A FACTOR ANALYSIS OF MEASURES OF COGNITIVE FLEXIBILITY AS AN ASPECT OF EXECUTIVE FUNCTIONING

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(UNDER THE DIRECTION OF LINDA F. CAMPBELL)

ABSTRACT

Cognitive flexibility (CF) is a neuropsychological construct that has recently seen increased interest in the research literature. With implications that span a range of scientific specialties, the construct has been studied utilizing a broad variety of measurement modalities. While the Wisconsin Card Sorting (WCST) test has been identified as the gold standard measure for studying CF, for a variety of reasons competing techniques have been applied each purportedly measuring the same underlying construct. In a clinical sample of 119 adult neuropsychological testing patients, performance on the Delis Kaplan Executive Functioning System Color-Word Interference test and the Trails-B test was compared to the WCST. A factor analysis of scores indicated a three factor solution with the WCST standing independent of performance on the other two measures. These results indicate that the three competing approaches cannot be used independently to measure CF.

INDEX WORDS: cognitive flexibility, executive functioning, neuropsychology

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DEDICATION

Beyond this manuscript, my entire academic career is dedicated to my family who supported me throughout this endeavor. First and foremost, I dedicate this to my loving and patient spouse, Rebeca F. Selagea who has been my foundation, my energy, and my purpose. I could not have done any of this without you and I am incredibly blessed to have a partner and friend to walk with me through this arduous and demanding path. I also must extend my deepest gratitude to my parents who extended to us all the support and encouragement I could ever need. I do not have the words to express how deeply humbled and grateful I am and I pray that my actions can convey my heartfelt appreciation where my words fail.

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Chapter 1

Introduction

In the conduct of scientific investigation, a set of guiding principles provide structure to the endeavor and lend credence to the veracity of the results or conclusions. Each scientific specialty has operationalized these principles to address the concepts, tools, techniques, and challenging in each respective discipline. While imperfect and at times a cumbersome process, the conduct of science has self-correcting mechanisms established in order to adapt new findings into the existing knowledge base. Through the process of replicating studies to verify findings, a field of study builds upon itself and prunes away unsupported conclusions. In this way knowledge in any field is anticipated to advance as new research aims to replicate findings, challenge previous research results or conclusions, refine the understanding of a concept or phenomena, or any combination of those aims.

Implicit and necessary to the process is a clear understanding among individuals as to the definitions of terms or concepts. In the communication of research, it is imperative that the parties involved have a common understanding of the respective subject matter independent of their perspective on the matter. Two researchers may disagree regarding a topic but the two must have a shared understanding of the topic in order to be able to discuss the topic and examine the evidence effectively. It is appropriate and beneficial to the advancement of science for researchers to disagree about the definition of a term, its conceptualization within a framework or theory, its operationalization, or any number of important elements. However, it is critical that parties clearly understand that there is disagreement and in those cases the debated quality may rightfully be the primary subject of the discourse. For instance, if the definition of a term is under debate, then it should be clear to all parties that this is the case. In the event that a researcher assumes agreement or common understanding, the discourse has the potential to be inefficient at best and confusing at worst.

This unfortunate circumstance is the case for the neuropsychological construct of Cognitive Flexibility (CF). The term has been used in a wide range of scientific specialties and subspecialties in a manner that resulted in confusion. CF has been studied in relation to a wide range of emotional, behavioral, cognitive, neurological, and sociological factors. For example, CF has been studied in relation to anorexia nervosa (Brockmeyer et al. 2014; Lounes, Khan, & Tchanturia, 2011), obsessive-compulsive disorder (Whitton, Henry, & Grisham, 2014), and the experience of bicultural stress (Lau, 2013). Researchers have operationalized CF in diverse ways and utilized instruments based on their conceptualization. Despite the heterogeny of conceptualization and operationalization, the term Cognitive Flexibility has continued to be used for essentially different concepts and the pursuit of different hypotheses.

Rather than progressing through the systematic process preferred in science, the current state of the research literature is opaque and inconsistent in regards to cognitive flexibility. The range of studies presented currently in the literature purport to measure CF but do so by defining it in diverse ways and studying it through diverse tools. There is no structured series of investigations where the competing conceptualizations are evaluated. Regarding CF, the plurality, if not majority, of articles currently published are conceptually independent of one another. This is a substantial limitation to progress in the understanding of cognitive flexibility, its relation to other phenomena, and ultimately in its application to individual or societal problems.

Purpose of the Study

The primary purpose of the study is to conceptualized CF as a multidimensional construct. Conceptualized as a multidimensional. construct, an examination of the interrelations between a sample of the various measures of CF acknowledges the contributions of the multiple approaches while moving towards clarity in the literature. An examination of the various approaches acknowledges the relationships. The current study is a factor analysis of CF and the degree to which each of the various measures provide valid measures of the construct. The Wisconsin Card Sorting Test (WCST) has been identified as the gold standard measure of CF (Corocan & Upton, 1993). To date there have been no studies that examine the relationships among the various measures of cognitive flexibility. Researchers have identified aspects of cognition that are theorized to operationalize CF (set switching, response to environmental information, problem solving, etc.) This study is an empirical examination of the degree to which competing measures of CF align with the WCST.

Nature and Scope of the Contribution

This current study aims to improve the measurement and study of cognitive flexibility by assessing the construct via multiple means in the same population. Currently there is debate regarding the definition of Cognitive Flexibility (CF) followed by respective varying modes of operationalization and measurement. The competing definitions of cognitive flexibility include the ability to alternate between sets (Huizinga & Hommel, 2009) the ability to switch between tasks (Huizinga, Dolan, & van der Molen, 2006), and the knowledge of multiple solution procedures and capacity to create new procedures (Star & Seifert, 2006). Due to a lack of conceptual consensus, the research literature is replete with differing measures each purportedly assessing a construct by the same name (Ionescu, 2012). To date there have been few published studies designed to assess the measure of convergent validity among the various measures. A sample of the diverse instruments include: the Change Card Sort Task (Ramscar, 2013), the DKEFS Sorting Task (Ramscar, 2013), Trail Making Test (Champagne-Lavau, Charest, Anselmo, Rodriguez, & Blouin, 2012), Go-no-Go Tasks (Murphy, 2011), and the Cognitive Flexibility Scale (Martin & Rubin, 1995.) In the introductory publication of the Cognitive Flexibility Inventory, Dennis and Vander Wal (2010) recommended that follow-up studies address the convergent validity between their self-report measure and performance-based tests currently employed.

The current study is designed to contribute to this particular gap in the research literature. Namely, it is intended to measure the nature and magnitude of interrelations of various competing measures of CF. Rather than assume equivalence, that assumption is the subject of this investigation. The study excludes the self-report measures present in the research literature and utilizes only performance-based tasks. This is due to the well-established research literature that identified self-report as an unreliable measure of ability (Seli et al, 2015).   Specifically chosen instruments and measurement modalities will be administered to a single population thereby allowing for direct comparisons across measures. The analysis will provide empirical data, which will hopefully elucidate the relations among the instruments and move the field towards greater clarity. This data will be brought to bear on the debates related to CF operationalization.

This study will call attention to the importance of clarity in language and in instrument selection. In doing so, it is hoped that the area of research will progress in ways that are increasingly clear and increasingly efficient. This study will improve the measurement of CF by providing empirical evidence regarding the interrelationships of the various approaches currently applied to purportedly measure CF. This will in turn encourage researchers to utilize caution when selecting an instrument for use in research and promote a more precise articulation when a researcher studies cognitive flexibility. There are certainly well-reasoned and data informed debates among neuropsychologists and experts leading to competing definitions and explanations (Ionescu, 2012). However, researchers with expertise in other areas may not be privy to the models, explanatory frameworks, and nuances and therefore make inappropriate decisions regarding instrument selection or research findings. For example, Lee and Orsillo (2014) utilized the CFS, a measure of self-reported flexibility in communication, to study the impact of mindfulness on symptoms of GAD via cognitive flexibility. The authors acknowledged the original purpose for which the CFS was developed, but justified its use solely by citing its use in other studies of cognitive flexibility.

This study will also examine and highlight the selected scores in the conduct of psychological and neuropsychological research. For example, the WCST is considered the gold standard for measuring CF (Cochran & Upton, 1993). On this measure, the scoring provides a diverse set of results based on participant performance. Researchers have been inconsistent in which score they select as being the indicator of CF and their conclusions are inexorably linked to that critical decision. Several scores from the tests administered are examined in this study in order to address the concern regarding score selection.

Significance of the Study: Implications and Applications for Psychology

The most direct and simple implication for the proposed study is methodological and psychometric. In comparing various instruments utilized to investigate CF, it may be possible to draw conclusions regarding their equivalence. This study will allow for both broad as well as specific comparisons of instrumentation and by extension the underlying theoretical basis of their use. Additional comparisons will indicate which, if any, of the measures of CF are related to one another. The study will thereby provide data as to whether the CF is a unitary construct or a collection of related but distinct cognitive abilities. Thus, the proposed study will contribute to the theoretical understanding of CF, which can then be extended to research and clinical applications.

Cognitive flexibility has thus far been in relation to a wide variety of cognitive, educational, neurological, and psychiatric constructs. Researchers have studied CF in relation to autism spectrum disorders (de Vries & Geurts, 2012); anorexia nervosa (Sato, et. Al., 2013; Lounes, Khan, & Tchanturia, 2011); and cognitive restructuring skills among older adults (Johnco, Wuthrich, & Rapee, 2012). A study demonstrated that cognitive flexibility is diminished by dysphoric ruminations (Ownes & Derakshan, 2013). Another recent study identified CF as a moderator in the direct relation between the experience of anti-bisexual prejudice and psychological wellbeing (Brewster, Moradi, DeBlaere, & Valez, 2013). A recent study examined the severity of gambling addiction as a relation of CF (Leppink, Redden, Chamberlain, & Grant, 2016). Leiberman, Gorka, Sarapas, and Shankman (2016) found CF to be a mediator between intolerance of uncertainty and heightened startle potentiation in individuals with panic disorder.

The examples provided above are exemplary of the wide range of clinical applications rather than an exhaustive list of the implications of CF. The applicability and utility of CF in psychological science depends greatly on the definition the respective clinician or researcher utilizes. If a psychologist views CF as being synonymous with (a) Executive Functioning EF, or (b) an ability to shift attention among task demands, or (c) an ability to recognize shifting governing rules, or (d) an ability to design and utilize varied problem solving and planning approaches, then their application will follow their particular perspective.

Additional implications include the utilization of CF in the clinical setting as a predictor of therapeutic outcomes, as an intervention strategy, as an aide in selecting the appropriate intervention strategy, or identified as a therapeutic goal. Much of therapeutic work is in aiding clients to implement and sustain change in their lives. Despite the varied definitions of CF, the vast majority indicates an ability to change- be it to changing rules, changing demands, or to change perspectives. In this way, CF promises to be a useful psychological construct across settings and identified problems.

For example, if a clinician is able to measure an individual's initial level of cognitive flexibility, they may be in a position to predict the likelihood of successful therapeutic outcomes. A person who demonstrates the ability to adapt to dynamic environmental rules, view a problem from multiple perspectives, or simultaneously consider multiple options is in a relatively stronger position for adaptive functioning. Related, this individual is possibly also more open and responsive to psychotherapeutic intervention. By knowing a client's CF, a clinician may be better able to provide a prognosis for a specific client presenting with a given problem.

In another circumstance, a clinician may utilize a measure of CF in order to select appropriate intervention strategies. Specifically, a CBT oriented clinician may select highly structured behaviorally oriented intervention strategies with a client demonstrating poor cognitive flexibility. Thus, the clinician utilizes empirical data (e.g. CF assessment) to tailor treatment for the client in order to maximize likelihood of positive therapeutic outcomes. Individuals with high levels of cognitive flexibility may be more willing or able to consider the effectiveness of their behaviors through awareness and reflection on cognitive schemas. They may be more willing or able to alter their behavioral repertoire and engage in various intervention activities. Conversely, clients low on CF may present a greater challenge for clinicians. Studies have demonstrated that elements of CF are responsive to training and so increasing a client's CF may be a mode of therapeutic intervention or itself be a therapeutic goal (Sali, Anderson, & Yantis, 2012). The level of CF may be of interest in terms of candidate selection, job applicants or academic program admissions. For these reasons, among others, the results of this study can contribute to the work of researchers and practitioners across the spectrum of psychological service and investigation.

Research Question

The research question of this study are related to larger overarching questions beyond the scope of this investigation. Namely, identifying the elusive definitive framework of executive functioning and the precise relations among its constituent elements (Jurado & Rosselli, 2007). Subsumed in this comprehensive description would be the conceptual and operational definitions of cognitive flexibility. While that remains an aspirational long-term goal, the purpose and scope of this study are more limited and focused. The current study is intended to add to the literature in addressing the interrelationships among three common measures of cognitive flexibility. The

WCST has been found to be the gold standard measure of cognitive flexibility and this study examines the relation of the CWI test and Trails-B test to this standard. Both instruments are widely utilized as measures of CF and while they measure aspects of cognitive switching they introduce additional variance that potentially interfere with the true measurement of CF.

There is currently a lack of consensus on the conceptual definition of cognitive flexibility and corresponding operational definition (Ionescu, 2013.) With rare exception, the overwhelming majority of research studies investigating cognitive flexibility have utilized a single CF measure, either the Trails-B or CWI, both from the DKEFS. The researchers often failed to specify why their instrument was selected in lieu of other available measures. Likewise, these studies often failed to comment on how these results related to studies that utilized different definitions or instruments. This gap was recognized by the authors of the Cognitive Flexibility Inventory (Denis & Vander Wal, 2010) but it has not yet been seriously addressed.

The research question addressed in this study is the extent and manner in which scores on various measures of cognitive flexibility relate to one another. Do the scores vary as a unitary factor or do the scores suggest multiple factors? The secondary question follows from the results of the first. Namely, if the scores load onto more than one factor, does the pattern present in a way that is conceptually meaningful?

Research Hypotheses

The research questions and their corresponding hypotheses intend to provide the empirical data that can provide evidence for a more robust and clear understanding of cognitive flexibility. Rather than assume equivalence and correspondence across measures and modalities of measurement, the null hypothesis is assumed. The battery selected for this investigation consists of three performance tests.

It is hypothesized that the factor analysis will evidence loadings onto multiple factors for the various performance tasks of cognitive flexibility. These measures were constructed to tap into non-redundant divergent cognitive functions and so the distribution of scores on one measure is expected to be largely independent of the distribution on other measures. Considering that the instruments each measure differing aspects of CF, it is anticipated that scores on the various measures will be primarily independent of other scores.

Results that support the research hypothesis will demonstrate the various functions do operate independently and suggest that performance tasks of CF could not be used interchangeably. Results that do not support the research hypothesis may suggest that the various functions do not operate independently. This would strongly suggest that performance tasks of cognitive flexibility could be used interchangeably. The loading of scores on 2 or more factors would suggest that loadings onto multiple factors The loading of scores on two or more factors would suggest that the respective instruments measure different aspects of CF or a different construct altogether.

Delimitations

Under guidance, the decision was made to focus research on a clinical sample in a neuropsychological clinic. The practice serves a population of adults age 18 and older who are referred for neuropsychological testing based on concerns of cognitive functioning. Included in the archival selection process are participants who were appropriate for neuropsychological testing and could participate in the evaluation at the time they were tested. The private practice in which the data were obtained utilized a flexible battery approach in which the tests administered were selected based on the presenting concerns as well as the individual's ability to participate in the task.

The scores and instruments utilized in the study were selected based on multiple factors. The three instruments selected are among the most widely used in the cognitive flexibility literature. Additionally, there were numerous occasions where a case in the database contained scores for two of the measures, but not the third. Likewise, there were occasions where a case included two of the measures as well as a different instrument that was found in the research literature. Due to the nature of the study, the decision was made to only include cases where a participant completed all three measures in the same encounter. Protocols for estimating and filling in missing data points were found to be problematic. Additionally, the relatively limited sample size rendered deviations from standard practice to be impractical. Rather than attempt to estimate values for missing data points, values were extracted for analysis using only those cases in which all data points were available.

Definitions of Key Terms

Executive functioning. The research literature is currently lacking consensus on a precise definition for executive functioning. While there is a general agreement regarding some of the proposed elements that comprise executive functioning or the "central executive", there are still multiple competing definitions with their respective subcomponents (Jurado & Rosselli, 2006.) Many definitions refer to the formulation of goals, controlling goal-directed behavior, marshalling and administering cognitive resources, direction of attention, and reasoning. Other definitions include elements such as the phonological loop, working memory, and visual-spatial processing. There are also conceptual questions open for debate such as whether to consider executive functioning as a unitary function where the various components are part of a unified ability or as a non-unitary set of functions that are combined as a gestalt based on their mutual coordination (Ionescu, 2012). The question here is not just regarding what executive functioning does, but also how it performs its duties. Studies on executive functioning continue utilizing traditional study paradigms as well as methodologies using newly available technology such as neuroimaging techniques (Collette & Van der Linden, 2002; Calzato, van den Wildenberg, & Hommel, 2013; and Logue & Gould, 2013). With these additional studies, the field is moving towards neurological localization, mechanistic explanations, and hopefully increasingly refined conceptualizations.

Cognitive flexibility. The definition of cognitive flexibility is currently ambiguous for a number of reasons and one of the driving forces motivating this study. There are multiple definitions and multiple operationalizations that this author considers to be confused and inconsistent. Different researchers define CF as attentional shifting, set shifting, responsiveness to environmental feedback, and the ability to generate novel solutions to problems, among others. A more thorough explanation of these approaches follows. These concepts illustrate that there are categorical differences in definitions that diverge in type and not simply degree.

There is a lack of consensus and clarity regarding whether CF is a function distinct and separate from executive functioning or if it is the quality of the activities of executive functioning that can be thought of as cognitive flexibility (Ionescu, 2012). Thus, it may be that cognitive flexibility can be thought of as the effectiveness and efficiency with which executive functioning performs its operations. Or, it may be that cognitive flexibility is an ability separate and distinct from executive functioning, a process that runs parallel to executive functioning.

For example, Geurts et al. (2009) describes CF as one of the components of executive functioning. This in contrast to Masley et al. (2009) who, when describing the Shifting Attention Test and Stroop test, argue that these tests measure what neuropsychologists call cognitive flexibility or executive functioning, as though the terms are interchangeable. Some researchers have defined cognitive flexibility more narrowly still, restricting it to a singular or small number of functions (Ionescu, 2012). Some have placed emphasis on the importance of set shifting (Colzato et al, 2009), others on adaptation to environmental stimuli (Garcia-Garcia, Barcelo, Clemente, & Escera, 2010), and yet others on the generation of novel solutions (Cretenet & Dru, 2009). While the literature consistently discusses CF in the context of executive functioning, it is unclear on the organization and definitions of constituent and related parts. A large question remains: is cognitive flexibility a specific ability or is it a property of executive functioning and other related cognitive processes?

Understandably then, when attempting to define and operationalize precisely what CF is and how it can be measured, theorists and researchers have diverged. Multiple measures have been developed specifically to measure cognitive flexibility and others have been adopted from neuropsychology instruments designed to measure elements of executive functioning. The research literature contains numerous studies utilizing various instruments that can be broadly categorized into two groups: self-report measures and performance tasks (Martin & Rubin, 1995; Dennis and Vander Wal, 2010; Murphy, 2011; Champagne-Lavau, Charest, Anselmo, Rodriguez, & Blouin, 2012; and Ramscar, 2013). The self-report measures are questionnaires that participants complete indicating their perception of their own cognitive flexibility. The performance tasks are neuropsychological measures that require participants to complete a series of tasks (i.e. select cards, stack blocks, trace lines, etc.) that are designed to tap into an underlying neurological function. Self-report measures ask participants to rate their abilities whereas performance tasks directly measure those abilities.

The state of the research literature is currently too fluid to permit the author of this study to endorse a given definition of cognitive flexibility. The competing definitions of cognitive flexibility include the ability to alternate between sets (Huizinga & Hommel, 2009) the ability to switch between tasks (Huizinga, Dolan, & van der Molen, 2006), and the knowledge of multiple solution procedures and capacity to create new procedures (Star & Seifert, 2006). It is imperative that the definition selected by any researcher be done so for rationally defensible reasons driven by empirical data. This is one of the motivations for the current study- to gather data in order to inform future decisions regarding conceptual understanding and research methodology.

Chapter 2

A FACTOR ANALYSIS OF MEASURES OF COGNITIVE FLEXIBILITY AS AN ASPECT OF EXECUTIVE FUNCTIONING

Review of Literature

The proposed study was born out of frustration and confusion with regard to the current state of the research literature on cognitive flexibility (CF). An initial search for an appropriate measure of CF led to disparate and perplexing results where previous researchers utilized definitions and instruments radically different from one another. A review of published studies required an evaluation of the operationalization of the concept of CF in addition to the evaluation of study methodology and subsequent conclusions. This state of affairs left subsequent researchers in a quandary as to how to proceed and how to conceptualize CF and its relation to other cognitive and psychological phenomena.

Cognitive flexibility is most frequently, but not exclusively, understood as existing under the umbrella of executive functioning. This categorization is apropos considering similarities in proposed cognitive functions, anatomical localization, and proposed mechanisms of functioning. Likewise, some of the conceptual and subsequent operationalization difficulties found in the literature relative to executive function are echoed in the study of cognitive flexibility. In the case of executive functioning there is a lack of clarity in the literature as competing theories, assumptions, definitions, and respective investigational methods vie for scientific acceptance. The study of both cognitive flexibility and executive functioning is an ongoing evolutionary process as theories and conceptualizations are testing using the latest technological tools. It should also be observed that these concepts are relatively new in cognitive science (Jurado &

Rosselli, 2007) and so are more prone to ambiguity and abrupt changes than more fully developed areas of study.

Despite these limitations a study of cognitive flexibility is best framed in the literature on executive functioning. This is due to the theoretical similarities in the two constructs and the overlap in the instrumentation used to study the two constructs. The Wisconsin Card Sorting Test (WCST), the Tower Test, the Trail Making Test, and variations of the Stroop test are neuropsychological measures utilized to study executive functioning as well as cognitive flexibility. Also, the body of literature is more fully developed in the study of EF and so insights developed in that area can contribute to the understanding of cognitive flexibility.

Theories of Executive Functioning

Executive functioning is most often described as the “higher order” cognitive processes. The opinions of most theorists and researchers converge upon the general framework of how intact executive functioning presents in an individual. Most theorists agree that the executive functions serve to solve complex problems and organize goal directed behavior. However, there are diverging perspectives on the nature of the concept, its enumerated components, and how to best measure the various facets subsumed under the term executive functioning (Jurado & Rosselli, 2007.) In their summary article Jurado and Rosselli provided a number of examples highlighting the variations in theorists’ conceptualizations. Examples include: Lezak (1983) conceptualized EF to include volition, planning, purposive action & effective performance; Braddeley and Hitch (1974) included the central executive, phonological loop, & visual-spatial sketchpad; while Anderson et al (2001b) conceptualized EF as attentional control, cognitive flexibility, & goal setting; and Delis et al. (2001) included flexibility in thinking, inhibition, problem-solving, planning, impulse control, concept formation, abstract thinking, and creativity. These are only a few of the examples of divergence in thinking showing both areas of agreement as well as disagreement.

According to Jurado & Rosselli (2007), theories of executive functioning can be grouped into one of several major frameworks. The first is a heirarchial cognitive model such as the ones proposed by Braddeley and Hitch (1974) and the model proposed by Norman and Shallice (1986.) According to Braddeley's model, EF is composed of a phonological loop, a visual-spatial sketchpad, and a central executive. The role of the central executive is to direct and switch attention among the cognitive processes in order to achieve the desired goal. Thus, the central executive is without information storage capacity as it functions to direct the activities of other cognitive activities. The model proposed by Norman and Shallice (1986) is known as the Supervisory Attentional System is similarly hierarchical. A central component of this theory is the distinction between automatic processes and controlled processes. Automatic and overlearned actions (such as reading) are insufficient to overcome complex problem solving, planning, or decision-making. They assert that the central executive serves a supervisory role, utilizing the automatic functions in sequence and combination in order to achieve a goal.

Similar to the aforementioned hierarchical models, Stuss (1992) proposed a model that humans progressively develop cognitively at three levels of monitoring. According to this model, the first level includes the automatic and over-learned cognitive processes, which are associated primarily with sub-cortical areas. The second level includes the supervisory and executive functions that work to synthesize information to organize goal-directed behavior. This level is associated with the development of connections between the frontal lobe and the limbic system.

The third level is awareness of self and awareness of environment and is said to be associated with the prefrontal cortex (Slattery, et al 2001.)

Jurado and Rosselli (2007) also highlighted the model proposed by Zelazo et. al (1997) which conceptualized EF as a complex function (or macrostructure) with executive sub functions working together to solve problems. Their theory identified four areas of executive processing that correspond with distinct phases of problem solving. The phases include: problem representation, planning, execution, and evaluation. This conceptualization placed the various functions in a temporal sequence allowing for the further isolation and identification of executive dysfunction in the case of a failure.

Development of Executive Functions

The cognitive abilities of executive functioning develop concurrent with neurological development from early childhood into adulthood. Because the term EF is used to describe a number of cognitive functions, researchers have examined the development of the various functions independently in order to determine their respective developmental trajectories (Romie and Reynolds, 2005). Cognitive abilities include verbal fluency, planning, inhibition, and perseveration. Results are inconsistent with some abilities improving up to age 19 and others continue to improve to past age 22 (Taylor, Baker, Heavey, & McHale, 2012). However, most abilities begin to plateau at this age, indicating that the most abrupt changes in development are complete by the time an individual enters adulthood.

In a study of multiple measures of executive functions, Huizinga, Dolan, & van der Molan, (2006) found similar results. In this study, participants age 7, 11, 15, and 21 were administered 9 neuropsychological tasks (3 for each selected domain.) Controlling for processing speed, factor analysis revealed a two-factor solution: set shifting and working memory. Their results indicated that set-shifting continued developing into adolescence while working memory continued developing into adulthood.

Studies have also shown that measures of EF are responsive to learning and environmental factors. In a study of 3-year-olds, Ramscar, Dye, Gufstafson, & Klein (2012) found that following instruction on related theoretical principles, participants were able to generalize this knowledge to improved performance on a card-sorting task. Three-year-olds who received training displayed a passing rate in excess of three times greater than the comparison group. Executive functioning is also responsive to the effects of parenting with higher quality parenting leading to improvements in executive functioning (Blair, Raver, & Berry, 2014; Cuevas et al. 2014).

Brain activity changes with age in healthy adults. A meta-analytic study by Turner and Spreng (2012) indicated that brain activity during executive functioning tasks increased recruitment of lateral aspects of the prefrontal cortex (PFC) bilaterally. The authors noted several hypotheses as to why this occurs. They indicated it could be related to increased PFC functioning to modulate noisier neuronal signaling in these areas, or greater demands on executive control as cognitive operations become less automated with age, or compensation for less efficient processing. Regardless of the explanation, the data clearly and consistently indicate changes in brain activity patterns in healthy older adults.

There is a curvilinear relationship between aging and executive functioning with EF improving from childhood through young adulthood and then declining in old age. Independent of illness or injury, studies of executive functioning demonstrate diminishing EF abilities in older adulthood (Allain et al. 2007; Hull, Martin, Beier, Lane, & Hamilton, 2008). Studies also suggest that executive functioning declines with age with differential impact on some executive functions (Silver, Goldman, Gur, Gur, &Bilker, 2011). In a study of older adults, Eggermont et al. (2009) found that executive functioning is mediated by physical health. The study found that older adults who were relatively more physically active and absent of heart disease had higher scores on measures of executive functioning.

Executive Functions and Brain Anatomy

As with many neurological investigations, lesion studies are indispensable in helping researchers localize brain functioning. For example, studies of individuals with traumatic brain injuries to the frontal lobes indicate subsequent impairments in attentional control, problem solving, abstraction, information processing, and cognitive flexibility (Salmon & Collette, 2005; Catroppa & Anderson, 2006). These are precisely the cognitive functions most commonly associated with executive functioning leading to the understanding that these functions are localized in these brain regions (Roca et al. 2010; Barbey, Colom, Solomon, Krueger, Frobes, & Grafman, 2012).

Specific areas within these larger regions correspond with specific elements of EF. In a study of comparing patients with lesions on the orbitofrontal cortex (OFC) with those with lesions on the lateral prefrontal cortex (LPFC), Lovstad et al. (2012) found different types of EF impairment. Patients with damage to the LPFC demonstrated deficits in sustained mental effort, response inhibition, working memory, and switching. Those patients with OFC damage demonstrated dysexecutive abilities in adaptive functioning.

Subcortical regions of the brain are also involved in complex cognitive functions and so injury to these areas can also effect an individual's executive functioning. This is the case with the thalamus, which performs a modulatory function connecting the frontal cortex with various other brain regions (Kolb & Whishaw, 2009.) In a study of a patient with a unilateral right-sided thalamic lesion, he was found to perform consistently lower than matched controls. Interestingly, his performance was in the normal range on tasks of low cognitive demand, but poorly on tasks with higher demands Edelstyn, Mayes, & Ellis, 2014).

The lesion studies also indicate that executive functioning is sensitive to injury and illness with long-lasting effects. A follow-up study of adults who sustained a childhood brain lesion indicated that impairments in EF continued into adulthood (Braun, Guimond, Payette, & Daineault, 2013). The timing of an injury is also important when determining the degree of impact a frontal lobe lesion has on an individual's executive functioning. A study of children who sustained such lesions suggested that if an injury occurs during a critical period of development, then the impact is more severe. Thus, children who sustained injuries prenatally or during middle childhood (times of peak synaptogenesis and dendritic arborization) suffered the greatest degree of injury (Jacobs, Harvey, & Anderson, 2007.) TBI to the frontal lobe and particularly the prefrontal cortex result in executive dysfunction, particularly in perseveration (Frankel & Penn, 2007).

There is a measure of adaptability in neurological functioning. The concept of plasticity is that the brain can adapt to injury and areas of the brain can be recruited to perform new functions. A study by Scheibel et al. (2003) with patients who suffered severe diffuse traumatic brain injury used fMRI technology demonstrated increased frontal lobe activation on tasks involving working memory and inhibition relative to healthy controls. Thus, the data suggest a reworking of neural circuitry in order to recover impairment in functioning. However, persons who suffer these types of injuries typically face chronic impairment.

Executive Functioning and Cognitive Flexibility

The relation between executive functioning and cognitive flexibility is dependent on the definitions and explanatory models a given researcher utilizes when elaborating on the terms. There are a number of conceptualizations in the research literature as described by Ionescu (2012) in a review article that highlights the current state of CF research. Congruent with the debates regarding the conceptualization of executive functioning, there is debate as to whether CF is a distinct cognitive function or if it is a property of various functions.

For example, Geurts et al. (2009) describes CF as one of the components of executive functioning; Colzato et. al. (2009) described it as a shifting between tasks and mental sets; and Diamond (2006) referred to CF as the ability to flexibly switch perspectives, focus of attention, or response mappings. These examples are indicative of researchers who have more narrowly defined CF to be a specific task or discrete set of tasks. This falls in line with the most common definition of CF, which is set-shifting (Stemme, Deco, & Busch, 2007). Accordingly, the researchers who define it this way select a measure of set-shifting in order to measure the construct. The most widely used measure of set-shifting in CF studies is the Wisconsin Card Sorting Test (Corcoran & Upton, 1993). Another measure of set shifting utilized in the study of cognitive flexibility is the Trail Making Test Part B (Kortte, Horner, & Windham, 2002). Investigators who define CF as an ability to inhibit responses have utilized a version of the stroop color-word interference task (Graf, Uttl, & Tuokko, 1995. Additionally, cognitive flexibility has been measured via a task-switching paradigm (Samanez-Larkin, et al. 2013) and an inhibition paradigm designed to measure individual's ability to ignore distracting stimuli (Owens & Derakshan, 2012). This approach to studying cognitive flexibility has the advantage of specificity, with this approach allowing for operationalization that excludes many extraneous variables (Jurado & Rosselli, 2007). However, this approach runs the risk of excluding elements pertinent to the construct of cognitive flexibility.

Other researchers have proposed broader and higher order conceptualizations of cognitive flexibility. Their formulations typically include multiple cognitive operations or the integration of multiple operations. Garcia-Garcia, Barcelo, Cemente, & Escera (2010) define cognitive flexibility as the ability to adapt goal-directed behavior in responses to changing stimuli. Similarly, Daek (2003) described CF as a dynamic activation and modification of cognitive processes in response to changing task demands. A study by Takeuchi et al. (2010) described flexibility as the ability to produce responses from a wide perspective. These conceptualizations are dramatically different from the narrow and specific perspectives noted above. Also evident is the congruence between how these researchers define CF and the way most researchers describe executive functioning. If executive functioning is the ability to marshal various cognitive resources in order to produce goal directed behavior, then it appears that for these researchers cognitive flexibility is the ability to do so efficiently and effectively.

Limitations in the Study of Cognitive Flexibility

One of the limitations in studying cognitive flexibility is a problem shared in the study of many mental operations: namely the task impurity problem (van der Sluis, Jong, & van der Leij, 2007.) Cognitive tasks are rarely discrete from other mental operations where multiple systems and operations must take place in order to achieve a goal. For example, when completing a common test of CF, the Trails B test, a participant must utilize cognitive resources related to visual scanning, motor movement, processing speed, set sequencing, set-shifting, and inhibition. In many cases, such overlap is inevitable as this is what is required to perform the task. However, it makes interpretation of results more challenging as there are additional factors to consider and introduces the possibility of confounds (de Almeida Valverde Zanini et al. 2012).

Cognitive Flexibility Literature

There is an increasing amount of research literature related to cognitive functioning with a common search producing thousands of results with the overwhelming majority of articles produced in the last 20 years. This interest has led to research into impact of this construct in a wide range of specialties and in relation to a wide array of problems. For example, the role of cognitive flexibility (or inflexibility) has been studied in relation to anorexia nervosa (Brockmeyer et al. 2014; Lounes, Khan, & Tchanturia, 2011), obsessive-compulsive disorder (Whitton, Henry, & Grisham, 2014), and the experience of bicultural stress (Lau, 2013). The range of topics also includes CF among individuals with developmental delays (Campbell, Landry, Russo, Flores, Jacques, & Burack, 2013), conduct disorder (Pihet, Suter, Halfon, & Stephan, 2012), and hypomanic personality (Fulford, Feldman, Tabak, McGillicuddy, & Johnson, 2013).

The instruments utilized to measure cognitive flexibility are as diverse as the areas in which researchers are interested. Some studies utilized the instruments used in the study of executive functioning. For example, studies have used the WCST (Dywan, Segalowitz, & Unsal, 1992; Van Eylen, Boets, Steyaert, Evers, Wagemans, & Noens, 2011; Juhnco, Wutherich, & Rapee, 2013) and the Trail Making Test Part B (Kortte, Horner, & Windham, 2002; Tchanturia et al. 2004; and Schirmbeck et al. 2013). Investigators have also employed the stroop color word inference test (Ramirez & Aida, 2012; Herschl, Highland, & McChargue, 2012) and versions of the Tower test (van der Linden, Frese, & Meijman, 2003.)

To add to the complexity, novel instruments were developed by researchers to measure specific elements presumed to be related to CF. For example, the task-switching paradigm was extended to include switching between alternate presentations of male and female faces with either angry or happy expressions (de Vries &Geurts, 2012). While this is a clever extension of a task-switching approach, it is not directly comparable to a switching task that requires individuals to switch governing rules. In a study of the relation between positive emotions and cognitive flexibility Nath & Papri (2014) utilized a shape detection task. A set of researchers developed an intervention based on Cognitive Remediation Therapy and called the results of their work an increase in client cognitive flexibility (Brockmeyer et al, 2014). It should be noted that these examples are not an exhaustive list of the instruments utilized in the study of cognitive flexibility.

The greatest problem facing the study of cognitive flexibility is the numerous measures employed to measure the construct. This would not be a problem if there was coherence in the array of available instruments. However, that is currently lacking and there are currently in use an abundance of tools all purportedly measuring the same construct. Without empirically established correspondence among the measures, it is not possible to draw comparisons across studies. Even when studies aim to measure the target phenomenon (i.e. cognitive flexibility in persons with depressive symptoms), conclusions are problematic at two levels. In the first place, if the study utilized a measure of CF lacking rigorous development then the results of that study are in question. Secondly, it is problematic to draw inferences across studies when any one of them utilizes instruments lacking previous empirical support or when the relation of one instrument to another is unknown.

Self-Report Measures of Cognitive Flexibility

The measures of cognitive flexibility previous noted were performance tasks. These instruments required participants to perform a physical task that presumably tapped into the construct of CF. The WCST required participants to sort cards according to rules that change without warning. The Trail Making Test Part B required participants to quickly draw a line on a page connecting alternating sequences of numbers and letters. The tower test measured someone's ability to move and stack pre-ordered blocks into a target configuration following specified rules. These instruments measure some aspect of CF by asking the participants to perform some action. In contrast, there are other researchers to have measured CF by asking participants to assess and rate their own abilities.

In addition to these types of instruments, two self-report measures of cognitive flexibility have also been developed. These instruments, like other questionnaires, ask participants to rate their abilities in relation to CF. The first instrument developed was the Cognitive Flexibility Scale (Martin and Rubin, 1995) and is the most commonly used self-report measure of cognitive flexibility. The Cognitive Flexibility Inventory (Dennis & Vander Wal, 2010) was developed more recently.

The Cognitive Flexibility Scale. The first published self-report measure of cognitive flexibility is the Cognitive Flexibility Scale (Martin & Rubin, 1995.) This 12-item instrument was originally developed to measure communication flexibility where participants select a response on a 6-point likert scale. Items on this instrument include: "I can communicate an idea in many different ways;" "I am willing to work at creative solutions to problems;" and "I have the self-confidence to try different ways of behaving." A generous assessment of this instrument would conclude that this instrument measures a self-appraisal of flexibility in thinking and behaving. A critical critique of this instrument would conclude that at best it is limited to self-evaluation of flexible communication.

This instrument is currently in use in the research literature as a measure of cognitive flexibility alongside the performance tasks previously described. Either knowingly or unknowingly, researchers are utilizing this instrument in ways that are likely beyond its limitations. For example, in a study recently published study on the interactions among minority stressors, bicultural self-efficacy, and cognitive flexibility in the mental health of bisexual individuals, the authors utilized the CFS (Brewster, Moadi, DeBlaere, & Valez, 2013.) The CFS was also used in a study that examined the predictive potential of attachment style, irrational beliefs, and current psychological symptoms on cognitive flexibility (Gunduz, 2013). This measure was also recently utilized in a study of resistance to organizational change (Su, Chung, & Su, 2012). Palm and Follette utilized the CFS to study the role of CF and experiential avoidance in explaining the psychological distress experience by survivors of interpersonal victimization. The authors use the term cognitive flexibility as synonymous with "psychological flexibility" and refer readers to another article for further explanation. In a study of use of mindfulness to improve cognitive flexibility in order to reduce symptoms of GAD, Lee and Orsillo (2014) utilized the CFS. The authors acknowledged that the CFS was originally designed to measure self-perception of communication flexibility, but justified using it by citing its use in other studies of cognitive flexibility.

The current utilization of this instrument in particular underscores the importance of clarifying what is meant by the term cognitive flexibility. Subsequently, it is imperative accepted practice develop as to which instruments and paradigms are appropriate for the study of CF. For example, the selection of the WCST and the utilization of a set-shifting paradigm would be appropriate given that the researcher was intentionally defining CF to include that particular set of mental operations. Likewise, a researcher may appropriately utilize a form of the tower test if that investigator defined CF as an ability to formulate and execute a plan.

These approaches are rationally defensible and supported by theoretical and empirical data to justify their use and give credibility to the validity of the results. An approach that does not meet this standard would be to cite that others have used an instrument and rely solely on precedent to justify its use. Likewise, selecting an instrument out of convenience (such as the 12-item CFS) lacks the methodological rigor one would expect of a professional researcher. When these methods are employed, it serves only to bring up questions as to the validity of the results and thereby introduce additional ambiguity to an already complex field of study.

The Cognitive Flexibility Inventory. The cognitive flexibility inventory (CFI) (Dennis &Vander Wal, 2010) was more recently developed. It is a 20-item questionnaire where participants select an response on a 7-point likert scale ranging from strongly disagree to strongly agree. This psychometric properties including both internal consistency (in the 0.84 to 0.91 range) and test-retest reliability (0.73). This test was developed to measure the degree of restricted cognition related to depression as informed by cognitive behavioral theory (Dennis and Vander Wal, 2009). The initial development study also found adequate convergent validity with the CFS and divergent validity with the Beck Depression Inventory- 2nd edition. In constructing this measure, the authors strove not only to create a psychometrically sound instrument, but also to begin to determine its relation to other measures of cognitive flexibility and other relevant constructs.

This instrument has been utilized by two other studies in the measurement of cognitive flexibility. In addition to the CFS, it was utilized by Moore (2013) to indicate that cognitive flexibility and mindfulness were predictors of what are called flow experiences. In a occupational psychology setting, Burkolter, Kluge, Sauer, & Ritzmann, 2009) used the CFI and personality variables to predict the performance of process control operators in the performance of their duties. It should be noted that the full text of this article is not currently available. Its publication date precedes the date of the publication date of the CFI. It is unclear if the authors obtained an advance copy of the instrument prior to final publication or if they used a different unpublished instrument under the same name. This example again underscores the level of ambiguity present in the research literature related to executive functioning.

For the purposes of this study, self-report measures are excluded from the test battery. They are described in order to provide context of the state of the research literature. The seriousness of the problem of heterogeneity of the operationalization of the CF is substantial and encumbers progress. To highlight the limitation, a meta-analysis of CF in the literature would be potentially misleading, at best.

Chapter 3

Procedures

Demographic Description of the Sample Population

The data were obtained from a database of patients who sought psychological and neuropsychological testing services at an outpatient health psychology practice. Each of the patients were referred for testing by a doctor for one of several possible reasons. The referral questions received by this practice include diagnostic clarification, to assess the degree of current cognitive impairment, and to provide treatment guidance. Referring physicians were primarily neurologists, but referrals were received from primary care physicians as well as psychologists. The scope of the outpatient practice includes other testing services. However, the database is dedicated to neuropsychological testing and excluded data from other types of testing conducted in the office.

Participants in the study are adults who were referred for neuropsychological testing. The participants range in age from 18 upwards. The participants are patients typically referred by another medical professional (e.g. neurologist, primary care physician, psychologist, counselor) for the purpose of diagnostic clarification. This resulted in a broad sampling of participants covering a wide age range as well as presenting problems. All participants signed an informed consent form prior to the beginning of testing.

Inclusion Criteria

For inclusion of the study, participants were adults who were able to complete neuropsychological testing at an outpatient health psychology practice. The practice is focused almost exclusively on an adult population. Although on rare occasion the practice will consult with a minor, only scores from adult patients were used in the analysis. The clinical sample also includes a broad range of abilities both innate to the individual and in relation to a medical or psychological condition. The data included scores from the individuals that were able to complete the test battery, independent of their actual performance. For example, an individual undergoing testing for concern regarding a degenerative neurological disease with global cognitive impact (i.e. Dementia) was included provided that the patient was able to complete the testing.

The individuals referred for testing were generally those for whom diagnostic testing would be beneficial and for whom a diagnosis is unclear. For instance, those individuals with advanced neurodegenerative processes would not be referred because the benefit of intensive neuropsychological testing is unwarranted. In the event that an individual was diagnosed with a condition such as dementia, these individuals were generally in the early stages of the disease. When performance on initial measures of cognitive functioning indicated that the patient's cognitive deficits were in excess of those reported by self or others, the test battery was modified to eliminate measures and substitute more appropriate measures. This frequently indicated removal of the Wisconsin Card Sorting Test and potential inclusion in the study database.

Exclusion Criteria

Participants were included as part of the study based on their ability to complete the necessary measures. Data from minors was excluded from the dataset. The data was excluded from participants where testing was prematurely terminated for any number of reasons (e.g. fatigue, desire to discontinue testing, interference from medical or psychological conditions that severely impeded testing.) In this clinical setting, the testing battery is flexible and tailored to the referral question. In accord with professional and ethical standards not all measures were administered to all patients but only those clinically appropriate for the referral. Thus, the data analysis excludes patients for whom the appropriate data points were unavailable. The study also excluded patients who presented to the clinic for bariatric pre-surgical clearance testing. The test battery for these patients included only one of the measures of interest (i.e. the Iowa Gambling Task) and so were inappropriate for the current study.

Currently, the practice serves adults age 18 and over and so the data extricated included only adults ($N = 119$). The age of participants ranged from 19 to 77 ($M = 53.79$, $SD = 13.80$). Women represented 57.1% of the sample ($n = 68$) and men constituted 42.9%, ($n = 51$). There were no statistically significant differences in the ages of men ($M = 55.37$, $SD = 14.33$) and women ($M = 52.6$, $SD = 13.28$). Additionally, women ($M = 14.78$, $SD = 2.55$) and men ($M = 15.33$, $SD = 2.60$) attained similar levels of formal education.

The sample population was predominately white ($N = 102$, 87.5%). The sample included ten participants that identified as African American (8.4%) and five participants that identified as Latina/o (4.2%.) One participant identified as Asian/Asian American while one other identified as multiracial. A one-way ANOVA indicated that there was no significant difference in age in terms of race/ethnicity ($F(4, 114) = 1.237$, $p = 0.299$. Additionally, the various racial/ethnic groups in the sample population did not differ in regards to formal education, One-way ANOVA $F(4, 114) = 0.217$, $p = 0.928$. A summary of the participant demographic characteristics is displayed on Table 1.

Study Design

The overarching question examined the underlying factor structure of the construct of cognitive flexibility. The study obtained data from a database of scores on neuropsychological tests administered to adults in an outpatient health psychology practice. The correlational study examined the performance of individuals on several measures in order to elucidate the underlying factor structure of the concepts under investigation.

The multiple debates and competing models attempting to conceptualize executive functioning (Jurado & Rosselli, 2007) and cognitive flexibility (Ionescu, 2012) indicate that there is still a lack of clarity regarding how to best understand and study these constructs. This also indicates that there is interest in studying these phenomena and studies that work to move the field forward would be welcomed. In particular, studies that demonstrate the interrelationships among the various relevant components would be beneficial. Given the current state of ambiguity in regards to the conceptualization and operationalization of both executive functioning and cognitive flexibility, the current study was designed in the context of uncertainty and limitations.

The design, methods, instruments, and analysis selected for this study are an appropriate and prudent approach to study the construct of cognitive flexibility. The measures included in this study reflect the tests most widely and frequently used in studies of cognitive flexibility. The study design also effectively addresses the primary research questions. Namely, whether and to what extent the various measures of CF load as a unitary factor or into multiple factors. Additionally, the study will provide data regarding the interrelationship among the various performance tasks and hence provide guidance as to whether one test is a suitable substitution for another.

Procedures

The study is to be conducted as a review of data collected from a clinical population in an outpatient health psychology practice. The data was obtained through the customary operation of neuropsychological testing with adult patients referred for evaluation. The testing was administered by either a licensed psychologist or by a professional psychometrist under the supervision of a psychologist. The spaces will contain desktop personal computers loaded with the required testing software as well as adequate furnishings and space for the person-administered elements of the study. Of the tests of interest for this study, two are computerized in which the participant completes the task by pointing a mouse on a computer screen. Two of the others are administered person to person following administration rules. All tests were then scored by computerized scoring programs in order to optimize scoring accuracy.

Instrumentation Selection

The individual test and subtests of this study were selected in order to measure distinct aspects of cognitive functioning. Each of these tests has been employed in the direct or indirect study of CF and so are included here. The contributions of each of instrument are displayed in Table X. The scores selected for analysis were those for instruments that have a history in the CF literature and were all completed by the participants on the same testing session.

The following battery of neuropsychology measures was constructed in order to assess the construct of cognitive flexibility via performance tasks. The tests were selected for this study in order to balance the goal of comprehensive investigation with respect for the burden placed upon participants. The instruments that were selected are described below along with the distinct contribution of each. The research literature contains examples of each of the measures having been previously utilized in studied of cognitive flexibility (Miyake et al., 2000; Champagne-Lavau, Charest, Anselmo, Rodriguez, & Blouin, 2012; Ramirez, Garcia, & Valdez, 2012). Though, in the majority of studies, only one measure of cognitive flexibility or if more than one measure was given, the two scores are not compared to one another (Huizinga, Dolan, & van der Molen, 2006; Rodriguez-Aranda & Sundet, 2006; Samanez0Larkin et al., 2013). The result is that direct comparison across measures is problematic.

Each of the measures described below can be conceptualized as a switching task, examination of the details of their administration and associated cognitive processes revealed that different types of switching were involved. Moreover, the modality of or paradigm of response varied between tests (e.g. verbal versus non-verbal, timed versus untimed, etc.) While a degree of similarity and overlap is understandable, there were substantive differences to the degree that simultaneous administration was justified as each contributed unique useful information.

The Wisconsin Card Sorting Test. The WCST is a neuropsychological instrument used to measure multiple aspects of executive functioning. In this case, it was utilized to measure CF conceptualized as a switching task. The most commonly used measure of CF has been the Wisconsin Card Sorting Test (WCST.) In fact, it has been called the gold standard for measuring the construct (Corcoran & Upton, 1993). The WCST is a neuropsychological instrument used to measure multiple aspects of executive functioning. In this case, it was used to measure CF historically conceptualized as a switching task. The instrument in its computerized form required participants to decide a rule by which to organize a set of cards (i.e. by number, color, or shape). The only feedback the participants received from the program was whether the selection was correct or incorrect. Once a participant figured out a rule and successfully completed a series of

10 correct card selections, the rule switched. In the WCST, CF is measured by a participant's ability to respond to feedback and switch with the rules and then maintain the new rule until it switched again. The test required the participants to apply abstract nonverbal reasoning to successfully respond. The participants had to use a recurrent sequence of valid deductive reasoning skills to discover the rule, followed by inductive reasoning skills in order to make accurate selections based on that rule, and deductive reasoning skills again when the rule switched.

Several scores were derived from performance on the WCST. These scores correspond to several elements of cognitive flexibility when conceptualized as an ability to switch between guiding rules in response to feedback. The scoring system provided an overall standardized score indicating the total number of correct selections. The scores provided include: Total Correct; Total Errors; Perseverative Responses; Perseverative Errors; Non-perseverative Errors; Conceptual Level Responses; Categories Completed; Trials to Complete 1st Category; Failure to Maintain Set; and Learning to Learn. For each of the error scores, an additional percentage score is available. For example, the Percent Perseverative Errors score would be a percentage of the total match attempts that were classified as perseverative errors. For example, standardized scores were available for the number of perseverative errors a participant committed. An error is considered preservative when, following a rule switch, a participant continues to use the previous rule to select cards. Thus, the participant is said to perseverate on the previous rule and not adapt in response to feedback. This was on the basis of continuous, albeit limited, feedback.

The multiple standardized and norms scores available for the WCST are useful for diagnostic purposes in neuropsychological practice assessing for executive functioning (Jodzio & Biechowska, 2010; Worford & Lewine, 2019; Martin, Oren, & Boone, 1991.) To measure cognitive flexibility with the WCST, previous studies focused on the Perseverative Errors score (Van Eylen, et al., 2011; Riley, Moore, Cramer, & Lin, 2011 or the Number of Categories Completed score (Bosia et al., 2010) when utilizing only one score. However, most researchers included several of the obtained scores in their analysis. Although all the above mentioned scores were available for each participant, for the purpose of addressing the research questions in this proposed study only a relevant subset of available scores was included in the analysis.

Among the research questions of this study is an analysis of the interrelations of the various measures utilized in the study of cognitive flexibility. Therefore, the instruments selected and scores obtained would be in a relatively stronger position to inform the research questions as they reflected what has been utilized in the field to this point. The following scores from the WCST were included in the study: Number of Perseverative Errors; Number of Non-Perseverative Errors; Number of Total Errors; and Categories Completed. Previous studies of CF selected a range of available WCST scores as the variable of interest (see Table 2). These data points were selected for analysis in order to be inclusive in relation to the research literature as well as for conceptual reasons. It was also important to consider the multiple types of score profiles that emerge from various levels of proficiency with the task. Perseverative errors are indicative of a perseveration on a concept. Non-perseverative errors are all other kinds of errors and may represent a search strategy, random responding, etc. It is possible for a participant to have few perseverative errors and yet have an unusually high number of non-perseverative errors. With a random response style such as that, a low score on perseverative errors would not indicate a flexible approach but rather highly disorganized performance. For this reason, both types of error scores were chosen. The total number of errors and, inversely, the number of categories completed can be conceptualized as a measure of overall proficiency with the task. It is possible for a participant to commit an average number of errors of either type and yet have a low number of completed categories due to a failure to maintain set. These four scores were selected in order to assess for an adequately broad range of possible performance profiles.

Delis-Kaplan Executive Functioning System. The Delis-Kaplan Executive Functioning System (D-KEFS) is a neuropsychological instrument designed to measure multiple aspects of executive functioning and is divided into six subtests. For this study, the subtest selected from this instrument was the Color-Word Interference test, (commonly known as the Stroop test) (CWI). This subtest was selected to address two distinct areas of executive functioning found in the research literature related to CF (Mouratidis, Bolla, Funderburk, Kimes, & Cadet, 2001; Mittal, Mehta, Solanki, & Swami, 2013; and van der Linden, Frese, & Meijman, 2003). The Color-Word interference test measures a form of switching different from that measured by the WCST. In this task, participants were required to switch from reading words to naming colors according to instructions. The test consisted of four iterations of this task, each with slightly different instructions and requirements. On the first variation, the participant was instructed to quickly name the color of a series of color patches (i.e. red, blue, or green). The next variation required participants to quickly read the names of the same colors printed in standard black ink on a white background. The third variation required participants to identify the color ink in which contrary color names are printed. For instance, if the word red was printed in green ink, the participant was instructed to say “green”. This task required the participant to inhibit the automatic process of reading in order to name the color ink. The fourth and last variation built off the previous one. In this case, each of the words was printed in a contrary color ink. However, this time some of the words were also enclosed in a small box. The participants were instructed to name the color ink for the words. But, if a word was inside a box, they were instructed to read the word and not name the color ink. The participant is challenged to switch between rules to inhibit the automatic process of reading.

The Color-Word Interference (CWI) test provided scores along two primary dimensions related to cognitive flexibility. It is a measure of inhibition, namely the ability to inhibit the automatic process of word reading in order to name the color ink in which it is printed. This is commonly knowns as the stroop task. The final variation required the participants to switch back and forth between reading the word and naming the color. In this way, participants alternated between the rules by which he or she responded. Being a timed task, scores were available for performance time and performance accuracy. For the purpose of this study, the scores extracted for analysis were Condition 3 Time, Condition 3 Errors, Condition 4 Time, and Condition 4 Errors.

As described above, Condition 3 and Condition 4 of the CWI test are the most closely related to the stroop task. Condition 3 is a pure version of the stroop task, while Condition 4 has the additional layer of switching. Thus, Condition 3 is a widely used measure of CF found in the literature. With the additional challenge of switching, Condition 4 more closely aligns with the conceptualization of CF as a switching task. And so, both conditions were selected in order to utilize a measure found in the research literature as well as address the questions of the study. In completing this timed task, it is important to measure both performance speed and accuracy as both dimensions are independent. It is possible for a participant to be quick and yet be highly inaccurate, slow but accurate, slow and inaccurate, etc. It was therefore decided to include both dimension and from both conditions in order to most fully address the research question.

Trails-B. The Trail Making Test (TMT) is one of the most widely used neuropsychological tests. In fact, it was one of the original six tests developed for the Army Individual Test Battery (Stanczak, Lynch, McNeil, & Brown, 1998.) Multiple versions of the test have been developed to address limitations such as its application to non-Western participants (Bancord & Wanlass, 2001; Zhao et al., 2013); its use with younger patients (Epsy &Cwik, 2004); and it is translated to other languages (Bezdicek, et al., 2012; Razzack, 2013.) Alternate forms of the TMT have also been developed as parallel forms in order to address the effects of learning as in the case where multiple administrations are given to track neurological recovery (Atkinson, Ryan, Kryza, & Charette, 2011).

The Trails-B test is a widely used instrument in neuropsychological practice and is often given in tandem with Trails-A (Chan et al, 2015). Trails-B requires participants to trace a sequence of characters on a page. This sequence alternates between numbers and letters in ascending order. For example, a participant will begin with the number one, then trace to the letter A, then to the number two, followed by the letter B, and so on. Thus, this task requires participants to hold both the numerical as well as the alphabetic position in their working memory in order to trace the proper sequence of points. The timed test is a switching task that requires the participant to alternate between sequential members of two distinct sets, measuring set switching. This test provides for a nonverbal measure of set shifting while the CWI test measures this construct via verbal presentation and response.

The test consisted of a series of characters randomly spaced on a page where participants were instructed to quickly and accurately draw lines sequentially from character to character. The items were spaced in such a way that tracing through the sequence correctly did not require participants to cross previously drawn lines. This was a timed test in which the score obtained was the number of seconds a participant requires to complete the trial.

While each participant completed both Trails-A and Trails-B, only the score from Trails-B was included in the study. In addition to the cognitive functions of processing speed, visual scanning, and motor speed, Trails-B included a set-switching component that implicated cognitive flexibility. Additionally, a recent reevaluation of the construct validity of the Trail Making Test confirmed a significant relationship between Part A and Part B (r= .73), suggesting the two tests share common factors (Sanchez-Cubillo, et al, 2009). Thus, the exclusion of Trails-A did not result in a significant loss but rather reflects an efficient way to measure corresponding cognitive processes.

Data Collection

The data utilized in the study was obtained from an existing database of neuropsychological instruments. The data was collected in the course of normal clinical operation and delivery of clinical services of an outpatient health psychology clinic. The data was archived in a secure database and stored in that same location for the purpose of availability for future research. Permission to use the archival data for this study was obtained through the University of Georgia Institutional Review Board for research involving human subjects. Participants were not recruited for the study and no participant was contacted regarding their previous involvement in testing. Scores were extracted according to the inclusion and exclusion criteria. Raw scores were utilized in the data analysis

Statistical Processes for Analysis

The primary aim of the study was to examine the factor structure of cognitive flexibility and the interrelationships between the various measures currently utilized in the research literature. Utilizing guidelines recommended by Izquierdo, I., Olea, J., & Abad, F. J., (2014), an exploratory factor analysis was employed. The current study had sufficient power to determine statistical significant in that the sample size exceeded the recommended 10 data points per variable. Given the exploratory nature of the study, this was determined to be the best initial statistical procedure. The study assessed whether scores on these measures correspond to a unitary factor or on multiple factors. Without previous studies available in the research literature as guidance, this study provided initial steps in addressing this gap in the literature. Descriptive statistics were utilized in order to describe the sample population measured in this study.

Limitations

There are several limitations to the study which should be noted when reviewing and considering the results and conclusions of the study. This factor may limit the generalizability of these results to the general population.

The composition of the study population was passively collected in the course of normal operation in an outpatient neuropsychological clinical. As such, the participants included were those systematically selected by pertinent factors. Each of the participants had healthcare benefits with a third-party payer at the time of their evaluation. As neuropsychological testing is expensive, this was a significant access barrier for individuals without some form of insurance (employer sponsored health plan, Medicare, etc.). While the practice did not exclude individuals based on economic status, the nature of a pay for service office in the current economic and healthcare systems may have limited or selected out those individuals with lower SES. The participants self-identified as White or Caucasian comprised the overwhelming majority of the study sample. The results of this analysis may have generalizable utility to White adult neuropsychology patients in a similar setting, but has limited utility for minority populations.

In the absence of a control group, it is unclear that the results are generalizable to healthy adults. Additionally, there was heterogeneity in the presenting problems for which participants were referred for testing. Thus there were individuals presenting for evaluation following a stroke, following a traumatic brain injury, following a concussion, due to complex medical problems, or concerned with memory functioning. Given the plurality of impairment etiologies and possible confounding variable no conclusions can be drawn regarding the impact of any specific condition on an individual's cognitive flexibility.

The order of test presentation is also a consideration. In a laboratory setting, researchers are afforded the opportunity for greater control in managing variables. In a clinical setting, the intrusion of extraneous variables is more difficult to avoid. When participants were administered the instruments of interest they were also administered the other measures as part of neuropsychological testing. Thus, two factors arise from this situation that have the potential of impacting study results. There was no standard administration order for the measures of interest. Therefore, no mechanism in place to counterbalance the order in which participants completed the tests. Moreover, there was no way to determine if each of the participants completed the tasks in the same order. In addition, the measures were completed immediately following and/or immediately preceding other measures. As a result, possible confounds including learning with repeated exposure, crossover effects, and fatigue cannot be ruled out.

Assumptions

There are assumptions regarding the study design, sample group, materials, and analysis that are pertinent to the study. These assumptions are considered reasonable and justifiable as part of the study process and are important to acknowledge. While the term assumption may have a negative connotation or valence, it is a necessary part of natural experience as well as scientific endeavor. The value is not in denying the presence of assumptions or working to eliminate them but in identifying and examining them.

In terms of participants, it is assumed that participants consented to participating in neuropsychological testing. As an extension, it is assumed that the participants provided full effort on the tests administered. Effort is a crucial component in performance based psychological measures (Foussias et al, 2015). This is particularly evident on timed tests and on measures where items are ordered in ascending levels of difficulty in which a ceiling is reached. It is assumed that the patients also had the physical capacity to complete the required tasks. These tasks required vision and hearing and psychomotor ability. It is assumed that in the event of a limitation, the participant had appropriate accommodations (e.g. prescription glasses, hearing aids, etc.). Otherwise, it is assumed that reasonable accommodations were provided (e.g. repeating instructions.) It is assumed that the participants were able to accurately distinguish between colors or that this deficit would have been made evident in the practice trials of the DKEFS-CWI test. It is further assumed that the participant was able to comprehend the test instructions in standard English.

In regards to the testing materials, it is assumed that that test stimuli were in a manner that accurately assessed the intended cognitive ability. Since only raw scores were extracted and no converted or standardized scores were utilized, the validity of the instruments is less of a factor but the reliability continues to be of importance. The WCST is available in both hand administered card version as well as the computerized version. In this study each of the participants completed the computerized version. It is assumed that the results of the computerized administration are a valid representation of the participant's cognitive functioning.

As it relates to the study design and statistical analysis, it is assumed that the impact of uncontrolled extraneous variable is reasonable. It is assumed that the current sample size is sufficient to address the research question given the statistical procedure. In the context of a lack of consensus of sample size necessary for an exploratory factor analysis, the current ratio of participants to variables is considered acceptable. In a laboratory setting where healthy participants can be recruited in large numbers a more stringent threshold might be required. In a clinical population where data collection is both time and resource intensive, a more tolerant threshold is the tradeoff for access to this limited population.

The Hypotheses

Cognitive flexibility has been defined in different ways and measured using differing methods and instruments in the research literature. Given the conceptual and psychometric differences in these approaches, there are a few logical explanations for the current state of affairs. Possibilities include that researchers happen to use the same term to describe different phenomena and are unaware of other uses. Authors might be using the term to describe an aspect of CF and acknowledge there are other aspects. Researchers are presenting their conceptualization and operationalization as the best description of the phenomena. The first two possibilities are considered more likely than the last possibility given the state of the research literature and lack of published investigations examining the study of the concept of cognitive flexibility as a primary concept. The first hypothesis is that different conceptualizations of a construct that are operationalized in different ways are not measuring the precise same construct. They may measure similar constructs, related constructs, or different aspects of the same construct but do not measure the same exact construct.

In the cognitive flexibility research literature, the three measures utilized in this battery conceptualize CF as a switching task but each do so in different ways. On Trails-B, it is conceptualized as switching between two parallel sets of series. In the Wisconsin Card Sorting Test, it is conceptualized as the ability to apply reasoning and logic to switch categories based on feedback. In the Color-Word Interference test, it is conceptualized as the ability to switch between sets of rules. While the three measures purport to measure CF as a switching task, they measure it in distinct ways.

The paradigm of test administration is also different for each of the three measures. The WCST is presented on a computer screen without time limit, allowing the participant ample time to reflect upon feedback and select their next response. Once a response is made and feedback is provided, participants cannot change their answers. They are instructed to use the feedback to respond on subsequent trials. Trails-B is a timed task with both visual scanning and psychomotor integration. The DKEFS-CWI tests require the participant to read and respond verbally. This measure is also administered under the added pressure of a time constraint. In addition to the differing conceptualizations of set-shifting or set-switching, the modality of the instruments differs. It surmised that while the three measures share features, they are not measuring the exact same construct. It was hypothesized that the scores on each measure would vary independently from the other measures.

The research hypothesis was that there were no differences between the scores on the various measures. A finding that there were no significant differences among the various scores (i.e. loading onto one factor) would indicate a failure to reject the null hypothesis. If the exploratory factor analysis (EFA) is indicative of more than one factor, this would lead to a rejection of the H_o and support for the research hypothesis. Investigation of the pattern of factor loadings was additionally informative as the conceptual understanding of the score pattern was meaningful.

Chapter 4

Research Findings

The primary aim of the study was to examine the extent to which the three selected measures of cognitive flexibility converged or were distinct. In the research literature these instruments, among others, were utilized interchangeably to assess CF. While there is debate as to how conceptualize the concept of CF, the most common conceptualization is that of cognitive switching. The three measures utilized in this study are all considered switching tasks. They are the Wisconsin Card Sorting Test (WCST), the Delis-Kaplan Executive Functioning System Color-Word Interference Test (DKEFS-CWI), and the Trails-B test. A cursory review of the measures might give the impression that the three measures assess the same cognitive construct. A relatively more detailed assessment of the instruments suggests that the three approaches measure different types of cognitive switching. Therefore, it was hypothesized that the three tests measure three different aspects of construct of CF rather being alternative approaches to measuring the same construct.

The three tests provide multiple scores for possible analysis and the scores most pertinent to the study question were selected. The only score available for the Trails-B test is the time (in seconds) needed to complete the test. On the DKEFS-CWI test, condition 3 and condition 4 were selected. Condition three corresponds to the stroop task widely used in psychological research. Condition 4 is an extension of stroop task with the additional component of switching between rules. Scores were available for time to complete the task as well as the total number of errors. Both scores were selected for both conditions. For the WCST the scores selected for analysis were the total Categories Completed, Total Errors, Number of Perseverative Errors, and Number of Non-Perseverative Errors. A total of nine scores were extracted for analysis for each participant.

The null hypothesis in this study was that the three instruments were equivalent measures of CF and assessed the same underlying cognitive construct. An exploratory factor analysis that provided a one factor solution would indicate a failure to support the null hypothesis. It would suggest that the scores on the various measures varied together as a unit measuring the same underlying factor. An exploratory factor analysis that provided a two or more factor solution would provide support to reject the null hypothesis. This would suggest that the instrument measured more than one latent factor. A decision to reject the null hypothesis would also support the conceptualization of cognitive flexibility as a multifactorial construct rather than as a unitary construct.

A total of 119 cases were identified in the database that met the inclusion and exclusion criteria. The statistical procedure selected to address the research question was an exploratory factor analysis. This technique is utilized as a way to assess the degree to which items vary in groups. The inference is that items that group together measure a common latent factor. In this case, the procedure was applied in order to assess the degree to which the scores from the selected instruments assessed the factor or factors of cognitive flexibility.

Correlation Matrix of Measures of Cognitive Flexibility

	Trails-B	CWIIT	CWIIST	CWIIE	CWISE	WCSTTE
Trails-B	1.000	-	-	-	-	-
CWIIT	.668	1.000	-	-	-	-
CWIIST	.566	.724	1.000	-	-	-
CWIIE	.201	.018	.035	1.000	-	-
CWISE	.394	.310	.556	.244	1.000	-
WCSTTE	.519	.313	.361	.028	.351	1.000
WCSTPE	.525	.272	.374	.054	.407	.867
WCSTNPE	.374	.265	.247	.017	.201	.866
WCSTCAT	-.451	-.209	-.230	-.045	-.243	-.871
*Sig.Trails-B						
CWIIT	.000	-	-	-	-	-
CWIIST	.000	.000	-	-	-	-
CWIIE	.014	.425	.351	-	-	-
CWISE	.000	.000	.000	.004	-	-
WCSTTE	.000	.000	.000	.383	.000	-
WCSTPE	.000	.001	.000	.278	.000	.000
WCSTNPE	.000	.002	.003	.429	.014	.000
WCSTCAT	.000	.011	.006	.312	.004	.000

Correlation Matrix of Measures of Cognitive Flexibility

		WCSTPE	WCSTNPE	WCSTCAT
	Trails-B	.525	.374	-.451
	CWIIT	.272	.265	-.209
	CWIIST	.374	.247	-.230
	CWIIE	.054	0.17	-.045
	CWISE	.407	.201	-.243
	WCSTTE	.867	.866	-.871
	WCSTPE	1.000	.502	-.769
	WCSTNPE	-	1.000	-.742
	WCSTCAT	-	-	1.000
*Sig.	Trails-B	.000	.000	.000
	CWIIT	.001	.002	.011
	CWIIST	.000	.003	.006
	CWIIE	.278	.429	.312
	CWISE	.000	.014	.004
	WCSTTE	.000	.000	.000
	WCSTPE	-	.000	.000
	WCSTNPE	-	-	.000
	WCSTCAT	-	-	-

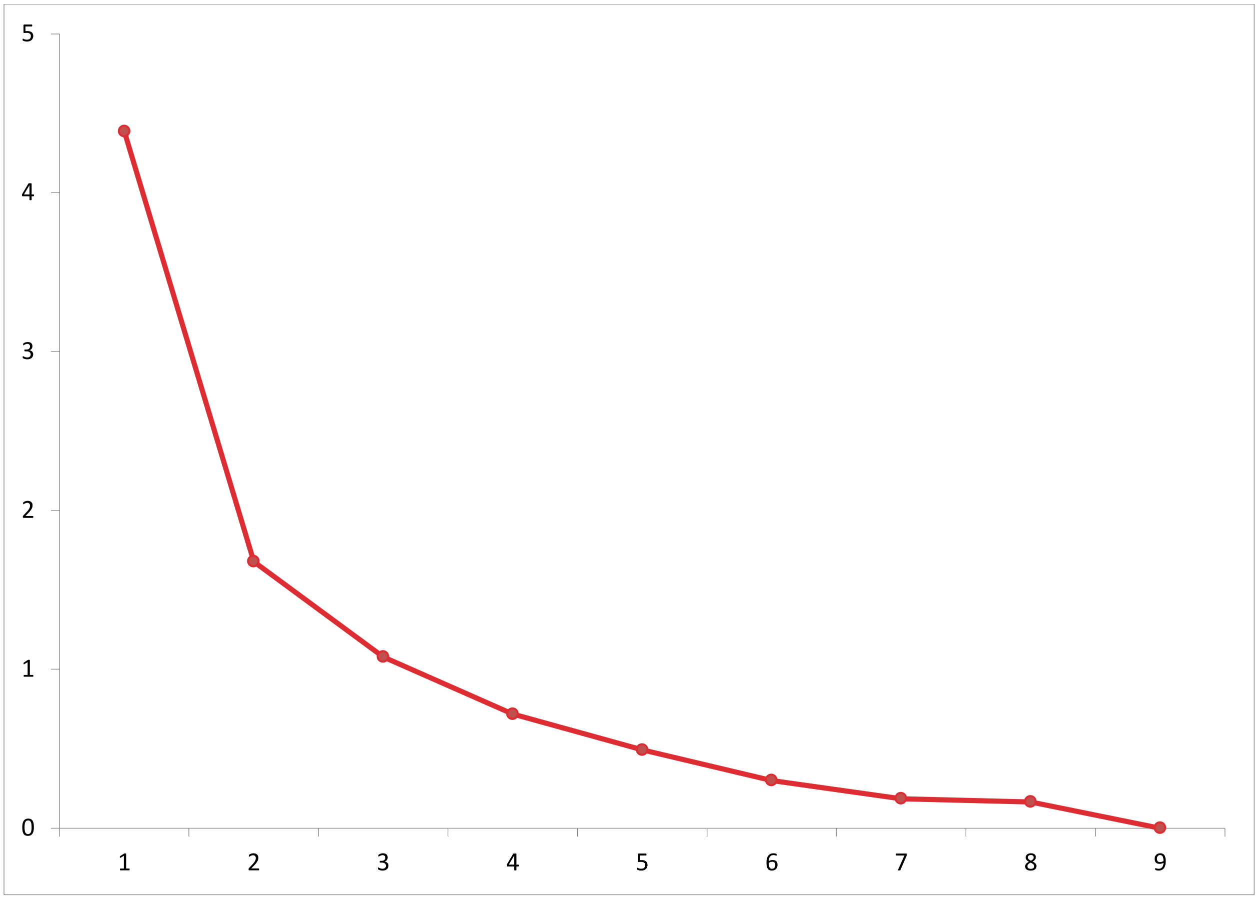
*Significance (1-tailed)

In order to test for sampling size adequacy, the Kaiser-Meyer-Olkin measure was applied and revealed a score of 0.517. With a minimum recommended score of 0.50, the study sample is considered an adequate clinical sample. Bartelett's test of sphericity revealed that there were significant differences X^2 (36, N=119) = 1616.725, p = .000. A principal component analysis was conducted and revealed that the majority of the variance in the scores was explained by the first three components.

Total Variance Explained

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	4.386	48.733	48.733
2	1.678	18.639	67.373
3	1.077	11.964	79.336
4	.718	7.977	87.314
5	.492	5.465	92.779
6	.300	3.337	96.116
7	.185	2.054	98.170
8	.165	1.829	100
9	2.767E-5	.000	100

Scree Plot



When displayed as a scree plot of eigenvalues, the scores indicated a three factor solution.

Component Matrix

	Component		
	1	2	3
WCSTTE	.909	-.390	-.007
WCSTPE	.831	-.248	.068
WCSTCAT	-.808	.473	-.038
TRAILSB	.755	.350	-.007
WCSTNPE	.743	-.429	-.058
CWIIST	.644	.608	-.201
CWIIT	.597	.592	-.332
CWISE	.553	.405	.324
CWIIE	.130	.219	.901

Extraction Method: Principal Component Analysis. 3 components extracted

Rotated Component Matrix

	Component		
	1	2	3
WCSTTE	**.959**	.237	.039
WCSTCAT	**-.930**	-.103	-.048
WCSTNPE	**.850**	.125	-.044
WCSTPE	**.813**	.279	.132
CWIIST	.140	**.896**	.044
CWIIT	.110	**.893**	-.092
Trails-B	.389	**.711**	.188
CWISE	.202	**.544**	**.489**
CWIIE	-.010	-.005	**.936**

Extraction Method: Principal Components Analysis. Rotation Method: Verimax with Kaiser Normalization. Rotation converged in 4 iterations. Loadings >.40 are in bold.

The factor analysis revealed a three factor solution with the scores from the Wisconsin Card Sorting Test loading consistently and exclusively onto one factor. Along with Trails-B, the two time scores from the Delis-Kaplan Executive Functioning System Color-Word Interference tests loaded onto a second factor. The Color-Word Interference Switching error score loaded onto the second as well as the third component. The Color-Word Interference error score loaded onto the third factor. In examining the pattern of scores, there are conceptual groupings that could explain the observed set of scores. The scores from the WCST grouped together and did not load onto any of the other factors. The items in which the score used was a total time score also grouped together. This factor could be considered a processing speed or performance speed factor. The third and final factor was less clear. The accuracy scores from the stroop task (CWIIE) loaded onto the third factor while the score for the stroop-switching task (CWISE) loaded onto both the factor with the speed measures and also the third factor.

Chapter 5

Summary Conclusions and Implications

Summary

Cognitive flexibility is a construct that has received increased attention in contemporary psychological research literature. It has been studied in relation to a wide range of emotional, behavioral, and cognitive phenomena. The construct has been examined in the study of schizophrenia, learning, circadian rhythms, deception detection, aging, and anorexia nervosa, to name a few. Thus researchers have demonstrated an interest in considering CF as a relevant factor in an array of phenomena and difficulties.

A major challenge for those interested in studying CF is that there is no consensus as to how to define the construct. By extension, there is also no consensus as to how to operationalize and measure CF. There are two primary groups of conceptualization. The most widely utilized conceptualization of cognitive flexibility is that of cognitive switching. Namely, it is the mental ability to shift between two or more cognitive sets or cognitive concepts. The other conceptualization is that of a problem solving ability (Barcelo, Cemente, & Escera, 2010; Daek, 2003; Takeuchi et. al, 2010). In this framework, it is conceptualized as the ability to generate multiple possible solutions to a problem and effectively select and apply the solution. The significant differences between the two approaches as well as within the two are highlighted when examining the differing ways in which it has been operationalized.

Within the research literature where researchers conceptualized CF as a set shifting ability there are significant differences in how the concept was operationalized. Studies utilized the Wisconsin Card Sorting Task (WCST), Trails-B test, stroop test, and various versions of the tower test. While these various measures can be broadly classified as switching tasks, careful examination indicates that the way in which the set-shifting or set-switching is operationalized varies from measure to measure. An additional layer of complexity was discovered in that researchers utilizing the same test did not consistently use the same scores from that test as a measure of CF. In Trails-B, participants trace lines that connect circles alternating between numbers and letters in ascending order. In version of the stroop test, participants are timed and challenged to inhibit the process of reading in order to name the color ink in which color words are printed. The WCST challenges participants to utilize feedback in order to determine the grouping principle of cards. Without warning, the grouping principle changes and participants are challenged to switch from the previous rule to a new rule.

The aim of the study was to test the assumption that the various measures of CF are equivalent alternative approaches of measuring the construct. The WCST was selected given its status in the study of CF. Scores selected for analysis included total errors, perseverative errors, non-perseverative errors, and categories completed. In addition to the WCST, two additional set-shifting measures were selected for analysis. The Delis-Kaplan Executive Functioning System Color-Word Interference test is a version of the stroop task. Two conditions were selected that were a version of the stroop task and also a version of the stroop task with an added switching component. For each of these measures, scores selected for analysis were total time and total errors. Total time scores for Trails-B were also extracted for analysis.

The assumption that the three instruments were alternative measures of the same construct was tested. The null hypothesis was that there are no differences between the measures and the scores would load onto one factor. This would suggest that the scores from the instruments measure the same underlying construct. The alternative hypothesis was that the scores would load onto two or more factors. This would suggest that the scores from the instruments tested measured two or more underlying constructs or aspects of a construct.

Findings

The results of the factor analysis indicated a three factor solution. The scores from the Wisconsin Card Sorting Test loaded exclusively onto one factor. A second factor contained scores related to the time required to complete a task. It could be conceptualized as a measure of processing speed. A third factor was less clear as it included scores from the accuracy of the DKEFS-CWI tasks. However, the accuracy score from the CWISE loaded nearly equally on this factor as well as the processing speed factor.

Given the results, the null hypothesis is rejected and alternative hypothesis is supported. The principal components analysis of the exploratory factor analysis indicated a two or possibly a three factor solution. The loading of WCST scores onto one factor was strong and clear. The loadings of all three time scores onto the second factor were also strong but less clear. This was due to the score from the Color-Word Interference Switching accuracy that loaded almost equally on the second as well as the third factor. Additionally, the third factor minimally met requirements to be considered a separate factor.

The alternative hypothesis indicates that the scores from the instruments assessed do not measure the same underlying factor. Thus, it does not support the use of these measures as equivalent interchangeable options in measuring cognitive flexibility. In light of the results, there are two possibilities as explanatory conceptualizations. The first possibility is that the instruments measure two different constructs. The second is that the instruments measure unique aspects of the same construct. The decision as to whether the instruments measure one construct with multiple aspects or if they measure distinct constructs is dependent upon the conceptualization of cognitive flexibility.

If CF is conceptualized as a set-switching ability, the distinct loading of scores onto their respective factors would suggest that there are different types of set-shifting. Ability in switching in one sense would not inform an individual's ability in another sense. If CF is conceptualized as a problem-solving

Implications

The strongest conclusion drawn from the study is that measures of cognitive flexibility cannot be used interchangeable as they measure distinct constructs or different aspects of the same construct. Caution is advised when selected an instrument to measure CF in order to enhance the likelihood that a researcher measure the intended mental operation. This requires an array of considerations in order to make a proper selection. A researcher should consider the manner in which the participant interacts with the test, the cognitive skills required to successfully complete the task, and which scores to utilize in the analysis.

For example, the Wisconsin Card Sorting Test was presented to participants via a computer program. There was no overall time limit and no limit on exposure to any trail stimuli. The participants were given vague instructions and then provided feedback following each item. The test required participants to remember the feedback from previous items, recognize a pattern by utilizing inductive reasoning and then sustain attention to keep using a rule. In this test, the switching was measured when following 10 consecutive correct responses, the rule switched and that participant had to switch with it by utilizing the skills described.

Switching, as measured on Trails-B, was operationalized in a significantly different way. The participant was tasked to quickly trace lines between ascending sets of numbers and letters. The skills involved were the ability to hold in working memory two sets of parallel lists, visual scanning, and psychomotor speed. Switching was operationalized as the speed with which an individual was able to successfully progress through the task. While both the WCST and the Trails-B test are considered switching tasks, they measure two different types of switching and require substantially different cognitive and physical skills.

In conjunction with the results of the factor analysis and the careful consideration of the demands of the various tasks, the study provides a data point to consider when defining cognitive flexibility. Posed as a question, when an individual stated the term cognitive flexibility do they mean the ability to quickly go back and forth between two lists? A definition so narrowed by the operationalization likely captures only a part of what the researcher intended to study. When using the term CF, researchers are likely intending a higher order cognitive process. Shifting or switching is a central element to cognitive flexibility.

An important consideration when selecting an instrument to measure CF is on what the researcher or clinician wants the participant or client to be flexible. For instance, when working with an individual following a traumatic brain injury or a stroke, the aim is to assess and hopefully enhance flexibility in a beneficial manner. If the client expressed difficulties with keeping track of information in a fast paced environment, then a timed measure such as Trails-B might be a more appropriate selection.

In a clinical setting the measurement of cognitive flexibility can be informative not only from a diagnostic perspective but also from a treatment perspective. As noted by Dennis and

Vander Wal (2010) individuals experiencing depression tend to have a narrowed view of their options and their future. These individuals have a difficult time generating solutions to their circumstances, which tends to increase or perpetuate symptoms of depression. An assessment of a client's CF as operationalized as a problem-solving task could inform the clinician as to the client's ability in this regard. It can also be used as a measure to track changes.

In other settings, such as the workplace CF can be utilized to identify strengths in individuals. For example an employer might want to identify employees for roles in which they must develop novel solutions to problems or to adjust strategies in real time in order to adapt to changing condition. Thus cognitive flexibility as a strength could be utilized to place individuals where they can thrive and maximize their skillset.

Recommendations for Future Research

There are multiple areas where future research could continue to develop in regards to CF. In the first place and consistent with the principles of scientific inquiry, replication of the study would be beneficial. This is particularly true given the limited sample size of the study group. The scores were aggregated for both men and women and across ethnicities. A future study would be informative examining possible differences related to gender and/or ethnicity.

This study focused on the measure of CF as defined as a switching task. A future study might include a wider range of measures found in the research literature. This study also utilized a clinical sample in an outpatient healthcare setting. Replication of the study with a control group of healthy individuals would be informative.

The research literature includes examples of studies in which CF was assessed in relation to other variables of interest. Continued study of CF in that manner would continue to be beneficial. It would be advisable that that researcher carefully selected the CF to address the type of flexibility of interest and then carefully note that the study measured an aspect of CF and not cognitive flexibility per se.

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Appendix

Table 1. Demographic Characteristics of Study Sample (Standard Deviation in Parentheses)

Ethnicity	n	Percentage	Education		Age	
African American	10	8.4	14.8	(2.89)	48.7	(16.0)
Asian/A. American	1	0.8	13.0		48.0	
Latina/o	5	4.2	14.8	(2.68)	44.4	(11.3)
White	102	85.7	15.1	(2.6)	54.9	(13.6)
Multiracial	1	0.8	16.0		45.0	

Table 2. Scores on WCST Utilized in Cognitive Flexibility Studies

Study	Scores									
	E	% E	P	% P	NP	% NP	CC	#- 1st	CLR	Set-M
1				X		X	X			
2				X		X	X	X	X	
3				X		X	X			X
4				X		X				X
5				X			X		X	
6	X		X		X					X
7		X		X		X				

Note. 1 = Tanner, Erdogan Baker, & Oner (2011); 2 = Kalwa, Rzewuska, & Borkowksa (2012); 3 = Verdejo-García, López-Torrecillas, Calandre, Delgado-Rodríguez, & Bechara, (2009); 4 = Davis & Nolen- Hoeksema (2000); 5 = Lorenza, Huizinga, & Hommel (2009); Pineda & Merchan, (2013); 7 = Sato et al. (2013); E = number of errors; %E = percentage of responses that were errors; P = perseverative reponses; %P = percentage of responses that were perseverative errors; NP = non-perseverative responses; %NP = percentage of responses that were non-perseverative errors; CC = number of categories completed; # - 1st = number of trials to first completed category; CLR = number of conceptual level responses; Set-M = number of set maintenance errors.

Table 3. Cognitive Flexibility Elements Measured by Self-Report and Performance Tests

Performance Task	Element
WCST	The ability to adapt to changing environmental stimuli in the form of feedback regarding rule changes- Task switching in a nonverbal test
DKEFS	
CWI	The ability to switch tasks and inhibit automatic processes in a verbal test
Trails Condition 2	Processing Speed, task switching, working memory
Trails-B	The ability to adapt to changing environmental stimuli in the form of feedback regarding risk ratio- Adaptation in a nonverbal test.

Note. WCST = Wisconsin Card Sorting Test; DKEF = Delis-Kaplan Executive Functioning System; CWI = Color-Word Interference (i.e. Stroop); DKEFS Trails condition 2