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Psychometric Issues Related to the Tinker Toy Test

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PSYCHOMETRIC ISSUES RELATED TO THE TINKER TOY TEST

by

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ABSTRACT

An evaluation of executive functioning is a critical component of a comprehensive assessment of higher cerebral functioning. The Tinker Toy Test (TTT) was introduced in 1982. This test allows an individual to demonstrate the extent of their executive capacities by permitting them to initiate, plan, and structure a potentially complex activity and carry it out independently in an unstructured fashion and administration is simple. This is a departure from more complex and structured tests of executive function. There is a dearth of research on the TTT and this study seeks to examine some of the psychometric properties of this instrument; i.e., working time minimum, gender effects, convergent and divergent validity, and potential intellectual correlates. Participants included 10 male and 30 female student volunteers from a large university in Central Florida. Participants had no history of neurologic disease/trauma or conditions that would affect motor functioning of the upper extremities. Participants completed a demographic questionnaire, the WASI-II, and the TTT.

A two-way mixed-design ANOVA examining TTT scores as a function of work time and gender revealed a non-significant gender main effect, $F(1, 21) = .09$, $p = .767$. The work time main effect was not significant, , $F(1, 21) = .324$, $p = .575$. A significant work time x gender interaction was observed, $F(1, 21) = 4.983$, $p = .037$. Convergent validity was assessed by comparing the TTT scores with the Matrix Reasoning subtest, $r(38) = .32$, $p = .044$, and the Similarities, $r(38) = .34$, $p = .03$, subtest on the WASI-II. Divergent validity was assessed by comparing TTT scores to the Block Design subtest of the WASI-II, $r(38) = .245$, $p = .127$. No significant correlation was found between intelligence and TTT (VCI, $r(38) = -.16$, $p = .335$; PRI, $r(38) = .15$, $p = .344$; and FSIQ, $r(38) = -.02$, $p = .928$).

The data supports the continued use of the 5-minute working time minimum presented by Lezak, as this temporal index was a more accurate representation of executive functioning. This study demonstrated no association between TTT scores and intellectual functioning. The findings of this study support the validity of this underutilized test of executive functioning and its inclusion in neuropsychological test batteries.

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TABLE OF CONTENTS

LIST OF ABBREVIATIONS

COWA	Controlled Oral Word Association
FSIQ	Full Scale Intelligence Quotient
PRI	Perceptual Reasoning Index
TTT	The Tinker Toy Test
VCI	Verbal Comprehension Index
WASI-II	Wechsler Abbreviated Scale of Intelligence – Second Edition
WAIS-IV	Wechsler Adult Intelligence Scale – Forth Edition
WCST	Wisconsin Card Sorting Test

CHAPTER ONE: INTRODUCTION

The Field of Clinical Neuropsychology

The field of clinical neuropsychology emerged from health care settings within the subspecialties of traditional neurosurgery and neurology services. At its inception, the focus was predominately concerned with cortical functioning of patients and the diagnosis of neurological disorders and dysfunction (e.g., tumors, strokes, traumatic brain injury, etc.). Neuropsychology experienced tremendous growth and began to move from the laboratory setting into the clinical world between 1960 and 1990. During this time period distinct neuropsychological organizations began to develop as well. Most recently in modern neuropsychological history, from the 1990s until today, the field has enjoyed greater growth compared to the prior three decades (Zilmer, Spiers & Culbertson, 2008).

Within the last 30 years, one of the biggest changes to the field of neurology and neuropsychology was the introduction and development of functional imaging (Kolb & Whishaw, 2009). Functional imaging has allowed the field to better understand the effects of cortical damage and neurological diseases on human cognition and behavior. As such, the role of clinical neuropsychologists has become multifaceted. For example, their role in rehabilitation and their ability to diagnosis neurocognitive deficits and related behavioral disturbance is crucial because functional imaging can show which areas are affected, but it cannot predict or explain the extent to which a person will suffer deficits secondary to cerebral injury or disease (Christensen & Uzzell, 2000).

Clinical neuropsychologists play a duel role due to their involvement in both the diagnosis and the rehabilitation process. In order to provide the best picture of an individual and their neuropsychological deficits, testing batteries that assess various aspects of neurological functioning are administered. These tests do not simply assess cognitive and emotional functioning, but can significantly influence treatment options. Proper administration and interpretation of a valid test battery can assist with formulation-appropriate treatment interventions that target the observed cognitive and emotional deficits, and strengths. The data generated from the neurobehavioral assessment are further used as confirmatory or disconfirmatory evidence for competing hypotheses related to the specific neuroanatomical substrates involved and the etiology of the observed deficits (Goldstein & McNeil, 2013).

The Battery Approach to Neuropsychological Assessment

For neuropsychologists, psychometric instruments are most often administered in batteries. A battery is defined as two or more tests, which are related by an assessment method (combination, comparison, etc.) for the purpose of interpretation (Russell, Russell, & Hill 2005). There are two main types of battery approaches: the standardized (a.k.a., fixed) battery approach and the individualized battery approach. A standardized battery is composed of a fixed grouping of tests that are administered to all individuals completing the battery. The most commonly used standardized batteries are the Halstead-Reitan and the Luria Nebraska (Guilmette & Faust, 1991). The assessments in an individualized battery are selected to match the referral question and the probable etiology of the examinee's purported deficits. The individualized battery approach often requires more particular theoretical knowledge in regards to administration and interpretation of the tests than may be needed for a standardized battery. The individualized battery approach can provide a large amount of qualitative data regarding the particular individual, not just quantitative data as is obtained with the standardized battery approach (Fennell & Bauer, 1997; Tramontana & Hooper, 1988). The use of this type of battery has led to a subcategory of the individualized battery approach, known as a composite battery. This battery type seeks to present additional information in which assessments are given in a formalized and structured manner with comparison norms while at the same time taking the qualitative data into consideration. Such an approach to neuropsychological testing is exemplified by the Boston Process Approach as advanced by Kaplan (1990; Ashendorf, Swenson, & Libon, 2013).

Testing batteries and assessment procedures are in constant change as revisions and developments are made in response to the results of their use in clinical and research settings. A comprehensive examination of higher cerebral functioning typically assesses orientation, achievement, general level of functioning (i.e., intelligence), language, spatial/perceptual/constructional functioning, attention/concentration, memory/learning (verbal and non-verbal), executive functioning, motor and sensory functioning, emotional status, and response bias (Rabin, Barr, & Burton, 2005).

There are many factors that influence the selection of instruments for use within a testing battery. First and foremost, it is essential that all tests be valid and reliable as demonstrated by the test creator and the scientific community. Following the demonstration of reliability and validity, standardization, and norming, it is important to select tests that can help in the diagnosis of numerous neuropsychological disorders and that are sensitive to the differences in etiology between different disorders (Benton, 1994). The selected tests must be able to aid in the identification of disorders caused by dysfunction of larger brain regions as well as the dysfunction caused by specific ailments such as a localized lesion (Damasio & Damasio, 1989). Specific assessment instruments should also be selected based on the demographics (e.g., age, education, gender, race/ethnicity) of the individual being tested (Kolb & Whishaw, 2009).

Executive Functioning

As previously noted, neuropsychological assessment batteries assess various aspects of cognitive and emotional functioning. Of particular interest to this study is the construct of executive functioning, which is most commonly associated with the frontal lobes. This construct is defined in various ways throughout the neuropsychological literature. Lezak, Howieson, and Loring (2004) described executive function as an individual's intrinsic ability to adaptively respond to situations through volition, planning, purposeful action, and effective performance. Baron (2004) conceptualized this construct as the metacognitive capacities of an individual that allow for the perception of stimuli from the environment and the ability to respond in an integrated, common sense way that makes use of adaptively responding, flexibly changing direction, anticipating future goals, and consideration of the consequences in order to achieve a goal. Executive function as defined by Gioia, Isquith, Guy, and Kenworthy (2000) refers to the various process that are required for guiding, directing, and managing cognitive, emotional, and behavioral functions when an individual is required to use active, novel problem solving. Shallice (1990) argued that the processes involved in executive function are most active when an individual is in an unfamiliar context or novel situation in which they do not have previously rehearsed ways of responding or routines for the situation. Miyake, Frieman, Emerson, Witzki, and Howerter (2000) divided executive functioning into three basic executive processes: the ability to shift back and forth between mental sets and/or multiple tasks; the processes related to the monitoring of incoming information to establish relevance to the task at hand and appropriate updating and replacing of older information; and the deliberate inhibition of dominant, automatic, or prepotent responses.

Underlying these various definitions and conceptualizations is the idea that executive functioning refers to higher-order supervisory brain computations; that is, processing related to the directing, controlling, and managing of behaviors (Burgess & Shallice, 1997; Zilmer, Spiers & Culbertson, 2008). Functions that are often attributed to executive functioning include: planning, flexible problem solving, working memory, attentional allocation, and inhibition. At the highest levels, executive functioning includes self-monitoring and self-assessment of behavior. Overall, executive functioning is related to sets of higher order behaviors, rather than just one type of behavior. It is also not limited to cognitive processes, but is highly involved in emotional and social behavioral regulation (Zilmer, Spiers & Culbertson, 2008).

Neuroanatomy and Functional Components of the Frontal Lobes

The frontal lobes are composed of all the cortical tissue anterior to the central sulcus and its major regions include the precentral gyrus (primary motor cortex), the prefrontal cortex, the premotor cortex, and the supplementary motor cortex. The primary motor cortex is associated with the control of fine movements and can be subdivided into separate areas that are each responsible for different, predominately contralateral, parts of the body. These areas can be approximated and mapped out, but within each area there is no set one-to-one relationship between the area and a specific muscle(s) (Graziano, Taylor, & Moore, 2002; Kalat, 2007). No direct connection exists between the primary cortex and muscles, but rather the axons from this area extend to the brain stem and spinal cord in order to generate patterns of activity and muscle control (Shik & Orlovsky, 1976). The prefontal cortex, the premotor cortex, and the supplementary motor cortices are responsible for the active preparation of movement and for directing messages to the primary motor cortex. The prefrontal cortex responds to sensory signals that could lead to movements, such as noises and lights, and assists in considering the probable outcomes of potential actions. Subsequently, the prefrontal cortex can assist in calculating and planning movements in accordance to the predicted outcomes (Tucker, Luu, &

Pribram, 1995). The prefrontal cortex is not the primary target for any single sensory system, but rather it receives and integrates information from all of them in different regions (Elston, 2000). This region of the frontal cortex is also associated with working memory, i.e., an individual's ability to remember and process recent stimuli (Goldman-Rakic, 1988). Related abilities moderated by the prefrontal cortex include completing delayed-response tasks (i.e., responding to a briefly presented stimulus after some delay; Kalat, 2007), simultaneously following two or more rules in the same situation (Ramnani & Owen, 2004), and controlling context dependent behaviors (Miller, 2000). The premotor cortex becomes active during movement preparation and remains somewhat active during the movement itself. This region processes information about the target of the movement in space, bodily direction during movement, and the current position and posture of the body (Hoshi & Tanji, 2000). The premotor cortex then sends an output signal to the primary motor cortex and the spinal cord to assist in the coordination of the movements in space (Kakei, Hoffman, & Strick, 2001). Lastly, the supplementary motor cortex plans and organizes rapid sequences of movements (Tanji & Shima, 1994).

Frontal Lobe Dysfunction

Diseases of the frontal lobes can affect executive functioning resulting in difficulties with planning, working memory, attentional abilities, and other related areas (Zilmer, Spiers & Culbertson, 2008). Due to the processes encompassed within executive function, executive dysfunction can present itself as part of a myriad of problems in an individual's life. Issues with executive dysfunction can include difficulties with maintaining and initiating appropriate behavior and social interactions, difficulties with sound decision-making and appropriate judgment, difficulties planning (devising, following, and shifting plans), difficulties with organization, increased distractibility and deficits in memory - particularly when it is required that an individual remember to carry out intended actions at a later time (Burgess & Shallice, 1997; Gioia et al., 2000).

In regards to assessment or testing performance, deficits in executive function will usually manifest as poor initiation, poor planning, disorganization, difficulties with inhibition, poor set shifting, difficulties with working memory, inflexibility, perseveration, carelessness, issues generating and implementing strategies, and an inability to correct errors or use feedback. Due to the large area of the brain that is included within the frontal lobes, the term "dysexecutive syndrome" has been proposed in order to allow a discussion of "function" separate from the exact anatomical location. Executive processes may also not be unitary and are likely to involve links between various parts of the brain, which can result in individuals whom present with executive function deficits without obvious frontal damage (Baddeley, 1998). Assessment of executive dysfunction within a neuropsychological assessment battery is crucial as these deficits can make it very difficult for an individual to return to their normal routines and levels of productivity, particularly after a traumatic brain injury or degenerative neurocognitive disease. Individuals suffering from these deficits are often required to take responsibility for applying compensatory and self-regulatory strategies to address their deficits or to help them process novel situations (Godefrey & Rousseux 1997; Shallice & Burgess, 1991).

Psychometric Assessment of Executive Functioning

Numerous neuropsychological instruments have been developed, and are widely used, for assessing executive function; for example, the Wisconsin Card Sorting Test (WCST; Heaton, Chelune, Talley, Kay, & Curtiss, 1993), the Wechsler Adult Intelligence Scale- Fourth Edition (WAIS-IV) Comprehension and Similarities subtests (Wechsler, 2008), Controlled Oral Word Association Test (COWA; Benton & Hamsher, 1989), Trail Making Test Part B (Delis, Kaplan,

& Kramer, 2001), the Wechsler Abbreviated Scale of Intelligence-Second Edition (WASI-II; Matrix Reasoning and Similarities subtests; Wechsler, 2011), and the Stroop Color Word Test (Golden & Freshwater, 2002).

With many of these tests, there is concern over the purity of the assessment, as most executive tasks require the use of nonexecutive cognitive processes. Deficits in other cognitive processes could confound the results of an executive function measure. It is suggested that the use of simpler assessment measures can aid in the isolation of the processes responsible for the impaired performance. (Mikaye, Emerson, & Friedman, 2000).

Intelligence and Executive Functioning

Research has demonstrated a relationship between various aspects of executive functioning and intelligence. Individuals with frontal lobe damage may demonstrate poor performance on neuropsychological tests of executive functioning and will often have deficits in areas related to planning, decision-making, and general regulation of everyday tasks. These areas are associated with executive functioning and are also considered hallmarks of intelligence (Friedman et al., 2006). Obansawin et al. (2002) observed that scores on many assessments of executive functioning are significantly correlated with FSIQ scores, between $r = 0.66$ and $r = 0.73$, on the Wechsler Adult Intelligence Scale – Revised. Recent research has shown a relationship between mental speed and intelligence (Sheppard & Vernon, 2008). Other tests of executive functioning, such as the Stroop Test and the Trail Making Test Part B, have significant processing speed components and are timed, thus scores are highly dependent upon the speed with at which the individual completes the required task (Nelson, Yoash-Gantz, Pickett, & Campbell, 2009). This relationship suggests that completion speed is potentially related to an individual's intelligence and executive functioning abilities.

The Tinker Toy Test

An underutilized and under-researched assessment measure of executive function is the Tinker Toy Test (TTT) developed by Lezak (1982). The TTT gives individuals an opportunity to show their executive capacities by making it possible for them to initiate, plan, and structure a potentially complex activity and carry it our independently. The TTT assesses many areas of frontal lobe functioning, and has been reported to show sensitivity to diminished executive functioning by assessing the abilities of planning, goal setting, and decision making (Varney & Stewart, 2004) and to be "significantly associated with separate clinical ratings of functional or executive impairment" (Roberts, Franzen, Furuseth, & Fuller, 1995, p. 161). The TTT is non-language based, unlike many other assessments of executive function (Lucas & Buchanan, 2012). Varney & Stewart (2004) reported that the TTT significantly correlated with verbal measures of executive function (the Story Telling Test), (r = 0.541, p = .000) and nonverbal measures (the Design Fluency test), (r = 0.325, p = 0.000). Due to the structured nature of most neuropsychological tests, evaluation of these functions may remain restricted or unexamined. The TTT also gives the participant the opportunity for "free" construction, or the ability to construct their model without the need for copying a preexisting model or a test-required predetermined solution.

Research on the TTT has demonstrated its potential within clinical settings. Allain et al. (2009) reported that the TTT is an effective tool in helping to identify executive dysfunction in patients with Alzheimer's disease. Mendez and Ashla-Mendez (1991) noted that patients with multi-infarct dementia who completed the TTT used fewer pieces and made simpler constructions when compared to patients with Alzheimer's type dementia, whom would use most of the pieces in multiple combinations of a few pieces. Mendez and Ashla-Mendez reported that the TTT was able to differentiate between the two types of dementia while the structured tests used did not differentiate between the two types. Bayless, Varney, and Roberts (1989) examined the relationship between Tinker Toy Test scores and the ability to return to work of 50 patients whom had suffered closed-head injuries. Twenty-five of these patients were unable to return to work and of these, approximately half scored below the worst score in the control group. The remaining 25 patients were able to return to their previous jobs and all but one of these patients scored within a normal range on the TTT. Honda (1999) reported on three individuals whom suffered an anterior communicating artery aneurysm rupture and their performance on the TTT before and after cognitive rehabilitation. The scores of two of the three patients improved post problem solving training. This study suggests that the TTT has potential to be used as a measure of executive rehabilitation.

Administration of the TTT involves giving examinees 50 pieces from a Tinker Toy set (see Appendix D) and asked to build something. The model, or structure, that the individual builds is then criteria-scored (see Appendix E). The test is not timed, but a 5-minute minimum is required according to the test's author. Lezak's (1982) pilot study reported that the time to complete the test would vary separate from neurological status or the quality of the performance. As it stands now, it is unknown how much scoring of the test quantitatively adds to its clinical utility. Much of the test's utility comes from the information that is gathered by being able to watch how a person performs and how they complete the task, akin to the Boston Process Approach (Lezak, Howieson, Bigler, & Tranel, 2012). Lezak et al. (2012) stated that the 5-minute minimum came about as a result of "bright, healthy-competitive subjects" (p. 684) performing poorly due to thinking it was a speed test and that poorly motivated, self-deprecating, or deteriorated patients need time to sit with the pieces.

Statement of Significance

There is a dearth of research on the TTT. Specifically, there are no known studies that address the construct validity of this intriguing and comprehensive measure of executive functioning. In addition, no prior work has addressed the link between intelligence and frontal lobe functioning on the TTT. Finally, no prior studies have been conducted to investigate the possible effects of performance time on test scores. The present study fills a significant gap in our current knowledge of a potentially useful addition to existing neuropsychological test batteries.

Statement of Hypotheses

Three hypotheses are presented for this study. First, no significant difference will be observed between scores of models completed and scored before and after the 5-minute time minimum as a function of gender. Second, convergent and divergent validity will be demonstrated on the TTT. Third, TTT completion times will be significantly correlated with Full Scale IQ.

CHAPTER TWO: METHODOLOGY

Participants

Participants were 40 male and female student volunteers attending the University of Central Florida. All participants had no history of neurologic disease/trauma or conditions that would affect motor functioning of the upper extremities. The age range of the sample was 19 to 74 years (*M* = 28.30, *SD* = 12.20). The sample consisted of 10 males between the ages of 21 and 41 years (*M* = 27.10, *SD* = 6.21) and 30 females between the ages of 19 and 74 years (*M* = 28.70, *SD* = 13.69). Racial/ethnic demographics were: Black or African-American (*n* = 3, 7.5%), Hispanic or Latino (*n* = 5, 12.5%), White (*n* = 31, 77.5%), and two or more races (*n* = 1, 2.5%). The highest levels of education completed at the time of assessment were: high school or GED (*n* = 2, 5%), Associate's degree (*n* = 35, 87.5%), and Bachelor's degree (*n* = 3, 7.5%). Participants were not compensated for their participation.

Materials and Apparatus

The Tinker Toy Test (TTT). Lezak introduced the TTT in 1982. This instrument allows an individual to demonstrate the extent of their executive capacities by permitting them to initiate, plan, and structure a potentially complex activity and carry it out independently in an unstructured fashion. The administration is simple. Examinees are given a specific set of pieces (*n* = 50) from a Tinker Toy set and instructed to make whatever they want. Examinees have at least five minutes and as much more time as necessary to finish their model. Models are scored on the following seven criteria: (1) whether the patient made any constructions (*mc*); (2) total number of pieces used (*np*); (3) whether the construction was given a name appropriate to its appearance (*name*); (4) mobility (e.g., wheels that work and moving parts) (*mov*); (5) whether it has three dimensions (*3d*); (6) whether the construction is free standing (*stand*); and (7) whether there is a performance error (e.g., errors related to misfit of parts due to forcing pieces together that are not meant to be combined, incomplete fit/connections not properly made, or dropping pieces on the floor with no attempt to pick them up or recover them) (*error*). The sum of all these variables results in a complexity score (*comp*). The model can also be scored without the number of pieces used for a modified complexity score (*mComp*). Criterion-referenced scores range from 0 to 12. In Lezak's original scoring criteria, no explicit cut offs for impairment are described (scoring criteria are outlined in Appendix E; Lezak et al., 2012).

Wechsler Abbreviated Scale of Intelligence-Second Edition (WASI-II). The WASI-II is intended to be a short and reliable measure of intelligence for clinical, psycho-educational, and research settings. The WASI-II is composed of four subtests: Block Design, Vocabulary, Matrix Reasoning, and Similarities. The Block Design subtest consists of 13 printed two-dimensional geometric designs, which increase in level difficulty. The examinee must reproduce these patterns within a set time limit using 2, 4, or 9 two-color cubes. This subtest measures an examinee's ability to analyze and synthesize abstract visual stimuli. The Block Design Subtest loads on an individual's nonverbal concept formation and reasoning, broad visual intelligence, fluid intelligence, visual perception and organization, simultaneous processing, visual-motor coordination, learning, and their ability to separate figure-ground in visual stimuli (Wechsler, 2011).

The Vocabulary subtest consists of 31 items (3 picture items and 28 verbal items). For the picture items an individual must name the object presented in the image and for the verbal items they must verbally define the words. This subtest measures an individual's word knowledge, verbal concept formation, crystallized intelligence, fund of knowledge, learning ability, long-term memory, and degree of language development. An individual will also use their auditory comprehension and verbal expression abilities during this subtest (Wechsler, 2011).

The Matrix Reasoning subtest consist of 30 incomplete matrices in which participants are asked to complete each item by choosing the correct option from the five choices provided. This subtest assesses an individual's fluid intelligence, broad visual intelligence, simultaneous processing, non-verbal abstract reasoning, and perceptual organization (Wechsler, 2011).

The final subtest of the WASI-II, Similarities, is made up of 3 picture items and 21 verbal items. In the picture items, two images sharing a common characteristic are presented. The individual must select which of the presented choices also shares this characteristic. For the verbal items, a pair of common objects or concepts is verbally presented and the individual provides a description of how they are similar. This subtest assesses the individual's verbal concept formation and reasoning, crystallized intelligence, verbal abstract reasoning, auditory comprehension, memory, associative and categorical thinking, distinction between nonessential and essential features, and verbal expression (Wechsler, 2011).

The four subtests are used to provide a Full Scale IQ (FSIQ-4) but may also provide a reliable measure of IQ using only two of the subtests (vocabulary and matrix reasoning) when there is a need to use a shorter test (FSIQ-2). FSIQ-4 scores significantly correlate 0.92 with Full-Scale IQ scores on the WAIS-IV and FSIQ-2 scores significantly correlate with the Full-Scale IQ scores on the WAIS-IV at 0.86. This suggests that the WASI-II assess similar constructs as those assessed in the WAIS-IV (Wechsler, 2011).

Electronic Time Keeper. An electronic timekeeper was used to track time on the TTT. It was also used when a WASI-II subtest required time keeping.

Procedures

Following acquisition of informed consent, participants completed a demographic questionnaire, the WASI-II, and the TTT. The test order (i.e., WASI-II and TTT) was counterbalanced across participants. With regard to the TTT, if a participant finished before the 5-minute mark, they were instructed to continue working. For models completed before the 5 minute, a picture was taken in order to facilitate scoring and prevent prolonged interruption of the participant's working time. This was necessary in order to compare scores before and after the 5-minute minimum. Participants spent approximately one hour in the entire study.

CHAPTER THREE: RESULTS

Work Time x Gender

A two-way mixed-design ANOVA was used to examine TTT scores as a function of work time (< 5 minutes and > 5 minutes) and gender (male and female). The work time main effect was not significant, $F(1, 21) = .324$, $p = .575$. The gender main effect was not significant, $F(1, 21) = .09$, $p = .767$. A significant work time x gender interaction was observed, $F(1, 21) = 4.983$, $p = .037$. Evaluation of the significant interaction effect revealed that males' performances deteriorated from < 5 min. ($M = 7.5$, $SD = 1.00$) to > 5 min. ($M = 6.75$, $SD = 1.71$), whereas females' performances improved from < 5 min. ($M = 6.26$, $SD = 1.37$) to > 5 min. ($M = 7.53$, $SD = 1.90$). The significant interaction effect argues for gender being demographically controlled for on the TTT by adding 1-point to males' scores. To assess the validity of this adjustment, male scores were adjusted upward 1-point and the two-way mixed-design ANOVA was re-run. The interaction effect was not significant, $F(1, 21) = 1.262$, $p = .274$.

Convergent Validity

The TTT > 5 min. scores were compared to two well-documented measures of executive functioning. A significant positive relationship was observed between TTT > 5 scores and the Matrix Reasoning subtest of the WASI-II, $r(38) = .32$, $p = .044$. The correlation between TTT > 5 scores and the Similarities subtest of the WASI-II was significant, $r(38) = .34$, $p = .03$. No significant correlations were noted when investigating < 5 min. scores (Matrix Reasoning: $r(21) = .12$, $p = 603$; Similarities: $r(21) = -.01$, $p = .969$).

Divergent Validity

To demonstrate that the TTT is not a pure measure of visuoconstructional functioning, > 5 min. scores were compared to a well-established measure of this construct. No significant relationship was observed between TTT > 5 min. scores and performance on the Block Design subtest of the WASI-II, $r(38) = .25$, $p = .127$. The correlation between < 5 min. scores and Block Design performance was not significant, $r(21) = .04$, $p = .846$.

Intelligence and Speed of Performance

The correlation between the > 5 min. times to complete TTT and VCI (Verbal Comprehension Index) was not significant, $r(38) = -.16$, $p = .335$. No significant relationship was observed between > 5 min. times and PRI (Perceptual Reasoning Index), $r(38) = .15$, $p = .344$. A negative non-significant correlation was observed between > 5 min. times and FSIQ (Full Scale Intelligence Quotient), $r(38) = -.02$, $p = .928$. The correlation between < 5 min. times to complete the TTT and VCI (Verbal Comprehension Index) was not significant, $r(21) = .13$, $p = .568$. No significant relationship was observed between < 5 min. times and PRI (Perceptual Reasoning Index), $r(21) = .08$, $p = .711$. A non-significant correlation was observed between < 5 min. times and FSIQ (Full Scale Intelligence Quotient), $r(21) = .12$, $p = .596$.

CHAPTER FOUR: DISSCUSSION

The purpose of the present study was to investigate various psychometric properties of the TTT. While this test was developed over three decades ago, no research has been conducted to address the issues raised in this study. The lack of empirical evidence on the validity of this instrument, and other psychometric issues, likely contributes to its scant use as part of a comprehensive assessment of higher cerebral functioning.

The first hypotheses was that no significant difference would be observed between scores of models completed and scored before and after the 5-minute time minimum as a function of gender. The data supported this hypothesis as the work time and gender main effects were not significant. The data lends support for the 5-minute working time minimum presented by Lezak (1982) suggesting that scores after 5-minutes are a more accurate representation of executive functioning using this test. Interestingly, a significant work time x gender interaction was observed. This suggests that the TTT should be demographically controlled for gender by adding 1-point to males' scores. Our finding that males' performances deteriorated when asked to work longer leads to interesting speculation. It is possible that the gender-based performance deterioration could be a result of male's proneness to boredom (Sundberg, Latkin, Farmer, & Saoud, 1991). That is, males could potentially be losing interest in this task the longer they are asked to work, which could lead to poorer performance.

Evidence of construct validity is absent on the TTT. As such, the second hypothesis was to demonstrate convergent and divergent validity on this instrument. The data supported this hypothesize and suggests that the TTT is a valid measure of executive functioning. The demonstration of construct validity in this study suggests that the TTT can be used as a valid measure of executive function within a neuropsychological test battery. Mikaye, Emerson, and

Friedman (2000) suggested that simpler tasks, or tasks that are not as confounded by non-executive cognitive processes, may provide a more accurate measure of executive function. Given the observed construct validity in this study, coupled with the relative simplicity of the TTT, it is reasonable to state that this underused instrument can provide an alternative to more complex measures of executive functioning and is worthy of inclusion in practitioners' neuropsychological test batteries.

Intelligence has been shown to have a relationship with both executive functioning and processing speed (Friedman et al., 2006; Sheppard & Vernon 2007). The third hypothesis of this study directly addressed these prior assertions. The data did not support the notion that intelligence plays a role in TTT time completion. The present data indicate that the TTT is an executive functioning task that is unaffected by an individual's level of intelligence. This supports the idea that the TTT can provide a less confounded and valid measure of executive function.

This measure can also provide a purer assessment of executive function due to its simplicity and lack of potential confounding due to intelligence. Previous studies using the TTT have shown its usefulness within clinical settings (i.e., Allain et al., 2009l; Bayless, Varney, & Roberts, 1989; Honda, 1999; Mendez & Ashla-mendez, 1991). With support for the validity of this measure, it is clear that the TTT has the potential to be an invaluable tool in the assessment of executive functioning.

While not a tested hypothesis in this study, the TTT can also provide benefits related to examinee-specific attitudes during a neuropsychological evaluation. One such benefit is that participants often find this test to be amusing (Lezak et al., 2012). One of the biggest concerns during a neuropsychological assessment is assuring that an individual is exerting their full effort during the evaluation. One method to do this is by reducing the amount of perceived effort as this can influence how readily people forfeit on difficult tasks due to the expenditure of a person's finite pool of self-regulatory resources. Interesting or amusing assessments, such as the TTT, can feel effortless and help an individual become intrinsically motivated to participate. Intrinsically motivated individuals may begin to associate positive feelings with task completion, thus restore self-regulatory resources (O'Keefe & Linnenbrink-Garcia, 2014). With this in mind, it is reasonable to assume that the TTT can help decrease the likelihood an individual may forfeit or reduce effort during the evaluation.

Perception is another important consideration as it can affect activity stereotypes and interpretation of past experiences (Eccles et al., 1983). For example, if an individual has had a negative experience with one of the tests in the test battery, they may come to perceive the current assessment in a negative manner. Alkharusi, Aldhafri, Alnabhani, and Alkalbani (2013) found that individuals will often avoid tasks that they perceive to exceed their abilities and approach ones they perceive themselves as being able to complete. Thus, it is argued that due to the relative simplicity of the TTT, most individuals will perceive themselves as capable of successfully completing the task, thereby increasing self-efficacy. If individuals see themselves as possessing self-efficacy, they are more likely to fully engage in the task which can increase their motivation, or their energy and drive to work effectively and achieve their potential (Alkharusi et al., 2013; Liem & Martin, 2012).

The role of the clinical neuropsychologist goes beyond diagnosis; they also actively participate in the rehabilitation process (Goldstein & McNeil, 2013). Thus, the TTT also has the potential to aid in cognitive rehabilitation. Due to the "purity" of the TTT, it could provide neuropsychologists with a clearer picture of an individual's executive dysfunction. This results in finer diagnostic accuracy and, in turn, leads to more targeted cognitive rehabilitation efforts within clinical settings. The TTT enhances the utilization of compensatory and self-regulatory strategies because it can identify deficits that could prevent their successful implementation, thus making it an excellent therapeutic tool during cognitive rehabilitation (Godefrey & Rousseux 1997; Shallice & Burgess, 1991).

The limitations affecting this study are predominantly related to the study's sample. First, the convenience sample consisted of college students from a large university in Central Florida. Such sampling is a threat to external validity thus reducing generalizability of the results. Secondly, this study had a relatively small sample size, which decreases the ability to detect a true difference if a difference actually exists (i.e., power). The small sample size may be responsible for the lack of support for hypothesis 3. Lastly, the sample contained a large gender disparity, which could have influenced the observed gender x work time interaction and created a gender bias. The proportions of males versus females could also affect the generalizability of the study, as it is not proportional or representative of the larger population.

Future research on the TTT should further explore the gender x work time interaction by utilizing a more gender-balanced sample. This could help to further explore the need to potentially demographically control for gender on the TTT, which the present data suggests. Future studies should also seek to increase the sample size in order to increase the generalizability of this study. Finally, it is suggested that future research compare the TTT to other well-known and utilized measures of executive functioning in order to further elucidate the validity of this assessment tool.

In conclusion, the present study addresses the relative dearth of empirical studies on the validity of the TTT. Further studies on the TTT are recommended and practitioners are urged to consider adding this neuropsychometric underdog to their existing neuropsychological test batteries.

APPENDIX A: IRB OUTCOME LETTER

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Homer Edward Fouty, Ph.D.** and Co-PI: **Daniel Guzman**

Date: **March 10, 2015**

Dear Researcher:

On 3/10/2015 the IRB approved the following human participant research until 03/09/2016 inclusive:

Type of Review:	Submission Response for UCF Initial Review Submission Form Expedited Review
Project Title:	An investigation of standardization procedures on a test of executive functioning
Investigator:	Homer Edward Fouty, Ph.D.
IRB Number:	SBE-15-11039
Funding Agency:	
Grant Title:	
Research ID:	N/A

The scientific merit of the research was considered during the IRB review. The Continuing Review Application must be submitted 30days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining IRB approval. A Modification Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at https://iris.research.ucf.edu .

If continuing review approval is not granted before the expiration date of 03/09/2016, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

Use of the approved, stamped consent document(s) is required. The new form supersedes all previous versions, which are now invalid for further use. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Participants or their representatives must receive a copy of the consent form(s).

All data, including signed consent forms if applicable, must be retained and secured per protocol for a minimum of five years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained and secured per protocol. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Signature applied by Patria Davis on 03/10/2015 03:24:55 PM EDT

IRB Coordinator

APPENDIX B: CONSENT FORM

An Investigation of Standardization Procedures on a Test of Executive Functioning

Informed Consent

Principal Investigator: Daniel Guzman

Faculty Supervisor: H. Edward Fouty, Ph.D.

Sub-Investigator(s): Erica L. Ailes, Katelyn Brown, and Samantha Lugar

Introduction: Researchers at the University of Central Florida (UCF) study many topics. To do this we need the help of people who agree to take part in a research study. You are being invited to take part in a research study which will include about 60 people. You have been asked to take part in this research study. You must be 18 years of age or older to be included in the research study. The person doing this research is Daniel Guzman of the Psychology Department; his Faculty Supervisor is H. Edward Fouty, Ph.D. UCF students learning about research are helping to do this study as part of the research team; their names are listed above.

What you should know about a research study:

- Someone will explain this research study to you.
- A research study is something you volunteer for.
- Whether or not you take part is up to you.
- You should take part in this study only because you want to.
- You can choose not to take part in the research study.
- You can agree to take part now and later change your mind.
- Whatever you decide it will not be held against you.
- Feel free to ask all the questions you want before you decide.

Purpose of the research study: The purpose of this study is to gather performance information on a popular testing instrument.

What you will be asked to do in the study: You construct models, perform several mental tasks, and complete a brief demographic questionnaire. You will interact with one of the investigators listed above. You do not have to answer any questions that make you feel uncomfortable.

Time required: We expect that you will be in this research study for a single session lasting approximately 60 minutes.

Risks: There are no reasonably foreseeable risks or discomforts involved in taking part in this study.

Benefits: There are no expected benefits to you for taking part in this study.

Compensation or payment: You will not receive compensation or payment for your participation in this study.

Confidentiality: No identifiable information will be collected from you. We will limit your responses (data) collected in this study to people who have a need to review this information. We cannot promise complete secrecy.

Anonymous research: This study is not anonymous. That means that some members of the research team (the one that you participate with) will know that the information you gave came from you.

Study contact for questions about the study or to report a problem: If you have questions, concerns, or complaints, or think the research has hurt you, talk to: H. Edward Fouty, Ph.D., Department of Psychology, University of Central Florida, 1200 W. International Speedway Blvd., Daytona Beach, FL 32120-2811, at (386) 506-4060 or by email at Ed.Fouty@ucf.edu.

IRB contact about your rights in the study or to report a complaint: Research at the University of Central Florida involving human participants is carried out under the oversight of the Institutional Review Board (UCF IRB). This research has been reviewed and approved by the IRB. For information about the rights of people who take part in research, please contact: Institutional Review Board, University of Central Florida, Office of Research & Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246 or by telephone at (407) 823-2901. You may also talk to them for any of the following:

- Your questions, concerns, or complaints are not being answered by the research team.
- You cannot reach the research team.
- You want to talk to someone besides the research team.
- You want to get information or provide input about this research.

APPENDIX C: RAW DATA

Participant)	TTT)before)5	Before)Time	TTT)after)5	After)Time	)Block)T	Vocab)T	Matrix)T
1	9	2:57	6	6:07	47	46	40
2	7	2:56	10	6:31	52	49	48
3	5	3:54	6	5:00	53	55	57
4	6	4:41	6	6:26	24	42	40
5	NA	NA)	7	6:13	53	71	58
6	NA	NA	8	8:21	44	42	52
7	NA	NA	8	5:20	42	47	34
8	5	3:30	6	5:05	57	32	20
9	NA	NA	9	7:23	61	71	73
10	7	3:42	10	5:03	38	46	40
11	5	2:19	10	5:03	42	41	52
12	6	2:16	7	5:01	43	53	42
13	6	1:30	7	5:18	45	50	48
14	NA	NA	6	8:16	36	55	55
15	7	3:32	7	5:35	46	57	52
16	6	3:45	9	8:50	51	55	57
17	NA	NA	5	6:19	51	55	42
18	4	3:00	4	5:12	49	63	54
19	5	4:10	8	5:23	47	57	44
20	NA	NA	6	12:51	48	37	44
21	NA	NA	10	5:01	38	47	41
22	7	2:13	9	5:04	52	57	54
23	NA	NA	7	10:44	47	56	57
24	NA	NA	8	8:14	48	35	54
25	7	4:16	7	5:04	56	55	50
26	7	4:37	7	5:15	48	28	42
27	8	4:35	8	5:01	51	65	50
28	NA	NA	7	5:07	51	40	27
29	NA	NA	7	5:10	55	61	44
30	4	3:00	5	5:05	43	55	34
31	7	1:06	6	7:54	36	42	43
32	NA	NA	8	5:20	65	52	56
33	9	2:33	11	5:00	53	45	54
34	NA	NA	8	6:42	45	57	46
35	NA	NA	6	5:30	38	46	34
36	NA	NA	5	7:20	41	49	27
37	8	3:12	9	5:33	53	57	40
38	7	1:59	5	5:00	32	37	42
39	7	3:09	7	5:03	26	39	48
40	NA	NA	6	5:08	34	30	46

Similarities)T	VCI)Comp.)Score	PRI)Comp.)Score	FSIQ(4)Comp.)Score	Gender
39	88	89	87	1
54	102	100	101	2
48	102	108	106	2
37	83	70	74	2
58	123	109	119	2
36	82	96	88	2
48	96	80	86	2
61	95	81	86	2
65	128	130	132	1
45	93	82	85	2
39	84	95	88	2
44	98	87	91	2
50	100	94	97	2
50	104	92	98	1
40	98	98	98	1
58	110	106	109	2
32	90	94	90	2
41	103	102	103	2
54	109	92	101	2
38	79	93	84	2
42	91	83	85	1
71	122	105	116	1
37	95	103	99	1
28	70	101	84	2
54	107	105	107	2
33	69	92	78	2
64	123	100	114	2
33	78	82	78	2
54	112	99	106	2
41	97	81	87	2
33	79	83	79	2
51	102	118	111	2
45	92	105	99	2
34	93	94	91	1
33	83	77	78	2
27	80	74	75	1
42	99	94	96	2
41	82	79	78	1
44	86	79	80	2
38	74	83	76	2

Age	Handedness	Education	Race
22	1	4	1
22	1	4	1
22	1	4	1
38	1	4	6
65	1	5	1
24	2	4	1
21	1	4	1
20	1	2	1
26	1	5	1
40	1	4	6
29	1	4	6
21	2	4	1
22	1	4	1
31	1	4	1
26	1	4	1
20	1	4	1
24	1	4	1
22	1	4	1
21	1	4	1
23	1	4	1
33	2	4	2
23	1	4	1
25	1	5	1
21	1	4	6
22	1	4	1
25	2	4	8
23	1	4	1
22	1	4	1
20	1	4	1
19	1	4	1
34	1	4	1
74	1	2	1
50	1	4	1
21	2	4	1
47	1	4	1
41	1	4	1
24	1	4	6
23	1	4	1
23	1	4	2
23	1	4	2

APPENDIX D: PIECES OUTLINE

Items Used in the Tinker Toy Tests

Wooden Dowels	Rounds	Others
Green (4)	Knobs (10)	Connectors (4)
Orange (4)	Wheels (4)	Caps (4)
Red (4)		Points (4)
Blue (6)		
Yellow (6)		

APPENDIX E: SCORING CRITERIA

Participant ID:		
Variable	Scoring Criteria:	Points
Any construction (*mc*)	Any combination of pieces (1)	/1
Number of pieces used (*nc*)	n < 20 (1) n = 20-29 (2) n = 30-39 (3) n = 40+ (4)	/4
Appropriately Named (*name*)	Appropriate (3) Vague / Inappropriate (2) Post hoc naming, description (1) None (0) ____________________ ____________________ ____________________	/3
Mobility (*mov*)	Mobility (has wheels) (1) Moving Parts (1)	/2
3 Dimensional (*3d*)	3-dimensional (1)	/1
Freestanding (*stand*)	Free standing, stays standing	/1
Errors (*error*)	For each error (-1) (misfit, incomplete fit, drop and not pick up)	-
	Total Points Earned:	/12

Time 1: _______

Time 2: _______

Notes:

APPENDIX F: F-TABLE

ANOVA Summary Table: Work Time x Gender

Source	*SS*	*df*	*MS*	*F*	*p*
TTT Score	0.435	1	0.435	0.324	0.575
Gender	0.350	1	0.350	0.090	0.767
TTT Score x Gender	6.696	1	6.696	4.983	0.037
Error	28.217	21	1.344		

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