74
Summary.....	75

CHAPTER V. DISCUSSION.....	77
Summary of Current Study.....	77
Discussion and Implications of Current Study.....	79
Language Ability.....	84
Attention.....	86
Memory.....	88
Visuospatial/Constructional.....	92
Language.....	93
Implications for the Field of Neuropsychology.....	94
Implications for Clinical Practice.....	94
Delimitations and Limitations of Current Study.....	96
Delimitations.....	96
Limitations.....	98
Direction for Future Research.....	99
Research with Different Measures of Neuropsychological Functioning.....	99
Research with Different Populations.....	101
Conclusions.....	102
REFERENCES.....	105

LIST OF TABLES

Table 1	50
<i>Summary of RBANS Subtests and Language Measures</i>	
Table 2	51
<i>Summary of RBANS Indices and Language Measures</i>	
Table 3	51
<i>Summary of Measured Language Abilities and Language Measures</i>	
Table 4	53
<i>Descriptive Statistics of Sample</i>	
Table 5	58
<i>Summary of RBANS Indices and Subtests</i>	
Table 6	67
<i>Mean and Standard Deviation Statistics for the RBANS, D-KEFS, and BNT-2 Standard, Scaled, and Z-Scores</i>	
Table 7	69
<i>Correlations Between BNT-2 Scores, D-KEFS Letter Fluency Scores, D-KEFS Category Fluency Scores, and RBANS Scores</i>	
Table 8	70
<i>Correlations Between RBANS Subtests, Language Measures, and Their Canonical Variates</i>	
Table 9	73
<i>Correlations Between RBANS Indices, Language Measures, and Their Canonical Variates</i>	

Table 1074
*Correlations Between BNT-2 Scores, D-KEFS Letter Fluency Scores, and D-KEFS Category
Fluency Scores*

LIST OF FIGURES

Figure 171

Canonical Correlation Loadings for the Variate Between Language Measures and RBANS

Subtests

Figure 273

Canonical Correlation Loadings for the Variate Between Language Measures and RBANS

Indices

CHAPTER I

INTRODUCTION

Overview

A central direction in the field of neuropsychology is for the early identification of neurocognitive deficits and monitoring of changes in neuropsychological functioning. With these goals, the field is in need of valid and reliable measures of neuropsychological functioning that are sensitive to neurocognitive deficits, brief to administer, and repeatable. There is a general lack of research investigating the impact other abilities may have on neuropsychological performance. Specifically, there is a lack of research considering the effects of language ability on neuropsychological measures for nonclinical and clinical populations. As a decline in language ability is often a key characteristic of neurocognitive decline, this lack of research is concerning. For example, symptomology of neurocognitive disorders such as Alzheimer's disease (AD), frontotemporal dementia, aphasia, autism spectrum disorder (ASD), and attention-deficit/hyperactivity disorder (ADHD), as well as many other developmental and neurocognitive conditions include a deficit in language abilities compared to neurotypical peers (Blair, Marcziński, Davis-Faroque, & Kertesz, 2007; Loucas et al., 2008; Sciberras et al., 2014; Taler & Phillips, 2008; Tippett et al., 2014). Understanding how language abilities may impact performance on neuropsychological assessment, including those measures which do not have an overt language requirement, is a chief rationale for the current study.

Previous research has investigated language functioning on some psychological and neuropsychological assessments; however, this research is limited and often specific to a clinical population, minimizing generalizability to nonclinical populations or other clinical populations. Additionally, there is limited research investigating the effects of language on performance on

brief neuropsychological assessments. This is an oversight, as brief neuropsychological assessments are useful when a comprehensive neuropsychological battery is not feasible, as well as to screen for deficits or monitor changes in neuropsychological functioning over time. One such brief neuropsychological measure is the *Repeatable Battery for the Assessment of Neuropsychological Status* (RBANS; Randolph, 2012). The RBANS measures attention, language, memory, and visuospatial skills and typically can be administered in approximately 30 minutes. The purpose of the current study is to investigate the relationship of language abilities and neuropsychological performance measured by the RBANS. Additionally, the current study may provide recommendations regarding interpretation of neuropsychological performance for those with limited language abilities.

Language Abilities and Their Importance in Neuropsychology

The language ability of individuals in clinical settings is worthwhile to consider as these abilities have been found to be significantly related to many areas of life, including socioeconomic status (SES; Jacobsen et al., 2017), parental level of education (Perkins, Finegood, & Swain, 2013), parental occupation (Eccles, 2005), engagement in problem behavior and illegal behavior (Petersen et al., 2013), and academic performance (Morgan, Farkas, Hillemeier, Hammer, & Maczuga, 2015). For example, language proficiency, measured as language processing skills and vocabulary, was found to be significantly different in children of higher-SES and lower-SES families as early as 18 to 24 months of age (Fernald, Marchman, & Weisleder, 2013). Children attending private school are more likely to have higher language abilities than children attending public school (Jacobsen et al., 2017). Children born to parents diagnosed with dyslexia and children with double-deficit (i.e., poor phonological awareness and dyslexia) are much more likely to have lower language abilities than their typical peers (Norton

et al, 2014; van Bergen, de Jong, Maassen, & van der Leij, 2014). Dollaghan et al. (1999) found maternal education was significantly positively correlated with three-year-olds' expressive and receptive language abilities. More recently, Park et al. (2016) found maternal education was a significant predictor of expressive language abilities in infants at 12-months. Language abilities, measured as verbal behavior and speech, at ages 6, 18, and 24 months were found to be significantly negatively correlated with future criminal activity (Stattin & Klackenber-Larsson, 1993). Additionally, language ability, as measured by receptive vocabulary, was a significant predictor of the development of later behavioral problems (i.e., inattention, hyperactivity, externalizing behaviors) in late childhood and adolescence (Petersen et al. 2013).

Language abilities have also been a significant predictor of other areas of functioning throughout the lifespan. Mayo, Chlebowski, Fein, & Eigsti (2013) found the age at which a child says their first word significantly predicts the child's overall cognitive abilities and adaptive functioning later in life. Infant vocabulary is significantly correlated with school-aged vocabulary, phonological awareness, reading accuracy, and reading comprehension (Duff, Reen, Plunkett, & Nation, 2015). Language proficiency has been found to be a significant predictor of reading comprehension and general reading abilities (Cutting & Scarborough, 2006; Strauss et al., 2006). Language abilities have also been found to predict whether or not a child is likely to benefit from an early reading intervention (Stage, Abbott, Jenkins, & Berninger, 2003). The development of appropriate emotional regulation behaviors in early childhood has been predicted based upon language abilities (Eisenberg, Sadovsky, & Spinrad, 2005). Overall, language performance predicts cognitive abilities not only with children, but with adults as well. (Bell, Lassiter, Matthews, & Hutchinson, 2001; Wechsler, 2008). Language abilities are also widely used as a predictor when estimating premorbid functioning in those after an acquired condition

(i.e., stroke, TBI) or onset of a neurocognitive condition (i.e., dementia, Alzheimer's disease, Parkinson's disease; Franzen, Burgess, & Smith-Seemiller, 1997; Lezak, 2012; Schoenberg, Lange, Marsh, & Saklofske, 2011). In sum, the importance of assessing language functioning in neuropsychological assessments is obvious when the connection between language and a wide number of risk and resiliency factors are considered.

Assessment of Receptive and Expressive Language

Language abilities, the processing of language input, and language expression are considered to be intermingled (Leonard, 2009). Additionally, receptive and expressive language skills are highly related in typically developing individuals; as such, it is important to ensure neuropsychological tests that aim to measure these functions are also related in neurotypical individuals. Research suggests performance on receptive and expressive language tasks are significantly correlated (Williams, 1997). Correlations between the *Peabody Picture Vocabulary Test – Fourth Edition* (PPVT-4; Dunn & Dunn, 2007), one of the most commonly used measures of receptive language, and the *Expressive Vocabulary Test – Second Edition* (EVT-2; Williams, 2007), a measure of expressive vocabulary, are similarly high ($r = .82$; Dunn & Dunn, 2007). Additionally, both receptive language and expressive language correlate highly with overall language abilities (Williams, 1997). Expressive language skills were not only strongly correlated with receptive language skills ($r = .76$), but also with overall core language skills ($r = .94$) on the *Clinical Evaluation of Language Fundamentals – Fifth Edition* (CELF-5; Wiig, Semel, & Second, 2003). These findings suggest when one area of language is measured, the corresponding area of language should be estimated with relatively high confidence in neurotypical individuals. Considering many tests measuring language abilities primarily emphasize demonstration of expressive language skills, this is quite important; a task measuring

expressive language may be considered an estimate of overall language functioning and abilities in some situations. Even tests measuring the construct of receptive language, as language comprehension tasks, could be confounded by the use of expressive language on the tasks. Because of this, measuring receptive language abilities is difficult without also assessing expressive language skills, as well as motor ability. Clinically, a task aimed at measuring receptive vocabulary may require the individual to respond using speech, a behavior of expressive language, or pointing which requires motor skills. For example, performance on comprehension tests of grammatical morphology has been found to be significantly lower in those with expressive language deficits (Leonard, 2009). Bates, Friederici, & Wulfeck (1987) found those with Broca's aphasia and those with Wernicke's aphasia had similar linguistic error patterns on tasks of grammatical morphology than compared to a non-aphasic sample. Additionally, imaging studies have found expressive areas and receptive areas of the brain show simultaneous activation during language tasks (Babajani-Feremi et al., 2016; Voyvodic, 2012), suggesting expressive language areas are active during tasks measuring the receptive language construct.

Receptive and expressive language should not be considered as independent functions and are dependent upon the integrity of other neuropsychological domains such as memory and learning (Lezak, 2012). Once linguistic information has been selected, classified, and integrated by the use of receptive language functions, the information is then stored for retrieval via memory and learning functions. This occurs with mental organization of the information by way of cognitive and executive functions. Expressive language functions are used when an individual expresses that information as a behavior, by action, or communication of thought. A breakdown

within any one of these neuropsychological domains or functions could present as a breakdown in receptive or expressive language functioning.

Additionally, tasks not aimed at measuring language abilities require a substantial level of language ability for the examinee to complete. Ortiz (2002) defined linguistic demand as the effect language abilities have on performance on that task. Tasks measuring nonverbal constructs (i.e., memory, attention, spatial skills, processing speed) have all been found to have varying levels of linguist demand (Flanagan, Ortiz, & Alfonso, 2013; Ortiz, 2005). Research investigating linguistic demand and the relationship of language abilities with specific neuropsychological assessments is lacking. It is reasonable to expect an individual with a deficit in language ability would perform at a lower level on neuropsychological tasks due to the levels of language ability needed to complete the task. Therefore, it is important to understand the extent to which a neurocognitive deficit measured by a task requiring the use of receptive or expressive language could be inflated by differences in language ability.

Assessment of Neurocognitive Domains in the Current Study

Verbal reasoning, nonverbal reasoning, executive functioning, memory, attention, and visuospatial skills are often assessed as neurocognitive domains (Morgan & Ricker, 2016). Verbal reasoning and language abilities are typically assessed using measures of receptive and/or expressive language. Common neuropsychological measures of language abilities include expressive tasks, such as confrontational naming and verbal fluency. The most commonly used measure of language in neuropsychological evaluation is the *Boston Naming Test – Second Edition* (BNT-2; Kaplan, Goodlass, & Weintraub, 2001; Rabin, Paolillo, & Barr, 2016). The RBANS also has a measure of naming ability, the Picture Naming subtest of the Language Index. Another commonly used measure is the *Delis-Kaplan Executive Function System* (D-

KEFS; Delis, Kaplan, & Kramer, 2001; Rabin et al., 2016). This set of tests includes both visual and verbal executive functioning; the latter includes measures which also tap into language abilities, specifically including the Verbal Fluency test. This measure of verbal fluency assesses phonemic fluency (i.e., Letter Fluency) as well as semantic fluency (i.e., Categorical Fluency). The Semantic Fluency subtest of the RBANS measures semantic fluency as part of the Language Index.

Measures of memory typically include tasks of immediate memory, delayed memory, and recognition. The Immediate Memory Index of the RBANS includes two verbal tasks, the Story Memory subtest and the List Learning subtest. Story Recall, List Recall, List Recognition, and Figure Recall are subtests of the RBANS Delayed Memory Index. Immediate and delayed memory tasks have been found to have high linguistic demand (Ortiz, 2005). This would suggest there is likely a strong relationship between language abilities and performance on neuropsychological measures of memory. In fact, performance on one of the most commonly used measures of memory, the *Wechsler Memory Scale – Fourth Edition* (WMS-IV; Wechsler, 2009), has been found to be correlated with language abilities as measured by the *Wechsler Adult Intelligence Scale – Fourth Edition* (WAIS-IV; Wechsler, 2008) Verbal Comprehension Index (VCI) ($r = .44-.57$; Wechsler, 2009). Similarly, the WMS-IV indices have been found to correlate with the RBANS Language Index ($r = .29-.54$; Wechsler, 2009).

Neuropsychological measures of attention often include span tasks and coding-type tasks. The RBANS Attention Index includes the Digit Span subtest and the Coding subtest, as a span task and coding task, respectively. While measures of attention are not typically thought to be related to language abilities, Ortiz (2005) outlined these commonly administered attention tasks have a moderate linguistic demand. Commonly administered coding and span tasks on the

WAIS-IV have been moderately correlated to language abilities, measured as the WAIS-IV VCI ($r = .38-.43$; Wechsler, 2008). Additionally, the RBANS Attention Index is moderately correlated with language abilities measured on the WAIS-IV ($r = .42$; Wechsler, 2008). This suggests those with language deficits may be more likely to exhibit lower performance on span tasks and coding tasks.

Commonly used measures of visuospatial skills include construction tasks and line orientation tasks. The RBANS measures this construct with the Figure Copy subtest and Line Orientation subtest of the Visuospatial/Constructional Index. Visuospatial skills measured by the *Kauffman Assessment Battery for Children – Second Edition* (KABC-II; Kaufman, 2004) suggest a moderate correlation with language abilities measured by the WAIS-IV VCI ($r = .18-.44$; Wechsler, 2008). Visuospatial skills and nonverbal reasoning measured by the RBANS are moderately to strongly correlated with language abilities measured by the WAIS-IV ($r = .51$). Research is mixed regarding the benefit of the use of language-based support (i.e., verbal coding behaviors) on visuospatial/construction tasks (Bek, Blades, Seigal, & Varley, 2009), suggesting the relationship between language abilities and this nonverbal performance could be due to the linguistic demand of the nonverbal task.

Rationale of the Current Study

The aim of the current study is to investigate the relationship of language abilities and neuropsychological performance as measured by the RBANS. Measures of psychological and neuropsychological domains have varying levels of linguistic demand, suggesting performance within those domains may be impacted by the individual's language abilities, rather than the actual abilities of the given domain. Deficits in language abilities could negatively impact the individual understanding verbal directions presented and/or their ability to express thoughts and

reasoning. As such, the primary rationale of this study is focused on examining and extending previous research in this area to three modern neuropsychological instruments, the BNT-2, RBANS, and D-KEFS. Research investigating the connection of language and these specific measures is lacking at this time. This is a concern, given the known relationship between language and most measures of neuropsychological functioning, and as these three measures are among the most commonly used assessment tools neuropsychological evaluation (Rabin et al., 2016).

Research has shown areas of the brain associated with receptive and/or expressive language are active even during nonverbal tasks. As there is seemingly no way to escape the tangle of language abilities and neuropsychological tasks, it is important to determine if measured deficits are true neuropsychological deficits, or due to lower language abilities. By investigating the impact of language abilities on RBANS performance, the current study may also help provide clinically relevant recommendations for the field of neuropsychology regarding interpretation of performance on the RBANS for those with language deficits. This is particularly true for the population in the current study; most research on the BNT-2 and RBANS has been conducted with older adults.

Significance of the Study

Given increased demand for valid and reliable neuropsychological measures, understanding of the relationship between neurocognitive domains and other abilities is necessary. At this time, there is little, to no, current research investigating the relationship of language and the RBANS. The results of the current study may provide information to the neuropsychological and psychological fields on how language abilities can affect performance on neuropsychological assessments, specifically on the RBANS. This relationship is important to

understand when interpreting neuropsychological results, as research on other psychological measures suggests the linguistic demand of the task may negatively impact performance for those with language deficits. If results of the current study suggest a strong relationship between language abilities and performance on the RBANS, recommendations to clinicians in the neuropsychology field may be made. These recommendations may include a new understanding of best practices of the use of the RBANS with patients with varying levels of language abilities. The results may suggest how greatly impacted performance on the RBANS may be by varying levels of language abilities, as well as which indices and subtests are least likely impacted by language. With this better understanding of which measures are most and least impacted by language ability, there is a possibility of better estimates of neuropsychological functioning for the patient. Insignificant results can also contribute to the neuropsychology field, as a lack of relationship may suggest the RBANS is a valid measure of estimated neuropsychological functioning for those with developmental or acquired deficits in language ability.

Additionally, this study may lead to further research considering the impact of language abilities on other neuropsychological assessments. If results of the current study are significant, the need to better understand the relationship between language abilities and neuropsychological assessments would be made more clear, hopefully prompting further research with other measures of neuropsychological functioning. If the results are not suggestive of a relationship between language and neuropsychological performance on the RBANS, this study may act as an additional, and necessary, validity study for the RBANS.

Research Questions

R₁: What is the canonical relationship of the measures of language (naming, semantic fluency, phonemic fluency) with the 12 subtests of the RBANS?

H₁: To explore the relationship between language ability and neuropsychological performance, it is hypothesized phonemic verbal fluency or semantic verbal fluency will contribute the most to this relationship, as compared to the BNT-2, given the fluency tasks tap a greater array of neuropsychological constructs.

H₂: It is hypothesized the Picture Naming and Semantic Fluency subtests of the RBANS will contribute most to this relationship, as these two subtests contribute to the RBANS Language Index.

H₃: It is hypothesized the subtests of the RBANS which require more verbal ability (e.g., Picture Naming, Semantic Fluency, List Learning, and Story Memory) will contribute more to the relationship than those which require less verbal ability (e.g., Figure Copy, Line Orientation, and Coding). It is also hypothesized, however, that even those subtests requiring minimal language ability will still somewhat contribute to the relationship.

R₂: What is the canonical relationship of the measures of language (naming, semantic fluency, phonemic fluency) with the 5 indices of the RBANS?

H₁: To explore the relationship between language ability and neuropsychological performance, it is hypothesized phonemic verbal fluency or semantic verbal fluency will contribute the most to this relationship, as compared to the BNT-2, given the fluency tasks tap a greater array of neuropsychological constructs.

H₂: It is hypothesized the Language Index of the RBANS will contribute most to this relationship.

H₂: It is hypothesized the indices of the RBANS which require more verbal ability (e.g., Language Index, Immediate Memory Index, and Delayed Memory Index) will contribute more to the relationship than those which require less verbal ability (e.g.,

Visuospatial/Construction Index and Attention Index). It is also hypothesized, however, indices requiring minimal language ability will still somewhat contribute to the relationship.

R₃: What is the relationship among the measures of language not part of the RBANS?

H₁: It is hypothesized there will be a strong, positive correlation found between naming ability, as measured by the BNT-2, and phonemic fluency, as measured by the D-KEFS Verbal Fluency Condition 1: Letter Fluency task.

H₂: It is hypothesized there will be a strong, positive correlation found between naming ability, as measured by the BNT-2, and semantic fluency, as measured by the D-KEFS Verbal Fluency Condition 2: Category Fluency task.

CHAPTER II

REVIEW OF THE LITERATURE

The following review is organized into two sections relevant to the investigation of the relationship between language abilities and performance on the *Repeatable Battery for the Assessment of Neuropsychological Status – Update* (RBANS, Randolph, 2012). The first section discusses language at a linguistic level, language proficiency, and language abilities. How language abilities may impact performance on measures of neuropsychological functioning is included, as is a discussion of linguistic demand. The second section is an overview of the neuropsychological functions and constructs assessed in the current study, along with a discussion of the neuroanatomical correlates, commonly associated disorders, and deficits for each construct. The known relationships between language abilities and performance on tasks measuring these constructs is also included. These constructs are presented in a format outlining the RBANS Indices: Attention, Visuospatial/Construction Abilities, Immediate Memory, Delayed Memory, and Language.

Language

Linguistic Levels of Language

One of the defining features of humans is the ability to communicate with other humans using unique and advanced cognitive processes. Language is the means in which this communication primarily occurs. The field of linguistics generally considers language in two parts: the lexicon and the system of rules. This lexicon includes the sounds, meanings, and words for a language. Words are considered one of the primary components of a language. Knowledge of words are stored in the brain. An average adult may have approximately 5,000 commonly used words in their lexicon and may comprehend that many, or more, with up to an estimated

70,000 lemmas, or base words, in their vocabulary (Segbers & Schroeder, 2016; Semrud-Clikeman & Ellison, 2009). For efficiency, frequently used words are organized in a way to be more accessible. Words may be organized using networks based on the relationships of the words to one another (Semrud-Clikeman & Ellison, 2009), as well as by the sounds of the words with phonological neighborhood networks (PNNs; Turnbull & Peperkamp, 2016). Language has been considered in terms of four distinct and fundamental systems in the field of linguistics, three come together as the lexicon and one as the system of rules for the language: phonology, morphology, syntax, and semantics.

Phonology is the branch of language that includes the smallest units of language; for example, phonemes are the discrete units which occur in speech (Trask & Stockwell, 2007). These phonemes change depending on the language of the individual (Semrud-Clikeman & Ellison, 2009). Humans are born with the ability to use all possible known phonemes. By age 6 to 8 months, infants typically begin discriminating these phonemes to use only their language-specific phonemes; adults who communicate a given language(s) are no longer able to discriminate phonemes that are not included in their language (Hannahs & Young-Scholten, 1997). In the spoken English language, phonemes are sounds or groups of sounds that hold the same function for all those who speak English. For example, the phonemes 'th', /æ/, 't' all hold the same function for all English speakers. There are currently considered 44 phonemes in the English language (Deng & Allahverdyan, 2016; Giegerich, 1992).

Morphology is the branch of language describing how sound units are formed in a language to provide meaning (Booij, 2016; Trask & Stockwell, 2007). Lexical morphemes are those that hold meaning by themselves. Grammatical morphemes specify the relationship of one lexical morpheme and another (i.e., at, in, -ed, -s). Morphemes can also be bound or unbound,

meaning sound unit groups may require a root to have meaning, or the sound unit group may have meaning itself. For example, 'meaning' is a group of sound units that has meaning itself, while '-ful' is a group of sound units that must be bound to a base or root morpheme to carry meaning, as in 'meaningful.' Morphemes may be root words (i.e., 'meaning'), suffixes (i.e., -ful), or prefixes (i.e., un-). The field of morphology concludes these sound units can only occur in combination, and that combination must be correct (Booji, 2016).

The linguistic branch of syntax considers how sound units, words, and word structures are combined or arranged into meaningful sentences. Syntax may include the rules of the language, or the grammar. These rules of language are used to determine how words and parts of speech are combined to create whole, meaningful sentences to communicate thoughts, ideas, and feelings (Aarts, 2013; Trask & Stockwell, 2007).

Finally, semantics is the branch of language that applies meaning to words, word structure, and sentences (Curzan & Adams, 2014; Trask & Stockwell, 2007). Semantics includes how the meaning of various words, phrases, and sentences may change in a given context. Semantics may also include literal meaning of a word, phrase, or sentence, as well as figurative meaning; this area of semantics is often considered part of the pragmatics field as well. While there is some current debate between the fields of semantics and pragmatics, research suggests these two branches of the linguistic field are heavily related and interact with one another to allow for the use of functional language abilities (Bera, Burton-Jones, & Wand, 2014). Used together, phonemes, morphemes, syntax, and semantics allow humans to communicate thoughts, ideas, knowledge, and feelings to one another by the understanding and demonstration of language.

Language as a Neuropsychological Construct

For the purposes of this literature review from the perspective of the neuropsychological field, language and the concept of *language abilities* will be limited to the use of verbal language; this will exclude written language and sign language. These latter abilities rely upon different neural networks and thus are beyond the scope of this study. *Verbal* abilities or functions refer to functions that mediate verbal and symbolic information, while *nonverbal* abilities or functions refer to functions involving data that cannot be communicated using words or symbols (Lezak, 2012). Throughout literature and research in the fields of linguistics and neuropsycholinguistics, the terms *language ability*, *language proficiency*, and *verbal abilities* are sometimes used interchangeably, due to small differences in the concepts (Astesano & Jucla, 2015). To speak a language successfully, an individual must have linguistic competence in that language; this competence may also be known as language ability. Language proficiency is often considered an individual's ability to use language appropriately in social situations (Trask & Stockwell, 2007). Verbal abilities relate to the skills seen in understanding and behaving appropriately with language. Language, as the use of verbal abilities, is often considered as two distinct and important constructs: receptive language and expressive language (Astesano & Jucla, 2015).

Receptive language can be considered the ability to understand and comprehend language. Receptive language is best defined as the input of language for the individual. This linguistic input is translated into a phonological code previously stored in the lexicon. That information is decoded into the appropriate word and the meaning of the word (Semrud-Clikeman & Ellison, 2009). For example, auditory input follows the auditory pathway, including the peripheral auditory system and the central auditory system, for the input to reach the auditory

cortex. Following the appropriate respective sensory pathways, this linguistic input converges in Wernicke's area at the superior temporal gyrus and near the auditory cortex (Semrud-Clikeman & Ellison, 2009). This cortex, in the dominant temporal lobe, is then responsible for the comprehension of language, primarily speech-based language (Nolte & Sundsten, 2002). Damage to Wernicke's area often results in dysfunction in comprehension and can also present as fluent aphasia, in which the individual's expressive language is largely fluent and grammatical but lacking in meaning (Astesano & Jucla, 2015; Benson & Ardila, 1996). Overall, aside from nonverbal cues, thoughts, ideas, and feelings are received from another human and understood by the use of receptive language skills of the individual.

Expressive language is often thought of as the outward demonstration of language (Trask & Stockwell, 2007). This demonstration of language communicates thoughts, ideas, and feelings to another. It may be in the form of written language, spoken or signed language, or in the form of gestures. Broca's area is primarily associated with expressive speech and language. This cortical area, found in the frontal lobe, labeled as Brodmann's Area (BA) 44, along the Sylvian fissure and motor cortices, is primarily responsible for the demonstration of language, including speech and written language (Ardila, Bernal, & Rosselli, 2017; Petrides, 2013). Damage to Broca's area often results in dysfunction of expressive language; this often presents as nonfluent or agrammatical aphasia, in which the individual's expressive language may be laborious and telegraphic (Benson & Ardila, 1996). Also, motor speech deficits such as apraxia or speech and unilateral upper motor neuron dysarthria. These motor speech deficits can severely impact the comprehensibility of an individual's verbal output. Overall, expressive verbal language includes the demonstration of language and communication through the ability to generate words, to use a lexicon or vocabulary, naming, and verbal fluency.

Psychological and neuropsychological assessments measuring a variety of constructs, not only language abilities, involve the use of expressive language. The majority of psychological and neuropsychological test batteries also involve some form of specific measure of language or/and communication (Mpofu & Ortiz, 2009). Expressive language tasks are relied upon heavily as a measure of overall language abilities in psychological and neuropsychological assessment. Therefore, performance on expressive language tasks may be considered by some to be a measurement of overall language abilities. Tasks measuring various constructs require the examinee to have a certain ability to use receptive language skills; the individual must be able to understand and comprehend the instructions, demonstrations, and feedback from the examiner. This level of language ability required by the task of the examinee and examiner is considered the linguist demand of the task.

Linguistic demand is the level of expressive language required by the task of the examiner to explain the task, and the level of language proficiency needed by the examinee to understand and respond appropriately to the items (Ortiz, Flanagan, & McGrew, 1998; Wang, 2015). Traditionally, the concept of linguistic demand has been considered regarding language-learning populations (Cioffi, 2015; Sotelo-Dynega, Ortiz, Flanagan, & Chaplin, 2013); however, the level to which a task requires language abilities remains the same whether or not the individual is a native speaker or a language-learner. Psychological and neuropsychological tests are normed primarily with monolingual, language-proficient individuals. As such, those who have not been exposed to the language at a similar level are likely to present with lower language proficiency overall, and lower test performance across virtually all constructs and tests compared to those whom the tests were normed (Flanagan & Harrison, 2012). Neuropsychological test items are typically structured presuming a certain level of language proficiency of the examinees

to understand the directions, know the concepts, be able to verbalize responses, and complete a given task with appropriate responses (Cummins, 1984). When tests have tasks that favor language proficiency, those with limited language proficiency typically do not fare as well. This discrepancy in performance should not be primarily considered as a fault in the psychometrics, particularly if the test has been found to be invariant for those populations. Rather, differences in interpretation should be considered in light of the expectations and assumptions of language proficiency levels and that effect on overall performance (Rhodes, Ochoa, & Ortiz, 2005).

Linguistic demand is considered low when performance on a given task is not dependent on the level of language abilities; linguistic demand is considered high when there is an effect on task performance given differences in language abilities (Ortiz, 2002). Tasks with low linguistic demand compared to high linguistic demand may have markedly different performance levels, up to 20 standard score points (Ortiz, 2005). A number of neuropsychological tests, including many tasks which purport to primarily assess nonverbal abilities, require receptive language as the test directions are spoken by the examiner. For example, tasks measuring non-verbal skills, including visuospatial abilities, have been found to have a moderate linguistic demand (Flanagan et al., 2013). As such, there is likely a largely disproportionate effect of language on neuropsychological functioning assessments. Unsurprisingly, research has found tasks measuring verbal comprehension have high linguistic demand. Tasks related to working memory, attention, and processing speed were found to have varying linguistic demand, from low to high. Tasks measuring executive functioning were found to primarily have high linguistic demand (Ortiz, 2005). Additionally, measures of memory, particularly verbal memory, were found to have high levels of linguistic demand (Ortiz, 2005). Given the strong influence of language abilities on both verbal and nonverbal tests it is critical for researchers and practitioners to understand the

influence of language on neuropsychological tests and to know which tasks of neuropsychological functioning are most linked to language abilities.

Neuropsychological Assessment of Neurocognitive Domains

Neuropsychological assessment has developed to include the measurement of a variety of neuropsychological functioning constructs, including: executive functioning, memory, verbal and nonverbal reasoning, attention, visuospatial skills, sensory/motor abilities, and functional performance (Morgan & Ricker, 2016). The construct of orientation and attention includes assessment of awareness, time, place, body orientation, directional orientation, space, attention-related capacity, working memory, mental tracking, concentration and focused attention, processing speed, divided attention, and functional attention. Assessment of the construct of perception includes visual perception, auditory perception, and tactile perception. Memory, as a construct, involves assessment of verbal memory, visual memory, tactile memory, incidental learning, prospective memory, remote memory, and recognition. Verbal functions and language abilities are assessed using expressive and receptive language. Reasoning skills as a construct is also assessed, including verbal and visual concept formation tasks, verbal and visual reasoning tasks, and math procedures. Nonverbal constructs, including construction, motor skills, and visuospatial skills, are assessed within neuropsychological evaluations as well. Finally, executive functioning is assessed with tasks of inhibition, planning, decision making, engagement in actions, self-regulation, and performance (McCloskey & Perkins, 2012).

A current shift in the field of neuropsychology involves a move toward early identification of neurocognitive conditions (Miller, 2009; Tramontana & Hooper, 2013). The earlier an impairment or condition is found, the better the prognosis. For example, children who are assessed and identified with autism spectrum disorder (ASD) at an earlier age have been

shown to respond more positively to intervention and have more positive life-long outcomes (Koegel, Koegel, Ashbaugh, & Bradshaw, 2014; Zwaigenbaum, Bryson, & Garon, 2013). As medical and psychological research continues, better treatments are available for many neurocognitive conditions. As such, there is an increasing need to identify those who may be likely to develop, or are developing a neurocognitive condition as early as possible. Early diagnosis of some other neurocognitive conditions can also be important, as those individuals can be provided survival-prolonging treatment and interventions to slow disease progression (Dubois et al., 2014; Prince, Bryce, Albanese, Wimo, Ribeiro, & Ferri, 2013). The use of valid and reliable assessments for this early identification is key. Additionally, brief, reliable, repeatable batteries of neuropsychological functioning are vital as screening and assessment tools for those who have a variety of neurology concerns, including traumatic brain injury (TBI), stroke, seizures, multiple sclerosis (MS), attention-deficit/hyperactivity disorder (ADHD), Parkinson's disease, Alzheimer's disease (AD), and dementias. Many individuals with these conditions may not be able to complete a full-length neuropsychology battery, which may involve testing for approximately 4 to 6 hours and expect a high level of vigilance from the patient throughout which may be a concern with some of the above mentioned conditions. With a brief assessment sensitive to impairment in neuropsychological functions, the need for a full-length battery would be minimized when screening and tracking rehabilitation for many conditions and injuries. One such brief neuropsychological assessment sensitive to neurocognitive impairment is the *Repeatable Battery for the Assessment of Neuropsychological Status* (RBANS; Randolph, 2012). Much of the current research on the RBANS includes many internal consistency studies, comparing the subtests and indices of the RBANS with one another,

and studies of the RBANS regarding specific clinical populations (i.e., populations with dementias, AD, TBI, and Parkinson's disease).

While studies do show the RBANS is a valid and reliable measure of the included neurocognitive constructs, research regarding the impact of language abilities on the RBANS is lacking as few measures of language have been researched with the RBANS.

Neuropsychological functioning as measured by RBANS Total Score has been shown to have a moderate correlation with measured language skill on the *Boston Naming Test* (BNT; Goodglass, Kaplan, Weintraub, 1983) and the *Controlled Oral Word Association Test* (COWAT; Benton & Hamsher, 1976) ($r = .66$, $r = .64$, respectively; Randolph, 2012). Language ability, measured by the RBANS Language Index, is moderately to strongly correlated with the BNT-2 and COWAT ($r = .75$, $r = .59$; Randolph, 2012). The RBANS includes the domains of attention, visuospatial/construction, immediate memory, delayed memory, and language. Descriptions of these neuropsychological constructs, neuroanatomical correlates, and assessment of these constructs is included in the sections below.

Attention

Attention is the capacity of an individual to be aware of and receive stimuli from the environment and begin to process that stimuli. In assessment and research, attention is considered a system which sequentially processes information in stages involving multiple neurological systems (Reynolds & Kamphaus, 2003a). Attention capacities vary from individual to individual (Barkley, 2014; Peng, Grant, Heath, Reiersen, Mulligan, & Anokhin, 2016). Additionally, an individual's ability to attend may be reliant on the external environment (i.e., distractions) and the internal environment. For example, attentional resources, especially ability to sustain attention, are often seen to decrease in those experiencing depression, anxiety, and

fatigue, as well in those who have experienced brain injury, atrophy, and neurocognitive disorders (American Psychiatric Association, 2013; Calderon et al., 2001; Yen, Ko, Yen, Wu, & Yang, 2007).

Immediate attention is considered the amount of information that is held and maintained at one time (Parasuraman & Yantis, 1998). Immediate attention is vital to an individual's overall attentional resources as it is relatively effortless and automatic. Four types of attention involve the effortful allocation of attentional resources; selective attention, sustained attention, divided attention, and alternating attention. Selective attention, sometimes referred to as focused attention or more commonly as concentration, allows an individual to suppressing the extraneous details and distractions while focusing on the few most important stimuli in the environment (Pashler, 2016). Sustained attention, commonly referred to as vigilance, refers to the ability to maintain the use of attentional resources to attend to and process stimuli for an extended period of time (Cohen & Swerdlik, 2002). Divided attention is the ability to process and act upon more than one stimulus at a time during the learning process; this may be multiple stimuli in the environment or multiple elements of the same external or internal task (Cohen & Swerdlik, 2002; Weeks & Hasher, 2016). Finally, alternating attention is the form of attention that allows the individual to shift attentional resources from one stimuli to another. While immediate attention may be more resistant to brain damage and aging, the four broad types of attention are extremely susceptible to impairment (Cohen, Malloy, Jenkins, & Paul, 2014; Pashler, 2016). Attention problems and poor concentration are one of the most commonly reported symptoms associated with brain damage and psychiatric conditions (Cohen et al., 2008; Leclercq, Deloche, & Rousseaux, 2002), suggesting attention-related performance is key in performance of many other cognitive functions.

The abilities of attention have been associated with activation and use of the frontal lobes (Young, Young, & Tolbert, 2008), although other neurological areas are also involved in this domain. Activation of the frontal lobes has long been associated with working memory tasks requiring temporary storage of information and manipulation of the information. The prefrontal cortex has also been shown with significant activation during tasks of selective attention (Baldauf & Desimone, 2014; Nelissen, Strokes, Nobre, & Rushworth, 2013). Research has suggested the right prefrontal cortex has been linked to sustained attention in particular (Nelissen et al., 2013; Rubia, Alegria, & Brinson, 2014). The prefrontal cortex may mediate the capacity to engage in shifting attention as well as to maintain vigilance. The prefrontal cortex is also implicated in the inhibition and the exclusion or filtering of distractor stimuli (Aron, Robbins, & Poldrack, 2014; Rae, Hughes, Anderson, & Rowe, 2015), which is important in the practical execution of attention and inhibition tasks. Divided attention on dual-task performance has also been connected with the activation of the prefrontal cortex (Aron et al., 2012); however, this activation is not seen when one task is performed separately (Langner & Eickhoff, 2013). Those with damage to the prefrontal cortex are often seen with deficits in processing speed and reaction time, an inability to maintain focus, and frequent distractibility to irrelevant stimuli (D'Esposito, 2003; Szczepanski & Knight, 2014). However, some patients with frontal lobe damage have little attention-related deficits (Stuss, 2011), suggesting there are also other cortical and subcortical structures which contribute to attention. The anterior cingulate is activated when concentration is on solving novel problems; when the novel task becomes automatic, this activation no longer occurs as concentration-related attentional resources are no longer necessary to complete the task (D'Esposito, 2003). Additionally, individuals with subcortical white matter lesions have been found to have attention deficits (Konrad et al., 2012) which again suggests a diffuse neural

network is associated with attention. The parietal lobe has also been found to be associated with attention (Lei et al., 2015). Inactivation of the parietal lobe, specifically the lateral intraparietal area, is associated with increased levels of distractibility and inattention (Suzuki & Gottlieb, 2013). Treatment (i.e., medication) leading to increased activity of the parietal lobes is associated with a decline in inattention symptoms (Rubia, Alegria, Cubillo, Brammer, & Radua, 2014). The assessment of attention is an important diagnostic tool when considering individuals with a wide array of neurological and psychiatric conditions.

Measures of attention may include assessment of attention capacity, concentration and focus, complex attention, divided attention, processing speed, attention span, and working memory or mental tracking. Span tests are often administered to assess attentional capacity and working memory or mental tracking (Lamar & Raz, 2007; Strauss, Sherman, & Spreen, 2006). Perhaps the most common span test is a digit span task (Boake, 2002; Jacobs, 1887; Strauss et al., 2006). During this type of task, the individual is required to repeat a series of stimuli increasing in length throughout the trials. The task includes the use of auditory attention as well as short-term retention capacity (Kaufman, Railford, & Coalson, 2015; Lamar & Raz, 2007). Often, two of three modalities constitute the digit span task: digits forward and digits backward; digit sequencing is less often included. The amount of correctly repeated digits on the forward condition is considered representative of the individual's attentional capacity (Rojas & Bennett, 1996). Digit span tasks requiring individuals to repeat numbers in reversed order, or backward, measure working memory and mental tracking (Crowe, 2000).

In addition to the activation of the prefrontal cortex, neuroimaging has associated the activation of the right dorsolateral prefrontal cortex as vital to accurate digits forward and digits backward performance (Aleman, & van't Wout, 2008). The inferior parietal lobe of the left and

right hemispheres, the anterior cingulate, and the medial occipital cortex also show activation during digits forward and digits backward (Berryhill & Olsen, 2008; Gerton et al., 2004). Those with damage to the left hemisphere and with visual field deficits have been found to have lower performance on digit span backward tasks (Gerton et al., 2004). Those who have experienced recent (i.e., 0 to 3 months) brain trauma perform at a level below typically functioning individuals but often return to normal functioning levels on the digit span task during the following years (Draper & Ponsford, 2008). Those who have experienced repeated head trauma and/or a high number of concussions may exhibit a long-term deficit in digit span forward performance (Draper & Ponsford, 2008). Digit span tasks are less sensitive to dementia (Vaughan et al., 2015); however, once in the more progressive stages of the disease, performance on digit span forward tasks declines substantially (Dauwan et al., 2016; Flicker, Ferris, & Reisberg, 1991).

Measurement of complex attention includes components of visual scanning, motor abilities, sustained attention, response speed, and visuomotor precision (Boake, 2002; Frazier, Demaree, & Youngstrom, 2004). Symbol substitution tasks often include the use of pencil and paper and may be referred to as coding tasks. On these types of tasks the individual must use a key to respond with the series of corresponding stimuli to match the stimuli presented.

Coding-type tasks have shown activation of the dorsolateral prefrontal cortex, in particular, as well as the supramarginal gyrus, the inferior frontal gyrus, and the angular gyrus (Hampshire, Chamberlain, Monti, Duncan, & Owen, 2010; Kane & Engle, 2002). In healthy individuals, the activation of the dorsolateral prefrontal cortex was related to faster performance speed; however, overall activation of the prefrontal cortex was related to slower performance speed (Woodward, Duffy, & Karbasforoushan, 2013). The activation of the middle frontal gyrus,

superior parietal cortex, and basal ganglia, and the anterior cingulate were associated with lower performance on coding tasks completed by those diagnosed with TBI (Draper & Ponsford, 2008).

Language and the Assessment of Attention

Attention has long been found to be a significant contributor to overall intelligence. Language has also been found to be a strong predictor of intelligence, and thus, attention and language have been found to be significantly correlated with standardization data from the *Children's Memory Scale* (CMS; Cohen, 1997) Attention/Concentration dimension and the *Wechsler Adult Intelligence Scale – Fourth Edition* (WAIS-IV; Wechsler, 2008) Verbal Comprehension Index (VCI) ($r = .76$; Sattler & Ryan, 2009). While attention measures often are considered not to tap complex language functions, many tasks measuring attention provide verbal instructions and require verbal responses. Frequently used tasks of attention, including span tests and symbol-substitution tasks of the *Wechsler Intelligence Scale for Children – Fourth Edition* (WISC-IV; Wechsler, 2004) and the WAIS-IV, have been found to have moderate linguistic demand (Ortiz, 2005). For example, a study investigating English-speakers' and Spanish-speakers performance on the *Wechsler Adult Intelligence Scale – Revised Edition* (WIAS-R; Wechsler, 1981) found Spanish-speaking performance on the Digit Span Forward task was significantly below performance of English-speakers (Lopez, Steiner, Hardy, IsHak, & Anderson, 2016). The RBANS Attention Index has been found to be moderately related to the Language Index of the RBANS with 175 adults completing a clinical neuropsychological evaluation ($r = .55$; Carlozzi, Horner, Yang, Tilley, 2008). The WAIS-IV VCI has been found to have a mild to moderate correlation with RBANS Attention Index with the respective standardization samples ($r = .42$; Sattler & Ryan, 2009). Overall, however, a search of the

literature reveals the RBANS has limited research suggesting the attention measures' relationship with measured language abilities measured by other assessments in non-clinical samples.

A common example of the digit span task is the Digit Span task on the Wechsler Intelligence Scales (WIS). Depending upon the age of the examinee and the iteration of the WIS, Digit Span can include forward, backward, and sequencing conditions. On the WIS, Digit Span is used to measure both immediate verbal recall and verbal working memory (Wechsler, 2008; Wechsler, 2014). The Digit Span subtest on the WAIS-IV has been found to be moderately correlated with overall measured verbal abilities measured as the VCI ($r = .53$; Sattler & Ryan, 2009). The RBANS has a digit forward span task as well, aimed at measuring auditory attention and short-term retention capacity of the phonological loop (Randolph, 2012). On this task, number sequences increase in difficulty. In a clinical sample of 57 adults with traumatic brain injury (TBI), the Digit Span subtest on the RBANS has been found to significantly correlate with the Wechsler Digit Span tasks of the *Wechsler Adult Intelligence Test – Third Edition* (WAIS-III) ($p < .01$, $r = .623$; McKay, Casey, Wertheimer, & Fichtenberg, 2007). Research of the RBANS Digit Span task with a clinical sample suggests it is correlated, weakly, with measures of language on the RBANS ($r = .27-.37$; Carlozzi et al., 2008).

A common task of symbol substitution is the Coding task for the WIS. The Coding subtest on the WAIS-IV is correlated with measured verbal abilities as the VCI in the standardization sample ($r = .43$; Sattler & Ryan, 2009; Wechsler, 2008). The RBANS also has a symbol-substitution task. The RBANS Coding task and the Wechsler Coding task of the WAIS-III are significantly correlated in a clinical sample ($r = .827$; McKay et al., 2007). The RBANS

Coding subtest is moderately correlated to the measures of language on the RBANS in a clinical sample ($r = .51, .58$; Carlozzi et al., 2008).

Overall, research suggests performance on attention tasks is moderately correlated with language abilities. Digit span tasks have a weak to moderate relationship with language abilities, suggesting language abilities may play less of a role in performance on these tasks as compared to other constructs commonly measured for psychological and neuropsychological evaluation. Coding tasks have a moderate relationship with language abilities. This suggests attention tasks requiring the individual to respond with verbal or written responses are similarly linked to language abilities.

Visuospatial/Construction

Visuospatial perception refers to the ability to process and interpret visual information presented in the environment (Lezak, 2012). Visual processing requires ocular movement, visual tracking, and ocular feedback to allow for visuospatial perception and the use of visuospatial abilities. Visuospatial ability includes the capacity to perceive the spatial relationships between objects in that environment (Reynolds & Kamphaus, 2003a). The ability to organize and interpret the visual environment in a meaningful way is also a component of visuospatial abilities.

Visuospatial abilities have been linked to activation of the non-dominant hemisphere. The parietal lobe is often associated with these abilities (Humphreys & Ralph, 2015; Suchan, 2008). Specifically, the right inferior parietal cortex is often associated with visuospatial skills (Shapiro, Hillstrom, & Husain, 2002). Additionally, the bilateral dorsolateral prefrontal cortices have been linked to activation during construction-type tasks (Burgess, Veitch, de Lacy Costello, & Shallice, 2000). The cerebellum has also been associated with visuospatial abilities as the

cerebellum has connection between the cortical areas and subcortical sites; cerebellar lesions have been seen to cause diminished visuospatial abilities, as well as decreased abstract reasoning, verbal fluency, attention, planning, working memory, memory, learning, and emotion regulation (Molinari, Petrosini, Misciagna, & Leggio, 2004).

Measurement of visuospatial abilities include a wide array of assessment approaches, including tests of visual scanning, color perception, construction, visual attention, visual recognition, and visual organization. Construction tasks require visuospatial perception and motoric responses (Mervis, Robinson, & Pani, 1999). Often these tasks include the ability to visually perceive an object or stimuli, consider the stimuli as parts of a whole, and construct a replica of the visual stimuli in the parts. These abilities are central to activities such as drawing, assembling, and a variety of activities of daily living (i.e., folding laundry). Assessment of construction abilities may include drawing tasks as copying tasks or free drawing, along with assembling and building tasks (Reynolds & Kamphaus, 2003a). Often drawing tasks include the copying of visual stimuli or figures and free-drawing (Beery & Beery, 2010). During typical figure copy tasks, the individual is presented with two-dimensional designs and required to copy the design using pencil and paper as accurately as possible with regard to size, orientation, shape, and relation to other parts of the figure.

In addition to the non-dominant parietal lobe, performance on figure copying tasks is related with the inferior parietal lobe and the frontal lobe (Kolb & Whishaw, 1983; Possin, Laluz, Alcantar, Miller, & Kramer, 2011). Individuals with brain damage tend to have a diminished score on figure copying tasks, suggesting this simple task is sensitive to neuropsychological impairment. Those with left hemisphere damage (LDH) tend to perceive and draw the figure parts as smaller units (Kolb & Whishaw, 1983). Those with right hemisphere

damage tend to omit units of the figure completely (Azouvi et al., 2002). Research has also suggested patients with aphasia were less accurate than patients with non-aphasic LHD (Stone et al., 1991). However, some patients with stroke show no differences in accuracy compared to healthy individuals (Blake, McKinney, Treece, Lee, & Lincoln, 2002). Patients with parieto-occipital lesions and those with frontal lobe impairment also showed impaired figure copy as well (Purves et al., 2001). Individuals who have sustained a TBI do not necessarily have a decreased figure copy performance. Those with certain types of dementia and those with Alzheimer's disease typically construct impaired figure copies (Possin et al., 2011).

Line orientation tasks typically incorporate visual perception and visuospatial abilities. These tasks require the individual to estimate the relationship of angular line segments and visually match those stimulus lines with an array of angular lines presented. Along with activation of the right parietal lobe, performance on line orientation tasks is linked with the right inferior parietal, the temporal, and the frontal areas (Grant, 2009). The right posterior parietal lobe, the inferior frontal gyrus, and the posterior dorsal intraparietal sulcus, and the anterior insula are involved (Calamia, Markton, Denberg, & Tranel, 2011). Those with typically poor performance on line orientation tasks include patients with dementia (Ska, Poissant, & Yoanette, 1990), although those with Parkinson's disease dementia have been found to have poor performance primarily due to the complexity of the demands of the task, rather than pure visuospatial deficits (Galvin, Pollack, & Morris, 2006). Those with a diagnosed TBI, William's syndrome, and those with dyslexia may also have poor performance on these tasks (Grant, 2009; Lezak, 2012).

Language and the Assessment of Visuospatial/Construction abilities

Nonverbal abilities, including visuospatial and construction abilities, have been highly correlated with overall cognitive abilities. Research suggests visuospatial/construction abilities are significantly related with verbal abilities in the standardization sample of the WAIS-IV between subtests of the VCI and Perceptual Reasoning Index (PRI; $r = .46-.59$; Sattler & Ryan, 2009). Certain language mechanisms are needed to efficiently integrate spatial information (Hermer-Vazquez, Spelke, & Katsnelson, 1999); for example, visuospatial representations can be supplemented by verbal coding (i.e., adding a linguistic label to a picture; Meilinger, Knauff, & Bulthoff, 2008). However, it has also been found core language mechanisms (i.e., semantic and syntactic processes) were not required for visuospatial representation (Bek et al., 2009). If language processes are not required for visuospatial/construction tasks, the significant relationship between verbal and nonverbal performance may be due to something else, such as the linguistic demand on these tasks. The commonly administered tasks of construction of the WAIS-IV and WISC-IV have been found to have moderate linguistic demand (Ortiz, 2005). Nearly all visuospatial and construction tasks include directions given orally by the examiner. While assessment of visuospatial-construction ability has long been found to correlate with verbal abilities, the research on the RBANS has primarily focused on correlations between the Visuospatial/Construction Index and the Language Index, specifically in clinical samples, ($r = .45$; Carlozzi et al., 2008) rather than with external measures of language abilities. Overall, research suggests performance on the RBANS Visuospatial/Construction Index is moderately correlated with overall language abilities on the WAIS-IV VCI ($r = .51$, Sattler & Ryan, 2009). Research suggesting the relationship between the RBANS Visuospatial/Construction Index and other, more pure measures of language abilities is lacking.

One of the most commonly administered figure copy tests are the iterations of the Bender-Gestalt tests (Lezak, 2012). This copy task involves requiring the individual to draw a simple figure immediately after a timed presentation of the visual stimulus to measure visuospatial/construction skills as well as immediate memory. Another commonly used assessment of visual construction is the *Rey Complex Figure Test*, copy trial (RCFT; Meyers & Meyers, 1995; Cherrier, Mendez, Dave, & Perryman, 1999; Poulton & Moffitt, 1995). This task requires the individual to accurately copy a complex figure presented, with no time limit. The RCFT has been found to be weakly, yet significantly, correlated with overall language abilities of the WISC-R VIQ in a non-clinical sample of 740 adolescents ($r = .37$; Poulton & Moffitt, 1995). The RBANS includes a task similar to the one of the RCFT Figure Copy, which includes the presentation of a complex figure the individual is required to copy. The RBANS Figure Copy subtest has been found to weakly correlate with the language measures of the RBANS in a clinical sample ($r = .34-.40$; Carlozzi et al., 2008).

Another commonly administered test of line orientation is the *Benton Judgment of Line Orientation* (J-Lo; Benton, Hamsher, Varney, & Spreen, 1983), available in two forms. The J-Lo test has been found to moderately correlate with verbal abilities as measured by naming ability on the BNT-2 and the WAIS-R VIQ in a non-clinical sample of the Mayo Clinic's Older Americans Normative Studies (MONAS) ($r \sim .50$; Steinberg, Bieliauskas, Smith, Langellotti, & Ivnik, 2005). Similar to this task, the RBANS includes a test of line orientation as well. The RBANS Line Orientation subtest was found to be moderately correlated with the RBANS measures of attention in a clinical sample ($r = .45-.52$; Carlozzi et al., 2008).

Memory

Central to all cognitive functions is arguably some aspect or component of memory. Memory allows humans to learn, access knowledge, and remember (Lezak, 2012). The processes of registration, storage, and retrieval are vital to day-to-day functioning. Memory has been associated with the neuroanatomical functioning of many areas of the brain. The prefrontal cortex, hippocampus, cerebellum, basal ganglia, and the amygdala are all involved in the processes of memory (Buckner, Logan, Donaldson, & Wheeler, 2000; Kapur et al., 1994). One of the primary functions of the temporal lobes is memory (Grant, 2009; Machulda et al., 2003). The dominant temporal lobe is associated with verbal memory, while the non-dominant temporal lobe is associated with memory of nonverbal information. The hippocampal complex is housed within the medial temporal lobes. Critical for memory, this hippocampus complex communicates with cortices of all senses (Preston & Eichenbaum, 2013). However, it is important to note memory is best thought of as occurring through pathways, rather than in a specific area. The ways in which these areas work together allows for memory processes to occur.

Any impairment in memory can be greatly distressing to an individual and their family. Impairment may occur through acquired injuries, resulting in memory deficits and even amnesia. Memory is also one of the cognitive functions most sensitive to aging (Lezak, 2012). Deficits beyond what may be typical for aging are associated with dementias, neurological disorders such as Alzheimer's disease and Parkinson's disease, and Korsakoff's syndrome (Eichenbaum, 2011). Three primary areas of memory assessment include immediate memory, delayed memory, and recognition which may be measured with verbal and visual tasks; these are discussed below.

Immediate Memory

Immediate memory is considered the process through which information from the input of senses is temporarily held, to then be manipulated and used, or to be stored for later use.

Immediate memory has a limited capacity to hold information. Immediate memory holds approximately seven (7) units of information at a time, plus or minus two (Miller, 1956). This construct is thought to hold this information for approximately 30 seconds to several minutes while the individual uses or stores it, before the information is lost. Information being held in immediate memory is not guaranteed to be recalled later. Immediate memory is also highly related to attention and working memory (Unsworth, Fukuda, Awh, & Vogel, 2014). For example, Shipstead, Lindsey, Marshall, and Engle (2014) highlight the need of attentional control for efficient use of working memory and immediate memory.

Immediate memory is primarily associated with the prefrontal cortex (Grant, 2009). The prefrontal cortex is thought to be the area in which information is temporarily held. The visual cortex as well as Broca's area are also sometimes associated with immediate memory, as the prefrontal cortex may use one or both of these neural loops to hold information; the visual cortex may hold visual-related information (Baddeley, 2003) while Broca's area, associated with the "inner voice," is used to hold verbal information (Paulesu, Frith, & Frackowiak, 1993; Petrides, Alivisatos, Meyer, & Evans, 1993). As immediate memory is related to both attention and working memory, as well as other executive functions, the measurement of immediate memory is critical to assess potential memory deficits and is commonly included in neuropsychological evaluations.

Measurement of verbal immediate memory may include tasks of list learning and story memory (Lezak, 2012; Strauss et al., 2006). These tasks assess the capacity of short-term

memory and are also sensitive to language verbal deficits. List learning tasks often require the individual to repeat words presented orally, through multiple trials. This test of rote verbal memory often shows with a positive learning curve in healthy individuals (Crossen & Wiens, 1994; Johnson, 2012). Another common test of verbal immediate memory is a test of story memory (Strauss et al., 2006). Tasks of story memory require the individual to repeat back stories presented orally. These tasks may also include multiple trials. Performance on immediate memory tasks has been associated not only with the prefrontal cortex, but also with left temporal lobe, left hippocampal area, the inferior parietal cortex, and right cerebellar hemisphere (Eichenbaum, 2011; Konstantinou, Constantinidou, & Kanai, 2017).

Delayed Memory

Delayed memory is associated with long-term memory via the retrieval of information through spontaneous recall. Long-term memory is the acquisition of new information by the individual's ability to store information and use it at a later time. Long-term memory is also often associated with the concept of learning (Kausler, 1994). Learning and long-term memory require the consolidation of information taken from the environment through the processes of immediate memory and working memory. When stored information is required, delayed memory processes retrieve that information for use. Retrieval of information from long-term memory tasks typically occur via the use of a request for spontaneous recall; this should not be confused with recognition, which is discussed below.

Delayed memory processes are commonly associated with the hippocampal complex, the medial temporal lobes, and the neocortex (Grant, 2009; Kahn, Davichi, & Wagner, 2004).

Memories are not thought to be stored in a single area but are organized and retrieved based on

meaning and associations using many pathways and systems of the brain. A breakdown in these storage or retrieval pathways causes individuals to present with a variety of memory disorders.

Measurement of delayed memory often includes both verbal and visual tasks (Davis, 2011, Reynolds & Fletcher-Janzen, 2013). Common verbal tasks of delayed memory include list recall and recognitions tasks, as well as story recall and recognition tasks. These recall tasks involve the individual freely recalling the word lists or the stories presented during the immediate memory tasks, after a delay. A typical delay may be 10-30 minutes.

Common visual tasks of delayed memory include figure copy tasks (Strauss et al., 2006). The individual may be required to recall a figure, design, or set of designs presented previously during immediate memory or visuospatial tasks after a delay. Again, this delay may be approximately 10-30 minutes.

Delayed memory on recall tasks has been associated with the prefrontal cortex, the hippocampal and parahippocampal regions of the medial temporal lobe, the anterior cingulate, the inferior parietal cortex, and cerebellum (Kahn et al., 2004; Kapur et al., 1994). In recall tasks, the anterior cingulate cortex, globus pallidus, thalamus, and cerebellum have been found to often be more involved than during recognition tasks (Kahn et al., 2004; Kozlovsky, Velichkovsky, Vartanov, Nikonova, & Velichkovsky 2012; Pergola, Ranft, Mathias, & Suchan, 2013). Research has suggested the right prefrontal cortex is related to retrieval (Henson, Shallice, & Dolan, 1999), the medial temporal lobes are related to the conscious recollection (Eichenbaum, Yonelinas, & Ranganath, 2007), the anterior cingulate is associated with the selection of the response (Einarsson & Nader, 2012), and the cerebellum is associated with self-initiated retrieval during recall tasks (Andreasen et al., 1999). Performance on recognition tasks of delayed memory has been associated with the visual ventral stream, the medial temporal lobes, the frontal lobes, and

parietal cortices, and the hippocampal cortices (Neufang, Heinze, & Duzel, 2006; Yonelinas, 2002). The medial temporal cortex has been associated with familiarity; the posterior cingulate has been related to recollection (i.e., recall) and the precuneus has been related to familiarity (i.e., recognition) (Fransson & Marrelec, 2008; Leech & Sharp, 2014; Squire, Stark, & Clark, 2004).

Recognition

Recognition should not be confused with delayed memory or recall ability. Rather than a recall of facts, recognition involves the ability to identify information that was previously presented. To efficiently recognize information, an individual must be able to match stimuli, rather than produce information from memory, which is typically more difficult. Research in this area tends to focus on recognition by a single-process model, in which information is encoded in one manner (Slotnick & Dodson, 2005), or by a dual-process model, in which information is encoded in both verbal and non-verbal modes (Slotnick, Jeye, & Dodaon, 2016; Yonelinas, 1994).

Measurement of recognition memory can include both visual and verbal tasks. Verbal recognition tasks often require the individual to state yes or no when asked if a specific word or story detail was part of the previously presented word list or story. Visual tasks of delayed memory may also include recognition tasks of designs; however, this is less commonly included in neuropsychological assessment.

Recognition is thought to include similar neurological structures to delayed memory, primarily including the hippocampus (Broadbent, Squire, & Clark, 2004), as the ability to recall information is primarily associated with the hippocampus. Research suggests the medial-temporal regions are correlated with recognition and familiarity. Additionally, the frontal lobe,

parietal lobes, and visual ventral stream are commonly associated with recognition memory (Pisoni et al. 2015; Uithol et al., 2015). It is important to note the neuroanatomical correlates of recognition memory depend on the mode of the stimulus. For example, recognizing printed words, recognizing spoken words, and recognizing faces are linked to different neurological structures.

Language and the Assessment of Memory

Overall, research suggests performance on memory tasks is moderately correlated with language abilities. Research investigating memory and verbal abilities has found auditory memory, working memory, immediate memory, and overall memory are significantly related to verbal abilities with standardization samples of the *Wechsler Memory Scale – Third Edition* (WMS-III; Wechsler, 1997) and the WAIS-IV ($r = .41-.54$; Satter & Ryan, 2008). Many common tasks of memory, specifically those of verbal memory, have been found to have high linguistic demand ($r = .48-.70$; Cormier, McGrew, & Ysseldkye, 2014). This suggests performance on memory tasks is highly related to overall verbal abilities. In fact, both immediate and delayed memory tasks were found to have high linguistic demand, overall, on commonly administered assessments including the *Stanford Binet – Fifth Edition* (SB-V; Gale, 2003), the *Cognitive Assessment System* (CAS; Naglieri & Das, 1997), the *Reynolds Intellectual Assessment Scales* (RIAS, Reynolds & Kamphaus, 2003b), the *Wide Range Assessment of Memory and Learning – Revised* (WRAML-2; Sheslow & Adams, 2003), the CMS, and the WMS-III (Ortiz, 2005).

Additionally, poor performance on language tests have been thought to correlate with deficits in memory, as well as potentially be sensitive to neurological problems. For example, performance on tests of verbal fluency have been found to predict developing and progressing

frontal lobe dementia and Alzheimer's disease (Henry, Crawford, & Phillips, 2004; Knopman & Ryberg, 1989; Pasquier, Lebert, Gyronprez, & Petit, 1995). Naming tasks, measuring verbal abilities, have also been found to significantly predict the mild cognitive impairment, the conversion from MCI to Alzheimer's disease, and Parkinson's Disease dementia (Ahmed, Arnold, Thompson, Graham, & Hodges, 2008; Levy et al., 2002; Tabert et al., 2006).

The Immediate Memory Index of the RBANS correlates highly with the Language index of the RBANS in a clinical sample ($r = .61$; Carlozzi et al., 2008). A common task of list-learning abilities, as a measure of verbal memory, is the *California Verbal Learning Test – Second Edition* (CVLT-II; Delis, Kramer, Kaplan, & Ober, 2000; Struass, Sherman, & Spreen, 2006). The CVLT-II is highly correlated with the RBANS List Learning subtest in a clinical sample ($r = .695$; McKay et al., 2007). The RBANS List Learning task requires the individual to repeat a list of unrelated words back verbally over multiple trials. The RBANS List Learning subtest is moderately correlated with the RBANS language measures in a clinical sample ($r = .47, .62$; Carlozzi et al., 2008).

As with list learning, story memory tasks are highly correlated with verbal abilities measured by the WISC-III and language proficiency measured by a grade-appropriate vocabulary test in a sample of 102 children (Cain, Oakhill, & Bryant, 2004). The CVLT-II 1-5 trials is also associated with the RBANS Story Memory subtest in an adult clinical sample ($r = .420$; McKay et al., 2007). This immediate memory task requires individuals to repeat back structured material in the form of short passages over two trials. The RBANS Story Memory subtest is moderately correlated with the RBANS measures of language in a clinical sample ($r = .51$; Carlozzi et al., 2008).

The Delayed Memory Index of the RBANS correlates highly with the Language Index in a clinical sample ($r = .64$; Carlozzi et al., 2008). Tasks of delayed memory typically involve the individual recalling or recognizing information presented during previous tasks after a timed delay. The CVLT-II Long Delay Recall requires the individual to recall the list of semantically-related words. This task of delayed memory is significantly related to verbal abilities in a clinical sample ($r = .37-.38$; McKay et al., 2007). The CVLT-II Long Delay Recall is highly correlated with the RBANS verbal delayed memory tasks of List Recall, List Recognition, and Story Recall in an adult clinical sample ($r = .753, .381, .705$, respectively; McKay et al., 2007). The RBANS List Recall task requires the individual to spontaneously recall the words presented previously on the List Learning task. The List Recognition task then requires the individual to identify a list of target and distractor items. The Story Recall task requires the individual to recall as many details of the stories presented previously as can be remembered. The RBANS verbal delayed memory tasks moderately correlate with the language measures of the RBANS in a clinical sample ($r = .33-.54$; Carlozzi et al., 2008).

As with the verbal delayed memory measures, the visual delayed memory measure on the RBANS requires the individual to recall information presented previously during the assessment. The RBANS Figure Recall task is moderately correlated with the measures of language on the RBANS in a clinical sample ($r = .45-.53$; Carlozzi et al., 2008).

Language

Measurement of language abilities, verbal abilities, and language proficiency is primarily assessed by tasks of expressive language, as discussed above. Measuring expressive language primarily involves naming tasks and verbal fluency tasks.

The ability to name objects is the ability to rapidly and correctly retrieve a word at will (Lass, 1988). Confrontational naming tasks require the individual to name presented physical stimuli or pictorial stimuli, often ranging from familiar objects to unfamiliar objects. Naming has been found to have great significance and importance, as it has been found to have particular relation to overall cognitive abilities as well as academic achievement in both reading and mathematics (Cornwall, 1992; Mazzocco & Grimm, 2013; Weiss, Saklofske, Holdnack, & Prifitera, 2016; Wolf & Goodglass, 1986). Additionally, naming has been considered an important diagnostic tool for neurologists and neuropsychologists. Naming is an ability that varies greatly in those who have experienced injury or atrophy of the brain (i.e., stroke, TBI/concussion, dementia; Goldstein, Beers, & Herse, 2004; Hoffman, Clarke, Jones, & Noonan, 2015; Lavoie, Bier, & Macoir, 2015; McDonald, Togher, & Code, 2013).

The development of naming abilities has been long associated with performance throughout the life span. By the age of 6, children are able to rapidly name letters and numbers with accuracy rates similar to adolescents and adults. The ability to name colors and shapes becomes more stable in the following years. Albert, Heller, and Milberg (1988) suggested naming ability remains constant from the age of 30 years through to the age of 70 years. A significant decline in naming speed has been found to begin occurring at the age of 50 years, with steady significant decline in speed from ages 50-55, 55-60, 60-65, 65-70, and 70 and beyond (Verhaegen & Poncelet, 2013). At the age of about 70 years, naming ability significantly declines in both speed and accuracy with normal aging (Harada, Love, & Triebel, 2013).

Naming has been associated with various neuroanatomical correlates. Both white matter and grey matter have been associated with naming ability (Baldo, Averalo, Patterson, Dronkers, 2013). Additionally, research has linked naming ability to the left temporal lobe (Mesulam et al.,

2013). Naming has been associated with the posterior superior temporal and inferior parietal regions of the brain, where semantic paraphasic errors occur (i.e., brush v. comb), as well as the insula, internal capsule, and putmen, from where phonological paraphasic errors are thought to stem (i.e., woof v. wife; Fridriksson et al., 2007). Naming has also been associated with the language-dominant hippocampus, as part of a neuroanatomical network of visual confrontational naming (Bonelli et al., 2011). Repetitive transcranial magnetic stimulation over posterior left temporal lobe has been found to facilitate picture naming (Wassermann et al., 1999).

Verbal fluency is the basic language ability to produce fluent speech (Lezak, 2012). Verbal fluency has long been an important feature of assessment, including assessment of executive functioning and language (Strauss et al., 2006). Verbal fluency is often associated not only with rapid word generation, but also with mental organization strategies, mental flexibility, set-switching, and self-monitoring abilities (Whiteside et al., 2016). Verbal fluency has been found to relate highly to overall cognitive abilities and academic achievement (Shao, Janse, Visser, & Meyer, 2014). While verbal fluency tasks are often considered executive functioning measures, Whiteside et al. (2016) found tasks of phonological fluency and semantic fluency loaded onto a language factor, rather than an executive functioning factor, suggesting verbal fluency is primarily a language skill. During this confrontational task, individuals are often given a set time limit in which to generate or produce as many words of the given set as possible. During the task, there is generally a decline in the rate of production of new items over time. Additionally, it has been found items are often produced in “bursts” of semantically-related words in both of the task conditions (Unsworth, Spillers, & Brewer, 2010). The two distinct facets of verbal fluency typically included in assessment tasks are semantic fluency and

phonemic fluency, although there are other types such as fluency/switching as seen on the *Delis-Kaplan Executive Function System* (D-KEFS; Delis, Kaplan, & Kramer, 2001).

Semantic fluency, or category fluency, tasks require the individual to produce words that are part of a given semantic category in a set amount of time. This test of word generation and category clustering has been shown to be very important in the assessment and differential diagnoses of many neuropsychological conditions, including: dementias and Alzheimer's disease, TBI, stroke, schizophrenia, aphasia, and ADHD (Andreou & Trott, 2013; Biesbroek et al., 2016; Cerhan et al., 2002; Martyr et al., 2012; Reverberi, Cherubini, Baldinelli, & Luzzi, 2014; Whiteside et al., 2016). The ability to produce words given a semantic category has been associated with the functioning of many brain areas. Most often, the temporal lobe is associated with semantic fluency (Baldo, Schwartz, Wilkins, & Dronkers, 2006; Gonzalez et al., 2016). Additionally, the left-frontal region has been found to have relation to the performance of individuals on semantic fluency tasks (Curtis et al., 2014). Research has suggested the left dorsolateral and superior medial frontal lobe are involved as well (Curtis et al., 2014, Meinzer et al., 2009).

Phonemic fluency, or letter fluency, tasks require the individual to produce words that begin with a given letter in set amount of time (Strauss et al., 2006). Phonemic fluency measures have been shown to be quite sensitive as a measure of impairment, meaning poor performance on the phonetic fluency task indicates some degree of neuropsychological dysfunction (Lezak, 2012). Additionally, phonemic fluency tasks have been found to be more sensitive to the presence of TBI than other commonly used tasks (Kave, Heled, Vakil, & Agranov, 2011). Overall, phonemic fluency measures have been used in the differential diagnosis of dementia and

Alzheimer's disease, aphasia, and ADHD (Andreou & Trott, 2013; Cerhan et al., 2002; Kurowski & Blumstein, 2016; Takacs, Kobor, Tarnok, & Csepe, 2014).

The development of verbal fluency begins later than the development of naming abilities due to the large tie in developing executive functions. Around the age of 7 years, children's activation patterns (i.e., primary activation of the left inferior frontal lobe and mid frontal lobe) during semantic verbal fluency tasks begin to stabilize and match adults' (Gaillard et al., 2003). Within the middle school years, children's activation patterns during phonemic tasks stabilizes (Gaillard et al., 2003). Within the next few years, semantic and phonemic organizational networks become much more established and performance on these tasks greatly increases (Sauzeon, Lestage, Raboutet, N'Kaoua, & Claverie, 2004). Young adults supply a steady increase in the number of responses on both semantic and phonemic tasks before a plateau in growth (Troyer, Moscovitch, & Winocur, 1997). Older adults tend to respond in bursts of responses, with an overall decrease in the number of responses (Bryan, Luszcz, & Crawford, 1997; Harada et al., 2013; Lee, Kim, Kim, Yoon, & Kim, 2015; Troyer et al., 1997). By the age of 60, older adults' first-word production time is significantly delayed during verbal fluency tasks (Lee et al., 2015). This growth with children and young adults and decline in verbal fluency performance with age occurs in both monolinguals and bilinguals (Friesen, Luo, Luk, & Bailystok, 2015).

Performance on phonemic fluency tasks have been found to be correlated to the functioning of many brain areas. A study including fMRI study and a phonemic fluency task found a left lateralized frontal pattern of activation (Meinzer et al., 2009). Additionally, lesions in the frontal cortex, either the left or right side, has caused impairment in the performance on this task; lesions in the left hemisphere cause a greater reduction in word production than lesions

in the right hemisphere (Baldo, Shimamura, Delis, Kramer, & Kaplan, 2001; Jurado, Mataro, Verger, Bartumeus, & Jungque, 2000).

Assessment of Naming and Verbal Fluency in Neuropsychological Assessment

As previously discussed, expressive language abilities are highly correlated with receptive language skills, as well as with overall verbal abilities. Two of the primary tasks measuring expressive language abilities include naming and verbal fluency tasks. By itself, naming, as measured by the *Boston Naming Test – Second Edition* (BNT-2; Kaplan, Goodlass, & Weintraub, 2001), is highly correlated with overall verbal abilities as well as with receptive language abilities as measured by the WAIS-III and PPVT-4 in clinical samples (Johnstone & Stonnington, 2012; Peterson, 2008). Verbal fluency is also highly correlated with overall verbal abilities measured by the Wechsler scales as VIQ and FSIQ in adult clinical samples (Johnstone & Stonnington, 2012; Henry & Crawford, 2004).

Many naming tasks are frequently used in neuropsychological assessment. Overall, naming tasks are significantly related with overall verbal abilities in standardization samples ($r = .85$; Strauss et al., 2006). One of the oldest and most used naming tasks is the *Boston Naming Test* (BNT; Kaplan, Goodglass, & Weintraub, 1983; Goodglass & Kaplan, 2001) with the newest version the BNT-2. The BNT-2 is highly correlated with other language-related skills, including reading performance ($r = .61-.81$; Graves & Carswell, 2003), word-finding and vocabulary in children and adults (Guilford & Nawojczyk, 1988; Whiteside et al., 2016), and verbal fluency (Whiteside et al., 2016). In a clinical sample, the RBANS Picture Naming subtest was strongly correlated with the BNT-2 ($r = .71$; Gontkovsky, Hillary, & Scott, 2002). The RBANS Picture Naming subtest is also highly correlated with the *Multilingual Aphasia Examination* (MAE; Benton, Hamsher, & Sivan, 1994) Visual Naming task in an adult clinical

sample ($r = .590$; McKay et al., 2007). The RBANS Picture Naming subtest requires the individual to name presented pictorial stimuli in a very similar way as the BNT-2. The RBANS Picture Naming subtest is moderately correlated to the Semantic Fluency subtest of the Language Index in an adult sample ($r = .41$; Carlozzi et al., 2008).

Verbal fluency can be assessed in many different ways, including on phonemic tasks and semantic tasks. Verbal fluency tasks have been significantly correlated with overall verbal abilities in clinical samples through meta-analysis ($r = .64-.87$; Henry & Crawford, 2004). The D-KEFS Verbal Fluency subtest includes phonemic, semantic, and switching conditions. The phonemic fluency condition on the D-KEFS has been found to be more highly correlated to overall verbal abilities as measured by the VCI of the WAIS-IV ($r = .53$) than is the semantic condition ($r = .35$; Sattler & Ryan); however, both verbal fluency measures are considered significantly related to verbal abilities. The RBANS Semantic Fluency subtest is significantly related to other measures of verbal fluency, specifically semantic fluency as measured by the COWAT ($r = .456$; McKay et al., 2007) and even more strongly in a sample of individuals with mixed neuropsychological conditions ($r = .74$; Gontkovsky, Hillary, & Scott, 2002). Gontkovsky, McSwan, and Scott (2002) suggested the RBANS Semantic Fluency subtest is similarly sensitive to neurocognitive dysfunction compared to the COWAT. The RBANS Semantic Fluency subtest requires the individual to produce words of a given category in a set amount of time. Again, this RBANS Semantic Fluency subtest of language moderately correlates to the Naming subtest in a clinical sample ($r = .41$; Carlozzi et al., 2008).

Summary

While there is undeniable interest in both language abilities and neuropsychological functioning, their relationship is not yet clear. Evaluation and diagnosis of a neuropsychological

condition requires more than the consideration of one assessment measure or component of the patient's life. Research has provided the field of neuropsychology with an abundance of conclusions regarding neuropsychological functioning within the perspective of the clinical referral concern (i.e., stroke, TBI/concussion, Alzheimer's disease, dementia, ADHD, etc.). However, the majority of research of neuropsychological functioning may then be too specific to this type of population, acting to limit generalizability. Research in the field is also in need of better understanding of repeatable neuropsychological batteries. As the medical field and technological field continue to advance, the neuropsychological field is in greater need of methods for serial assessment for those with neuropsychological conditions with new treatment options to monitor the progression of the condition. Additionally, the field currently lacks generalizable conclusions regarding neuropsychological assessments and other functioning areas, such as language abilities. While language abilities have been studied and tied to many outcomes (i.e., achievement, cognitive abilities, occupation, etc.), the impact of language abilities on the performance of an individual on a neuropsychological functioning assessment has not been fully studied. It is likely the fields of psychology and neuropsychology may most benefit from research investigating the relationship between language abilities and a repeatable neuropsychological battery, such as the RBANS.

CHAPTER III

METHODOLOGY

This chapter is organized into four sections: research questions; participant selection; instrumentation, validity, and reliability; and statistical procedures and data analysis. The purpose of this chapter is to provide explanation of how participants were selected, which procedures were followed, and how the data collected was analyzed in this study.

Research Questions

R₁: What is the canonical relationship of the measures of language (naming, semantic fluency, phonemic fluency) with the 12 subtests of the RBANS? These measures are summarized in Table 1.

H₁: To explore the relationship between language ability and neuropsychological performance, it was hypothesized phonemic verbal fluency or semantic verbal fluency will contribute the most to this relationship as compared to the BNT-2 given the fluency tasks tap a greater array of neuropsychological constructs.

H₂: It was hypothesized the Picture Naming and Semantic Fluency subtests of the RBANS will contribute most to this relationship, as these two subtests contribute to the RBANS Language Index.

H₃: It was hypothesized the subtests of the RBANS which require more verbal ability (e.g., Picture Naming, Semantic Fluency, List Learning, and Story Memory) will contribute more to the relationship than those which require less verbal ability (e.g., Figure Copy, Line Orientation, and Coding). It was also hypothesized, however, that even those subtests requiring minimal language ability will still somewhat contribute to the relationship.

TABLE 1

Summary of RBANS Subtests and Language Measures

RBANS Subtest	Language Measure Test/Subtest
List Learning	Boston Naming Test - Second Edition (BNT-2)
Story Memory	D-KEFS Verbal Fluency, Condition 2: Category Fluency
Digit Span	D-KEFS Verbal Fluency, Condition 1: Letter Fluency
Coding	
Figure Copy	
Line Orientation	
Picture Naming	
Semantic Fluency	
List Recall	
List Recognition	
Story Recall	
Figure Recall	

R₂: What is the canonical relationship of the measures of language (naming, semantic fluency, phonemic fluency) with the 5 indices of the RBANS? These measures are summarized in Table 2.

H₁: To explore the relationship between language ability and neuropsychological performance, it was hypothesized phonemic verbal fluency or semantic verbal fluency will contribute the most to this relationship as compared to the BNT-2 given the fluency tasks tap a greater array of neuropsychological constructs.

H₂: It was hypothesized the Language Index of the RBANS will contribute most to this relationship.

H₃: It was hypothesized the indices of the RBANS which require more verbal ability (e.g., Language Index, Immediate Memory Index, and Delayed Memory Index) will contribute more to the relationship than those which require less verbal ability (e.g.,

Visuospatial/Construction Index and Attention Index). It was also hypothesized, however, indices requiring minimal language ability will still somewhat contribute to the relationship.

TABLE 2

Summary of RBANS Indices and Language Measures

RBANS Index	Language Measure Test/Subtest
Immediate Memory	Boston Naming Test - Second Edition (BNT-2)
Attention	D-KEFS Verbal Fluency, Condition 2: Category Fluency
Visuospatial/Constructional	D-KEFS Verbal Fluency, Condition 1: Letter Fluency
Language	
Delayed Memory	

R₃: What is the relationship among the measures of language not part of the RBANS? Measures of language and related language ability are summarized in Table 3.

H₁: It was hypothesized there will be a strong, positive correlation found between naming ability, as measured by the BNT-2, and phonemic fluency, as measured by the D-KEFS Verbal Fluency Condition 1: Letter Fluency task.

H₂: It was hypothesized there will be a strong, positive correlation found between naming ability, as measured by the BNT-2, and semantic fluency, as measured by the D-KEFS Verbal Fluency Condition 2: Category Fluency task.

TABLE 3

Summary of Measured Language Abilities and Language Measures

Language Ability	Test/Subtest
Naming Ability	Boston Naming Test - Second Edition (BNT-2)
Semantic Fluency	D-KEFS Verbal Fluency, Condition 2: Category Fluency
Phonemic Fluency	D-KEFS Verbal Fluency, Condition 1: Letter Fluency

Procedures

The participants recruited for the study, *Evaluating the Relationship Between Independent Living, Neuropsychological Functioning, and Language* (IRB #790911), were scheduled for a research study testing session with a duration of approximately two hours. Prior to the administration of the measures, the participant provided their written, informed consent for participation in the research study. The demographic questionnaire was completed using an interview format. IRB approval for the current study and analysis was obtained on December 6, 2017, IRB 1166782-1.

The study, *Evaluating the Relationship Between Independent Living, Neuropsychological Functioning, and Language*, included the administration of the RBANS, D-KEFS Verbal Fluency subtest, and BNT-2, as well as the *Wechsler Test of Adult Reading* (WTAR; Wechsler, 2001) and the *Independent Living Scale* (ILS; Loeb, 1996). Due to possible practice effects, administration of the assessments followed a partially counterbalanced order, with the RBANS being administered first for all participants and the remaining measures counterbalanced.

All measures were administered by trained, Master's Degree-holding graduate students trained in psychological assessment and in these instruments. Training on standardized administration procedures and scoring procedures was completed by each researcher prior to beginning research with participants. Data was cleaned via scores for each measure for each participant a second time by a second researcher to ensure correct coding of responses and scoring. Data entry was also then verified by a second researcher. All research data remained locked; identifying information (i.e., informed consent form) was kept confidential and secure apart from the research of the measures.

Participant Demographics

Participants included adults recruited from two psychological research pools at a Midwestern university. This group was initially comprised of 71 undergraduate students. Sixty-four (64) participants were included in the current sample after three (3) were excluded for missing data (i.e., obtained scores) and four (4) were identified as outliers using Mahalanobis distance. Descriptive statistics are summarized in Table 4. There were 47 females, 16 males, and 1 transgender female.

TABLE 4

Descriptive Statistics of Sample

Variable	<i>N</i>	(%)
<i>Gender</i>		
Male	18	25.0
Female	47	73.4
Transgender	1	1.6
<i>Ethnicity</i>		
White/Caucasian	55	85.9
Black/African American	6	9.4
Asian	2	3.1
Biracial/Multiracial	1	1.6
<i>Handedness</i>		
Right Dominant	57	89.1
Left Dominant	7	10.9
<i>Diagnoses</i>		
Learning Disability	2	3.1
ADHD	8	12.5
Physical/Mental Health	12	18.8
Concussion/TBI	12	18.8

N = 64

ADHD = Attention/Deficit/Hyperactivity Disorder

TBI = Traumatic Brain Injury

They ranged in age from 18.00 to 23.17 years (mean = 18.84 years; standard deviation = 1.16).

Number of completed years of education ranged from 12.00 to 16.00 years (mean = 12.95;

standard deviation = 1.10). College grade-point average (GPA) was self-reported for 52 participants and ranged from 2.40 to 4.00, on a 4.00 scale (mean = 3.24; standard deviation = 0.42). Participant's ethnicities were reported to be 85.9% White/Caucasian, 3.1% Asian, 9.4% Black/African American, and 1.6% Biracial/Multiracial. Fifty-seven (57) participants reported themselves to be right-hand dominant, with seven (7) participants left-hand dominant. Two (2) participants reported a history of a Learning Disability. Eight (8) participants reported a history of Attention-Deficit/Hyperactivity Disorder (ADHD). Twelve (12) participants reported a history of head injury and/or traumatic brain injury (TBI). Twelve (12) participants reported physical or mental health diagnoses, primarily including: anxiety-related disorders, depression-related disorders, and asthma. Twenty-eight (28) participants were prescribed medications, primarily including: contraception, anti-anxiety medication, anti-depression medication, ADHD medication, and pain medication. Students were given research participation credit in their course for their participation. As noted, data from this study was drawn from a larger study being conducted at the institution; the Internal Review Board at the university in which this research was originally conducted approved both the larger study and the current study.

Instrumentation

Demographics Questionnaire

All participants were administered a demographics questionnaire asking participants to provide their age, gender, ethnicity, handedness, college GPA, SAT/ACT score, height, weight, parental level of education, parent occupation, number of years of education, current medications, and a history of diagnosed physical or mental health condition (i.e., ADHD, learning disabilities, TBI and concussion).

Boston Naming Test

The construct of naming was measured by the *Boston Naming Test – Second Edition* (BNT-2; Kaplan, Goodglass, & Weintraub, 2001). The BNT-2 was developed to test for the diagnosis and characterization of aphasia. It has been found to be the most commonly administered language measure for neuropsychological assessment, with 61% of those surveyed reporting inclusion of the BNT-2 in evaluation (Rabin et al., 2016). It has also been commonly included in evaluations considering mild cognitive impairment, Alzheimer’s disease, and dementias. The BNT-2 consists of 60 items, with appropriate start points determined by age and a discontinue rule established by performance. A typical adult (over the age of 18) may be administered 30 items, on average, decreasing in familiarity (Kaplan, Goodglass, & Weintraub, 2001). Short form versions of the BNT-2 include 30-item and 15-items and are typically administered clinically to populations who may be unable to complete the full 60-item test (i.e., patients with aphasia, dementia, Alzheimer’s disease; del Toro et al., 2011; Graves, Bezeau Fogarty, & Blair, 2004; Saxton et al., 2000). Administration consists of a visual stimuli presented and the requirement that the participant names the item within a time limit. If the participant misperceives the item or does not respond, a semantic cue is provided to the participant by the examiner and additional time is provided. If the item is again misperceived, a phonetic cue is provided, with additional time provided. After all appropriate items are completed, following standardization rules, the participant is presented multiple-choice options for any and all items the participant did not respond to correctly with the first presentation of the item. Scores derived from the BNT-2 include raw scores of Total Score, Number of correct responses following a stimulus cue, Number of correct responses following the phonemic cue, and Number of correct [multiple] choices. Paraphasia types can also be tallied. Norms for children and adults include

the mean and standard deviation of the Total Score for each age range (Kaplan, Goodglass, & Weintraub, 2001). For the current study, the Total Score were calculated into z-scores for analysis.

The BNT-2 is considered a reliable and valid measure of the construct of naming for adults through the age of 88-years (Ivnik et al., 1990; Ivnik, Malec, Smith, Tangalos, & Peterson, 1996; Lucas et al., 2005; Sachs et al., 2012). The BNT-2 has been validated with other measures of naming, including the *Multilingual Aphasia Examination* ($r = .76-.86$; MAE; Benton, Hamsler, & Sivan, 1994; Axelrod, Ricker, & Cherry, 1994) and the Neuropsychological Assessment Battery (NAB; White & Stern, 2003). The BNT-2 has an internal consistency of .78 to .96 (Graves et al., 2004; Storms, Saerens, & De Deyn, 2004) and test-retest reliability of up to .92 in neurotypical adults (Dikmen, Heaton, Grant, & Temkin, 1999) and .94 in clinical populations (Sawrie, Chelune, Naugle, & Luders, 1996). The BNT-2 has a short administration time of approximately 10 to 20 minutes.

Delis-Kaplan Executive Functioning Scale

The construct of semantic fluency and phonemic fluency was measured by the *Delis-Kaplan Executive Function System* (D-KEFS; Delis, Kaplan, & Kramer, 2001) Verbal Fluency task. The D-KEFS was developed to measure executive functions in children and adults. It has also been used as a sensitive measure of executive dysfunction, neurocognitive disorders (i.e., dementias), mild frontal-lobe injury, and traumatic brain injury (Bott et al., 2014; Delis, Kaplan, & Kramer, 2001; Kilgore, 2015). The Verbal Fluency subtest has been found to be one of the most commonly used measures of language in neuropsychological evaluation (Rabin et al., 2016). The D-KEFS Verbal Fluency subtest consists of three timed conditions. Condition 1: Letter Fluency (Letter Fluency) consists of timed items, requiring the participant to respond with

words beginning with a given letter/sound. Condition 2: Category Fluency (Category Fluency) consists of timed items, requiring the participant to respond with words in a given category in a given time. The task-switching condition consists of a single timed item, requiring the participant to respond with words alternating between two given categories in a given time; the task-switching condition was not included in the present study as it is primarily a measure of executive functioning rather than language (Latzman & Markon, 2009). Phonemic fluency was measured by the Letter Fluency Total Correct scaled score. Semantic fluency was measured by the Category Total correct scaled score. Each score is reported as a scaled score, with a mean of 10 and standard deviation of 3. Additional scores that may be derived from the Verbal Fluency subtest include: Set-Loss Errors, Repetition Errors, Total Responses, and Total Correct by interval (i.e., First Interval, Second Interval, Third Interval, and Fourth Interval); these additional scores were not analyzed for the current study.

The D-KEFS Verbal Fluency subtest is considered a reliable and valid measure of the construct of semantic fluency and phonemic fluency for those ages 8:0 through 89:11 in neurotypical populations, clinical samples, and bilingual samples (Delis, Kramer, & Kaplan, 2004; Friesen et al., 2015; Strong, Tiesma, & Donders, 2011). The D-KEFS Verbal Fluency subtest has an internal consistency of 0.80 and 0.60 for the 16-19 age range considering letter fluency total and category fluency, respectively (Delis, Kaplan, & Kramer, 2001). The internal consistency of the 20-29 age range is 0.85 and 0.61, respectively (Delis, Kaplan, & Kramer, 2001). The test-retest reliability of the phonemic fluency condition is 0.80 and 0.79 for the semantic fluency condition considering ages 8-89 (Delis, Kaplan, & Kramer, 2001). The D-KEFS Verbal Fluency subtest has a short administration time of approximately 10 to 15 minutes.

Repeatable Battery for the Assessment of Neuropsychological Status

The *Repeatable Battery for the Assessment of Neuropsychological Status* (RBANS Update; Randolph, 2012) is a neuropsychological battery developed with the purpose of measuring and identifying atypical cognitive decline. While the RBANS was originally targeted at measuring and diagnosing dementia in older adults (Randolph, 1998), it has been found a beneficial and sensitive clinical tool in the identification in a variety of other clinical populations, such as brain injury (Batty et al., 2016; Lippa, Hawes, Jokic, & Caroselli, 2013), dementias (Duff et al., 2008), multiple sclerosis (Davis, Williams, Gupta, Finch, & Randolph, 2015), stroke (Gontkovsky, 2014), and depression (Moore et al., 2013). The RBANS can be used as a neuropsychological battery for those ages 12 years, 0 months through 89 years, 11 months. Four parallel versions exist; Version A was administered.

The RBANS has well known validity with other measures of neuropsychological and psychological functioning (Randolph, 2012). Additionally, RBANS indices have been found to have moderately high correlations with measures of respective constructs (Strauss et al., 2006; Randolph, Tierney, Mohr, & Chase, 1998; Schmitt, Livingston, Reese, & Davis, 2010). The RBANS Total Score is strongly correlated with overall cognitive functions as measured by the FSIQ on the WAIS-IV ($r = .75$; Wechsler, 2008). The Language Index of the RBANS is highly correlated with measures of language (i.e., BNT-2 and COWAT; $r = .59-.75$; Randolph, 2012).

Indices and subtests of the RBANS are outlined in Table 5. The RBANS includes five Indices: Attention, Visuospatial/Constructional Abilities, Immediate Memory, Delayed Memory, and Language. Five index scores and a Total Scale score is provided. Each index score is reported as a standard score, with a mean of 100 and a standard deviation of 15. The RBANS includes 12 subtests: List Learning, Story Memory, Figure Copy, Line Orientation, Digit Span,

Coding, Picture Naming, Semantic Fluency, List Recall, List Recognition, Story Recall, and Figure Recall. Each subtest score is reported as a scaled score, with a mean of 10 and standard deviation of 3, or a percentile rank range. For the current study, the raw scores were calculated into z-scores for analysis. One advantage of the administration of the RBANS is the short administration time of approximately 30 minutes compared to a typical, traditional neuropsychology battery.

TABLE 5

Summary of RBANS Indices and Subtests

Index	Subtest
Immediate Memory	List Learning Story Memory
Attention	Digit Span Coding
Visuospatial/Constructional	Figure Copy Line Orientation
Language	Picture Naming Semantic Fluency
Delayed Memory	List Recall List Recognition Story Recall Figure Recall

Attention Index

The Attention Index measures attention, processing speed and working memory, components of executive functioning (Randolph, 2012). The tasks of Digit Span and Coding require the individual to hold and manipulate simple auditory and visual information. The

Attention Index has an internal consistency overall average reliability of .84 (Randolph, 2012). The stability coefficient for the Attention Index is .69 for ages 12-19, and .77 for ages 20-89 (Randolph, 2012).

Digit Span

The Digit Span subtest requires the individual to repeat a series of digits presented orally. Digit Span is a measure of the individual's short-term sequential auditory attention and memory (Randolph, 2012). The Digit Span subtest has an internal consistency overall average reliability of .83 (Randolph, 2012). The stability coefficient for the Digit Span subtest is .59 for ages 12-19, and .73 for ages 20-89 (Randolph, 2012).

Coding

The Coding subtest requires the individual to pair unrelated symbols using pencil and paper. The Coding subtest is a novel task requiring the speed and accuracy of visual-motor coordination, mental operation, attention, visual scanning, and cognitive flexibility (Randolph, 2012). The Coding subtest has an internal consistency average reliability of .81. The stability coefficient for the Coding subtest is .75 for ages 12-19, and .76 for ages 20-89 (Randolph, 2012).

Visuospatial/Constructional Index

The Visuospatial/Construction Index measures visuospatial processing and motor coordination. The tasks of Figure Copy and Line Orientation comprise this index. The Visuospatial/Constructional Index has an internal consistency average reliability of .75 and a stability coefficient of .53 for ages 12-19, and .65 for ages 20-89 (Randolph, 2012).

Figure Copy

The Figure Copy subtest requires the individual to copy a complex, multipart, geometric design using pencil and paper when presented a printed stimulus. The Figure Copy subtest has an

internal consistency overall average reliability of .50 (Randolph, 2012). The stability coefficient for Figure Copy is .46 for the 12-19 age group, and .47 for the 20-89 age group (Randolph, 2012).

Line Orientation

The Line Orientation subtest requires the individual to match the angle and orientation of stimulus lines. The Line Orientation subtest has a stability coefficient of .72 for ages 12-19, and .49 for ages 20-89 (Randolph, 2012).

Immediate Memory Index

The Immediate Memory Index measures immediate memory and working memory, as part of short-term memory. List Learning and Story Memory tasks are included. The Immediate Memory index has an internal consistency average reliability of .88 and a stability coefficient of .73 in ages 12-19, and .62 for ages 20-89 (Randolph, 2012).

List Learning

The List Learning subtest requires the individual to hold and immediately repeat back a series of unrelated words. The List Learning subtest has an internal consistency overall average reliability of .85 (Randolph, 2012). The stability coefficient for the List Learning subtest is .68 for the 12-19 age group, and .49 for the 20-89 age group (Randolph, 2012).

Story Memory

The Story Memory subtest requires the individual to recall, verbatim, a short story. This task is used to measure immediate recall and working memory (Randolph, 2012). The Story memory subtest has an internal consistency overall average reliability of .78 (Randolph, 2012). The stability coefficient for the Story Memory subtest is .65 for the 12-19 age group, and .45 for the 20-89 age group (Randolph, 2012).

Delayed Memory Index

The Delayed Memory Index measures retrieval of information presented previously in the assessment. It is comprised of the List Recall, List Recognition, Story Recall, and Figure Recall subtests. The Delayed Memory Index has an internal consistency average of .84 (Randolph, 2012). The stability coefficient for the Delayed Memory Index is .70 for ages 12-19, and .77 for ages 20-89 (Randolph, 2012).

List Recall

The List Recall subtest requires the individual to recall words presented during the List Learning subtest. This task is used to measure the ability to spontaneously recall information after a delay. The List Recall subtest yields a percentile score which has a small reliability value and was not reported (Randolph, 2012). The List Recall stability coefficient is .66 for ages 12-19, and .60 for ages 20-89 (Randolph, 2012).

List Recognition

The List Recognition subset requires the individual to indicate which words and distractor words were included in the list of words presented during the List Learning subtest. This task is used to measure recognition and long-term memory storage (Randolph, 2012). The List Recognition subtest yields a percentile score, which has a small reliability value that was not reported. The List Recognition stability coefficient is .70 for ages 12-19, and .27 for ages 20-89 (Randolph, 2012).

Story Recall

The Story Recall subtest requires the individual to spontaneously recall story details presented previously during the Story Memory subtest. This task is used to measure long-term storage and retrieval by cueing (Randolph, 2012). The Story Recall subtest has an internal

consistency overall average reliability of .54. The stability coefficient for the Story Recall subtests .48 for ages 12-19, and .52 for ages 20-89.

Figure Recall

The Figure Recall subtest requires the individual to spontaneously recall and draw the complex figure presented previously during the Figure Copy subtest. This task measures long-term visual memory and recall. The Figure Recall subtest has an internal consistency overall average reliability of .59. The stability coefficient for the Figure Recall subtest is .58 for ages 12-19, and .55 for ages 20-89 (Randolph, 2012).

Language

The Language Index measures expressive language abilities through the confrontational tasks of Picture Naming and Semantic Fluency. The Language Index has an internal consistency overall average reliability of .80. It has a stability coefficient of .79 for ages 12-19, and .64 for ages 20-89 (Randolph, 2012).

Picture Naming

The Picture Naming subtest was developed as a measure of verbal naming by confrontation. Participants are required to name the picture presented within a time limit. This task is reported by percentile score. Reliability for the Picture Naming subtest was not reported, as an atypical distribution of scores was found in “nonclinical populations” (Randolph, 2012, p. 41), as would be expected in the current study. The stability coefficient for the Picture Naming subtest is .73 for ages 12-19, and .50 for ages 20-89 (Randolph, 2012).

Semantic Fluency

The Semantic Fluency subtest was developed as a measure of categorical verbal fluency by confrontation. The subtest requires participants to generate words in a given category in a

given amount of time. The Semantic Fluency subtest has an internal consistency overall average reliability of .57 (Randolph, 2012). The stability coefficient of the Semantic Fluency subtest is .67 for ages 12-19, and .49 for ages 20-89 (Randolph, 2012).

Statistical Procedures and Data Analysis

Descriptive analyses were conducted to analyze the participant's obtained assessment results and demographic information, including: chronological age at testing, gender, ethnicity, handedness, years of education, and history of psychological and medical condition. Raw scores of the BNT-2 and 12 RBANS subtests were converted into z-scores specific to the sample using the procedure: $z\text{-score} = \frac{X - \mu}{\sigma}$. Due to the nature of the derivation of the RBANS Indices as standard scores and the D-KEFS scaled scores, these scores remained standard scores and scaled scores, respectively, and were not converted into z-scores. Descriptive statistics were also reported for the means, standard deviations, and ranges of scores obtained from the BNT-2, D-KEFS, and RBANS. A Pearson's correlation analysis was conducted to answer Research Question 3. A second Pearson's correlation was completed to examine the relationship between the measures of language, RBANS indices, and RBANS subtests.

To investigate Research Question 1 a canonical correlation was conducted as a multivariate analysis to assess the relationship between the measures of language and performance on the 12 RBANS subtests. The first set of variables included BNT-2 z-scores, D-KEFS Letter Fluency scaled scores, and D-KEFS Category Fluency scaled scores. The second set of variables included the RBANS subtest z-scores: List Learning, Story Memory, Figure Copy, Line Orientation, Semantic Fluency, Picture Naming, Digit Span, Coding, List Recall, List Recognition, Story Recall, and Figure Recall.

A second canonical correlation was conducted to investigate Research Question 2, to assess the relationship between the measures of language and obtained scores of the RBANS indices. The first set of variables included BNT-2 z-scores, D-KEFS Letter Fluency scaled scores, and D-KEFS Category Fluency scaled scores. The second set of variables included the RBANS index standard scores: Attention, Immediate Memory, Delayed Memory, Language, and Visuospatial/Constructional.

CHAPTER IV

RESULTS

This chapter includes the results investigating the relationship between measures of neuropsychological functioning and language ability in a non-clinical, college sample. In this chapter, the results of statistical analyses are summarized. This chapter is composed of three sections: (1) description of sample, (2) analyses and results, and (3) summary.

Results and Analyses

Descriptive Statistics of Measures Used

Descriptive statistics for obtained results from the *Repeatable Battery for the Assessment of Neuropsychological Status - Normative Update* (RBANS; Randolph, 2012), the Verbal Fluency task of the *Delis-Kaplan Executive Function System* (D-KEFS; Delis, Kaplan, & Kramer, 2001), and the *Boston Naming Test – Second Edition* (BNT-2; Kaplan, Goodglass, & Weintraub, 2001) for the sample are included in Table 6. The RBANS index scores and D-KEFS normative data were based on separate samples representative of the United States population (Delis, Kaplan, & Kramer, 2001; Kaplan, Goodglass, & Weintraub, 2001). Raw scores were converted to Z-scores for the BNT-2 and RBANS subtests specific to the current sample (mean = 0.00, standard deviation = 1.00) using the following procedure: $z\text{-score} = \frac{X - \mu}{\sigma}$.

The RBANS normative data stipulates a mean standard score of 100 and a standard deviation of 15 for index scores. Mean index standard scores for the current sample ranged from 93.65 (Delay Memory Index) to 98.95 (Immediate Memory Index). All mean index scores fell within the average range, suggesting a typical adult sample. The RBANS subtest z-scores ranged from a minimum of -3.63 (Picture Naming) to 3.34 (Coding).

The D-KEFS data stipulated a mean scaled score of 10, with a standard deviation of 3 for the Letter Fluency and Category Fluency tasks administered to the current sample. The mean scaled score on the Letter Fluency subtest of the sample was 11.23, and the mean scaled score on the Category Fluency subtest for the sample was 11.56. Mean D-KEFS scaled scores fell in the average range compared to the standardization sample (Delis, Kaplan, & Kramer, 2001).

TABLE 6

Mean and Standard Deviation Statistics for the RBANS, D-KEFS, and BNT-2 Standard, Scaled, and Z-Scores

Variable	Mean	SD
D-KEFS Verbal Fluency Letter Fluency	11.23	2.78
D-KEFS Verbal Fluency Category Fluency	11.56	2.95
RBANS Index Scores		
Attention	98.45	14.33
Immediate Memory	98.85	16.23
Delayed Memory	93.66	8.15
Language	96.64	12.05
Visuospatial/Constructional	98.53	15.27
Variable	Minimum z-score	Maximum z-score
BNT-2 Z-Scores	-3.40	2.00
RBANS Subtest Z-Scores		
List Learning	-2.55	1.60
Story Memory	-3.00	2.06
Figure Copy	-2.83	1.20
Line Orientation	-2.61	1.31
Semantic Fluency	-1.90	2.87
Picture Naming	-3.63	1.00
Digit Span	-2.28	2.61
Coding	-3.00	3.34
List Recall	-2.12	1.33
List Recognition	-2.86	0.34
Story Recall	-3.77	1.24
Figure Recall	-3.08	1.39

N = 64

Raw scores for the current sample on the BNT-2 ranged from 37 to 59 of 60 items, with a mean of 50.89 and a standard deviation of 4.11. A comparison to the general population could not be made for BNT-2 scores, as no agreed upon, age-appropriate, standardized set of norms is available for the age-range of the current sample. Research with the BNT-2 has largely focused on ethnically-similar older adult populations (i.e., 55 years and older) and child populations, with no agreed upon set of norms for a diverse, college-age sample. For comparison of obtained BNT-2 raw scores, these raw scores were converted to z-scores specific for the current sample. BNT-2 z-scores ranged from -3.40 to 2.00. These results are summarized in Table 6.

The relationships among RBANS index standard scores, RBANS subtest z-scores, D-KEFS Letter Fluency scaled scores, and D-KEFS Category Fluency scaled scores, and BNT-2 z-scores were assessed using a Pearson's correlation. Results of this correlation analysis are summarized in Table 7. Following guidelines set by Cohen (1988), relationships with a large effect size have a correlation of $r = .50$ or greater, with medium effect size with $r = .30-.49$ and small effect size with $r = .00-.29$. Regarding the RBANS indices and measures of language, several correlations were statistically significant. The BNT-2 was found to have no statistically significant correlations with RBANS indices, with small effect sizes with each index. The D-KEFS Letter Fluency was found to have statistically significant relationships, with small effect sizes, with the Immediate Memory Index, Language Index, and Visuospatial/Constructional Index. The D-KEFS Category Fluency was found to have a statistically significant relationship, with a small effect size, with the Immediate Memory Index. Additionally, the relationships between D-KEFS Category Fluency and the Attention Index, Language Index, and Visuospatial/Constructional Index were found to have a medium effect size.

Several RBANS subtests were also found to have statistically significant correlations with individual measures of language, summarized in Table 7. The BNT-2 was found with a significant relationship with Story Memory, Line Orientation, and Story Recall, with small effect size. The BNT-2 was also significantly correlated with the Picture Naming subtest, with a medium effect size. The D-KEFS Letter Fluency was found to have no significant correlations with RBANS subtests, with small effect sizes. The D-KEFS Category Fluency found to have significant relationships with Semantic Fluency and Coding, with medium effect sizes.

TABLE 7

Correlations Between BNT-2 Scores, D-KEFS Letter Fluency Scores, D-KEFS Category Fluency Scores, and RBANS Scores

	Boston Naming Test - Second Edition (BNT-2)	D-KEFS Verbal Fluency, Condition 1: Letter Fluency	D-KEFS Verbal Fluency, Condition 2: Category Fluency
Attention	-.059	.165	.329**
Immediate Memory	.188	.263*	.267*
Delayed Memory	.059	-.029	-.002
Language	.241	.255*	.478**
Visuospatial/Constructional	.139	.292*	.319*
List Learning	.084	.154	.180
Story Memory	.290*	.136	.136
Figure Copy	-.014	.194	.217
Line Orientation	.268*	.076	.206
Semantic Fluency	.174	.129	.440**
Picture Naming	.306*	.026	.123
Digit Span	.120	.142	.076
Coding	-.167	.071	.371**
List Recall	.042	.014	.054
List Recognition	-.083	-.097	.153
Story Recall	.282*	.035	.007
Figure Recall	-.116	.071	.097

* Significant at the $p < .05$ level

** Significant at the $p < .01$ level

Research Question 1 and Canonical Correlation

A Canonical Correlation was used to assess the strength and nature of the relationship between language measures and the RBANS subtests to answer the first research question: What is the canonical relationship of the measures of language (naming, semantic fluency, phonemic fluency) with the 12 subtests of the RBANS? Results for this canonical correlation analysis are summarized in Table 8. The canonical correlation between measures of language and the RBANS subtests produced one statistically significant result as the first variate, $p = .020$. This variate had a canonical correlation value of .631 and a canonical R^2 of .398, suggesting that approximately 40% of the variation in one set of variables was shared the other.

TABLE 8

Correlations Between RBANS Subtests, Language Measures,, and Their Canonical Variates

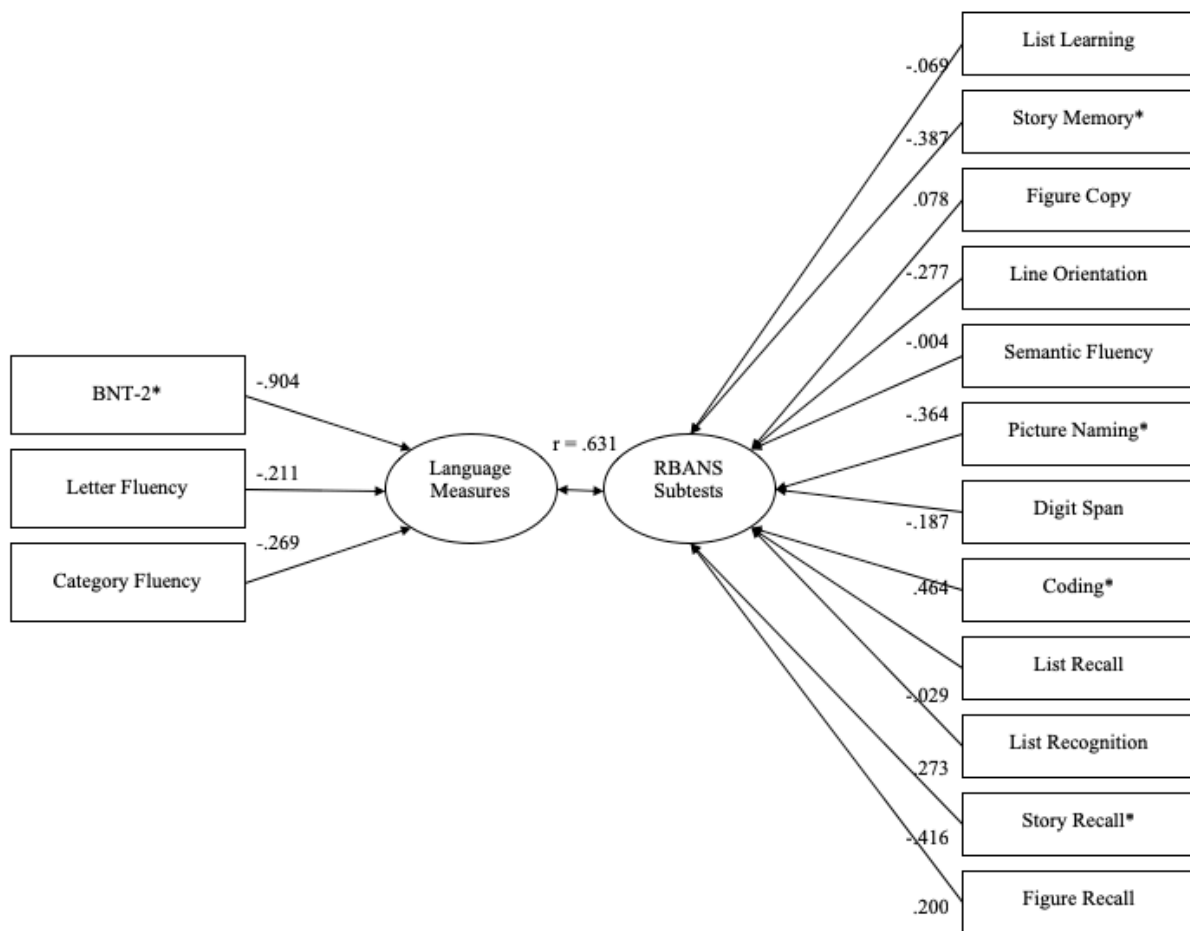
Variable	Canonical Loadings
Language Measures	
BNT-2	-.904*
D-KEFS Verbal Fluency: Letter Fluency	-.211
D-KEFS Verbal Fluency: Category Fluency	.269
RBANS Subtests	
List Learning	-.069
Story Memory	-.387*
Figure Copy	.078
Line Orientation	-.277
Semantic Fluency	-.004
Picture Naming	-.364*
Digit Span	-.187
Coding	.464*
List Recall	-.029
List Recognition	.273
Story Recall	-.416*
Figure Recall	.200

* *Significant Contributor to Overall Relationship*

Variable canonical loadings of more than .30 are considered to indicate an important contributor to the overall relationship between the two variable sets (Tabachnick & Fidell, 2007). The BNT-2 was the only language measure to have a canonical loading above the threshold with respect to the overall relationship within the first variate. Regarding the RBANS Subtests, Story Memory, Picture Naming, Coding, and Story Memory were important contributors to the canonical variable for the second set. The results of this variate, indicating a statistically significant relationship, are summarized in Figure 1.

FIGURE 1

Canonical Correlation Loadings for Variate Between Language Measures and RBANS Subtests



* Significant Contributor to Overall Relationship, at moderate correlation level

Analyses of canonical cross loadings and variance statistics suggest this variate has no redundancy problems. Redundancy was checked by comparing canonical loading values for each variable sets with cross loading values; this analysis indicated all variables acted to measure the respective variable set better than variables from the other set. The proportion of variance was also used to address redundancy; this analysis indicated each variable set explained more variance than was explained by the opposite variable set (.311 > .124; .076 > .030).

Research Question 2 and Canonical Correlation

A canonical correlation was also used to assess the strength and nature of the language measures and the RBANS Index scores to answer the second research question: What is the canonical relationship of the measures of language (naming, semantic fluency, phonemic fluency) with the 5 indices of the RBANS? The canonical correlation between measures of language and the RBANS indices produced one statistically significant result as the first variate, $p = .010$. This variate had a canonical correlation value of .590 and a canonical R^2 of .348, suggesting approximately 35% of the variation in one set of variable was shared by the other. The results of this analysis are summarized in Table 9.

All three measures of language were found to be related to the overall canonical variable, based on the .30 cut-value for canonical loadings. Regarding the RBANS Indices, the Language Index, Visuospatial/Constructional Index, Immediate Memory Index, and Attention Index were all found to be significantly related to the overall RBANS canonical variable. The results of this analysis, indicating a statistically significant relationship between the language measures and RBANS indices, are summarized in Figure 2.

Analyses of canonical cross loadings and variance statistics suggest this variate has no redundancy problems. Redundancy was checked by comparing canonical loading values for each

variable sets with cross loading values; this analysis indicated all variables acted to measure the variable set better than variables from the other set. The proportion of variance was also used to address redundancy; this analysis indicated each variable set explained more variance than was explained by the opposite variable set (.446 > .156; .348 > .121).

TABLE 9

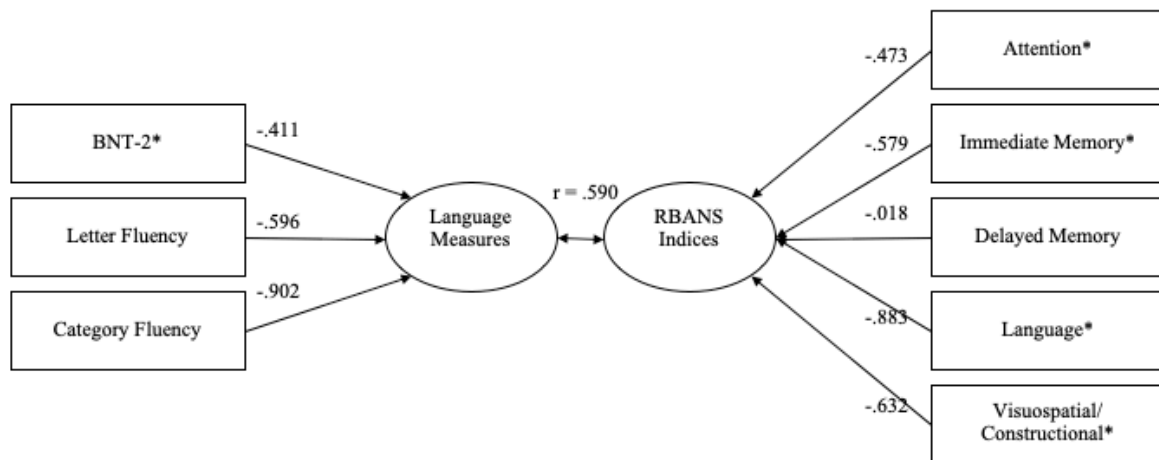
Correlations Between RBANS Indices, Language Measures, and Their Canonical Variates

Variable	Canonical Loadings
Language Measures	
BNT-2	-.411*
D-KEFS Verbal Fluency: Letter Fluency	-.596*
D-KEFS Verbal Fluency: Category Fluency	-.902*
RBANS Indices	
Attention	-.473*
Immediate Memory	-.579*
Delayed Memory	-.018
Language	-.883*
Visuospatial/Constructional	-.632*

* Significant Predictor of Overall Relationship

FIGURE 2

Canonical Correlation Loadings for Variate Between Language Measures and RBANS Indices



* Significant Predictor of Overall Relationship

Research Question 3 and Correlation Analysis

A Pearson's correlation analysis was used to assess the strength of the relationship between the measures of language ability. Specifically, these correlations investigated the relationship between the measures of phonemic fluency, semantic fluency, and naming ability to answer the third research question: What is the relationship among the measures of language not part of the RBANS? Results of this correlation analysis are summarized in Table 10. A nonsignificant relationship was found between the BNT-2 z-scores and D-KEFS Letter Fluency scaled scores ($r = .087$, $p = .494$). A nonsignificant relationship was found between the BNT-2 z-scores and D-KEFS Category Fluency scaled scores ($r = .060$, $p = .638$). A moderate degree of correlation (Cohen, 1988) was found between the D-KEFS Letter Fluency subtest and the D-KEFS Category Fluency subtest ($r = .390$, $p = .001$).

TABLE 10

Correlations Between BNT-2 Scores, D-KEFS Letter Fluency Scores, and D-KEFS Category Fluency Scores

	BNT-2	Letter Fluency	Category Fluency
BNT-2	-	.087	.060
Letter Fluency		-	.390**
Category Fluency			-

* Significant at the $p < .05$ level

** Significant at the $p < .01$ level

Statistical Assumptions

Data were assessed to ensure statistical assumptions of the analyses were met. Normality was assessed for all variables by skewness, kurtosis, and histogram plots. Skewness and kurtosis tests suggest variables approximate normal distributions. Visual analysis of histograms also suggests variables approximate normal distributions, with a slight positive skew across all variables. Univariate normality was assessed by analysis of P-P plots, and visual analysis

suggests variables approximate normal distributions. Multivariate normality was assessed by use of Mardia's test. Results suggest multivariate normality overall, with multivariate normality ($p > 0.05$) for the language measure variable set and the RBANS index variable set; the RBANS subtest variable set showed multivariate normality regarding kurtosis ($p > 0.05$) with slight positive skew indicates ($p = 0.03$). Linearity was assessed by use of a scatterplot matrix; upon visual analysis, no relationships were found to be non-linear. Homoscedasticity was assessed by analysis of scatterplot for all variable sets, including the language measure canonical variable set, RBANS subtest canonical variable set, and RBANS index canonical variable set. The width of the scatterplots was similar for the language measures, with most clustered ranging from -2 to 2. The widths of the scatterplots were also similar for RBANS subtest and RBANS index scatterplots, with most clustered ranging from -1 to 1. Considering all models, no evidence of multicollinearity was found, as variance inflation factors (VIF), models ranged from 1.008 to 3.395.

Summary

The participants demonstrated average performance on obtained RBANS Index standard scores and D-KEFS scaled scores. Z-scores were calculated, specific to the current sample, for BNT-2 scores and RBANS subtest scores. Pearson correlation analyses indicate positive correlations between the D-KEFS Letter Fluency at the $p < .05$ level of significance and the following measures: D-KEFS Category Fluency, Immediate Memory Index, Language Index, and Visuospatial/Constructional Index. The D-KEFS Category Fluency was found with positive correlation at least at the $p < .05$ significance level with the following measures: Attention Index, Immediate Memory Index, Language Index, Visuospatial/Constructional Index, Semantic Fluency, Coding, and D-KEFS Letter Fluency. The BNT-2 was found with positive correlations

at the $p < .05$ significance level for the following: Story Memory, Line Orientation, Picture Naming, and Story Recall. Results of the first canonical correlation analysis indicated a significant relationship between the measures of language and subtests of the RBANS. This variate had a canonical correlation value of .631 and a canonical R^2 of .398, suggesting approximately 40% of the variation in one set of variable accounted for by the other, with significance at the .05 level. The BNT-2 was found to be the best contributor to the overall relationship of the language measures, with several RBANS subtests also significant contributors. Results of the second canonical correlation analysis indicated a significant relationship between the measures of language and the RBANS Indices. This variate had a canonical correlation value of .590 and a canonical R^2 of .348, suggesting approximately 35% of the variation is explained, with significance at the .05 level. All measures of language were found to be significant contributors to the overall relationship, with four of five RBANS Indices also significant contributors.

CHAPTER V

DISCUSSION

The following chapter offers a discussion of the current study and includes four sections: (1) summary of the current study, (2) discussion of the results, (3) delimitations and limitations of the current study, and (4) directions for future research.

Summary of the Current Study

The purpose of this study was to investigate the relationship between language ability and performance on neuropsychological measures, specifically the *Repeatable Battery for the Assessment of Neuropsychological Status, Update* (RBANS; Randolph, 2012) in a sample of 64 college students enrolled at a Midwestern university. All participants were administered a measure of language ability and a measure of neuropsychological functioning as part of a larger study. Language ability was assessed with a classic and well-validated measure of naming ability and a newer verbal fluency measure. Naming ability was measured by the administration of the *Boston Naming Test – Second Edition* (BNT-2; Kaplan, Goodglass, & Weintraub, 2001). Verbal fluency was measured with the *Delis-Kaplan Executive Functioning Scale* (D-KEFS: Delis, Kaplan, & Kramer, 2001) Verbal Fluency subtest Condition 1: Letter Fluency (Letter Fluency) and Condition 2: Category Fluency (Category Fluency). The RBANS was administered, assessing five domains: Attention, Immediate Memory, Delayed Memory, Language, and Visuospatial/Constructional. The Attention Index is comprised of the Digit Span and Coding subtests. List Learning and Story Memory are included in the Immediate Memory Index. The Delayed Memory Index includes List Recall, List Recognition, Story Recall, and Figure Recall. The Language Index is comprised of Picture Naming and Semantic Fluency. Figure Copy and Line Orientation are included in the Visuospatial/Constructional Index.

The relationship between the language measures and neuropsychological functioning measure was investigated by use of Pearson's correlations and canonical correlations. Mean standard scores and scaled scores for RBANS Indices and D-KEFS fell in the average range, which was largely expected given this was a non-referred college sample. Calculated z-scores for the BNT-2 and RBANS subtests indicate these scores ranged widely (i.e., -3.63 to 3.34), with some below average, suggesting a relatively representative sample of the general population. Indeed, it is not uncommon for variation in performances in healthy individuals on cognitive tests (Hebben & Milberg, 2009; Strauss et al., 2006.)

The first canonical correlation produced a significant variate, suggesting a significant relationship between the set of language measures and performance on the set of RBANS subtests, at the $p < .05$ level. This variate indicated approximately 40% of the variance in one set was accounted for by the other set. The BNT-2 was found to be a significant contributor to the overall relationship. The other measures of language ability, Letter Fluency and Category Fluency, were not found to be significant contributors to the relationship. Of the RBANS subtests, Story Memory, Picture Naming, Coding, and Story Recall were significant contributors to the relationship, while the others were not. The second canonical correlation also produced a significant variate, suggesting a significant relationship between the set of language measures and set of RBANS indices, at the $p < .05$ level. This variate indicated approximately 35% of the variance in one set was accounted for by the other. All three language measures were significant contributors to the relationship. Four RBANS indices were significant contributors: Attention Index, Immediate Memory Index, Language Index, and Visuospatial/Constructional Index.

Pearson's correlations indicate, of the language measures, Letter Fluency and Category Fluency were significantly correlated with each other at the $p < .01$ level. Letter Fluency was

significantly correlated with the RBANS Indices Immediate Memory, Language, and Visuospatial/Constructional all at the $p < .05$ level, but not with any RBANS subtests. Category Fluency was significantly correlated at the $p < .01$ level with the RBANS Indices Attention and Language as well as the RBANS subtests Semantic Fluency and coding, and at the $p < .01$ level with the RBANS Indices Immediate Memory and Visuospatial/Constructional. The BNT-2 was significantly correlated with the RBANS subtests Story Memory, Line Orientation, Picture Naming, and Story Recall, although not with any RBANS indices.

Discussion and Implications of Current Study

The current study investigated the relationship between language ability and neuropsychological functioning in a non-clinical, college sample. This study aimed to add to and expand on existing literature regarding the impact of language ability on performance on neuropsychological measures by investigating this relationship with a common measure of neuropsychological functioning, the RBANS (Rabin et al., 2016). While the relationship between language ability and performance on cognitive, academic, memory, and executive functioning measures has been investigated for quite some time, this relationship has not been fully explored with regards to the distinct, comprehensive neuropsychological measures used in this study. It is important to understand this relationship as deficits in language abilities may negatively impact an individual's performance on tasks of neuropsychological functioning with varying levels of linguistic demand. This study contributes to the field by elucidating this relationship using a commonly administered measure of neuropsychological functioning, the RBANS. The RBANS is considered a well-validated measure of neuropsychological functioning (Randolph, 2012) and is widely used by neuropsychologists (Rabin et al., 2016). This comprehensive measure of neuropsychological functioning also has a brief administration time, adding to its usefulness with

a variety of populations and referral questions. The fact the RBANS is so widely used, and represents a brief approach to assessing a number of neuropsychological conditions, mandates the construct validity be well understood, including the influence of language on the various tasks. Indeed, the results of the current study also provided more information about the relationship between the BNT-2 and D-KEFS Verbal Fluency tasks, as measures of language ability.

The results of the canonical correlations and correlations demonstrate there is a significant relationship between language ability and other measures of neuropsychological performance on a commonly used assessment measure. While several of the variables were negative contributors to the relationship between language measures and RBANS performance, the overall relationship was found to be positive. Several language measure variables and RBANS variables were found to be significant contributors of this overall relationship.

Regarding the first research question, “What is the canonical relationship of the measures of language (naming, semantic fluency, phonemic fluency) with the 12 subtests of the RBANS?,” an overall significant and positive relationship was found. The common variance shared between the set of language measure variables and set of RBANS subtest variables was approximately 40%. Generally, this indicates more developed language ability was related with increased RBANS subtest performance. Inconsistent with the first hypothesis of the current study, “[I]t was hypothesized phonemic verbal fluency or semantic verbal fluency will contribute the most to this relationship as compared to the BNT-2 given the fluency tasks tap a greater array of neuropsychological constructs.”, results indicate the BNT-2 contributed the most to the overall relationship. Additionally, there was partial evidence found related to the second and third hypotheses, “It was hypothesized the Picture Naming and Semantic Fluency subtests of the

RBANS will contribute most to this relationship, as these two subtests contribute to the RBANS Language Index.” and “It was hypothesized the subtests of the RBANS which require more verbal ability (e.g., Picture Naming, Semantic Fluency, List Learning, and Story Memory) will contribute more to the relationship than those which require less verbal ability (e.g., Figure Copy, Line Orientation, and Coding). It was also hypothesized, however, that even those subtests requiring minimal language ability will still somewhat contribute to the relationship.”, respectively. While Picture Naming, Story Memory, and Story recall all were significant contributors to the relationship, List Learning was not significant to the relationship.

With consideration of the second research question, “What is the canonical relationship of the measures of language (naming, semantic fluency, phonemic fluency) with the 5 indices of the RBANS?”, the common variance between language variables and RBANS indices was approximately 35%. As a whole, the significant and positive relationship indicates more developed language abilities are related to increased performance on the RBANS indices. Evidence was found related to the first hypothesis, “[I]t was hypothesized phonemic verbal fluency or semantic verbal fluency will contribute the most to this relationship as compared to the BNT-2 given the fluency tasks tap a greater array of neuropsychological constructs.” The BNT-2 was found to be a significant contributor, but to a lesser degree compared to Letter Fluency and Category Fluency. Evidence to the second hypothesis was also found, “It was hypothesized the Language Index of the RBANS will contribute most to this relationship.” Finally, partial evidence was found for the third hypothesis, “ It was hypothesized the indices of the RBANS which require more verbal ability (e.g., Language Index, Immediate Memory Index, and Delayed Memory Index) will contribute more to the relationship than those which require less verbal ability (e.g., Visuospatial/Construction Index and Attention Index). It was also

hypothesized, however, indices requiring minimal language ability will still somewhat contribute to the relationship.” While the Language Index and Immediate Memory Index were found to be a significant contributor to the overall relationship, the Attention Index and Visuospatial/Constructional Index were also significant contributors, while the Delayed Memory Index was not a significant contributor. Additionally, The Visuospatial/Constructional Index was found to actually contribute more to the overall relationship compared to the Immediate Memory Index.

Regarding the third and final research question, “What is the relationship among the measures of language not part of the RBANS?”, results indicate the BNT-2 was not significantly related to the D-KEFS Verbal Fluency tasks, while Letter Fluency and Category Fluency were significantly related to one another. These results are considered inconsistent with the hypotheses, “It was hypothesized there will be a strong, positive correlation found between naming ability, as measured by the BNT-2, and phonemic fluency, as measured by the D-KEFS Verbal Fluency Condition 1: Letter Fluency task.” and “It was hypothesized there will be a strong, positive correlation found between naming ability, as measured by the BNT-2, and semantic fluency, as measured by the D-KEFS Verbal Fluency Condition 2: Category Fluency task.”

The overall results of the study were expected, as previous research suggests a strong, positive relationship between language ability and performance on other psychological and neuropsychological measures (i.e., Flanagan et al., 2013; Flanagan & Harrison, 2012; Ortiz, 2005; Sattler & Ryan, 2009; Wechsler, 2008). Higher language ability has been found to be positively related to higher performance on language measures, including naming and verbal fluency measures. Similar positive correlations have been found between language ability and

visuospatial measures (Carlozzi et al., 2008), attention measures (Sattler & Ryan, 2009; Ortiz, 2005), and measures of memory (Carlozzi et al., 2008; Cormier et al., 2014).

One explanation of the shared variance found in this study is there is a level of language ability required to understand and complete each task on the RBANS. Language ability includes both receptive language ability and expressive language ability (Astesano & Jucla, 2015).

Psychological and neuropsychological assessments commonly include some specific measure of language and/or communication (Mpofu & Ortiz, 2009), including the RBANS.

Neuropsychological tasks not explicitly measuring language (i.e., memory, attention, spatial skills, processing speed) often require a certain degree of language ability, or have a level of linguistic demand. For example, even on some visual problem solving tasks, when administration includes verbal instructions, the examinee must possess receptive language abilities to understand those task instructions. Expressive abilities are often required, as the examinee may be required to respond in a verbal modality. For example, some fluid reasoning and visual-spatial intellectual tasks permit, or even require, a verbal response. Tasks measuring nonverbal constructs have been found to have varying levels of this linguist demand (Flanagan et al., 2013; Ortiz, 2005). Conversely, language ability is also dependent on neuropsychological functions, including attention and memory, which also helps explain the relationship uncovered in this study. In sum, results of this study suggest neuropsychological deficits may contribute to assessed deficits in language ability, and language deficits may impact performance on neuropsychological tasks. The following sections provide discussion of results of the current study regarding each included neuropsychological domain: language, attention, memory, and visuospatial/constructional.

Language Ability

The individual measures of language included in the present study were found to be partially correlated to one another. Specifically, while the BNT-2 was not found to be significantly related to Letter Fluency or Category Fluency, the D-KEFS tasks were significantly related to one another. As these tasks are well-validated measures of language, these relationships suggest the current study involved several different facets of language ability. The current study primarily measured facets of expressive language ability. Receptive language and expressive language are highly correlated (Leonard, 2009) and measurement of expressive language may be considered an estimate of overall language abilities. Specifically, expressive language ability was measured by the most commonly used measure of language in neuropsychological assessments, the BNT-2 (Rabin et al., 2016), as a measure of word finding ability and naming. Language ability was also measured by the use of another commonly used assessment in neuropsychological evaluation, the D-KEFS (Rabin et al., 2016) Verbal Fluency test, including measurement of phonemic verbal fluency and semantic verbal fluency.

The BNT-2 was a significant contributor to the canonical relationship between language measures and the RBANS indices and subtests. Overall, higher BNT-2 scores were associated with higher performance on the RBANS. Higher BNT-2 scores were associated with higher scores on the Attention Index, Immediate Memory Index, Language Index, and Visuospatial/Constructional Index. Higher BNT-2 scores were associated with higher scores on Story Memory, Picture Naming, and Story Recall, with lower scores on Coding. This result is expected, as language ability has been linked to neuropsychological functioning (Lezak, 2012; Wade, Browne, Madigan, Pladmondon, & Jenkins, 2014) and cognitive functioning (Bell et al., 2001; Wechsler, 2008). Only the BNT-2, and not the verbal fluency tasks, was a significant

contributor to the relationship between language measures and RBANS subtests. This suggests the RBANS subtests may be more sensitive to changes in language as compared to language-based executive functioning, due to the more pure nature of the BNT-2 in regards to language. The BNT-2 is considered to be a valid and pure measure of language (i.e., naming ability), while the D-KEFS Verbal Fluency tasks are also considered to measure some components of executive functioning (John et al., 2016; Shao et al., 2014; Strauss et al., 2006); it is important to note, while some research suggests executive functioning is measured in some capacity (Spencer, Kitchen Andren, & Tolle, 2018), the RBANS includes no standardized measure or composite of executive functioning. As basic, naming language ability increases it would be expected performance on other measures of neuropsychological functioning would also rise; this was found in the current study, with performance on the BNT-2 and RBANS subtests.

Despite not contributing to the relationship between language and the RBANS subtests, Letter Fluency was a significant contributor to the relationship between language measures and RBANS indices. As scores on the Letter Fluency task rose, scores on four of the five RBANS indices also rose. Additionally, Category Fluency was a significant contributor to this relationship, with higher Category Fluency scores related to high RBANS scores on the indices: Attention, Immediate Memory, Language, and Visuospatial/Constructional. It was expected D-KEFS Verbal Fluency tasks would have contributed more to the relationship with performance on the RBANS than was found. This expectation can be understood, given verbal fluency tasks measure language ability and components of executive functioning, neuropsychological functioning and executive functioning are commonly associated with one another, and research has indicated the RBANS does tap some executive functions (O'Bryant et al., 2011; Randolph, 2012; Spencer et al., 2018).

Overall, although there were some variations, individuals with higher language abilities present with higher measured performance on the RBANS, and those with lower language abilities show are measured with lower performance on the RBANS. Consistent with previous research, this suggests language ability and several areas of neuropsychological functioning may have an impact on one another. Research has previously suggested notable linguistic demand, defined as effect language abilities have on performance on that task, of tasks measuring verbal and nonverbal (i.e., memory, attention, spatial skills, processing speed) constructs (Flanagan et al., 2013; Ortiz, 2002; Ortiz, 2005). Additionally, previously research has shown a moderate correlation between performance on the RBANS, an overall measure of neuropsychological functioning, with measured language skill on the *Boston Naming Test* (BNT; Goodglass, Kaplan, Weintraub, 1983) and the *Controlled Oral Word Association Test* (COWAT; Benton & Hamsher, 1976) ($r = .66$, $r = .64$, respectively; Randolph, 2012).

Attention

Results of the current study found the RBANS Attention Index significantly contributed to the overall relationship between language measures and RBANS indices, suggesting the importance of attention in the overall relationship. Higher Attention Index scores were related to higher scores on all three of the individual measures of language. This result is not surprising as this relationship between attention-related abilities and language ability has been shown in previous research. Several neuroanatomical correlates are shared between attention and language, including the frontal cortex (Young et al., 2008), parietal lobes (Fridriksson et al., 2007; Suzuki & Gottlieb, 2013), and subcortical regions (Baldo et al., 2013; Konrad et al., 2012). Additionally, the level of linguistic demand on attention-related tasks on other psychological batteries has shown the importance of this relationship as well. Indeed, previous research

suggests tasks designed to measure attention, including span tests and symbol-substitution tasks, have a moderate linguistic demand (Ortiz; 2005). Results of the current study suggest the ability to attend to and process stimuli in the environment may be impacted by language ability.

The Attention Index included the Digit Span subtest and Coding subtest. Consistent with the hypothesis of this study, Digit Span, a measure of attentional capacity, did contribute to the overall relationship, but to a lesser extent compared to several other subtests with historically more linguistic demand. Digit Span was not significantly correlated to any individual language measures. This may suggest performance on the Digit Span subtest was relatively unimpacted by performance on language measures. Similarly, research regarding the linguistic demand of digit span tasks have shown a low to moderate linguistic demand (Ortiz, 2005). Additionally, similar span tasks have been found with generally low to moderate correlations with overall verbal abilities; the correlation values between the *Wechsler Adult Intelligence Scale – Fourth Edition* (WAIS-IV; Wechsler, 2008) Digit Span task and Verbal Comprehension Index (VCI) throughout the norming samples ranges from $r = .38$ to $r = .61$.

The Coding subtest, a measure of sustained attention and response speed, was a significant contributor to the overall relationship to language measures, with the strongest correlation of the RBANS subtests. Higher Coding scores were related to a higher overall relationship between the language measures and RBANS subtests. Additionally, higher Coding scores are related to higher scores on Category Fluency. This finding is unsurprising when considering Category Fluency and Coding tasks are considered to require executive functioning (Davis & Pierson, 2012; Homack, Lee, & Riccio, 2005). Additionally, coding-type tasks and semantic fluency tasks share many neuroanatomical correlates, including the prefrontal cortex (Chu, Yi, Byun, Lee, & Lee, 2017; Hampshire et al., 2010). Conversely, Coding had an inverse

relationship with the BNT-2 and Letter Fluency. Coding-type tasks primarily measure attention, processing speed, and executive functioning, while naming tasks primarily measure naming ability, word knowledge, and expressive language. Additionally, brain imaging suggests coding tasks and naming tasks require very little similar activation, as research has suggested coding tasks require activation of the dorsolateral prefrontal cortex, supramarginal gyrus, the inferior frontal gyrus, and the angular gyrus (Hampshire et al., 2010; Kane & Engle, 2002), while naming tasks require activation primarily of the dominant temporal lobe (Mesulam et al., 2013), posterior superior temporal and inferior parietal regions, insula, internal capsule, putmen, and dominant hippocampus (Bonelli et al., 2011; Fridriksson et al., 2007)

Memory

The Immediate Memory Index was found to be a significant contributor to the overall relationship, with higher Immediate Memory Index scores found to be related to higher scores on the individual language measures. This is consistent with the hypothesis, expecting this index to be found as a significant contributor to the relationship with measures of language, given tasks of the Immediate Memory Index include only language-based tasks. The Immediate Memory Index was comprised of the List Learning and Story Memory subtests. List Learning, a measure of short-term memory capacity and encoding, was not a significant contributor to the overall relationship, inconsistent with the current hypothesis. Additionally, List Learning was not significantly correlated to any individual language measures. Given the verbal nature of the subtest, it might be expected List Learning would be a significant contributor. However, the nature of this task suggests it relies more upon encoding and consolidation of non-contextual information such that the stimuli, although containing verbal information, likely relies little upon language processing and more upon attention and working memory.

Conversely, the Story Memory subtest, a measure of verbal immediate memory, was a significant predictor of the overall relationship between RBANS subtests and measures of language, with a moderate correlation to the relationship. Additionally, results are consistent with the study hypothesis, suggesting higher Story Memory scores were related to higher scores on the BNT-2 and Letter Fluency. Previous research investigating the linguistic demand has shown memory tasks, including verbal stimuli provided in context, have high levels of linguistic demand (Ortiz, 2005). This current finding may suggest performance on Story Memory may be significantly impacted by language ability given the need to encode verbal contextual information.

Overall, results of the current study suggest the ability to temporarily hold and quickly use verbal information may be impacted by language ability. Immediate memory is often considered to rely heavily on language-based processes. For example, Broca's area, an area of language expression in the brain, has long been associated with immediate memory and the ability to hold verbal information (Paulesu et al., 1993; Petrides et al., 1993). Learning theory also suggests verbal, subvocal rehearsal mechanisms (i.e., the phonological loop) are often used by individuals required to briefly hold verbal information, as an individual may mentally repeat the information until use (Baddeley, 1992; Baddeley, 2017; Gathercole & Baddeley, 2014). While both immediate memory and delayed memory have both been found to be moderately correlated with language abilities, immediate memory tends to rely more heavily on these language-based mechanisms compared to delayed memory. Verbal immediate memory has been associated primarily with the prefrontal cortex (Grant, 2009) and Broca's area, while delayed memory has been associated with the prefrontal cortex, the hippocampal and parahippocampal regions of the medial temporal lobe, the anterior cingulate, the inferior parietal cortex, and

cerebellum (Kahn et al., 2004; Kapur et al., 1994). With use of more neural systems, delayed memory makes use of additional memory mechanisms which are not all primarily language-based, including use of emotional arousal, linking to previous information, and construction in addition to practice and rehearsal mechanisms (Cahill & McGaugh, 1998; Hassabis & Maguire, 2007; Norman, 1969).

The Delayed Memory Index had a non-significant relationship with the overall relationship between RBANS indices and measures of language. This suggests performance on the language measures did not significantly impact scores of the Delayed Memory Index. The Delayed Memory Index was not significantly correlated to any individual measures of language. Overall, this may suggest the RBANS Delayed Memory Index may be less impacted by language ability as compared to the other four RBANS indices, indicating general delayed memory may not be heavily impacted by language ability. As this index included a visual memory task, this finding may not be surprising; the Delayed Memory Index includes Figure Recall, in addition to Story Recall, List Recall, and List Recognition. Neural systems used to recall and/or recognize information are often dependent on the type of information (i.e., verbal or nonverbal information), which may be related to the lack of findings in the current study. For example, recall and recognition of visuospatial information is considered to require the use of the posterior parietal lobes, occipital lobe, and cerebellum.

List Recall, a measure of simple delayed memory, was not a significant contributor to the overall relationship. It was also not significantly correlated to any individual measures of language. This is considered inconsistent with the hypothesis as List Learning, and the related List Recall, are essentially verbal tasks; previous research investigating linguistic demand has suggested a high level of linguistic demand on similar tasks (Ortiz, 2005). It is possible the

stimuli included in List Learning, and therefore List Recall, are even less context-dependent than other similar tasks. When stimuli is stored in the memory, it is often stored with context, if available; the stored stimuli is then more easily cued by context upon retrieval (Smith, 1994). When context is not available, these seemingly verbal stimuli may be stored with little linguistic context, and therefore not be as dependent on language abilities.

List Recognition, a measure of recognition memory, was also not a significant contributor to the relationship. No significant correlations were found between List Recognition and the individual language measures. Again, this is considered somewhat inconsistent with the current hypothesis given this task's verbal nature. List Recognition may be less likely to be impacted by language ability compared to other RBANS subtests. Similar to List Recall, while this task appears verbal in nature, this task requires the recognition on non-contextual stimuli which may be stored with little or no linguistic context and require less language ability overall.

The Story Recall subtest, a measure of delayed verbal memory, was found to be a significant contributor to the overall relationship of RBANS subtests and language measures, with a weak correlation. Consistent with research regarding context and memory, the use of contextual cueing is one of the most basic memory mechanisms for stimuli with context (Smith, 1994), as stored contextual information would act to cue stored stimuli. Results of the current study suggest higher Story Recall scores were related to higher BNT-2 scores. Story Recall was found with no significant relation with Letter Fluency or Category Fluency. These findings are unsurprising as the BNT-2 and Letter Fluency measure language ability with a heavier reliance on the linguistic and verbal compared to Category Fluency, for example. Overall, this is consistent with the hypothesis that RBANS subtests with more verbal stimuli would be more related to language ability.

Figure Recall, a measure of delayed visual memory, was not a significant contributor to the overall relationship. Performance on Figure Recall did contribute to the overall relationship, but to a lesser extent compared to several other subtests with historically more linguistic demand. It was not significantly correlated to any individual measures of language.

Visuospatial/Constructional

Findings suggest nonverbal, visuospatial, constructional skills were moderately correlated with the language measures. This correlation suggests higher scores on the RBANS Visuospatial/Constructional Index were related with higher scores on the individual measures of language. This finding is consistent with the hypothesis, expecting this index to contribute to the relationship between RBANS indices and the measures of language, as these visuospatial and constructional tasks require receptive language to complete the task. For example, although these tasks on the RBANS are clearly visual-spatial and construction-oriented in nature, the patient receives the instruction auditorily. Research on linguistic demand also suggests low to moderate impact of language on performance on similar tasks (Ortiz, 2005). The results of the current study suggest the general ability to process and interpret visual stimuli may be impacted by language ability, particularly when instructions are given orally by the examiner.

Consistent with the study hypothesis expecting these task to contribute less to the overall relationship between RBANS subtests and the measures of language, Figure Copy and Line Orientation contributed to the overall relationship to a lesser extent compared to some tasks with more linguistic demand. Figure Copy, a measure of construction, was not a significant contributor to the overall relationship between language measures and RBANS subtests. Line Orientation, a measure of visual perception, was also not a significant contributor to the overall relationship. Similar tasks have been shown with low levels linguistic demand (Ortiz, 2005),

suggesting Figure Copy and Line Orientation may be less impacted by varying levels of language ability. Overall, these findings suggest that while the Visuospatial/Constructional Index may be impacted by language ability, the individual subtests may be less influenced.

Language

The Language Index was found to be the largest contributor to the overall relationship between language measures and RBANS indices, consistent with the study hypothesis expecting this index to contribute the most to the relationship between RBANS indices and the measures of language. Higher Language Index scores were found to be related to higher scores on the individual measures of language. Given this RBANS index is meant to measure language functioning, this result was expected and acts to further strengthen the construct validity of the RBANS.

The Picture Naming subtest and Semantic Fluency subtest comprise the Language Index. Picture Naming, a measure of naming ability, was found to be a significant contributor to the overall relationship between language measures and RBANS subtests. The results suggest higher Picture Naming scores are related to higher scores on the BNT-2 and Letter Fluency. Given the nature of the Picture Naming task, and its similarity to the BNT-2, this result is not surprising. This result lends to the validity of the RBANS Picture Naming subtest as a measure of naming given the long history of validation of the BNT-2.

The Semantic Fluency subtest, a measure of semantic verbal fluency, was not found to be a significant contributor to the overall relationship. This finding is inconsistent with the hypothesis expecting this subtest to contribute most to the relationship compared to other RBANS subtests given the verbal nature of the task, as well as what would seem an obvious connection to the D-KEFS Verbal Fluency tasks. The Semantic Fluency subtest was not

significantly correlated to the Letter Fluency task; these tasks assess different aspects of verbal fluency (semantic and phonemic fluency, respectively), and Letter Fluency and Category Fluency were found with only a moderate correlation during the current study. The Semantic Fluency subtest was found to be significantly correlated to the Category Fluency task. The Semantic Fluency subtest may measure constructs above and beyond language in the current study, similar to previous research suggesting verbal fluency tasks measure language and executive functioning.

Implications for the Field of Neuropsychology

Implications for Clinical Practice

The findings of the current study add to the understanding of the relationship between language ability and performance on neuropsychological tasks, in this case on a widely used neuropsychological measure. This study shows the importance of considering language ability when interpreting performance on the RBANS. In essence, a measure of neuropsychological functioning that may be impacted by language ability may inadvertently measure a language deficit, rather than neuropsychological functioning. Several clinical referral questions to practicing neuropsychologists may include language impairment; neurocognitive disorders, Alzheimer's disease, Fronto-temporal Dementia, neurodevelopmental disorders (i.e., autism spectrum disorder), and acquired neurological deficits (i.e., traumatic brain injury) may all present with a component of language impairment or language deficits (American Psychological Association, 2013; Baron, 2018; Eramudugolla, Mortby, Sachdev, Meslin, Kumar, Anstey, 2017; Kansal, Abraham, Rao, & Onyike, 2016; Szatloczki, Hoffmann, Vincze, Kalman, & Pakaski, 2015). Patients with suspected or measured language deficits should have some elements of the RBANS results interpreted with a certain degree of caution when considering the non-language

domains and subtests, specifically including: Story Memory and Story Recall. Additionally, in the current study, lower language abilities were found to be associated with lower scores on the Attention Index, Immediate Memory Index, Language Index, and Visuospatial/Constructional Index.

In clinical practice, an individual with language impairment may present with significant deficits in several areas of neuropsychological functioning which may lead to erroneous diagnoses and treatment recommendations. These language deficits may artificially depress their performance on the RBANS, specifically on the Attention Index, Immediate Memory Index, Language Index, and Visuospatial/Constructional Index, and lead to inaccurate diagnoses and inappropriate treatment planning. For example, an individual with language impairment may perform particularly poorly on the Immediate Memory Index, as this index contains Story Memory (found in this study to be influenced by language), and as language-based mechanisms are commonly used to complete tasks requiring immediate memory (i.e., phonological rehearsal mechanisms; Baddeley, 1992). Additionally, for example, an individual with autism spectrum disorder (ASD) may have lower language abilities, consistent with common characteristics of this disorder. That individual may struggle to understand and/or express themselves through the administration of the RBANS and obtain relatively low scores on the Attention and Immediate Memory domains. Given these indices were sensitive to language impairment, this score profile may lead a clinician to erroneously recommend treatment interventions based on results that do not best represent the individual's true functioning. This is not to suggest clinicians should avoid use of the RBANS, rather careful consideration of scores should be made when assessing an individual with suspected or measured language deficits.

Clinicians may choose to interpret RBANS performance at the subtest-level for patients with suspected or measured language deficits to minimize the possible negative effects poor language abilities may have on the performance on the RBANS, as four of the five indices were found for a significant relationship with language ability. When interpreting RBANS performance at the subtest-level, clinicians may consider the relationship between language ability and performance on each individual RBANS subtest found in this study. Several RBANS subtests were found to have nonsignificant relationships with language ability, including: List Learning, Figure Copy, Line Orientation, Semantic Fluency, Digit Span, List Recall, List Recognition, and Figure Recall. This study may lend to some confidence that performance on these tasks may be less influenced by language abilities. This finding is particularly important to note, as these subtests then comprise RBANS indices, of which several were found with a significant relationship with language ability, as noted above. With individuals with suspected or measured language deficits, using a subtest-level interpretation of the individual neuropsychological constructs, rather than a composite or index, may provide a clearer picture of those neuropsychological abilities without such an impact of language. Additionally, as Story Memory and Story Recall may be significantly impacted by varying language abilities, clinicians may choose to administer a secondary measure of these neuropsychological constructs when evaluating individuals with suspected or measured language deficits and/or consider that language may be interfering with interpretation.

Delimitations and Limitations of Current Study

Delimitations

The current study is an analysis of the relationship between language ability and performance on neuropsychological assessment, specifically the RBANS. Previous research

provides a framework for the current study, suggesting the impact of language ability and linguistic demand of many commonly administered measures of cognitive ability, achievement, executive functioning, and memory. The current study aimed to broaden these areas and investigate this impact on a specific neuropsychological battery, an area that had not yet been fully investigated. This study included the investigation of sixty-four (64) participants, a sample which may be considered representative of the on-campus undergraduate population at which recruitment occurred as well as United States Census data from 2016. Enrolled, on-campus undergraduate students for the 2015-2016 year included 59% female students with 41% male students, 81% White/Caucasian students with 19% minority students, and a mean age range of 20-25 years. U.S. Census data from 2016 notes nationwide demographics of citizens including 50.8% females, with 76.9% White/Caucasian, 13.3% Black/African American, 5.7% Asian, and 2.6% Biracial/Multiracial (U.S. Census Bureau, 2016). The current sample included 70.4% female participants, with 87.3% White/Caucasian, 8.5% Black/African American, 2.8% Asian, and 1.4% Biracial/Multiracial participants, with an average participant age of 20.74 years. Additionally, the mean scores of the participants in the current study were average following standardized, national norms, suggesting a largely typical college sample. Finally, the investigation of language ability and performance on a specific neuropsychological battery using relevant instruments, including the BNT-2 and D-KEFS, acts to advance research on the RBANS, which is one of the most commonly used neuropsychological measures for clinical evaluations (Rabin et al., 2016). Finally, the inclusion of participants with mental health diagnoses may be considered a delimitation, as the sample more accurately reflects the population, rather than only including neurotypical individuals. For example, eight (8) participants, or 12.5%, reported diagnoses of attention-deficit/hyperactivity disorder (ADHD).

This neurological-based disorder (American Psychological Association, 2013), may have negatively impacted their performance on the administered measures. However, it is important to note this percentage closely approximates the national prevalence of ADHD in the United States, perhaps leading to increased generalizability to the U.S. population, with approximately 10% of children and adolescents in the U.S. being diagnosed with ADHD at some point in time (Danielson et al., 2018).

Limitations

A primary limitation of the current study is the possibility of task impurity with regards to the measurement of language ability. While it is commonly agreed upon that naming ability and verbal fluency are valid measures of overall language ability (Axlerod et al., 1994; Shao et al., 2014; Sugarman & Axelrod, 2015; Yochim et al., 2015), the BNT-2 and D-KEFS may also measure other constructs, other than purely language ability. For example, the D-KEFS Verbal Fluency test aims overall to measure executive functioning (Delis, Kaplan, & Kramer, 2001). To attempt to rectify this, the tasks included in the current study consisted only of the phonemic fluency condition and semantic fluency condition; the condition measuring verbal fluency along with executive functioning and set-shifting (D-KEFS Verbal Fluency, Condition 3: Category Switching) was not included in the current study. It is also likely these measures have a cultural component given the relationship between language and acculturation (Clement, 1986; Jia, Gottardo, Chen, Koh, & Pasquarella, 2016; Schumann, 1986), and the fact acculturation is associated with neuropsychological test performance (Boone, Victor, Wen, Razani, & Ponton, 2007; Cioffi, 2015; Nogin, 2017), which could have impacted results. A third limitation may be found in the inclusion of only one version of the RBANS. The RBANS exists in four parallel versions (Randolph, 2012). RBANS Version A was the only version of the assessment included

in the current study. Excluding the use of the Version B, Version C, and Version D may limit the generalizability of the results to these three versions of the RBANS. While the sample may be considered representative of the United States with regards to ethnicity, as noted above, the sample also allows for some limitations of the current study. The small sample size may have limited variability in obtained scores; for example, calculated standard deviations for some RBANS indices and D-KEFS Verbal Fluency tasks were somewhat small relative to typical standard deviations (i.e., 2.78, 8.15, 12.05). Additionally, the current sample included individuals living in the Midwestern region of the United States, were English speaking adults, and were enrolled in college; this may reduce the generalizability of results as the sample may not be reflective of the general population in all aspects.

Directions for Future Research

Research with Different Measures of Neuropsychological Functioning

While the RBANS is considered a comprehensive measure of neuropsychological functioning, many other similar neuropsychological measures that assess short-term memory (STM), language, attention, and visuospatial skills are commonly administered in clinical practice and research. Similar to the RBANS, many of these confrontational measures require the examinee to use receptive and expressive language skills. Future research may include investigating the relationship of language ability and performance on other comprehensive measures of neuropsychological functioning. Future research may begin by replicating the current study using the three remaining parallel versions of the RBANS. The *Cognistat* (Kiernan, Langston, & Mueller, 1995) also includes the neuropsychological constructs of language, construction, memory, and attention, as well as executive skills, orientation, and consciousness. The *Neuropsychological Assessment Battery* (NAB; Stern & White, 2003) measures similar

constructs as well, including attention, language, spatial skills, and memory, as well as executive functioning. The *Dementia Rating Scale – Second Edition* (DRS-2; Jurica, Leitten, & Mattis, 2004) also assesses attention, memory, and construction, as well as initiation, perseveration, and conceptualization in geriatric populations at risk for dementia. The *Halstead-Reitan Neuropsychological Battery* (Reitan & Wolfson, 1993) and *Luria-Nebraska Neuropsychological Battery* (Golden, Purisch, & Hammeke, 1985) are also common assessments measuring attention, memory, reasoning, and intellectual processes (Rabin et al., 2012). Additionally, future research could involve individual measures of these neuropsychological constructs, as they too would require the examinee to use language skills. While Ortiz and Flanagan (i.e., 2013, 2005, 1998) have previously researched linguistic demand on a number of measures and subtests, continued research from a neuropsychological perspective may add to the literature in this area. For example, objective measures of attention, such as the *Test of Variable Attention* (TOVA; Greenberg, 2011) or *Continuous Performance Test – Third Edition* (CPT-3; Connors, 2015) could be included in future research, as these computerized tasks still include language-based instructions. Further research into the relationship between language ability and performance on neuropsychological measures may produce more specific and more relevant clinical recommendations for populations with varying language abilities. Future research may also broaden the current study's inclusion of primarily expressive language measures to also include more practical, real-word components and language use. This may include the inclusion of receptive language, pragmatic knowledge, and/or discourse analysis. A similar study could investigate the relationship between these more functional language abilities and performance on neuropsychological measures.

Research with Different Populations

Future research investigating language ability and performance on measures of neuropsychological functioning should include investigating this relationship with different populations. The current study included a sample with average performance overall, limited in ethnicity, education, and age, as discussed above. Future research may include replicating this study with populations including bilingual and/or multilingual individuals, individuals with learning disabilities and/or language impairment, individuals with intellectual impairment and/or development delay, individuals with history of head injury and/or traumatic brain injury (TBI), individuals with history of cardiovascular accident (CVA) and/or stroke, and individuals with neurocognitive decline and/or dementia.

Research is needed to investigate this relationship in bilingual and multilingual populations, as much of the currently available research highlights differences measured on neuropsychological assessments, but does not necessarily consider the level of language ability and linguistic demand of the measures. Research has long shown weakness in receptive vocabulary and verbal fluency for child and adult bilingual populations (Mindt et al. 2008; Toomey, 2017). Studies have even concluded diagnostic classifications of bilingual populations may be invalid for certain neuropsychological measures, as differences in cognitive decline profile were measured for this population (Anderson, Saleemi, & Bialystok, 2017).

Given the results of the current study, future research is needed to consider the validity of measured neuropsychological functioning in those with language impairment, intellectual disabilities, and/or development delay. Language impairment is often a trait, symptom, or result of intellectual disability, developmental delay, head injury, TBI, CVA, stroke, and neurocognitive decline/dementia (American Speech-Language-Hearing Association [ASHA],

2016; Papathanasiou, Coppens, & Davidson, 2016; Tay et al., 2015). Future research is especially important in this area, as populations with these conditions and/or injuries are often referred for neuropsychological evaluation (Piotrowski, 2017). The degree to which language ability may negatively impact performance on these neuropsychological measures may greatly impact diagnostic criteria, monitoring, and treatment planning for these populations.

Conclusions

The results of the current study suggest significant shared variance between measures of language and performance on a measure of neuropsychological functioning. Analyses using canonical correlations indicate a moderate percentage of variance in one set of measures is accounted for by the other set. All included measures of language were found to contribute to the relationship with RBANS indices. Several of the RBANS indices were significant contributors. The BNT-2 contributed more to the relationship with RBANS subtests than the other measures of language. The Coding subtest contributed the most to this relationship, with Story Memory, Picture Naming, and Story Recall also significant contributors. Overall, language ability was found to have a significant relationship with neuropsychological functioning, as measured by the RBANS.

Implications of the current study suggest clinicians may be cautious when administering or interpreting obtained results of several RBANS indices and subtests, as deficits in language ability may negatively impact performance; evidence of this possible impact was found for the Attention Index, Language Index, Visuospatial/Constructional Index, and Immediate Memory Index, as well as the Story Memory, Picture Naming, Coding, and Story Recall subtests. The current study also provides some evidence to strengthen the validity of the RBANS, as well as continue to add to the validity of the BNT-2 and D-KEFS Verbal Fluency; several significant

correlations, at the $p < .01$ and $p < .05$ level, between the measures of language and RBANS indices and subtests were found. Of note are the significant relationships found for the language measures of the RBANS, with a significant ($p < .01$ level) relationship between the RBANS Language Index and multiple independent measures of language, the significant ($p < .01$) relationship between the RBANS Semantic Fluency subtest and Category Fluency, and the significant ($p < .05$ level) relationship between the RBANS Picture Naming subset and the BNT-2. These findings suggest evidence for the validity of the RBANS Language Index, Semantic Fluency subtest, and Picture Naming subtest. Additionally, the finding that the BNT-2 contributed more to the relationship with RBANS subtests than did the two measures of the D-KEFS suggests the RBANS subtests may be more impacted by pure language (i.e., naming ability) as compared to executive functioning.

This study also expands upon the relationship between two of the most commonly used measures of language ability, the BNT-2 and D-KEFS Verbal Fluency. With regards to the use of multiple measures of language to assess overall language ability, the current study suggests this continued practice, as measures of naming and verbal fluency were found to have varying relationships with one another and performance on the RBANS. While Letter Fluency and Category Fluency were significantly correlated, with a moderate correlation, the BNT-2 was not significantly correlated with either Letter Fluency or Category Fluency. This suggests each assessment measured slightly variable aspects of language ability, suggesting the multiple measures of language may be needed to fully measure and estimate overall language ability.

While this study suggests there may be a strong link between language ability and measured neuropsychological performance on the RBANS, this relationship requires continued investigation and broader exploration with various populations. This analysis does follow

previous research and theory. These results include important considerations for clinicians administering neuropsychological assessments, particularly the RBANS, with patients who may have atypical language ability. Being aware of and understanding this relationship between language ability and performance on neuropsychological measures is important for accurate diagnosis and development of appropriate and meaningful treatment.

REFERENCES

- Aarts, B. (2013). *English syntax and argumentation*. Palgrave Macmillan.
- Ahmed, S., Arnold, R., Thompson, S. A., Graham, K. S., & Hodges, J. R. (2008). Naming of objects, faces and buildings in mild cognitive impairment. *Cortex*, 44(6), 746-752.
- Albert, M. S., Heller, H. S., & Milberg, W. (1988). Changes in naming ability with age. *Psychology and aging*, 3(2), 173.
- Aleman, A., & van't Wout, M. (2008). Repetitive transcranial magnetic stimulation over the right dorsolateral prefrontal cortex disrupts digit span task performance. *Neuropsychobiology*, 57(1-2), 44-48.
- American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders (DSM-5)*. Arlington: American Psychiatric Publishing.
- American Speech-Language-Hearing Association [ASHA]. (2016). *Scope of practice in speech-language pathology*.
- Anderson, J. A., Saleemi, S., & Bialystok, E. (2017). Neuropsychological assessments of cognitive aging in monolingual and bilingual older adults. *Journal of Neurolinguistics*, 43, 17-27.
- Andreasen, N. C., O'Leary, D. S., Paradiso, S., Cizadlo, T., Arndt, S., Watkins, G. L., ... & Hichwa, R. D. (1999). The cerebellum plays a role in conscious episodic memory retrieval. *Human Brain Mapping*, 8(4), 226-234.
- Andreou, G., & Trott, K. (2013). Verbal fluency in adults diagnosed with attention-deficit hyperactivity disorder (ADHD) in childhood. *ADHD Attention Deficit and Hyperactivity Disorders*, 5(4), 343-351.

- Ardila, A., Bernal, B., & Rosselli, M. (2017). Should Broca's area include Brodmann area 47?. *Psicothema (Oviedo)*, 73-77.
- Aron, A. R., Robbins, T. W., & Poldrack, R. A. (2014). Inhibition and the right inferior frontal cortex: one decade on. *Trends in cognitive sciences*, 18(4), 177-185.
- Astesano, C., & Jucla, M. (Eds.). (2015). *Neuropsycholinguistic perspectives on language cognition: Essays in honour of Jean-Luc Nespoulous*. Psychology Press.
- Axelrod, B. N., Ricker, J. H., & Cherry, S. A. (1994). Concurrent validity of the MAE visual naming test. *Archives of Clinical Neuropsychology*, 9(4), 317-321.
- Azouvi, P., Samuel, C., Louis-Dreyfus, A., Bernati, T., Bartolomeo, P., Beis, J. M., ... & De Montety, G. (2002). Sensitivity of clinical and behavioural tests of spatial neglect after right hemisphere stroke. *Journal of Neurology, Neurosurgery & Psychiatry*, 73(2), 160-166.
- Babajani-Feremi, A., Narayana, S., Rezaie, R., Choudhri, A. F., Fulton, S. P., Boop, F. A., ... & Papanicolaou, A. C. (2016). Language mapping using high gamma electrocorticography, fMRI, and TMS versus electrocortical stimulation. *Clinical Neurophysiology*, 127(3), 1822-1836.
- Baddeley, A. (1992). Working memory. *Science*, 255(5044), 556-559.
- Baddeley, A. (2003). Working memory: Looking back and looking forward. *Nature Reviews Neuroscience*, 4(10), 829-839.
- Baddeley, A. D. (2017). The concept of working memory: A view of its current state and probable future development. In *Exploring Working Memory* (pp. 99-106). Routledge.
- Baldauf, D., & Desimone, R. (2014). Neural mechanisms of object-based attention. *Science*, 344(6182), 424-427.

- Baldo, J. V., Arévalo, A., Patterson, J. P., & Dronkers, N. F. (2013). Grey and white matter correlates of picture naming: Evidence from a voxel-based lesion analysis of the Boston Naming Test. *Cortex*, 49(3), 658-667.
- Baldo, J. V., Schwartz, S., Wilkins, D., & Dronkers, N. F. (2006). Role of frontal versus temporal cortex in verbal fluency as revealed by voxel-based lesion symptom mapping. *Journal of the International Neuropsychological Society*, 12(06), 896-900.
- Baldo, J. V., Shimamura, A. P., Delis, D. C., Kramer, J., & Kaplan, E. (2001). Verbal and design fluency in patients with frontal lobe lesions. *Journal of the International Neuropsychological Society*, 7(05), 586-596.
- Barkley, R. A. (Ed.). (2014). *Attention-deficit hyperactivity disorder: A handbook for diagnosis and treatment*. Guilford Publications.
- Baron, I. S. (2018). *Neuropsychological evaluation of the child: Domains, methods, & case studies*. Oxford University Press.
- Bates, E., Friederici, A., & Wulfeck, B. (1987). Comprehension in aphasia: A cross-linguistic study. *Brain and Language*, 32(1), 19-67.
- Batty, R. A., Francis, A., Thomas, N., Hopwood, M., Ponsford, J., & Rossell, S. L. (2016). Predicting co-morbid traumatic brain injury and psychosis from neuropsychological profile. *Schizophrenia Research*, 172(42430), 143-144.
- Beery, K. E., & Beery, N. A. (2010). *The Beery-Buktenica developmental test of visual-motor integration (Beery VMI) with supplemental developmental tests of visual perception and motor coordination and stepping stones age norms: Administration, scoring and teaching manual*. Minneapolis, MN: NCS Pearson.

- Bek, J., Blades, M., Siegal, M., & Varley, R. (2009). Linguistic processes in visuospatial representation: Clarifying verbal interference effects. 2723-2728.
- Bell, N. L., Lassiter, K. S., Matthews, T. D., & Hutchinson, M. B. (2001). Comparison of the peabody picture vocabulary test - third edition and Wechsler adult intelligence scale - third edition with university students. *Journal of Clinical Psychology*, 57(3), 417-422.
- Benson, D. F., & Ardila, A. (1996). *Aphasia: A clinical perspective*. Oxford University Press.
- Benton, A. L., & Hamsher, K. D. S.(1976). *Multilingual aphasia examination*. Iowa City: University of Iowa.
- Benton, A. L., Hamsher, K. D., Varney, N. R., & Spreen, O. (1983). *Judgment of line orientation*. New York: Oxford University Press.
- Benton, A., Hamsher, K., & Sivan, A. (1994). *Multilingual aphasia examination – third edition*, Psychological corporation. San Antonio, TX.
- Bera, P., Burton-Jones, A., & Wand, Y. (2014). Research note - How semantics and pragmatics interact in understanding conceptual models. *Information Systems Research*, 25(2), 401-419.
- Berryhill, M. E., & Olson, I. R. (2008). Is the posterior parietal lobe involved in working memory retrieval?: Evidence from patients with bilateral parietal lobe damage. *Neuropsychologia*, 46(7), 1775-1786.
- Biesbroek, J. M., Zandvoort, M. J., Kappelle, L. J., Velthuis, B. K., Biessels, G. J., & Postma, A. (2016). Shared and distinct anatomical correlates of semantic and phonemic fluency revealed by lesion-symptom mapping in patients with ischemic stroke. *Brain Structure and Function*, 221(4), 2123-2134.

- Blair, M., Marczyński, C. A., Davis-Faroque, N., & Kertesz, A. (2007). A longitudinal study of language decline in Alzheimer's disease and frontotemporal dementia. *Journal of the International Neuropsychological Society*, *13*(02), 237-245.
- Blake, H., McKinney, M., Treece, K., Lee, E., & Lincoln, N. B. (2002). An evaluation of screening measures for cognitive impairment after stroke. *Age and ageing*, *31*(6), 451-456.
- Boake, C. (2002). From the Binet–Simon to the Wechsler–Bellevue: Tracing the history of intelligence testing. *Journal of clinical and experimental neuropsychology*, *24*(3), 383-405.
- Bonelli, S. B., Powell, R., Thompson, P. J., Yogarajah, M., Focke, N. K., Stretton, J., ... & Koepp, M. J. (2011). Hippocampal activation correlates with visual confrontation naming: fMRI findings in controls and patients with temporal lobe epilepsy. *Epilepsy Research*, *95*(3), 246-254.
- Booij, G. (2016). Morphology: The structure of words. *The Routledge Handbook of Linguistics*, 104-117.
- Boone, K. B., Victor, T. L., Wen, J., Razani, J., & Pontón, M. (2007). The association between neuropsychological scores and ethnicity, language, and acculturation variables in a large patient population. *Archives of Clinical Neuropsychology*, *22*(3), 355-365.
- Bott, N. T., Johnson, E. T., Schuff, N., Galifianakis, N., Subas, T., Pollock, J., ... & Possin, K. L. (2014). Sensitive measures of executive dysfunction in non-demented Parkinson's disease. *Parkinsonism & Related Disorders*, *20*(12), 1430-1433.

- Broadbent, N. J., Squire, L. R., & Clark, R. E. (2004). Spatial memory, recognition memory, and the hippocampus. *Proceedings of the National Academy of Sciences of the United States of America*, *101*(40), 14515-14520.
- Bryan, J., Luszcz, M. A., & Crawford, J. R. (1997). Verbal knowledge and speed of information processing as mediators of age differences in verbal fluency performance among older adults. *Psychology and Aging*, *12*(3), 473.
- Buckner, R. L., Logan, J., Donaldson, D. I., & Wheeler, M. E. (2000). Cognitive neuroscience of episodic memory encoding. *Acta Psychologica*, *105*(2), 127-139.
- Burgess, P. W., Veitch, E., de Lacy Costello, A., & Shallice, T. (2000). The cognitive and neuroanatomical correlates of multitasking. *Neuropsychologia*, *38*(6), 848-863.
- Cahill, L., & McGaugh, J. L. (1998). Mechanisms of emotional arousal and lasting declarative memory. *Trends in Neurosciences*, *21*(7), 294-299.
- Cain, K., Oakhill, J., & Bryant, P. (2004). Children's reading comprehension ability: Concurrent prediction by working memory, verbal ability, and component skills. *Journal of Educational Psychology*, *96*(1), 31.
- Calamia, M., Markon, K., Denburg, N. L., & Tranel, D. (2011). Developing a short form of Benton's Judgment of Line Orientation Test: An item response theory approach. *The Clinical Neuropsychologist*, *25*(4), 670-684.
- Calderon, J., Perry, R. J., Erzinclioglu, S. W., Berrios, G. E., Dening, T., & Hodges, J. R. (2001). Perception, attention, and working memory are disproportionately impaired in dementia with Lewy bodies compared with Alzheimer's disease. *Journal of Neurology, Neurosurgery & Psychiatry*, *70*(2), 157-164.

- Carlozzi, N. E., Horner, M. D., Yang, C., & Tilley, B. C. (2008). Factor analysis of the Repeatable Battery for the Assessment of Neuropsychological Status. *Applied neuropsychology, 15*(4), 274-279.
- Cerhan, J. H., Ivnik, R. J., Smith, G. E., Tangalos, E. C., Petersen, R. C., & Boeve, B. F. (2002). Diagnostic utility of letter fluency, category fluency, and fluency difference scores in Alzheimer's disease. *The Clinical Neuropsychologist, 16*(1), 35-42.
- Cherrier, M. M., Mendez, M. F., Dave, M., & Perryman, K. M. (1999). Performance on the Rey-Osterrieth Complex Figure Test in Alzheimer disease and vascular dementia. *Cognitive and Behavioral Neurology, 12*(2), 95-101.
- Chu, K., Yi, D., Byun, M. S., Lee, J. H., & Lee, D. Y. (2017). Clustering and switching indices of verbal fluency tasks and their functional neuroanatomical correlates in mild cognitive impairment. *Alzheimer's & Dementia: The Journal of the Alzheimer's Association, 13*(7), 1150-1151.
- Cioffi, F. L. (2015). *One day in the life of the English language: A microcosmic usage handbook*. Princeton University Press.
- Cioffi, P. E. (2015). *Examining the cultural loading and linguistic demand of three neuropsychological assessment batteries for children in a mixed clinical population* (Doctoral dissertation, Texas Woman's University).
- Clément, R. (1986). Second language proficiency and acculturation: An investigation of the effects of language status and individual characteristics. *Journal of Language and Social Psychology, 5*(4), 271-290.

- Cohen, A. L., Fair, D. A., Dosenbach, N. U., Miezin, F. M., Dierker, D., Van Essen, D. C., ... & Petersen, S. E. (2008). Defining functional areas in individual human brains using resting functional connectivity MRI. *Neuroimage*, *41*(1), 45-57.
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. 2nd.
- Cohen, M. (1997). *Children's memory scale*. San Antonio, TX: Psychological Corporation.
- Cohen, R. A., Malloy, P., Jenkins, M., & Paul, R. (2014). *Disorders of attention*. American Psychological Association.
- Cohen, R. J., & Swerdlik, M. E. (2002). *Psychological testing and assessment: An introduction to tests and measurement*. McGraw-Hill.
- Conners, C. K. (2015). *Conners Continuous Performance Test 3rd edition™(Conners CPT 3™), Conners Continuous Auditory Test of Attention (Conners CATA™) manual*.
- Cormier, D. C., McGrew, K. S., & Ysseldyke, J. E. (2014). The influences of linguistic demand and cultural loading on cognitive test scores. *Journal of Psychoeducational Assessment*, *32*(7), 610-623.
- Cornwall, A. (1992). The relationship of phonological awareness, rapid naming, and verbal memory to severe reading and spelling disability. *Journal of Learning Disabilities*, *25*(8), 532-538.
- Crossen, J. R., & Wiens, A. N. (1994). Comparison of the Auditory-Verbal Learning Test (AVLT) and California Verbal Learning Test (CVLT) in a sample of normal subjects. *Journal of Clinical and Experimental Neuropsychology*, *16*(2), 190-194.
- Crowe, S. F. (2000). Does the letter number sequencing task measure anything more than digit span?. *Assessment*, *7*(2), 113-117.

- Cummins, J. (1984). *Bilingualism and special education: Issues in assessment and pedagogy* (Vol. 6). Clevedon: Multilingual Matters.
- Curtis, V. A., Bullmore, E. T., Brammer, M. J., Wright, I. C., Williams, S. C., Morris, R. G., ... & McGuire, P. K. (2014). Attenuated frontal activation during a verbal fluency task in patients with schizophrenia.
- Curzan, A., & Adams, M. P. (2014). *How English works: A linguistic introduction*. Pearson Higher Ed.
- Cutting, L. E., & Scarborough, H. S. (2006). Prediction of reading comprehension: Relative contributions of word recognition, language proficiency, and other cognitive skills can depend on how comprehension is measured. *Scientific Studies of Reading, 10*(3), 277-299.
- D'Esposito, M. (2003). *Neurological foundations of cognitive neuroscience*. MIT press.
- Danielson, M. L., Bitsko, R. H., Ghandour, R. M., Holbrook, J. R., Kogan, M. D., & Blumberg, S. J. (2018). Prevalence of parent-reported ADHD diagnosis and associated treatment among US children and adolescents, 2016. *Journal of Clinical Child & Adolescent Psychology, 47*(2), 199-212.
- Dauwan, M., van der Zande, J. J., van Dellen, E., Sommer, I. E., Scheltens, P., Lemstra, A. W., & Stam, C. J. (2016). Random forest to differentiate dementia with Lewy bodies from Alzheimer's disease. *Alzheimer's & Dementia: Diagnosis, Assessment & Disease Monitoring, 4*, 99-106.
- Davis, A. S. (2011). *Handbook of pediatric neuropsychology*. Springer.
- Davis, A. S., & Pierson, E. E. (2012). The relationship between the WAIS-III digit symbol coding and executive functioning. *Applied Neuropsychology: Adult, 19*(3), 192-197.

- Davis, A., Williams, R. N., Gupta, A. S., Finch, W. H., & Randolph, C. (2015). Evaluating neurocognitive deficits in patients with multiple sclerosis via a brief neuropsychological approach. *Applied Neuropsychology: Adult*, 22(5), 381-387.
- del Toro, C. M., Bislick, L. P., Comer, M., Velozo, C., Romero, S., Rothi, L. J. G., & Kendall, D. L. (2011). Development of a short form of the Boston naming test for individuals with aphasia. *Journal of Speech, Language, and Hearing Research*, 54(4), 1089-1100.
- Delis, D. C., Kaplan, E., & Kramer, J. H. (2001). *Delis-Kaplan executive function system (D-KEFS)*. Psychological Corporation.
- Delis, D.C., Kramer, J.H., Kaplan, E., & Ober, B.A. (2000). *California verbal learning test – second edition, adult version. Manual*. Psychological Corporation, San Antonio, TX.
- Deng, W., & Allahverdyan, A. E. (2016). Stochastic model for phonemes uncovers an author-dependency of their usage. *PloS one*, 11(4).
- Dikmen, S. S., Heaton, R. K., Grant, I., & Temkin, N. R. (1999). Test–retest reliability and practice effects of expanded Halstead–Reitan Neuropsychological Test Battery. *Journal of the International Neuropsychological Society*, 5(4), 346-356.
- Dollaghan, C. A., Campbell, T. F., Paradise, J. L., Feldman, H. M., Janosky, J. E., Pitcairn, D. N., & Kurs-Lasky, M. (1999). Maternal education and measures of early speech and language. *Journal of Speech, Language, and Hearing Research*, 42(6), 1432-1443.
- Draper, K., & Ponsford, J. (2008). Cognitive functioning ten years following traumatic brain injury and rehabilitation. *Neuropsychology*, 22(5), 618.
- Dubois, B., Feldman, H. H., Jacova, C., Hampel, H., Molinuevo, J. L., Blennow, K., ... & Cappa, S. (2014). Advancing research diagnostic criteria for Alzheimer's disease: the IWG-2 criteria. *The Lancet Neurology*, 13(6), 614-629.

- Duff, F. J., Reen, G., Plunkett, K., & Nation, K. (2015). Do infant vocabulary skills predict school-age language and literacy outcomes?. *Journal of Child Psychology and Psychiatry*, 56(8), 848-856.
- Duff, K., Clark, J. D. H., O'Bryant, S. E., Mold, J. W., Schiffer, R. B., & Sutker, P. B. (2008). Utility of the RBANS in detecting cognitive impairment associated with Alzheimer's disease: sensitivity, specificity, and positive and negative predictive powers. *Archives of Clinical Neuropsychology*, 23(5), 603-612.
- Dunn, L. M., & Dunn, D. M. (2007). *PPVT-4: Peabody picture vocabulary test*. Pearson Assessments.
- Eccles, J. S. (2005). Influences of parents' education on their children's educational attainments: The role of parent and child perceptions. *London Review of Education*, 3(3), 191-204.
- Eichenbaum (2011). *The cognitive neuroscience of memory: An introduction*. Oxford University Press.
- Eichenbaum, H., Yonelinas, A. P., & Ranganath, C. (2007). The medial temporal lobe and recognition memory. *Annual Review of Neuroscience*, 30, 123-152.
- Einarsson, E. Ö., & Nader, K. (2012). Involvement of the anterior cingulate cortex in formation, consolidation, and reconsolidation of recent and remote contextual fear memory. *Learning & Memory*, 19(10), 449-452.
- Eisenberg, N., Sadovsky, A., & Spinrad, T. L. (2005). Associations of emotion-related regulation with language skills, emotion knowledge, and academic outcomes. *New Directions for Child and Adolescent Development*, (109), 109.

- Eramudugolla, R., Mortby, M. E., Sachdev, P., Meslin, C., Kumar, R., & Anstey, K. J. (2017). Evaluation of a research diagnostic algorithm for DSM-5 neurocognitive disorders in a population-based cohort of older adults. *Alzheimer's research & therapy*, 9(1), 15.
- Fernald, A., Marchman, V. A., & Weisleder, A. (2013). SES differences in language processing skill and vocabulary are evident at 18 months. *Developmental science*, 16(2), 234-248.
- Flanagan, D. P., & Harrison, P. L. (Eds.). (2012). *Contemporary intellectual assessment: Theories, tests, and issues*. Guilford Press.
- Flanagan, D. P., Ortiz, S. O., & Alfonso, V. C. (2013). *Essentials of cross-battery assessment* (Vol. 84). John Wiley & Sons.
- Flicker, C., Ferris, S. H., & Reisberg, B. (1991). Mild cognitive impairment in the elderly predictors of dementia. *Neurology*, 41(7), 1006-1006.
- Fransson, P., & Marrelec, G. (2008). The precuneus/posterior cingulate cortex plays a pivotal role in the default mode network: Evidence from a partial correlation network analysis. *Neuroimage*, 42(3), 1178-1184.
- Franzen, M. D., Burgess, E. J., & Smith-Seemiller, L. (1997). Methods of estimating premorbid functioning. *Archives of Clinical Neuropsychology*, 12(8), 711-738.
- Frazier, T. W., Demaree, H. A., & Youngstrom, E. A. (2004). Meta-analysis of intellectual and neuropsychological test performance in attention-deficit/hyperactivity disorder.
- Fridriksson, J., Moser, D., Bonilha, L., Morrow-Odom, K. L., Shaw, H., Fridriksson, A., ... & Rorden, C. (2007). Neural correlates of phonological and semantic-based anomia treatment in aphasia. *Neuropsychologia*, 45(8), 1812-1822.

- Friesen, D. C., Luo, L., Luk, G., & Bialystok, E. (2015). Proficiency and control in verbal fluency performance across the lifespan for monolinguals and bilinguals. *Language, cognition and neuroscience*, 30(3), 238-250.
- Gaillard, W. D., Sachs, B. C., Whitnah, J. R., Ahmad, Z., Balsamo, L. M., Petrella, J. R., ... & Grandin, C. B. (2003). Developmental aspects of language processing: fMRI of verbal fluency in children and adults. *Human brain mapping*, 18(3), 176-185.
- Gale H. Roid. (2003). *Stanford Binet intelligence scales*. Itasca, IL; Riverside Pub.
- Galvin, J. E., Pollack, J., & Morris, J. C. (2006). Clinical phenotype of Parkinson disease dementia. *Neurology*, 67(9), 1605-1611.
- Gathercole, S. E., & Baddeley, A. D. (2014). *Working memory and language*. Psychology Press.
- Gerton, B. K., Brown, T. T., Meyer-Lindenberg, A., Kohn, P., Holt, J. L., Olsen, R. K., & Berman, K. F. (2004). Shared and distinct neurophysiological components of the digits forward and backward tasks as revealed by functional neuroimaging. *Neuropsychologia*, 42(13), 1781-1787.
- Giegerich, H. J. (1992). *English phonology: An introduction*. Cambridge University Press.
- Golden, C., Purisch, A. D., & Hammeke, T. A. (1985). Luria-Nebraska Neuropsychological Battery: Forms I & II.
- Goldstein, G., Beers, S. R., & Herse, M. (2004). *Comprehensive handbook of psychological assessment*. John Wiley & Sons.
- Gontkovsky, S. T. (2014). Screening cognition during inpatient rehabilitation: a comparison of the mini-mental state examination (MMSE) and the repeatable battery for the assessment of neuropsychological status (RBANS) in classifying global impairment. *Functional Neurology, Rehabilitation, and Ergonomics*, 4(1), 3.

- Gontkovsky, S. T., Hillary, E. G., & Scott, J. G. (2002). REPORTS-cross-validation and test sensitivity of the repeatable battery for the assessment of neuropsychological status (RBANS). *Journal of Cognitive Rehabilitation*, 20(4), 26-31.
- Gontkovsky, S. T., McSwan, K. L., & Scott, J. G. (2002). Sensitivity of the semantic fluency subtest of the repeatable battery for the assessment of neuropsychological status. *Psychological reports*, 90(3), 858-860.
- González, G. G., Trimmel, K., Haag, A., van Graan, L. A., Koepp, M. J., Thompson, P. J., & Duncan, J. S. (2016). Activations in temporal areas using visual and auditory naming stimuli: A language fMRI study in temporal lobe epilepsy. *Epilepsy Research*, 128, 102-112.
- Goodglass, H., Kaplan, E., & Weintraub, S. (1983). Boston naming test. ProEd.
- Grant, I. (2009). *Neuropsychological assessment of neuropsychiatric and neuromedical disorders*. Oxford University Press.
- Graves, R. E. & Carswell, L. (2003). *Prediction of premorbid boston naming and california verbal learning test scores*. Paper presented to the International Neuropsychology Society, Honolulu, HI.
- Graves, R. E., Bezeau, S. C., Fogarty, J., & Blair, R. (2004). Boston naming test short forms: A comparison of previous forms with new item response theory based forms. *Journal of Clinical and Experimental Neuropsychology*, 26(7), 891-902.
- Greenberg, L. M. (2011). *The Test of Variables of Attention (Version 8.0) [Computer software]*. Los Alamitos: The TOVA Company.

- Guilford, A. M., & Nawojczyk, D. C. (1988). Standardization of the Boston Naming Test at the kindergarten and elementary school levels. *Language, Speech, and Hearing Services in Schools, 19*(4), 395-400.
- Hampshire, A., Chamberlain, S. R., Monti, M. M., Duncan, J., & Owen, A. M. (2010). The role of the right inferior frontal gyrus: Inhibition and attentional control. *Neuroimage, 50*(3), 1313-1319.
- Hannahs, S. J., & Young-Scholten, M. (Eds.). (1997). *Focus on phonological acquisition* (Vol. 16). John Benjamins Publishing.
- Harada, C. N., Love, M. C. N., & Triebel, K. L. (2013). Normal cognitive aging. *Clinics in geriatric medicine, 29*(4), 737-752.
- Hassabis, D., & Maguire, E. A. (2007). Deconstructing episodic memory with construction. *Trends in cognitive sciences, 11*(7), 299-306.
- Hebben, N., & Milberg, W. (2009). *Essentials of neuropsychological assessment* (Vol. 70). John Wiley & Sons.
- Henry, J. D., & Crawford, J. R. (2004). A meta-analytic review of verbal fluency performance following focal cortical lesions. *Neuropsychology, 18*(2), 284.
- Henry, J. D., Crawford, J. R., & Phillips, L. H. (2004). Verbal fluency performance in dementia of the Alzheimer's type: a meta-analysis. *Neuropsychologia, 42*(9), 1212-1222.
- Henson, R. N. A., Shallice, T., & Dolan, R. J. (1999). Right prefrontal cortex and episodic memory retrieval: a functional MRI test of the monitoring hypothesis. *Brain, 122*(7), 1367-1381.
- Hermer-Vazquez, L., Spelke, E. S., & Katsnelson, A. S. (1999). Sources of flexibility in human cognition: Dual-task studies of space and language. *Cognitive psychology, 39*(1), 3-36.

- Hoffman, P., Clarke, N., Jones, R. W., & Noonan, K. A. (2015). Vocabulary relearning in semantic dementia: Positive and negative consequences of increasing variability in the learning experience. *Neuropsychologia*, *76*, 240-253.
- Homack, S., Lee, D., & Riccio, C. A. (2005). Test review: Delis-Kaplan executive function system. *Journal of clinical and experimental neuropsychology*, *27*(5), 599-609.
- Humphreys, G. F., & Ralph, M. A. (2015). Fusion and fission of cognitive functions in the human parietal cortex. *Cerebral Cortex*, *25*(10), 3547-3560.
- Ivnik, R. J., Malec, J. F., Smith, G. E., Tangalos, E. G., & Petersen, R. C. (1996). Neuropsychological tests' norms above age 55: COWAT, BNT, MAE token, WRAT-R reading, AMNART, STROOP, TMT, and JLO. *The Clinical Neuropsychologist*, *10*(3), 262-278.
- Ivnik, R. J., Malec, J. F., Tangalos, E. G., Petersen, R. C., Kokmen, E., & Kurland, L. T. (1990). The auditory-verbal learning test (AVLT): norms for ages 55 years and older. *Psychological Assessment: A Journal of Consulting and Clinical Psychology*, *2*(3), 304.
- Jacobs, J. (1887). Experiments on "prehension". *Mind*, *12*, 75-79.
- Jacobsen, G. M., Prando, M. L., Moraes, A. L., Pureza, J. D. R., Gonçalves, H. A., Siqueira, L. D. S., ... & Fonseca, R. P. (2017). Effects of age and school type on unconstrained, phonemic, and semantic verbal fluency in children. *Applied Neuropsychology: Child*, *6*(1), 41-54.
- Jia, F., Gottardo, A., Chen, X., Koh, P., & Pasquarella, A. (2016). English proficiency and acculturation among Chinese immigrant youth in Canada: a reciprocal relationship. *Journal of Multilingual and Multicultural Development*, *37*(8), 774-782.

- John, S. E., Gurnani, A. S., Bussell, C., Saurman, J. L., Griffin, J. W., & Gavett, B. E. (2016). The effectiveness and unique contribution of neuropsychological tests and the δ latent phenotype in the differential diagnosis of dementia in the uniform data set. *Neuropsychology, 30*(8), 946.
- Johnson, C. A. (2012). Similarities and differences among commonly used verbal list learning tests.
- Johnstone, B., & Stonnington, H. H. (Eds.). (2012). *Rehabilitation of neuropsychological disorders: A practical guide for rehabilitation professionals*. Taylor & Francis.
- Jurado, M. A., Mataro, M., Verger, K., Bartumeus, F., & Junque, C. (2000). Phonemic and semantic fluencies in traumatic brain injury patients with focal frontal lesions. *Brain Injury, 14*(9), 789-795.
- Jurica, P. J., Leitten, C. L., & Mattis, S. (2004). DRS-2 dementia rating scale-2: Professional manual. *Psychological Assessment, 631*.
- Kahn, I., Davachi, L., & Wagner, A. D. (2004). Functional-neuroanatomic correlates of recollection: implications for models of recognition memory. *The Journal of Neuroscience, 24*(17), 4172-4180.
- Kane, M. J., & Engle, R. W. (2002). The role of prefrontal cortex in working-memory capacity, executive attention, and general fluid intelligence: An individual-differences perspective. *Psychonomic bulletin & review, 9*(4), 637-671.
- Kansal, K., Abraham, E., Rao, A., & Onyike, C. (2016). Longitudinal analysis of electronic messages to characterize language decline in frontotemporal dementia with bulbar amyotrophic lateral sclerosis: p124. *Journal of Neurochemistry, 138*, 289.

- Kaplan, E. F., Goodglass, H., & Weintraub, S. (1983). The Boston naming test. *Philadelphia: Lea & Febiger*.
- Kaplan, E., Goodglass, H., & Weintraub, S. (2001). Boston naming test - second edition (BNT-2). ProEd.
- Kapur, S., Craik, F. I., Tulving, E., Wilson, A. A., Houle, S., & Brown, G. M. (1994). Neuroanatomical correlates of encoding in episodic memory: Levels of processing effect. *Proceedings of the National Academy of Sciences, 91(6)*, 2008-2011.
- Kaufman, A. S. (2004). KABC-II: Kaufman Assessment Battery for Children.
- Kaufman, A. S., Raiford, S. E., & Coalson, D. L. (2015). *Intelligent testing with the WISC-V*. John Wiley & Sons.
- Kausler, D. H. (1994). *Learning and memory in normal aging*. San Diego, CA:: Academic Press.
- Kave, G., Heled, E., Vakil, E., & Agranov, E. (2011). Which verbal fluency measure is most useful in demonstrating executive deficits after traumatic brain injury?. *Journal of clinical and experimental neuropsychology, 33(3)*, 358-365.
- Kiernan, R. J., Langston, W. J., & Mueller, J. (1995). *Cognistat-the Neurobehavioral Cognitive Status Examination*. Northern California Neurobehavioral Group.
- Killgore, W. D. (2015). *A model for predicting cognitive and emotional health from structural and functional neurocircuitry following traumatic brain injury*. Arizona University, Tucson.
- Knopman, D. S., & Ryberg, S. (1989). A verbal memory test with high predictive accuracy for dementia of the Alzheimer type. *Archives of Neurology, 46(2)*, 141-145.

- Koegel, L. K., Koegel, R. L., Ashbaugh, K., & Bradshaw, J. (2014). The importance of early identification and intervention for children with or at risk for autism spectrum disorders. *International journal of speech-language pathology, 16*(1), 50-56.
- Kolb, B., & Whishaw, I. Q. (1983). Performance of schizophrenic patients on tests sensitive to left or right frontal, temporal, or parietal function in neurological patients. *The Journal of nervous and mental disease, 171*(7), 435-443.
- Konrad, A., Dielentheis, T. F., El Masri, D., Dellani, P. R., Stoeter, P., Vucurevic, G., & Winterer, G. (2012). White matter abnormalities and their impact on attentional performance in adult attention-deficit/hyperactivity disorder. *European archives of psychiatry and clinical neuroscience, 262*(4), 351-360.
- Konstantinou, N., Constantinidou, F., & Kanai, R. (2017). Discrete capacity limits and neuroanatomical correlates of visual short-term memory for objects and spatial locations. *Human Brain Mapping, 38*(2), 767-778.
- Kozlovsky, S. A., Velichkovsky, B. B., Vartanov, A. V., Nikonova, E. Y., & Velichkovsky, B. M. (2012). The role of the domains of the anterior cingulate cortex in the functioning of human memory. *Experimental Psychology (Russia), 5*(1), 12-22.
- Kurowski, K., & Blumstein, S. E. (2016). Phonetic basis of phonemic paraphasias in aphasia: Evidence for cascading activation. *cortex, 75*, 193-203.
- Lamar, M., & Raz, A. (2007). Neuropsychological assessment of attention and executive functioning. *Cambridge Handbook of Psychology, Health, and Medicine, 290-294*.
- Langner, R., & Eickhoff, S. B. (2013). Sustaining attention to simple tasks: A meta-analytic review of the neural mechanisms of vigilant attention. *Psychological bulletin, 139*(4), 870.
- Lass, N. J. (1988). *Handbook of speech-language pathology and audiology*. BC Decker.

- Latzman, R. D., & Markon, K. E. (2009). The factor structure and age-related factorial invariance of the Delis–Kaplan Executive Function System (D-KEFS). *Assessment*.
- Lavoie, M., Bier, N., & Macoir, J. (2015). Effectiveness of technologies in the treatment of poststroke anomia: A systematic review. *Journal of Communication Disorders*.
- Leclercq, M., Deloche, G., & Rousseaux, M. (2002). Attentional complaints evoked by traumatic brain-injured and stroke patients: Frequency and importance. *Applied neuropsychology of attention: theory, diagnosis and rehabilitation*, 89-109.
- Lee, S. H., Kim, H., Kim, J., Yoon, J. H., & Kim, S. R. (2015). Initial phase performance in a 30-s verbal fluency task as being reflective of aging effect. *Geriatrics & gerontology international*, 15(4), 496-500.
- Leech, R., & Sharp, D. J. (2014). The role of the posterior cingulate cortex in cognition and disease. *Brain*, 137(1), 12-32.
- Leonard, L. B. (2009). Is expressive language disorder an accurate diagnostic category?. *American Journal of Speech-Language Pathology*, 18(2), 115-123.
- Levy, G., Jacobs, D. M., Tang, M. X., Côté, L. J., Louis, E. D., Alfaró, B., ... & Marder, K. (2002). Memory and executive function impairment predict dementia in Parkinson's disease. *Movement Disorders*, 17(6), 1221-1226.
- Lezak, M. D. (2012). *Neuropsychological assessment*. Oxford university press.
- Lippa, S. M., Hawes, S., Jokic, E., & Caroselli, J. S. (2013). Sensitivity of the RBANS to acute traumatic brain injury and length of post-traumatic amnesia. *Brain injury*, 27(6), 689-695.
- Loeb, P. A. (1996). *Independent Living Scales (ILS)*. Psychological Corporation.

- López, E., Steiner, A. J., Hardy, D. J., IsHak, W. W., & Anderson, W. B. (2016). Discrepancies between bilinguals' performance on the Spanish and English versions of the WAIS Digit Span task: Cross-cultural implications. *Applied Neuropsychology: Adult*, *23*(5), 343-352.
- Loucas, T., Charman, T., Pickles, A., Simonoff, E., Chandler, S., Meldrum, D., & Baird, G. (2008). Autistic symptomatology and language ability in autism spectrum disorder and specific language impairment. *Journal of Child Psychology and Psychiatry*, *49*(11), 1184-1192.
- Lucas, J. A., Ivnik, R. J., Smith, G. E., Ferman, T. J., Willis, F. B., Petersen, R. C., & Graff-Radford, N. R. (2005). Mayo's older african americans normative studies: Norms for boston naming test, controlled oral word association, category fluency, animal naming, token test, wrat-3 reading, trail making test, stroop test, and judgment of line orientation. *The Clinical Neuropsychologist*, *19*(2), 243-269.
- Machulda, M. M., Ward, H. A., Borowski, B., Gunter, J. L., Cha, R. H., O'brien, P. C., ... & Ivnik, R. J. (2003). Comparison of memory fMRI response among normal, MCI, and Alzheimer's patients. *Neurology*, *61*(4), 500-506.
- Martyr, A., Clare, L., Nelis, S. M., Marková, I. S., Roth, I., Woods, R. T., ... & Morris, R. G. (2012). Verbal fluency and awareness of functional deficits in early-stage dementia. *The Clinical Neuropsychologist*, *26*(3), 501-519.
- Mayo, J., Chlebowski, C., Fein, D. A., & Eigsti, I. M. (2013). Age of first words predicts cognitive ability and adaptive skills in children with ASD. *Journal of autism and developmental disorders*, *43*(2), 253-264.

- Mazzocco, M. M., & Grimm, K. J. (2013). Growth in rapid automatized naming from grades K to 8 in children with math or reading disabilities. *Journal of Learning Disabilities, 46*(6), 517-533.
- McCloskey & Perkins. (2012). *Essentials of executive functions assessment* (Vol. 68). John Wiley & Sons.
- McDonald, S., Togher, L., & Code, C. (2013). *Social and communication disorders following traumatic brain injury*. Psychology press.
- McKay, C., Casey, J. E., Wertheimer, J., & Fichtenberg, N. L. (2007). Reliability and validity of the RBANS in a traumatic brain injured sample. *Archives of Clinical Neuropsychology, 22*(1), 91-98.
- Meilinger, T., Knauff, M., & Bühlhoff, H. H. (2008). Working memory in wayfinding—A dual task experiment in a virtual city. *Cognitive Science, 32*(4), 755-770.
- Meinzer, M., Flaisch, T., Wilser, L., Eulitz, C., Rockstroh, B., Conway, T., ... & Crosson, B. (2009). Neural signatures of semantic and phonemic fluency in young and old adults. *Journal of Cognitive Neuroscience, 21*(10), 2007-2018.
- Mervis C.B., Robinson B.F., Pani J.R. (1999). Visuospatial construction. *American journal of human genetics, 65*(5).
- Mesulam, M. M., Wieneke, C., Hurley, R., Rademaker, A., Thompson, C. K., Weintraub, S., & Rogalski, E. J. (2013). Words and objects at the tip of the left temporal lobe in primary progressive aphasia. *Brain, 136*(2), 601-618.
- Meyers, J. E., & Meyers, K. R. (1995). *Rey Complex Figure Test and recognition trial professional manual*. Psychological Assessment Resources.

- Miller, D. C. (Ed.). (2009). *Best practices in school neuropsychology: Guidelines for effective practice, assessment, and evidence-based intervention*. John Wiley & Sons.
- Miller, G. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *The psychological review*, 63, 81-97.
- Mindt, M. R., Arentoft, A., Germano, K. K., D'Aquila, E., Scheiner, D., Pizzirusso, M., ... & Gollan, T. H. (2008). Neuropsychological, cognitive, and theoretical considerations for evaluation of bilingual individuals. *Neuropsychology review*, 18(3), 255-268.
- Molinari, M., Petrosini, L., Misciagna, S., & Leggio, M. G. (2004). Visuospatial abilities in cerebellar disorders. *Journal of Neurology, Neurosurgery & Psychiatry*, 75(2), 235-240.
- Moore, R. C., Davine, T., Harmell, A. L., Cardenas, V., Palmer, B. W., & Mausbach, B. T. (2013). Using the repeatable battery for the assessment of neuropsychological status (RBANS) effort index to predict treatment group attendance in patients with schizophrenia. *Journal of the International Neuropsychological Society*, 19(02), 198-205.
- Morgan, J. E., & Ricker, J. H. (Eds.). (2016). *Textbook of clinical neuropsychology*. Taylor & Francis.
- Morgan, P. L., Farkas, G., Hillemeier, M. M., Hammer, C. S., & Maczuga, S. (2015). 24-month-old children with larger oral vocabularies display greater academic and behavioral functioning at kindergarten entry. *Child development*, 86(5), 1351-1370.
- Mpofu, E. & Ortiz, S. O. (2009). Equitable assessment practices in diverse contexts. *Multicultural psychoeducational assessment*, 41-76.
- Naglieri, J. A., & Das, J. P. (1997). *Das-Naglieri cognitive assessment system*. Itasca, IL: Riverside.

- Nelissen, N., Stokes, M., Nobre, A. C., & Rushworth, M. F. (2013). Frontal and parietal cortical interactions with distributed visual representations during selective attention and action selection. *Journal of Neuroscience*, *33*(42), 16443-16458.
- Neufang, M., Heinze, H. J., & Düzcel, E. (2006). Electromagnetic correlates of recognition memory processes. *Clinical EEG and neuroscience*, *37*(4), 300-308.
- Nogin, M. M. (2017). The effects of acculturation, age and years in the United States on RBANS performance in Russian bilinguals. (Doctoral dissertation, Ball State University).
- Nolte, J., & Sundsten, J. (2002). *The human brain: an introduction to its functional anatomy* (Vol. 5, p. 650). St. Louis: Mosby.
- Norman, D. A. (1969). *Memory and attention: An introduction to human information processing*.
- Norton, E. S., Black, J. M., Stanley, L. M., Tanaka, H., Gabrieli, J. D., Sawyer, C., & Hoeft, F. (2014). Functional neuroanatomical evidence for the double-deficit hypothesis of developmental dyslexia. *Neuropsychologia*, *61*, 235-246.
- O'Bryant, Sid E., Jed Falkowski, Valerie Hobson, Leigh Johnson, James Hall, Gregory W. Schrimsher, Ohmar Win, Bichthy Ngo, and Andrew Dentino. "Executive functioning mediates the link between other neuropsychological domains and daily functioning: a Project FRONTIER study." *International Psychogeriatrics* *23*, no. 1 (2011): 107-113.
- Ortiz, S. O. (2002). Best practices in nondiscriminatory assessment. *Best practices in school psychology IV*, *2*, 1321-1336.
- Ortiz, S. O. (2005). The culture-language test classification (C-LTC) and the culture language interpretive matrix (C-LIM). *Unpublished document obtained from Dr. SO Ortiz. New York: St Johns University.*

Ortiz, S. O., Flanagan, D. P., & McGrew, K. S. (1998). Gf-Gc cross-battery interpretation and selective cross-battery assessment: Referral concerns and the needs of culturally and linguistically diverse populations. *The Intelligence Test Desk Reference (ITDR): Gf-Gc Cross-Battery Assessment*, 401-444.

Papathanasiou, I., Coppens, P., & Davidson, B. (2016). Aphasia and Related Neurogenic Communication Disorders: Basic Concepts, Management, and Efficacy. *Aphasia and Related Neurogenic Communication Disorders*, 3.

Park, S., Bellinger, D. C., Adamo, M., Bennett, B., Choi, N. K., Baltazar, P. I., ... & Acosta, L. P. (2016). Mechanistic pathways from early gestation through infancy and neurodevelopment. *Pediatrics*, e20161843.

Pashler, H. (Ed.). (2016). *Attention*. Psychology Press.

Pasquier, F., Lebert, F., Grymonprez, L., & Petit, H. (1995). Verbal fluency in dementia of frontal lobe type and dementia of Alzheimer type. *Journal of Neurology, Neurosurgery & Psychiatry*, 58(1), 81-84.

Paulesu, E., Frith, C. D., & Frackowiak, R. S. (1993). The neural correlates of the verbal component of working memory. *Nature*, 362(6418), 342.

Peng, C. Z., Grant, J. D., Heath, A. C., Reiersen, A. M., Mulligan, R. C., & Anokhin, A. P. (2016). Familial influences on the full range of variability in attention and activity levels during adolescence: A longitudinal twin study. *Development and psychopathology*, 28(02), 517-526.

Pergola, G., Ranft, A., Mathias, K., & Suchan, B. (2013). The role of the thalamic nuclei in recognition memory accompanied by recall during encoding and retrieval: an fMRI study. *Neuroimage*, 74, 195-208.

- Perkins, S. C., Finegood, E. D., & Swain, J. E. (2013). Poverty and language development: Roles of parenting and stress. *Innovations in clinical neuroscience, 10*(4), 10-19.
- Petersen, I. T., Bates, J. E., D'Onofrio, B. M., Coyne, C. A., Lansford, J. E., Dodge, K. A., ... & Van Hulle, C. A. (2013). Language ability predicts the development of behavior problems in children. *Journal of abnormal psychology, 122*(2), 542.
- Peterson, E. K. (2008). *Correlation of the Boston Naming Test-with Normed Cognitive Measures in an Intellectually Disabled Sample*. ProQuest.
- Petrides, M. (2013). *Neuroanatomy of language regions of the human brain*. Academic Press.
- Petrides, M., Alivisatos, B., Meyer, E., & Evans, A. C. (1993). Functional activation of the human frontal cortex during the performance of verbal working memory tasks. *Proceedings of the National Academy of Sciences, 90*(3), 878-882.
- Piotrowski, C. (2017). Neuropsychological testing in professional psychology specialties: Summary findings of 36 studies (1990-2016) in applied settings. *Journal of the Indian Academy of Applied Psychology, 43*(1), 134.
- Pisoni, A., Turi, Z., Raithel, A., Ambrus, G. G., Alekseichuk, I., Schacht, A., ... & Antal, A. (2015). Separating recognition processes of declarative memory via anodal tDCS: boosting old item recognition by temporal and new item detection by parietal stimulation. *PloS one, 10*(3), e0123085.
- Possin, K. L., Laluz, V. R., Alcantar, O. Z., Miller, B. L., & Kramer, J. H. (2011). Distinct neuroanatomical substrates and cognitive mechanisms of figure copy performance in Alzheimer's disease and behavioral variant frontotemporal dementia. *Neuropsychologia, 49*(1), 43-48.

- Poulton, R. G., & Moffitt, T. E. (1995). The Rey-Osterreith Complex Figure Test: Norms for young adolescents and an examination of validity. *Archives of Clinical Neuropsychology, 10*(1), 47-56.
- Preston, A. R., & Eichenbaum, H. (2013). Interplay of hippocampus and prefrontal cortex in memory. *Current Biology, 23*(17), R764-R773.
- Prince, M., Bryce, R., Albanese, E., Wimo, A., Ribeiro, W., & Ferri, C. P. (2013). The global prevalence of dementia: a systematic review and metaanalysis. *Alzheimer's & Dementia, 9*(1), 63-75.
- Purves, D., Augustine, G. J., Fitzpatrick, D., Katz, L. C., LaMantia, A. S., McNamara, J. O., & Williams, S. M. (2001). *Lesions of the frontal association cortex: Deficits of planning*.
- Rabin, L. A., Paolillo, E., & Barr, W. B. (2016). Stability in test-usage practices of clinical neuropsychologists in the United States and Canada over a 10-year period: A follow-up survey of INS and NAN members. *Archives of Clinical Neuropsychology, acw007*.
- Rae, C. L., Hughes, L. E., Anderson, M. C., & Rowe, J. B. (2015). The prefrontal cortex achieves inhibitory control by facilitating subcortical motor pathway connectivity. *Journal of Neuroscience, 35*(2), 786-794.
- Randolph, C. (2012). *Repeatable Battery for the Assessment of Neuropsychological Status Update: Examiner's Manual*. New York: Pearson Assessment.
- Randolph, C. (1998). RBANS manual: Repeatable battery for the assessment of neuropsychological status. *San Antonio, TX: The Psychological Corporation*.
- Randolph, C., Tierney, M. C., Mohr, E., & Chase, T. N. (1998). The repeatable battery for the assessment of neuropsychological status (RBANS): preliminary clinical validity. *Journal of clinical and experimental neuropsychology, 20*(3), 310-319.

- Reitan, R. M., & Wolfson, D. (1993). The Halstead-Reitan neuropsychological test battery: Theory and clinical applications.
- Reverberi, C., Cherubini, P., Baldinelli, S., & Luzzi, S. (2014). Semantic fluency: Cognitive basis and diagnostic performance in focal dementias and Alzheimer's disease. *Cortex*, *54*, 150-164.
- Reynolds, C. R., & Kamphaus, R. W. (Eds.). (2003a). *Handbook of psychological and educational assessment of children: Personality, behavior, and context* (Vol. 2). Guilford Press.
- Reynolds, C. R., & Kamphaus, R. W. (2003b). *Reynolds Intellectual Assessment Scales* (RIAS). Lutz, FL: Psychological Assessment Resources.
- Reynolds, C., & Fletcher-Janzen, E. (2013). *Handbook of clinical child neuropsychology*. Springer.
- Rhodes, R. L., Ochoa, S. H., & Ortiz, S. O. (2005). *Assessing culturally and linguistically diverse students: A practical guide*. Guilford Press.
- Rojas, D. C., & Bennett, T. L. (1996). The neuropsychology of attention: by Ronald A. Cohen, New York: Plenum Press, 1993, 545 pp. *Archives of Clinical Neuropsychology*, *11*(3), 257-259.
- Rubia, K., Alegria, A. A., & Brinson, H. (2014). Brain abnormalities in attention-deficit hyperactivity disorder: a review. *Revista de neurologia*, *58*(S01), S3-S18.
- Rubia, K., Alegria, A. A., Cubillo, A. I., Smith, A. B., Brammer, M. J., & Radua, J. (2014). Effects of stimulants on brain function in attention-deficit/hyperactivity disorder: a systematic review and meta-analysis. *Biological Psychiatry*, *76*(8), 616-628.

- Sachs, B. C., Lucas, J. A., Smith, G. E., Ivnik, R. J., Petersen, R. C., Graff-Radford, N. R., & Pedraza, O. (2012). Reliable change on the Boston naming test. *Journal of the International Neuropsychological Society, 18*(02), 375-378.
- Sattler, J. M., & Ryan, J. J. (2009). *Assessment with the WAIS-IV*. Jerome M Sattler Publisher.
- Sauzéon, H., Lestage, P., Raboutet, C., N’Kaoua, B., & Claverie, B. (2004). Verbal fluency output in children aged 7–16 as a function of the production criterion: Qualitative analysis of clustering, switching processes, and semantic network exploitation. *Brain and Language, 89*(1), 192-202.
- Sawrie, S. M., Chelune, G. J., Naugle, R. I., & Lüders, H. O. (1996). Empirical methods for assessing meaningful neuropsychological change following epilepsy surgery. *Journal of the International Neuropsychological Society, 2*(6), 556-564.
- Saxton, J., Ratcliff, G., Munro, C. A., Coffey, E. C., Becker, J. T., Fried, L., & Kuller, L. (2000). Normative data on the Boston Naming Test and two equivalent 30-item short forms. *The Clinical Neuropsychologist, 14*(4), 526-534.
- Schmitt, A. L., Livingston, R. B., Reese, E. M., & Davis, K. M. (2010). The Relationship Between the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) and Olfaction in Patients Referred for a Dementia Evaluation. *Applied neuropsychology, 17*(3), 163-171.
- Schoenberg, M. R., Lange, R. T., Marsh, P., & Saklofske, D. H. (2011). Premorbid intelligence. In *Encyclopedia of clinical neuropsychology* (pp. 2004-2010). Springer New York.
- Schumann, J. H. (1986). Research on the acculturation model for second language acquisition. *Journal of multilingual & multicultural development, 7*(5), 379-392.

- Sciberras, E., Mueller, K. L., Efron, D., Bisset, M., Anderson, V., Schilpzand, E. J., ... & Nicholson, J. M. (2014). Language problems in children with ADHD: A community-based study. *Pediatrics*, peds-2013.
- Segbers, J., & Schroeder, S. (2016). How many words do children know? A corpus-based estimation of children's total vocabulary size. *Language Testing*, 0265532216641152.
- Semrud-Clikeman, M., & Ellison, P. A. T. (2009). *Child neuropsychology: Assessment and interventions for neurodevelopmental disorders*. Springer Science & Business Media.
- Shao, Z., Janse, E., Visser, K., & Meyer, A. S. (2014). What do verbal fluency tasks measure? Predictors of verbal fluency performance in older adults. *Frontiers in psychology*, 5.
- Shapiro, K., Hillstrom, A. P., & Husain, M. (2002). Control of visuotemporal attention by inferior parietal and superior temporal cortex. *Current Biology*, 12(15), 1320-1325.
- Sheslow, D., & Adams, W. (2003). *Wide Range Assessment of Memory and Learning - Second Edition (WRAML-2)*. Administration and Technical Manual. Wide Range. Inc.: Wilmington, DE.
- Shipstead, Z., Lindsey, D. R., Marshall, R. L., & Engle, R. W. (2014). The mechanisms of working memory capacity: Primary memory, secondary memory, and attention control. *Journal of Memory and Language*, 72, 116-141.
- Ska, B., Poissant, A., & Joannette, Y. (1990). Line orientation judgment in normal elderly and subjects with dementia of Alzheimer's type. *Journal of Clinical and Experimental Neuropsychology*, 12(5), 695-702.
- Slotnick, S. D., & Dodson, C. S. (2005). Support for a continuous (single-process) model of recognition memory and source memory. *Memory & cognition*, 33(1), 151-170.

- Slotnick, S. D., Jeye, B. M., & Dodson, C. S. (2016). Recollection is a continuous process: evidence from plurality memory receiver operating characteristics. *Memory, 24*(1), 2-11.
- Smith, S. M. (1994). Theoretical principles of context-dependent memory. *Theoretical aspects of memory, 2*, 168-195.
- Sotelo-Dynega, M., Ortiz, S. O., Flanagan, D. P., & Chaplin, W. F. (2013). English language proficiency and test performance: an evaluation of bilingual students with the woodcock-johnson III tests of cognitive abilities. *Psychology in the Schools, 50*(8), 781-797.
- Spencer, R. J., Kitchen Andren, K. A., & Tolle, K. A. (2018). Development of a scale of executive functioning for the RBANS. *Applied Neuropsychology: Adult, 25*(3), 231-236.
- Squire, L. R., Stark, C. E., & Clark, R. E. (2004). The medial temporal lobe. *Annu. Rev. Neurosci., 27*, 279-306.
- Stage, S. A., Abbott, R. D., Jenkins, J. R., & Berninger, V. W. (2003). Predicting response to early reading intervention from verbal IQ, reading-related language abilities, attention ratings, and verbal IQ—word reading discrepancy: Failure to validate discrepancy method. *Journal of Learning Disabilities, 36*(1), 24-33.
- Stattin, H., & Klackenber-Larsson, I. (1993). Early language and intelligence development and their relationship to future criminal behavior. *Journal of Abnormal Psychology, 102*(3), 369.
- Steinberg, B. A., Bieliauskas, L. A., Smith, G. E., Langellotti, C., & Ivnik, R. J. (2005). Mayo's Older Americans Normative Studies: Age-and IQ-adjusted norms for the Boston naming test, the MAE Token test, and the judgment of Line Orientation Test. *The Clinical Neuropsychologist, 19*(3-4), 280-328.

- Stone, S. P., Wilson, B., Wroot, A., Halligan, P. W., Lange, L. S., Marshall, J. C., & Greenwood, R. J. (1991). The assessment of visuo-spatial neglect after acute stroke. *Journal of Neurology, Neurosurgery & Psychiatry*, *54*(4), 345-350.
- Storms, G., Saerens, J., & De Deyn, P. P. (2004). Normative data for the Boston Naming Test in native Dutch-speaking Belgian children and the relation with intelligence. *Brain and language*, *91*(3), 274-281.
- Strauss, E., Sherman, E. M., & Spreen, O. (2006). *A compendium of neuropsychological tests: Administration, norms, and commentary*. Oxford University Press, USA.
- Strong, C. A. H., Tiesma, D., & Donders, J. (2011). Criterion validity of the Delis-Kaplan Executive Function System (D-KEFS) fluency subtests after traumatic brain injury. *Journal of the International Neuropsychological Society*, *17*(02), 230-237.
- Stuss, D. T. (2011). Functions of the frontal lobes: relation to executive functions. *Journal of the international neuropsychological Society*, *17*(05), 759-765.
- Suchan, B. (2008). Neuroanatomical correlates of processing in visual and visuospatial working memory. *Cognitive processing*, *9*(1), 45-51.
- Sugarman, M. A., & Axelrod, B. N. (2015). Embedded measures of performance validity using verbal fluency tests in a clinical sample. *Applied Neuropsychology: Adult*, *22*(2), 141-146.
- Suzuki, M., & Gottlieb, J. (2013). Distinct neural mechanisms of distractor suppression in the frontal and parietal lobe. *Nature neuroscience*, *16*(1), 98-104.
- Szatloczki, G., Hoffmann, I., Vincze, V., Kalman, J., & Pakaski, M. (2015). Speaking in Alzheimer's disease, is that an early sign? Importance of changes in language abilities in Alzheimer's disease. *Frontiers in aging neuroscience*, *7*, 195.

Szczepanski, S. M., & Knight, R. T. (2014). Insights into human behavior from lesions to the prefrontal cortex. *Neuron*, 83(5), 1002-1018.

Tabachnick, B. G., & Fidell, L. S. (2007). *Using multivariate statistics*. Allyn & Bacon/Pearson Education.

Tabert, M. H., Manly, J. J., Liu, X., Pelton, G. H., Rosenblum, S., Jacobs, M., ... & Devanand, D. P. (2006). Neuropsychological prediction of conversion to Alzheimer disease in patients with mild cognitive impairment. *Archives of general psychiatry*, 63(8), 916-924.

Takács, Á., Kóbor, A., Tárnok, Z., & Csépe, V. (2014). Verbal fluency in children with ADHD: Strategy using and temporal properties. *Child Neuropsychology*, 20(4), 415-429.

Taler, V., & Phillips, N. A. (2008). Language performance in Alzheimer's disease and mild cognitive impairment: a comparative review. *Journal of clinical and experimental neuropsychology*, 30(5), 501-556.

Tay, L., Lim, W. S., Chan, M., Ali, N., Mahanum, S., Chew, P., ... & Chong, M. S. (2015). New DSM-V neurocognitive disorders criteria and their impact on diagnostic classifications of mild cognitive impairment and dementia in a memory clinic setting. *The American Journal of Geriatric Psychiatry*, 23(8), 768-779.

Tippett, D. C., Sebastian, R., Davis, C., Gomez, Y., Newhart, M., Tsapkini, K., ... & Hills, A. E. (2014). Patterns of Decline on Language Testing in Primary Progressive Aphasia.

Toomey, R. (2017). Culturally Informed Neuropsychological Assessment. *Clinical Psychology: A Global Perspective*, 99.

Tramontana, M. G., & Hooper, S. R. (Eds.). (2013). *Assessment issues in child neuropsychology*. Springer Science & Business Media.

- Trask, R. L., & Stockwell, P. (2007). *Language and linguistics: the key concepts*. Taylor & Francis.
- Troyer, A. K., Moscovitch, M., & Winocur, G. (1997). Clustering and switching as two components of verbal fluency: evidence from younger and older healthy adults. *neuropsychology*, *11*(1), 138.
- Turnbull, R., & Peperkamp, S. (2016). What governs a language's lexicon? Determining the organizing principles of phonological neighbourhood networks. In *International Workshop on Complex Networks and their Applications* (pp. 83-94). Springer International Publishing.
- Uithol, S., Franca, M., Heimann, K., Marzoli, D., Capotosto, P., Tommasi, L., & Gallese, V. (2015). Single-pulse transcranial magnetic stimulation reveals contribution of premotor cortex to object shape recognition. *Brain stimulation*, *8*(5), 953-956.
- Unsworth, N., Fukuda, K., Awh, E., & Vogel, E. K. (2014). Working memory and fluid intelligence: Capacity, attention control, and secondary memory retrieval. *Cognitive psychology*, *71*, 1-26.
- Unsworth, N., Spillers, G. J., & Brewer, G. A. (2010). Variation in verbal fluency: A latent variable analysis of clustering, switching, and overall performance. *The Quarterly Journal of Experimental Psychology*, *64*(3), 447-466.
- van Bergen, E., de Jong, P. F., Maassen, B., & van der Leij, A. (2014). The effect of parents' literacy skills and children's preliteracy skills on the risk of dyslexia. *Journal of abnormal child psychology*, *42*(7), 1187-1200.
- Vaughan, L., Hogan, P. E., Rapp, S. R., Dugan, E., Marottoli, R. A., Snively, B. M., ... & Sink, K. M. (2015). Driving with mild cognitive impairment or dementia: Cognitive test

- performance and proxy report of daily life function in older women. *Journal of the American Geriatrics Society*, 63(9), 1774-1782.
- Verhaegen, C., & Poncelet, M. (2013). Changes in naming and semantic abilities with aging from 50 to 90 years. *Journal of the International Neuropsychological Society*, 19(02), 119-126.
- Voyvodic, J. T. (2012). Reproducibility of single-subject fMRI language mapping with AMPLE normalization. *Journal of magnetic resonance imaging*, 36(3), 569-580.
- Wade, M., Browne, D. T., Madigan, S., Plamondon, A., & Jenkins, J. M. (2014). Normal birth weight variation and children's neuropsychological functioning: links between language, executive functioning, and theory of mind. *Journal of the International Neuropsychological Society*, 20(9), 909-919.
- Wang, K. (2015). *Quantifying the Linguistic Demand of the WISC-IV's Test Directions* (Doctoral dissertation, University of Alberta).
- Wassermann, E. M., Blaxton, T. A., Hoffman, E. A., Berry, C. D., Oletsky, H., Pascual-Leone, A., & Theodore, W. H. (1999). Repetitive transcranial magnetic stimulation of the dominant hemisphere can disrupt visual naming in temporal lobe epilepsy patients. *Neuropsychologia*, 37(5), 537-544.
- Wechsler, D. (1981). *WAIS-R manual: Wechsler adult intelligence scale-revised*. Psychological Corporation.
- Wechsler, D. (1997). *WMS-III: Wechsler memory scale administration and scoring manual*. Psychological Corporation.
- Wechsler, D. (2001). *Wechsler Test of Adult Reading: WTAR*. Psychological Corporation.

- Wechsler, D. (2004). Wechsler intelligence scale for children—Fourth Edition (WISC-IV). *San Antonio, TX: The Psychological Corporation.*
- Wechsler, D. (2008). Wechsler Adult Intelligence Scale—Fourth Edition (WAIS-IV). *San Antonio, TX, USA: The Psychological Corporation.*
- Wechsler, D. (2009). Advanced clinical solutions for the WAIS-IV and WMS-IV. *San Antonio, TX: The Psychological Corporation.*
- Wechsler, D. (2014). Wechsler Intelligence Scale for Children (5th ed.). San Antonio, TX: NCS Pearson
- Weeks, J. C., & Hasher, L. (2016). Divided attention reduces resistance to distraction at encoding but not retrieval. *Psychonomic Bulletin & Review*, 1-6.
- Weiss, L. G., Saklofske, D. H., Holdnack, J. A., & Prifitera, A. (2016). WISC-V: Advances in the assessment of intelligence. *The WISC-V assessment and interpretation: Scientist-practitioner perspectives*, 3-24.
- White, T., & Stern, R. A. (2003). *NAB, Neuropsychological Assessment Battery: Demographically Corrected Norms Manual*. Psychological Assessment Resources.
- Whiteside, D. M., Kealey, T., Semla, M., Luu, H., Rice, L., Basso, M. R., & Roper, B. (2016). Verbal fluency: Language or executive function measure?. *Applied Neuropsychology: Adult*, 23(1), 29-34.
- Wiig, E. H., Semel, E. M., & Secord, W. (2003). *CELF 5: Clinical Evaluation of Language Fundamentals*.
- Williams, K. T. (1997). Expressive Vocabulary Test Second Edition (EVT™ 2). *Journal of the American Academy of Child & Adolescent Psychiatry*, 42, 864-872.
- Williams, K. T. (2007). *EVT-2: Expressive vocabulary test*. Pearson Assessments.

Wolf, M., & Goodglass, H. (1986). Dyslexia, dysnomia, and lexical retrieval: A longitudinal investigation. *Brain and language*, 28(1), 154-168.

Woodward, N. D., Duffy, B., & Karbasforoushan, H. (2013). Prefrontal cortex activity during response selection predicts processing speed impairment in schizophrenia. *Journal of the International Neuropsychological Society*, 19(07), 782-791.

Yantis, S. (1998). *The attentive brain* (pp. 221-56). R. Parasuraman (Ed.). Cambridge, MA: MIT Press.

Yantis, S. (1998). *The attentive brain* (pp. 461-487). R. Parasuraman (Ed.). Cambridge, MA: MIT Press.

Yen, J. Y., Ko, C. H., Yen, C. F., Wu, H. Y., & Yang, M. J. (2007). The comorbid psychiatric symptoms of Internet addiction: attention deficit and hyperactivity disorder (ADHD), depression, social phobia, and hostility. *Journal of adolescent health*, 41(1), 93-98.

Yochim, B. P., Beaudreau, S. A., Fairchild, J. K., Yutsis, M. V., Raymond, N., Friedman, L., & Yesavage, J. (2015). Verbal naming test for use with older adults: development and initial validation. *Journal of the International Neuropsychological Society*, 21(3), 239-248.

Yonelinas, A. P. (1994). Receiver-operating characteristics in recognition memory: Evidence for a dual-process model. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 20(6), 1341.

Yonelinas, A. P. (2002). The nature of recollection and familiarity: A review of 30 years of research. *Journal of Memory and Language*. 46(3): 441-517.

Young, P. A., Young, P. H., & Tolbert, D. L. (2008). *Basic clinical neuroscience*. Lippincott Williams & Wilkins.

Zwaigenbaum, L., Bryson, S., & Garon, N. (2013). Early identification of autism spectrum disorders. *Behavioural Brain Research*, 251, 133-146.