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DEVELOPMENTAL AND NEUROPSYCHOLOGICAL PERSPECTIVES ON THE
WISCONSIN CARD SORTING TEST
IN NORMAL CHILDREN

BY

I. SIMONA BUJOREANU

A DISSERTATION PROPOSAL SUBMITTED IN PARTIAL FULFILMENT OF THE
REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN

PSYCHOLOGY

UNIVERSITY OF RHODE ISLAND
2007

742361721

ABSTRACT

Contemporary efforts in neuropsychological assessment of children are directed towards the use of developmentally sensitive instruments especially when targeting cognitive abilities, such as executive function, which are known to have a protracted period of development. The purpose of the present study was to advance the understanding of the WCST as a measure of executive function in six-year-old children. The test requires subjects to sort cards by three criteria: color, shape, and number of objects on the card. This study investigated the level of difficulty for young children required to use number as a sorting criterion. Based on developmental research on perceptual and conceptual behavior for color, shape, and number, it was hypothesized that the use of a concept with higher cognitive demands contributes to the impaired performance of six-year-old children when compared to that of older children or adolescents. Additionally, performance on the test was analyzed in an attempt to reflect possible developmental trends in the preference for the initial sorting criteria across the three age groups.

One hundred and ninety six participants of three different ages groups (6, 11-12, and 18-19 years old), were administered either the standard or modified versions of the WCST. A between-subjects Multivariate Analysis of Variance (MANOVA) and a frequency study were used to analyze the data, given the characteristics of the variables and the research questions.

Results revealed several developmental trends across the age groups: increases in the number of categories completed, increases in test efficiency, and difficulty in sorting

by number. Analyses focused on the position of number in the test sequence revealed its interference on test performance across all ages and highlighted the difficulty that six-year-old children have in sorting by number. No significant differences were observed in the choice of the first sorting criterion across the three age groups.

Implications of these findings are discussed regarding the frequent use of the WCST with young children, the clinical implications for diagnosis and intervention, the contemporary status of developmental neuropsychological assessment instruments, and future research.

ACKNOWLEDGEMENTS

Many people have helped to make this research project possible and there are many I would like to thank, beginning with all the participants in the study, children, parents, freshmen, and teachers. Without their willing involvement this study could not have taken place. I am particularly thankful to those who facilitated my access to the participating schools, Mr. Henry Fiore and Mr. John Hernandez, the past and current principals of the Monsignor Matthew F. Clarke Catholic Regional School in Wakefield; Mrs. Judy Ryan, Director of Education and Mr. Dan Corley, Head of School and at the Community Preparatory School in Providence; Mrs. Francis Rotella, past principal of the Anthony Carnevale Elementary School in Providence; and Mr. Eusebio Lopes, the principal at George J. West Elementary School, Providence.

For continuous support and encouragement, I am especially grateful to my family and to my sister, Corina Palmer. To my friend and partner, Sean Martin I am indebted for his role as a partner in brainstorming, editor and active presence in the data analysis task, and especially for creating the scoring programs which have significantly improved the accuracy of the data.

I must also acknowledge the inspiration I received from Dr. Karen Holler of Brown University/Butler Hospital who has been an important role model for my professional development, from the days of formulating my interests in child neuropsychology to the finalizing of my dissertation. Similarly, I am thankful to Dr. Jane Bernstein, Children's Hospital Boston, for her availability to consult on this dissertation and share her knowledge, as well as for her gentle critical and insightful feedback, and of course her encouragement.

Lastly, but not the least, I am most thankful to my professors, Dr. Allan Berman for his unfailing support and trust, Dr. Grant Willis for his acute critical mind and contributions to the current design of this dissertation study, and the other members (past and present) of my doctoral committee for their thoughtful guidance and support.

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STATEMENT OF THE PROBLEM

One objective of child clinical neuropsychologists is to determine the presence of an underlying neuropsychological process that might be contributing to the clinical presentation (Baron, 2004; Puente & McCaffrey, 1992). To this end, tests of executive function are often employed in neuropsychological assessment. Executive function is an umbrella concept that includes higher-order functions such as planning, organizing, cognitive response, set maintenance, mental flexibility, and impulse control. From its creation in 1948, the Wisconsin Card Sorting Test (WCST, Heaton, Chelune, Tally, Kay, & Curtiss, 1993) has been used to assess abstract reasoning and the ability to shift cognitive strategies in response to changing environmental contingencies. Although the test was developed for adult use, it has been frequently employed for assessing executive function in children. It was only in 1993 that norms for children as young as six and a half year old were included in the test manual (Heaton et al., 1993).

Given that the WCST has become well-established as a neuropsychological measure of executive function in children and adolescents, it is important to assure its developmental sensitivity. This study was designed to analyze the appropriateness of the WCST for use with young children (six year old) when adopting a developmental and neuropsychological perspective on higher cognitive functioning. The WCST stimuli involve four cards that display figures of various forms (triangles, stars, crosses, or circles), colors (red, green, yellow, or blue), and quantity/number (one, two, three, or four). Past research supports the fact that color, shape, and number are on different developmental schedules, and tasks of matching and sorting for children have reflected perceptual preferences for certain types of stimulus characteristic. The goal of this study

was accomplished by analyzing the impact of number as an abstract sorting criterion on the WCST performance and by interviewing children and adolescents about their conceptualization of the task. It is hoped that the results of the study will contribute to improve knowledge of the WCST as used with young children, specifically through a better understanding of the cognitive factors affecting negatively the WCST performance. This would then further contribute to the developmental outlook on pediatric neuropsychological assessment and to the manner in which neuropsychological assessment tools are used with children.

CHAPTER I: INTRODUCTION

The Wisconsin Card Sorting Test

The Wisconsin Card Sorting Test was initially developed in 1948 by Berg in order to “assess abstraction abilities in normals” (Heaton, 1981, p. 3). As the test gained popularity, it was seen as a source of information about possible cognitive difficulties in the patient, with an emphasis on those involving executive functioning. Given the nature of the task, the WCST offers the clinician a view on patients’ ability to make use of external cues to guide behavior, self-monitor, generate hypothesis, and shift responses (Romine, Lee, Wolfe, Homack, George, & Riccio, 2004). The test also measures failures such as inefficient initial conceptualization, tendency to perseverate, failure to maintain set, or inefficient learning across the several stages of the test (Heaton, 1981).

The choice of the WCST for this study was determined by three considerations. First, the instrument is a well-established measure of executive function for individuals aged 6 years, 6 months to 89 years (Greve, Stickley, Love, Bianchini, & Stanford, 2005; Heaton et al., 1993). Baron (2004) includes the WCST in the cluster of child executive function tests based on its focus on the child’s ability to plan, organize, reason, and shift. Secondly, the WCST is an instrument with wide usage for neuropsychological diagnosis and research: 75 percent of neuropsychologists include it in their battery of tests (Butler, Retzlaff, & Vanderploeg, 1991) and over 600 papers have been written about its use (Greve et al., 2005). Thirdly, based on studies of the cognitive processes involved in the WCST, this test can be viewed both as a developmental task and as a neuropsychological tool for identifying impaired executive function.

Given the complexity of the executive function and its reliance on multiple higher order cognitive processes, several authors suggested the need for alternative explanations (cognitive or developmental) to children's poor performances on this test, other than executive problems (Cinan & Tanör, 2002; Romine et al., 2004). Similarly, when adopting a developmental perspective, some behaviors of young children may not be straightforwardly considered deviant, therefore making it imperative that developmental explanations of executive function are well understood (Anderson, 2002). It has been recommended that more research be conducted to better understand the cognitive nature of impairment in the WCST performance for children, in order to improve the diagnostic process and treatment planning (Romine et al., 2004).

In the years following its creation, the test's reputation increased as a measure of cognitive deficits following brain injury in adults. Its popularity led to the extension of the test's usage in the assessment of children with suspected neuropsychological problems. Starting with the mid 1980's studies focused on children's performance on the WCST began to provide developmental norms and to analyze the application of the test in younger age groups. The first study, conducted by Chelune and Baer (1986), examined the cognitive abilities of normally-developing children ages 6 through 12 as reflected in the WCST performance. The authors' goal was to determine the time at which children's ability to solve the problem and conceptualize the task approaches the performance of normal adults. They started from the idea that formulating problem solving strategies, shifting sets, and responding selectively to different stimulus dimensions are important developmental tasks of great concern to child neuropsychologists. They argued furthermore that it is possible to use adult tests such as the WCST in the

neuropsychological assessment of children, provided that “the use incorporates a dynamic view of skill acquisition based on neurodevelopment principles” (Chelune & Baer, 1986, p. 225).

Another important study was designed in 1993 to augment the child developmental norms for the WCST, by expanding the age range to five years and by accounting for gender and socioeconomic status as possible confounding variables to the performance on the test (Roselli & Ardila, 1993). The common finding in these two studies was that overall, children’s performance on the WCST changes with advancing age, but not in a linear manner. In analyzing the nonlinearity of change in WCST performance across ages, Chelune and Baer made reference to stages of brain growth (Reines & Goldman, 1980) and reflected on the correspondence with Piaget’s stages of cognitive development. One point of divergence between these two normative studies was in the number of categories achieved by children six years of age: Chelune and Baer found that six-year olds achieve on average only 2.73 categories, in contrast to an average of 4.20 categories for the same age group in Roselli and Ardilla’s study. This contradictory evidence has constituted the starting point for this explorative study of young children’s performance on the WCST and of the cognitive demands of the task. The low average value for categories achieved (2.73) could be interpreted as a difficulty in attaining the third sorting category of the test, when number is the sorting criteria to be inferred and used.

The third major study contributing to the use of the WCST for neuropsychological assessment of children is that of Chelune and Thompson (1987) which focused on the apparent sensitivity of the WCST. The authors measured the test’s ability to differentiate

among two groups of children (ages 7 to 15) who were either referred for neuropsychological evaluation or part of a control group. Their conclusion was that although the WCST was developed for adults, it can differentiate degrees of acquisition of cognitive skills in children. However, the authors cautioned that the developmental utility of the WCST as a pediatric neuropsychological instrument needed to be examined in a broader context by incorporating notions of rate of development, lag, and delay in skills development (Chelune & Thompson, 1987).

To date, children's poor performances on tasks of executive function (the WCST included) have been conceptualized as neurologically based and have acquired negative connotations. Children have been described as displaying (1) lack of behavioral control, (2) inability to make use of feedback (positive or negative) in formulating problem solving strategies, (3) inability to suppress ongoing activity despite environmental feedback that such activity was no longer appropriate, (4) inability to shift, or (5) increased reactivity to extraneous stimuli (Passler, Isaac, & Hynd, 1985). It is generally accepted that the WCST involves a considerable number of different executive function components and cognitive skills, making the interpretation of impaired performance on the test challenging. In the attempt to adopt a developmental perspective in interpreting the WCST performance of young children, a specific look at the cognitive demands of the task for six-year-old children was employed in the present study.

Test Description, Reliability, and Validity

The WCST is a categorization task based on the requirement to match simple stimuli to one of four possible targets. There are four cards that display figures of various shapes (triangles, stars, crosses, or circles), colors (red, green, yellow, or blue), and

quantity/number (one, two, three, or four). The stimulus cards are arranged in a line (from participant's left to right): one red triangle, two green stars, three yellow crosses, and four blue circles. Two identical decks of 64 cards are given consecutively to the participant, one card at the time; the cards display all the possible combinations of the forms, colors, and numbers. The participant is instructed to place each consecutive card in front of one of the four stimulus cards, wherever he or she thinks it should go. Correct matches are based on one of the three principles - color, shape, or number – which respondents must induce from feedback given by the examiner (respondents are told whether each of their answers is right or wrong). When respondents have correctly categorized ten stimuli in a row, the matching principle is changed without warning. Respondents must avoid perseveration; explicitly they must recognize that the old principle no longer holds, induce the new principle, and then apply it in order to perform well on the test (Bowden, Fowler, Bell, Whelan, Clifford, Ritter, & Long, 1998). The test proceeds in this manner until the three possible sorting principles are repeated twice in the following order: color, form, and number, color, form, and number, for a total of six categories completed.

Prior to 1981, at the time of the first publication of the WCST manual, every aspect of the test administration had been changed in clinical and research settings; a survey of the existing studies revealed that up to 32 different scoring methods had been used (Heaton, 1981). For that reason, the 1993 edition of the WCST manual was developed as an expert source of standard administration, recording, scoring, reliability, and validity studies. While the WCST procedure had been standardized through the publication of the first manual (Heaton, 1981), this latest manual presents refined scoring rules and provides clear examples of the scoring procedures for the purpose of addressing

the ambiguities and the sources of scoring difficulty (Heaton et al., 1993). There are also different administrations of the WCST, such as the 64-card version (Kongs, Thompson, Iverson, & Heaton, 2000) and the computer administered versions of 64 and 128 cards (Heaton, Goldin, & PAR Staff, 2003).

While there are numerous studies about the psychometric properties of the Wisconsin Card Sorting Test, the focus here is only on the reliability and validity studies using the test with children and adolescents. At the time of the publication of the latest edition of the WCST manual, reliability studies revealed excellent inter-scorer and intra-scorer reliability, with coefficients ranging from 0.91 to 0.93 (Axelrod, Goldman, & Woodland, 1992). The manual reports moderate to good reliability for the majority of the scoring variables considered (0.35 to 0.72, with a median of 0.60) for scores obtained by a sample of children and adolescents, ages 6 years, 6 months to 17 years old. Alternate-form reliability in a study of undergraduate students revealed reliability values of 0.60 for number of categories achieved and 0.51 for the total number of errors (Bowden et al., 1998).

Validity studies with children and adolescents presented in the manual show that the WCST differentiated between groups of children with different locations of brain lesions and that group identification accounts for approximately 19% of the variance (Heaton et al., 1993). Similarly, the manual reads that the WCST was found to differentiate between children and adolescents with ADHD, seizure disorder, learning disability, and traumatic brain injury, with the diagnostic category accounting for 10% of the variance in the WCST scores. Both studies, however, are weakened by unequal sample sizes within the diagnostic conditions and small number of participants in each

condition; in addition, the researchers pieced together in the diagnostic groups children ages 6 years, 6 months to 17 years old, ignoring the obvious age-related developmental differences in cognitive functioning between the participants. Even validity studies by other authors such as Chelune and Thompson (1987) suffer from similarly weak research designs and small sample sizes, affecting ultimately the psychometric reputation of the test and the clinical utility when used with children and adolescents. Despite the questionable research designs and relatively discouraging psychometric characteristics, Heaton and colleagues conclude that “the WCST may be helpful in evaluating executive function in these conditions” (Heaton et al., 1993, p. 57).

The norms for children and adolescent age groups in the manual have been derived from 453 normal children and adolescents enrolled in public schools in the community surrounding a large urban area in the southeastern United States. The sample consisted of 52% females and 48% males enrolled in kindergarten through 12th grades. Ages ranged from 6 years, 6 months to 17 years, 11 months. Of the 379 subjects for which race data were recorded, 87% were white, 11% were black, and 2% were other racial minorities. The cell size for each age group varies from a minimum of 28 participants (for 6 years, 6 month old group) to a maximum of 55 participants (for the 12 years old group) (Heaton et al., 1993). There are three additional normative studies for the classic 128-card administration of the test, for children 6 to 12 years old (Chelune & Baer, 1986), for children from Colombia, South America ages 5 to 12 years old (Roselli & Ardilla, 1993), and for Canadian children ages 9 to 14 years old (Paniak, Miller, Murphy, Patterson, & Keizer, 1996). For the computerized administration of the 128-card version of the WCST, there are additional norms published on a Taiwanese sample of

children ages 6 to 11 years old (Shu, Tien, Lung, & Chang, 2000). It is important to mention that all but the Paniak normative study have unreasonably small cell sizes per age and gender groups when considering the employed analyses (such as 11 or 12 children per age in the Chelune and Baer study or 8 or 13 for the Roselli and Ardilla study) .

In order to examine the potential effects of age on the WCST performance, Heaton and his colleagues conducted a hierarchical polynomial regression analysis. Results revealed a significant quadratic effect for age on all the WCST variables, with a substantial increase in the proficiency on the WCST from 6 years, 6 months to 19 years of age (Heaton et al., 1993). All the WCST studies discussed up to this point reflect similar performance changes with advancing age.

The classic examiner-administered version of the WCST takes about 20 minutes to administer and comes with a computerized scoring program; the examiner hand-scoring can take up to 30 additional minutes.

Uses of the WCST

The first use of the WCST was as a measure of mental flexibility and cognitive shift for “children, aged, psychotics, feeble-minded, and brain-damaged people” (Grant & Berg, 1948, p. 404). Since then, the test has been used for various purposes, some of which are assessing changes in cognitive functioning due to brain injury or neuropsychological disorders in adults (Love, Greve, Sherwin, & Mathias, 2003) or prediction of neurological, psychological, and functional status in adult clinical populations with diagnoses of schizophrenia or substance abuse (Bellack, Blanchard, Murphy, & Podell, 1996; Burgess, Alderman, Evans, Emslie, & Wilson, 1998).

Specifically in the use with children and adolescents, the WCST had been employed as a measure of impulsivity and behavioral dysfunctions in inpatient population (Borgaro, 1999; Riccio, Hall, Morgan, Hynd, Gonzalez, & Marshall, 1994), a measure of attention deficit disorder in outpatient and inpatient children with or without medical disorders (Heinrichs, 1990; Ozonoff & Jensen, 1999; Shallice, Marzocchi, Coser, Del Savio, Meuter, & Rumati, 2002), or as a diagnostic measure for dyslexia (Helland & Asbjørnsen, 2000), learning disabilities (Snow, 1998), Asperger and Tourette Syndromes (Ozonoff & Jensen, 1999), and nonverbal learning disability (Fisher, DeLuca, & Rourke, 1997). Studies have also looked at the WCST and frontal lobe pathology (Mountain & Snow, 1993; Rybash & Colilla, 1994). A meta-analytic study by Romine and colleagues (2004) found that the test has good sensitivity and specificity in its use with pediatric clinical groups. The test differentiated developmental trends between performance for children and adolescents with a diagnosis of learning disability and normal participants; children with anxiety diagnoses were found to have a tendency to perseverate and were unable to use negative feedback in a productive manner suggesting a rigid adherence to a specific pattern and a decreased ability to shift focus. Furthermore, children diagnosed with conduct disorder were found to have impaired performances in several WCST scores, as had children with Autistic Spectrum Disorders. The authors concluded that in order for a measure to be clinically useful, it must contribute to the clinical aspects of differential diagnosis, rehabilitation, or prediction of outcome. Based on their meta-analysis, the WCST seems to be a sensitive measure providing needed clinical information on children's ability to use external cues to guide behavior, self-monitor,

their perseverative tendencies, hypothesis generation, and cognitive flexibility (Romine et al., 2004).

The WCST Scoring Dimensions

Clear procedures for the scoring variables have been introduced with the most recent version of the WCST manual (Heaton et al., 1993) and the criteria for measuring perseverative responses and perseverative errors were further discussed in an article by Flashman, Horner, and Freides (1991). Bowden and his colleagues (1998) refer to six principal and several additional scores that are arithmetically derived. Below are summary definitions for each of the eleven the WCST scores:

1. Number of Categories Achieved (NCA): this score measures how many correct categories were built by the participant in completing the test (either by completing six categories or by using all of the 128 cards). This basic score speaks to the participant's ability to solve problems through the use of feedback, each time he or she is presented with a cognitive challenge.
2. Total Number of Correct Responses: this basic score measures how many correct responses the participant gave in completing the test.
3. Total Number of Errors: this basic score measures how many errors (responses that match an incorrect category or do not match any category) the participant gave in completing the test.
4. Perseverative Responses: a perseverative response is a response that would have been correct in the previous stage of the test and is carried on after the completion of the 10 consecutive correct answers needed for a category. This basic score is considered the most diagnostic measure of the test, as it was

found to predict the presence or absence of brain damage and of frontal lobe involvement in focal cases (Flashman et al., 1991; Heaton, 1981; Lezak, 2004).

5. Perseverative Errors (PE): this basic score measures the perseverative responses that are also errors.
6. Non-perseverative Errors: this basic score measures erroneous responses that are not perseverative errors.
7. Trials to Complete the First Category: this score gives an indication of the participant's initial conceptualization of the sorting criterion before a shift of set is also required. This score is considered a measure of conceptual ability (Heaton et al., 1993).
8. Failure to Maintain Set: this score measures the number of times in the test the participant makes five correct responses in a row but fails to get the ten responses required for a complete category. This score, too is considered a measure of conceptual ability (Heaton et al., 1993).
9. Learning to Learn (L2L): this score reflects participant's average change in conceptual efficiency across the consecutive categories (stages) of the test. If this score has a positive value, it speaks of the participant's improved efficiency in sorting across successive categories presumably due to learning. Normative data allows some negative scores within the normal limits of performance because the percent error difference score between a preceding and the following completed categories can be negative (this difference is part of the calculation process). If the score has a negative value and is outside the

average normative range, it speaks of the participant becoming less rather than more efficient on the consecutive stages of the WCST (Heaton et al., 1993).

10. Trials Administered: this score measures how many cards were used by the participant before the test was finished (either because the six required categories have been achieved or because all 128 cards were used).
11. Conceptual Level Responses: this score measures consecutive correct responses occurring in runs of three or more. It is presumed that some insight into the correct sorting strategy is required in order to make three or more correct matches and that a correct series of this length would be unlikely to occur by chance alone. This score is considered a measure of conceptual ability (Heaton et al., 1993).

Historically, there are additional WCST “percentage” scores used mainly to assist researchers, as they account for differences in numbers of trials administered when designing comparisons across multiple participants. These scores (Percent Conceptual Level Responses, Percent Nonperseverative Errors, Percent Perseverative Responses, Percent Errors Overall, and Percent Total Correct Responses) are not recommended for clinical interpretation of the WCST since they involve correcting scores by a measure of overall success on the test (i.e. the number of trials required to complete the WCST) and because the reliability of these percent scores is lower than those of their respective elemental scores (Heaton et al., 1993).

The test has been criticized for not offering, de facto, much valuable clinical information, since there is much redundancy in the calculation of the basic six standard scores. A study of internal validity of the WCST through exploratory factor analysis

found that the six basic scores actually load significantly on just one factor that underlies the participants' performance, and that it is necessary to estimate the correlations amongst observed errors in order to identify a fitting model (Bowden et al., 1998). By inference, the authors warned about the redundancy in the clinical interpretation of these WCST basic scores, and as such, they cautioned against the overall clinical utility of the WCST. Greve et al. (2005) decided to re-employ a proper factor analysis for the cognitive processes involved in the WCST performance, since the preexisting 16 studies on this topic had only used exploratory factor analysis or had inappropriately small samples for the use of the confirmatory factor analysis, such as the Bowden et al. study cited above. Greve and his colleagues found that the WCST is actually a good measure of executive functioning and that performance on this test may serve as a gross indicator of other cognitive processes involved. Consequently, while the presence of poor results on variables such as Failure to Maintain Set, Perseverative Errors, and Nonperseverative Errors may warrant further testing of the cognitive processes involved, correspondingly good scores may have little clinical meaning (Greve et al., 2005).

This dissertation looked at selected WCST scores (NCA and L2L) in the effort to understand the nature of the cognitive processes involved in solving the test, as they pertain to developmental aspects. For the purpose of this study, an additional score has been selected: Percent Errors Score (%ES) for achieving number the first time it appears in the test. This score is part of the computations for the L2L score and has been calculated in this study as a measure of difficulty experienced by each participant in sorting by each criterion.

Executive Function

Executive function is an umbrella term that incorporates several inter-related processes; therefore, it has been defined in many ways, with the focus shifting between from neurological components to the observable behaviors that signify it (Gioia, Isquith, & Guy, 2001, cited in Anderson, 2002; Mahone, Hagelthorn, Cutting, Schuerholtz, Pelletier, Rawlins, Singer, & Denckla, 2002). Baron (2004) provides a list of subdomains of executive function as they have been derived from empirical studies: “set shifting, hypothesis generation, problem-solving, concept formation, abstract reasoning, planning, organization, goal setting, fluency, working memory, inhibition, self-monitoring, initiative, self-control, mental flexibility, attentional control, anticipation, estimation, behavioral regulation, common sense, and creativity” (2004, p. 134). Barkley (1998) defines executive functioning as a set of self-regulatory abilities guiding behaviors within the context of goals and rules. Mahone and his colleagues defined executive function as the ability to develop and implement an approach to performing a task that has not been habitually performed (Mahone, Cirino, Cutting, Cerrone, Hagelthorn, Hiemenz, et al., 2002). Weyandt and Willis (1994) conceptualized executive function as a sum of abilities that enable individuals to maintain an appropriate problem-solving set for attaining future goals, such as strategic planning, impulse control, organized speech, and flexibility of thought and action. Lezak defined executive function as a sum of capacities that allow a person “to engage successfully in independent, purposive, self-serving behavior” (2004, p. 35).

Depending on who is identifying the term, executive function has been conceptualized as including various domains (Zelazo, Müller, Frye, & Marcovitch,

2003). Riccio attempted to summarize the existing knowledge about executive function into an encompassing explanation:

Executive function is a multidimensional construct that covers a range of higher order cortical functions including goal-directed behavior, attentional control, temporal organization, and planning for purposeful, goal-directed behavior. Conceptualized from a variety of contexts with demonstrated importance in the development of behavioral, academic, and social competence, executive function is comprised of those composite psychological processes necessary for problem solving and self-regulation; components of executive function collectively allow for the developmental shift from external controls and cues to internal, mental representations and self-control. The constructs included under executive function umbrella vary depending on researchers, but generally include distinct, yet related cognitive components, such as cognitive flexibility, planning and goal setting, inhibition, organization, sequencing, and information processing (Riccio, personal communication, October 28, 2006).

Models of executive function have been derived using factor analytic studies based on outcome parameters from executive functioning test batteries (Zelazo et al., 2003).

Anderson proposed a comprehensive four-domain model by considering clinical neuropsychological knowledge (2002). His model is building on the one offered by Alexander and Stuss (2000) which contains four inter-related but distinct components: attentional control, information processing, cognitive flexibility, and goal setting. These executive domains are considered discrete functions yet are operating in an integrative manner, likely to be related to specific frontal systems. The attentional control domain

includes the capacity to selectively attend to specific stimuli and inhibit prepotent responses, the ability to focus attention for a long period, self-regulation, and self-monitoring of actions according to the established plan. Information processing refers to fluency, efficiency, and processing speed, as they reflect the neural and functional integration of the frontal system. Cognitive flexibility refers to the ability to shift between response sets, learn from mistakes and feedback, devise alternative strategies, and process multiple sources of information simultaneously; this domain includes working memory as a key element. Finally, the goal setting domain incorporates the ability to develop new initiatives, the ability to plan actions and approach tasks in efficient and strategic manners, strategy use, and organization abilities. The attentional control domain greatly influences the functioning of the other three domains, while information processing, cognitive flexibility and goal setting are interrelated and interdependent. Also, each domain involves highly integrated cognitive processes and each receives and processes stimuli from various sources (Anderson, 2002).

Zelazo, Carter, Reznik, and Frye (1997) attempted to ground the construct of executive function in a problem solving paradigm in order to integrate the distinct aspects of executive function (temporally and functionally) within a coherent framework. Consequently, executive function was defined as a macro-construct that spans four phases of problem solving: representation, planning, execution, and evaluation. In addition to providing a coherent characterization of executive function, this framework allowed the authors to review an extensive literature and reflect on the normal development of problem solving in preschool children.

The authors believe that in order to solve a problem, one must first represent the problem in a way that is conducive to solving it: the developmental skills studied for this ability were selective attention and flexibility, defined as the ability to attend selectively to some aspects of a situation and ignore others and the ability to be flexible in attentional sets. For planning, as the second phase of problem solving, the authors reviewed research focused on systematicity (the number of steps involved in a problem that children can solve), event planning, mazes planning, logical search (making inferences), integration of information, and planning to remember. Execution, the third step in problem-solving involves, in the authors' view, keeping a plan in mind and translating that plan into action. This skill was studied through prospective memory, sustained attention, and rule use (the need to consider conditional statements in guiding behavior). Executive function is deemed successful when it leads to the solution of a given problem, but bears equally important roles in recognizing an error, hence including the ability to formulate and carry out an alternative plan. This last stage of problem solving - evaluation - was studied through error detection and error correction. Zelazo and his colleagues concluded, based on the existing research on executive function in early childhood, that there are age-related changes in all four aspects of executive function as a problem-solving process. The authors' coherent description of executive function at different ages has been proposed as the first step towards an understanding and an explanation of developmental changes in executive function (1997).

The importance of studying and understanding executive function in children stems from its integral role in the development of self-regulation (Barkley, 1998; Denkla, 1998), social competence (Hughes, 1998, cited in Riccio, 2006), for the role it plays in

academic and social readiness (Riccio, 2006), and for its presence in multiple developmental psychopathologies and disorders. In her work, Riccio cites recent research of Chaytor, Schmitter-Edgecombe, and Burr (2006) who revealed that specific measures of executive functions can account for additional variance in every day functioning of the person, above and beyond IQ. It is for all these reasons that understanding the nature of executive function and dysfunction and using the appropriate instruments to measure it bare crucial weight in informing assessment, intervention and treatment planning (Anderson, 2002).

Development of the Brain and Neural Basis of Executive Function

Although executive function encompasses multiple cognitive processes, traditionally, it has been associated with frontal and prefrontal regions of the brain, as neuroimaging studies have observed significant activation within the prefrontal cortex in individuals of all ages performing executive function tests (Anderson, 2002). Executive function has been found to emerge in infancy and develop throughout childhood and adolescence into early adulthood.

Epstein has been a pioneer in understanding and promulgating knowledge of brain-mind development (phrenoblysis) as it affects education and learning. In 1978, he proposed the theory that increases in brain development are not continuous, but rather occur at discrete periods during life; therefore one has to think in terms of stages of brain development. He also discussed the correlations between stages of brain development and stages of cognitive development. According to Epstein, human brain growth occurs primarily during the age intervals of 3 to 10 months, 2 to 4 years, 6 to 8, 10 to 12, and 14 to 16 years; he found that these periods correlate well in timing with increases in body

weight and with stages of cognitive/mental growth, such as Piaget's stages of cognitive development. When analyzing brain development across genders, Epstein found that, for the last two periods of development, brain and body weight generally occur slightly earlier for females.

Reines and Goldman (1980) studied the physiological changes that take place in the frontal lobes based on age and reflected on the processes of myelination and cortical fissuration in the frontal cortex: myelination of the frontal lobes proceeds rapidly from the age of 4 to about 13 years, while cortical fissuration, which is associated with extended and refined control of behavior, shows growth spurts in the frontal regions at ages 2 and 6 (Rourke, Bakker, Fisk, & Strang, 1983). Knowledge of synaptogenesis and synapse elimination in the developing human prefrontal cortex was also provided by the work of Goldman-Rakic and her colleagues, pioneers in the anatomical study of primate brain development (Goldman-Rakic, Bourgeois, & Rakic, 1997). These observations augmented the initial argument of Epstein and, to this day, amount to sound scientific evidence for the presence of and ability for executive functioning in children. Similarly, neuropsychological research has shown that by age seven, children surpass the WCST performance of adults with focal frontal lesions, but not that of adults with focal nonfrontal lesions, suggesting that the frontal regions are beginning to become operational, although not functionally mature (Cheune & Baer, 1986).

Similar brain-behavior connections are reflected through the changes in the educational demands of children across ages, as Epstein suggested in 1978. Other authors have reflected that from being expected to learn how to read and “learn how to learn” in the first grade (5-6 years old), children are expected to read in order to learn during the

fourth grade (9-10 years old). In middle school (11-13 years) children are expected to learn how to organize their learning, while in high school (14 years on) adolescents are required to be proficient and organized learners, interested in and good at synthesizing new knowledge (Holmes, 1987).

Brain development and maturation have been considered numerous times as the basis for behavioral change. Having the knowledge of developmental neuroanatomy augments the understanding of normal human functioning and provides a basis for analysis for the deviations from normal developmental sequences (Willis, 2005). Neuroanatomical research reveals that in certain circumstances it is experience that determines behavioral changes, through its influence on gene expression (Johnson, Munakata, & Gilmore, 2002). More, some of the research of Goldman-Rakic and her colleagues offered counterintuitive results about brain development and behavioral change: adolescence, a period of intense and efficient learning and rapid behavioral modification “does not appear to be paralleled by either significant net accretion of net loss of synapses” (1997, p. 42). Their research reveals that systemic and experiential factors are influential in improving synaptic efficiency more so than genetically determined shifts in synaptic density. In the end, a constructivist perspective seems to be the most accurate account for developmental progress, as the interaction between genetic inheritance and environment is most of the times the underlying factor in development (Johnson et al., 2002).

Many studies have summarized the behaviors assessed by the WCST and all behaviors are thought of as developmentally appropriate for children (Mattes, 1980, cited in Chelune & Baer, 1986); however, when analyzing such behaviors from a

neuropsychological perspective, one needs to consider the developmental rates of specific skills (Anderson, 2002) and the neural and functional substrates of young children's brain.

The developing brain is characterized by varying degrees of electrophysiological, biological, and morphological maturity across different neural regions and across various age groups (Johnson & Alimi, 1978, cited in Chelune & Baer, 1986; Willis, 2005). It has been shown that performance on the WCST involves various areas of the brain in addition to the frontal cortex; activation has been observed in complex networks such as the inferior parietal lobe, visual association area, inferior temporal cortices, as well as portions of the cerebellum. Activation in the dorsolateral prefrontal cortex was found to remain significant even after training and practice on the test, reflecting the importance of working memory in responding to the WCST demands (Berman, Ostrem, Randolph, Gold, Goldberg, Coppola, Carson, et al. 1995).

The neural-system underpinnings of executive function are numerous, complex, and interrelated with the prefrontal cortex, and are dependent on efferent and afferent connections with virtually all other brain regions including the brain stem, occipital, temporal, and parietal lobes, as well as limbic system and subcortical regions (Stuss & Benson, 1984, cited in Anderson, 2002). Findings from neurological and functional neuroimaging research on tests of executive functioning also show that is difficult to conceptualize tests of executive function as pure measures of a single skill; it is likely that performance on executive tasks is contaminated by the ability to perform on other non-executive requirements of the task. Along these lines, Cinan and Tanör (2002) believe that the WCST involves a considerable number of different executive functions,

making the interpretation of impaired performance on the test equivocal. In their work, they provide a very interesting and comprehensive summary of four executive functions/processes that seem to be activated during the WCST performance: maintenance of different kinds of information (feedback from current trials, mental set or a current hypothesis about the sorting criterion), regulation and reorganization of responses according to environmental cues (comparison of feedbacks across trials, generation of a new hypothesis about the sorting criterion or the process of shifting the mental set in accordance to the new criterion), concept formation (for color, form, and number), and inhibition of inappropriate responses or well-learned responses. Similarly, Romine and colleagues (2004) believe that in addition to its focus on executive function, the WCST involves non-executive components that are most likely not specific to prefrontal cortex. As mentioned before, given the involvement of a number of cognitive functions such as attention, memory, verbal processing, and problem solving, executive functioning occupies a central role in children's intellectual development, academic achievement, personality, social skills, relationships, and communication (Anderson, Anderson, Northam, Jacobs, & Mikiewicz, 2002).

Executive function emerges in childhood and follows an extremely protracted development course that extends well beyond adolescence (Lamm, Zelazo, & Lewis, 2006). An implication of the intermittent development of brain structures is that in many instances neurodevelopmental disorders or functional deficits for children may not manifest until later in life, even though the neurobiological basis of the condition may be present earlier (Mahone, 2004). As mentioned above, executive function in children is a task that developmentally is not fully observable (in the way that it would be observed in

adults) until past their early teen years. This understanding has been reflected by Chelune and Thompson (1987) who argued that, from a developmental perspective, measurement of behaviors thought to be dependent of brain development are acceptable in pediatric neuropsychology because such behaviors do not need to be fully mastered before they became of interest to child neuropsychologists.

Anderson's model of executive function is accompanied by projected developmental trajectories for each of the four domains, with a cautionary note that these are hypothetical approximations awaiting verification in future developmental studies. Nevertheless, the proposed trajectories are a good starting point, based on existing literature: the processes within the attentional control domain appear to undergo considerable development during infancy and early childhood – by middle childhood self-control and self-regulation processes are found as relatively mature. Despite following slightly different developmental trajectories, information processing, cognitive flexibility, and goal setting are all relatively mature by the age of 12 years, although many executive processes are not fully established until mid-adolescence or early adulthood (Anderson, 2002).

Similarly, the model of executive function proposed by Zelazo and his colleagues also discusses the development of various skills included in the four steps of problem-solving (Zelazo, Carter, et al., 1997; Zelazo, Müller et al., 2003). Preschool children's thinking tends to be inflexible, therefore affecting their ability to represent the problem in ways conducive to solving it; however, the authors report changes sensitive to developmental variation. For preschoolers' ability to plan, research indicates that there are marked changes along the age continuum, with overall increases well into the school-

age years. With regards to the execution of a plan, as a third step of problem solving, preschoolers have the ability to represent and use a pair of arbitrary rules, can sustain attention, but are likely to perseverate if required to shift from one set of rules to an incompatible set. The authors discuss the role of executive function in “interference conditions” when executive function and automatic processes are put into opposition, versus “facilitation conditions” when executive function and automatic processes work together. They further suggest that it is possible to derive estimates of the influence of executive function on children’s behavior at different ages and in different situation by comparing these two roles. Finally, there is strong evidence to support the existence of a developmental trajectory in children’s ability to correct their errors as part of evaluating their problem-solving strategy; however, the authors highlight the slow extinction of perseverative behaviors in young children, despite error information feedback.

Knowledge of the various areas of the brain activated by the WCST task and knowledge of brain’s developmental trajectory become essential for understanding children’s performances on the WCST. For example, it has been shown that the myelination process starts within the sensori-motor/posterior area of the brain and evolves during lifetime to the anterior brain where the association areas are located (Goldman-Rakic et al., 1997; Mahone, 2004). Similarly, longitudinal studies show that white-matter volume from myelinization of afferent and efferent nerves increases into adolescence for association cortices of the frontal and parietal lobes (Huttenlocher & Dabholkar, 1997; Sowell, Peterson, Thompson, Welcome, Henkenius, & Toga, 2003). As initially proposed by Epstein in 1978, contemporary research on myelination reflects the existence of critical periods of brain-behavior development, as well as the non-linear

maturation of the brain; peak growth periods for cortical thickness and increased synaptic connections happen between the ages of 6-8 years, 10-12 years, and 14-16 years. Many authors offer reports of the ontological and developmental brain growth as “a dynamic process of increasing cortical specialization... that develops within the hemisphere in a vertical (subcortical-cortical) and horizontal (anterior-posterior) progression during infancy and childhood (Satz, Strauss, & Whitaker, 1990, p. 61, cited in Spreen, Rissel, & Edgell, 1995). These developmental views are based on theory of Hughlings Jackson in 1869 who proposed that “development proceeds along the y-axis, upward along the neuraxis from spinal cord to neocortex, as well as along the z-axis, the anterior-posterior dimension, and the x-axis, the lateral dimension that shows progressive lateralization” (Spreen et al., 1995, p. 73). Luria developed a theoretical view of the brain’s “functional systems” as interactive areas of the brain that mediate behavior (1966). All these functional systems involve three basic units of the brain: the arousal unit (reticular formation and related structures), the sensory input unit (posterior portions of the hemispheres), and the output/planning unit (mainly the frontal lobes). The sensory and output units can be further divided into primary, secondary, and tertiary areas which represent increasing levels of complexity and integration in information processing. Following the ideas of brain development, Luria created his theory of ontogenetic development of brain-behavior relations: he described how major cognitive synthesis occur after the development of the secondary zones, which, in turn could not take place without the full development of the primary zones. Luria offered a timeline of the ages of development for each of the functional systems and brain areas involved. From birth to 12 months the reticular formation effects cortical arousal and input modulation, and the

primary motor and sensory areas become responsible for the analysis of sensory inputs and cross-modal integrations. The development of secondary sensory and motor areas continue well into the fifth year of life, followed by a dominance of parietal lobes which allow, as a tertiary sensory input area, further integration of information. From 12 years of life on, the development of the prefrontal lobes takes precedence, and this brain structure assumes the dominant role in the adult. Based on Luria's model, the full development of the higher cortical zones happens in early adulthood and the individual attains the highest functional level of the brain, which is responsible for planning and carrying out of behavior (Spree et al., 1995).

The neuronal substrate of the brain as it pertains to the ability to switch set, integrate feedback, or devise alternative strategies was studied by Konishi and colleagues: by using fMRI, they found sound evidence of transient activation of the posterior part of the bilateral inferior frontal sulci, with larger activation as the number of dimensions (relevant stimulus attributes that had to be recognized) was increased. These results suggest that the inferior frontal areas play an essential role in the flexible shifting of cognitive sets (Konishi, Nakajima, Uchida, Kameyama, Nakahara, Sekihara, & Miyashita, 1998).

Further studies similarly revealed the involvement of frontal brain structures in the tasks required by the WCST. In assessing WCST task efficiency for adults, Barcelo and Knight (2002) analyzed the types of errors made by healthy adults in contrast to the WCST errors made by brain impaired adults. They found that for healthy adults, most test errors were efficient errors, meaning "the non-perseverative errors made by the subjects early in the WCST series in order to find the new sorting rule" (p. 350), with a lesser

amount of random errors. Patients with prefrontal lesions had a larger number of perseverative errors and significantly more random errors, as a reflection of an inability to efficiently change the sorting rule on the basis of previous feedback and a failure to keep the rule in mind through varying stimulus conditions while ignoring irrelevant aspects of stimulation (Barcelo & Knight, 2002). Booth and colleagues established that brain-behavior correlations in children depend on the nature of the neurocognitive network. They found that behaviors such as set shifting, when mediated by relatively mature brain networks in children may show negative correlations with accuracy because better performers are more automatic and efficient at utilizing existing neurocognitive resources. By contrast, similar tasks that rely on relatively immature brain networks may show positive correlations with accuracy because a more extensive utilization of the relevant neurocognitive resources is required to perform the task well (Booth, Burman, Meyer, Trommer, Davenport, Parrish, et al., 2004). Studies such as the ones presented here draw attention to the importance of understanding the relationship between brain and behaviors in a developmental perspective. This becomes even more important, especially in the context of neuropsychological assessment of the child, as neuropsychologists focus on understanding the person by formally assessing brain function (Baron, 2004). By using scientifically validated objective tests, neuropsychologists cover a range of mental processes from simple motor performance to complex reasoning and problem-solving. The combination of objective scores, behavioral and processing observations across settings and pattern of results, along with comprehensive clinical history constitute the art and science of neuropsychological assessment (Mahone, 2004). In addition, clinical neuropsychologists interpret the emerging profile and its impact on the person's everyday

life (behavior, social relationships, academic or professional performance, and mental health), to provide a better understanding of the current fit between child's biology and the environment, to predict future concerns, and to provide extensive recommendations for educational or treatment planning (Baron, 2004; Bernstein, 2000; Cohen, Branch, Willis, Weyandt, & Hynd, 1992; Hynd, 1988; Mahone, 2004).

Assessment of Executive Function in Children: Controversies

The majority of executive function tests used in the assessment of children have been developed for and validated on adult populations. The practice of using either adult-derived tests or scaled-down versions for children's assessment is questionable, particularly for diagnostic purposes, as adult measures may tap into different skills in children (Anderson, 2002). Nowakowski and Hayes proposed a simple but efficient framework for understanding the development of the central nervous system. They suggested asking three questions: "when" – to address the aspect of time and timing of brain development; "where" – to address the location and various parts of the brain; and "what" – to depict the cellular processes and interaction taking place during brain development (2002). This framework has been frequently used to guide neuropsychological assessment. For adults, the connection between brain and behavior is best depicted in the answer to the question of "where" in the brain is the affected structure responsible for the impairment in behavior. For children, however, brain-behavior relation embodies complex answers to all three questions: "when" the possible toxic event occurred (e.g. two days post conception, at birth, at four years of age, etc); "where" in the brain is the structure that was affected and is responsible for the observed behavior; and "what" is going on with the brain from the perspective of development

before, at the time of, and after the toxic event (cell migration or assembly, synaptogenesis, myelogenesis, etc.) (Bernstein, personal communication, September 27, 2006). Research conducted by Bates and her colleagues on children with focal brain injury found that the brain is able to develop alternative patterns for information, similar to the patterns of brain organization for language observed under normal conditions of development (Bates, Thal, Trauner, Fenson, Aram, Eisele, et al., 1997). By considering the three questions above, this research provided an argument against the beliefs based on adult brain functioning that there is an innate localization for linguistic representations. In addition, the findings speak of the plasticity of developing brains. Along these lines, Mahone suggests that tests devised for children may not necessarily attempt to diagnose disorders *per se*, but attempt to more accurately characterize the development of skills for the purpose of planning appropriate behavioral, academic, and possibly pharmacological intervention, as well as to aid in monitoring effects of interventions (2005).

Diamond and colleagues have studied executive function in children. Their work is remarkable for the efforts towards modifying preexisting neuropsychological tests in order to measure developmentally appropriate skills in preschool-age children. Specifically, they focused their investigations on the Stroop test and have modified it in various ways to make it suitable to children as young as three years old (Gerstadt, Hong, & Diamond, 1994). Espy and her colleagues provide another example of the efforts to develop theoretically driven tests for measuring executive function in young children (Espy, 1997; Espy, Bull, Martin, & Stroup, 2006). Their findings revealed that children as young as two and a half years old are able to switch sorting criteria when the dimensions of the sorting objects are separated. Separating color and shape, the

characteristics targeted as the sorting criteria, reduced toddlers' need for perspective switch (inhibit the old way of thinking about the object) (Diamond, Carlson, & Beck, 2005). The research of Diamond' and Espy's groups is relevant in the context of this dissertation as they based their predictions on a thorough understanding of the presence and complexity of the cognitive processes required by the tests from children at different developmental levels. Secondly, the work of these researchers imposes standards for successful scientific study of children's cognitive abilities through the use of neuropsychological tests, in that the assessment measures have to include developmentally relevant behaviors and use developmentally relevant tasks (Diamond et al., 2005; Gerstadt, et al., 1994; Kirkham, Cruess, & Diamond, 2003).

During the early 1980's, the scientific community initiated a debate about the appropriateness of neuropsychological testing of children, suggesting that tests of higher cognitive functioning are not appropriate for the assessment of preadolescent children (Fletcher & Taylor, 1984; Golden, 1981). Continuing research in neurological and psychological sciences within the last decade have eliminated the debate by providing pediatric neuropsychologists with grounds for completing neuropsychological evaluations of executive function in young children: studies have proven that executive function can be reliably evaluated in preschool children, ages three and up (Diamond et al., 2005; Espy, Kaufman, Glisky, & McDiarmid, 2001; Mahone, 2005). Diamond's studies of object retrieval and delayed responses in infants (A not B Piagetian task) have shown that self-control and planning can be successfully executed by 11 or 12 months old (Diamond, 1990; Diamond & Doar, 1989). The abilities to maintain set over periods of time and to inhibit responses have also been successfully displayed by and observed in

children between the ages of 18 to 36 months (Espy et al., 2001; Goldman-Rakic, 1987). Furthermore, as discussed earlier, the ability to solve-problems, specifically plan, implement and sustain the plan, and the ability to evaluate performance have been observed and measured in preschool age children (Zelazo, Carter, et al., 1997; Zelazo, Müller et al., 2003). Passler and colleagues were among the first to demonstrate the presence of executive function and the different skill levels in children of younger ages. Their 1985 study similarly revealed that when adjusting the nature of the task in a developmentally sensitive manner for both verbal and non-verbal abilities, behaviors reflective of frontal lobes functioning such as proactive and retroactive inhibition, and perseveration inhibition can be found as developing between ages of 6 to 8 years, as approximately mastered by children around age 10, or as completely mastered by the age of 12 years. Mental flexibility was found to be fully developed by the age of 6 and behavioral inhibition was mastered by the age of 8 or 10 years (Passler et al., 1985).

Chelune and Baer (1986) concluded in their study of normal children (first through sixth grades) that performances on the WCST such as

...the ability to use environmental feedback in the development of problem-solving strategies, the capacity to shift set and suppress inappropriate responding, and the ability to selectively attend to relevant stimulus dimensions without distraction are developmental tasks that appear to reach adult levels of maturity by the age of 10 years (Chelune & Baer, 1986, p. 225).

They also examined their findings against the brain's growth curves proposed by Epstein (1978) and Reines and Goldman (1980) and found correspondences in

performance improvement and plateaus for the cognitive abilities involved in some of the WCST scores (perseverative errors and failure to maintain set).

More recent findings reveal that the achievement of the executive functions in children as reflected through the WCST performance does not end around the age of 10 years. Rather, the development continues into adolescence and may never reach adult level (Heaton et al., 1993; Lin, Chen, Yang, Hsiao, & Tien, 2000; Paniak et al., 1996; Roselli & Ardilla, 1993; Shu et al., 2000). In this regard, Cohen and his colleagues discussed the existence of confounding variables in child neuropsychological assessment in general, in the form of ontogenetic differences in behaviors and greater variability of performance across age groups; therefore, “paramount importance must be given to the use of test instruments that are sensitive to developmental changes in behavior” (1992, p. 63).

The goal of this dissertation was to understand the cognitive and developmental aspects involved in the WCST that may directly affect the performance of young children on the test. Specifically, this study explored the impact of number as a sorting criterion on test performance given that color, form, and number, have been proved to hold different degrees of relevance for children of various ages in tasks of matching or sorting (Brown & Campione, 1971; Moss & Case, 1999)

Cognitive Development

Starting in 1921, Jean Piaget’s career spanned nearly sixty years in which he developed and refined a theory of child development that made major contributions to the fields of child psychology and education. This dissertation has attempted to combine a domain-general approach to children’s cognitive development such as Piaget’s with a

more domain-specific approach to a specific skill (neuropsychological take on executive function in children). Specifically, Piaget's theory has been adopted here in order to provide the basis for understanding the development of cognitive development across the ages of interest for this study.

Piaget is relevant to this research for his qualitative approach to the study of cognition and behavior. His focus on understanding in minute detail all the components of behaviors responsible for successful completion of a task provided a procedural basis for the current research design. In addition, Piaget's dynamic view of development accounting for the influences of the environmental and biological context is in correspondence with what this study strives to address. Piaget emphasized the active, constructive nature of the child's cognitive development. He believed that human organisms inherit similar genetic make-up on which they build the necessary cognitive structures that will mediate their interaction with the environment. These cognitive structures help the organism adapt to changes in the environment, become stable over time, and develop into intelligence, defined as the ability to make adaptive changes (1963). Intellectual development for Piaget was a process of adaptation: a sum of continual, reciprocal, and simultaneous changes in the organization and reorganization of internal structures based on what the environment has to offer (the process of assimilation), with each new organization integrating the previous ones into itself and acting back on the environment, changing it (the process of accommodation). Although the intellectual development process is continuous, the results are discontinuous, as they are qualitatively different between ages; thus, the periods and stages of intellectual development.

Piaget is well known for his stages theory in which he describes, with multiple observational vignettes, the cognitive processes and abilities of children from birth to 15 years of age. He observed that there were periods when assimilation dominated, periods when accommodation dominated, and periods when there was a relative equilibrium (Phillips, 1981). In an effort to tap into various periods of cognitive development for mapping a developmental profile in normal children and adolescents' performance on the WCST, this study addressed three age groups (6 , 11 to 12, and 18 to19 years olds). The position taken by Piaget and his followers is that development from weak cognitive structure to strong ones takes the form of qualitatively different structures that are transformed in an invariant sequence.

Piaget has created a revolution with his approach to the study of children's behaviors and cognitive development. Like any successful legacy, his theory has been the focus of criticism and revisions over the years. While his theory has been weakened in the light of the criticisms, it has certainly contributed significantly to furthering the scientific understanding of child intellectual development. Most of Piaget's basic observations have been replicated in later years and by different researchers, under conditions where children were asked to perform tasks in an exact replication of the original experiments. In that respect, Piaget's precise operationalization of behaviors has proven robust. However, there are several significant changes that scientists have proposed, both within the neo-Piagetian tradition and in currents less favorable to Piaget's work. One first reaction was triggered by the idea of "the child as a scientist". Piaget built his theory on logico-mathematical principles which transform children's behaviors in purposeful interactions with the tasks for an ultimate goal of adaptation to

the environment. When considering various cultures (which Piaget did not do), it becomes clear that this concept does not hold - only a few cultures have developed sciences or function in the logio-mathematical model adopted by Piaget, yet children are able to think and develop their cognitive abilities. Critics have reacted variously to the lack of cultural sensitivity of Piaget's observations. Piaget has also been criticized for importing into psychology and into his theory too much terminology from other disciplines (biology and logic), making his theory at times too difficult to understand. Similarly, the Piaget's claims for the existence of underlying logical structures could not be sustained through other research in cognitive development. Critics further claim that Piaget was only focused on the universal aspects of the mind, specifically, on intelligence as observed in all human beings. This was seen as theoretical and scientific weakness, as the most important question in intellectual development has to do with differences among human beings (differences among individuals within a culture and the differences across cultures). Similarly, Piaget believed that, independent of the context and content, the same cognitive characteristics would emerge in a predictable order in all humans. Piaget suggested that specific cognitive operations exist and can be activated irrespective of nature of the content towards they are directed. These aspects have been mostly debated and refuted as research and theory have shown the importance of context in intellectual development. Depending on the content of a problem, children may appear less precocious, and several theories have supported clearly that there is more than one type of intelligence. A final criticism is related to Piaget's claim that intellectual development ends in adolescence. Research has demonstrated that cognitive development goes beyond the formal operations stage. For example, adolescents rarely are able to demonstrate the

ability to conceptualize theories or to systematize and synthesize knowledge in the way mature experts in various domains can. Similarly, development has been proven to not happen only in stages, as Piaget suggested, but rather development is a smother process, with fewer qualitative shifts along the years (Feldman, personal communication, October 19, 2001).

In the neo-Piagetian perspectives, some of the strengths of Piaget's work are seen as related to his unique ability to tie abstract concepts and theory to intensive longitudinal observations sensitive to the nuances of children's behavior. Also, Piaget has shown a remarkable creativity in generating age-appropriate tasks to test systematically children's activities and to relate them to the ontogenetic theory of transformation (Fischer & Hencke, 1996). The specific additions that Neo-Piagetians made to the initial theory revolved around preserving the concept of broad stages of development. The theories of Case and Fischer are examples of adding finer detail to the stages and developing more precise methods for determining the stage/level at which a child is performing. These two authors looked more broadly into development, taking into account social and emotional development and suggesting, unlike Piaget, that training cognitive skills is possible. Consequently, neo-Piagetians are more interested in educational issues, emphasizing the importance of context and of content of development. In their theoretical view, children can function at one stage with materials that are familiar, and a lower stage with respect to materials or contexts that are unfamiliar. Neo-Piagetians seek "to determine general cognitive structures and their developmental sequences while, at the same time, they search for domain specific knowledge organizations that are the products of specific experiences with the environment" (Strauss, 2000). In their view, conceptual

understanding has a distinctive organization at each level, higher-order structures include lower order ones, and attaining an abstract status in conceptual understanding is the final point of cognitive development (Case, 1987). A major addition of the neo-Piagetian scholars was to operationalize the concept of stages as a series of hierarchical integrations (Dawson-Tunik, Fischer, & Stein, 2004). The hierarchical emergence of new, complex, and sophisticated knowledge results from the process of reflective abstraction which refers to the integration of previously existing intellectual activities into new forms (Piaget, 1985). This new perspective offered by the neo-Piagetian authors augmented the value and relevance of Piaget's theory in that hierarchical integration became a construct used in the description and understanding of behavior (as opposed to reflective abstraction which was seen mostly as a hypothesized psychological process). Because at least some of the products of hierarchical integration are observable in behavior, this concept had become central to much neo-Piagetian research on cognitive development, making it possible to explore a wide variety of developmental questions. One of these questions was on the relevance of developmental stages. In his later career, Piaget concluded that the stages should not be the heart of the theory of development, but an instrument for the analysis of formative processes (Piaget, 1987, cited in Dawson-Tunik et al., 2004). As a consequence, neo-Piagetians placed at the center of Piaget's theory, fundamental principles that can explain and predict developmental phenomena, not simply describe them. Such processes are equilibration, as the central problem of intellectual development (Piaget, 1985) and reflective abstraction as a vital component of equilibration. It is from these generative processes that the concepts of stage and hierarchy of increasingly complex intellectual capabilities emerged (Dawson-Tunik et al.,

2004).

Following is a summary of the key concepts used to explain the process of intellectual development proposed by Piaget (1937) and supported by neo-Piagetian research on children's cognitive functioning. This summary will focus on factors that are thought to be salient in the context of the hypotheses of this study. In early childhood, cognitive development undergoes significant qualitative changes reflected by the ability of the child to be a thinking presence in his or her environment (Piaget & Inhelder, 1987). The thinking of the young child generally lacks flexibility in comparison with later ages and tends to be dominated by figural and perceptual aspects rather than by mature patterns of analyzing and synthesizing information. Depending on the focus of research, in studies such as the one of Gelman and her colleagues, the perceptually-bound thinking of young children is not seen as an obstacle in the measurement of abstract abilities. They point out that even though children do not have the cognitive abilities to reflect numerical knowledge, they do perceive numerosity (variations in quantity) as early as 2.5 years of age (Gelman, Mweck, & Merkin, 1986). Yet, as measured by Piagetian tasks, the perceptual confinement of young children's thinking appeared as a weakness to take into consideration. Thinking processes characteristic of younger children lack the mobility within a conceptual structure to tolerate perception of objects in their entire complexity (i.e. seeing objects holding more than one quality at the time) (Diamond et al., 2005; Zelazo et al., 1997). A significant Piagetian concept that can further describe the thinking of the six year old children is the concept of equilibration – the process of “coming into equilibrium” as it happens during major transitions from one cognitive level to a more advanced one (Piaget, 1985). Equilibration requires a constant balancing between

external environmental intrusions and the internal representations and mental activities of the organism, a skill which is, essentially, the fundamental requirement of the WCST task. Piaget also describes another behavior which proves relevant for the WCST performance, irreversible thinking. This concept has also been observed in early childhood and measured in the work of others, such as Anderson (2002) and Zelazo et al. (1997)

Around middle childhood, children become gradually able to generate possibilities and test hypotheses. They are able to actively keep in mind multiple possibilities for classification of objects, even though they still require manipulation of concrete objects. Based on their increased mobility of thought, children are able to de-center in relationship with objects and assume other people's perspective (Piaget & Inhelder, 1967). Previous research in concordance with the findings of this study, that the sorting performance of children in this age group on the WCST reveals much improvement for all measured dimensions such as number of categories achieved, ability to switch set, ability to integrate feedback, etc. (Chelune & Baer, 1986; Paniak et al., 1996).

According to Piaget, from the age of early adolescence into adulthood, children and adolescents attain the capability to think abstractly and logically by taking the semiotic function to its ultimate potential and by having a complex understanding of classification, causality, space, time, and reality versus possibility (hypothetical thinking). Again, based on the WCST studies, such abilities are reflected in the adolescent and adult performance on the test (Dunbarr & Sussman, 1995).

The WCST, Conceptual Abilities, and Abstract Thinking

The majority of the literature focusing on the WCST and abstract thinking comes from the work of researchers in the late 1940's and early 1950's. Wiegand was the first author to have introduced the categorization task in the study of conceptual behaviors (Wiegand, 1927, cited in Rioch, Landis, & Goldstein, 1941). During five years of studying several aspects of the Wiegand-type task (from 1949 through 1954), Grant and his collaborators decided to develop the WCST. While there are numerous studies on the WCST published by this group of researchers, for the purpose of this dissertation study, only the work pertaining to concept formation, concept difficulty, and abstraction in the WCST performance was reviewed.

Grant, Jones, and Tallantis (1949) were interested in assessing the relative difficulty of the three WCST sorting principles (form, color, and number) and in determining the abstraction processes that can cause differences in the level of difficulty of each category. By varying the standard order of categories in the task, they found that college students sorted most easily for number, next most easily for form, and had most difficulty for color, as it required more reinforcement when compared to the number-sorting responses. Further, Grant and his colleagues discovered that once learned, the response of sorting for number tended to persevere more than the form or color sorting responses. When asking participants to explain their sorting criteria, the authors found that a relatively significant number of participants reported sorting according to configuration when they were referring to the number, therefore implying a visuo-spatial component in the task responses.

In pursuing this particular finding, Grant and Curran assessed to what extent the conventional and configurational aspect of the stimulus cards influenced the formation of the number concept in the WCST task (1952). The study revealed that the perceptual aspect of the number cards helped in the learning of the number categorization criterion, and that when the configurational aspect of the number cards was eliminated, the number criterion was not as easily discovered or maintained. They concluded that when given the opportunity, college students responded perceptually rather than analytically for the number sorting criterion.

These research findings raised important questions for the areas of study targeted in this dissertation. From a developmental perspective, these studies provide an argument for the need to understand the cognitive processes that are activated during performance on WCST across different age groups. One goal of this dissertation was to analyze the conceptual difficulty of number as a sorting criterion within and across three age groups of various neuropsychological and cognitive developmental levels.

Past research has shown that there is a developmental schedule for perceptual awareness and behavioral preference towards different qualities of objects in tasks of similarity and sorting. It was found that children and adults distinctively preferred shape to color as a basis for similarity, and that color was preferred over size (Brown & Campione, 1971; Kagan & Lemkin, 1961). Prevor and Diamond (2005) provide an excellent summary of the perceptual and behavioral aspects involved in and affecting sorting preferences across ages. The consensus in research findings is that prior to the age of 4.5 years children prefer color, while from 5.5 years on, they prefer shape when assessing the similarity between objects. This documented developmental difference

between shape and color preference increases significantly and linearly with age, with an exclusive dominance of shape with advancing age (Prevor & Diamond, 2005).

Two models have been offered in an attempt to understand children's early awareness of number. These models have focused on young children's counting skills as a means to connect behavioral observations with cognitive skills. One theory proposed that children lack initial understanding of numbers; various counting skills (reciting the count list, habitually repeating the last tag in the list, etc.) are learned through reinforcement and only later will be abstracted to a principled understanding of numbers (Baroody, 1984, cited in Gelman, et al., 1986). The other model proposed that numerical skill acquisition is guided by an implicit understanding of the principles of counting and of representing the cardinal value of a set (Gelman, et al., 1986). Gelman and colleagues believe in the existence of a sum of invariant arithmetic structures of mind and concept development is seen as facilitated when existing conceptual structures overlap with the structure of the to-be-learned data (Gelman, 2000; Hartnett & Gelman, 1998). The authors make a distinction between children's numerical competence and performance, thereby identifying possible factors of variability in children's performance on tasks that focus on number. Specifically, the authors' analysis distinguishes between conceptual, procedural, and utilization competence. Their experiments have shown that young children's poor numerical performances can be traced to difficulties in assessing the task (utilization competence) or plan solutions (procedural competence) rather than to constraints in children's conceptual competence. In conclusion, preschool children (2.5 to 5 years old) are seen as able to engage in abstract concepts and not fatally bound by perceptual, pre-logical, or egocentric thinking. Therefore, number conceptual competence

can be considered as available to the mind of young children, despite the fact that it cannot be articulated (Gelman et al., 1986; Gelman 2006), with a well developed sense of whole numbers becoming evident only later in elementary school ages (Moos & Case, 1999).

In everyday life, adults and children alike are required to go “beyond the information given” and make inferences; more often than not, when there are gaps in knowledge, people have to reason by induction. Generalizing on the basis of a known example, making an inductive inference from a particular premise, or drawing an analogy are all examples of inductive reasoning at work (Goswami, 2003). The WCST has been conceptualized as a problem-solving task and in this perspective the test can be viewed as a task of inductive reasoning. The participants are asked to use analogical reasoning several times in the test; specifically, the participants need to compare two similar cases and infer that what was true for the first case is not necessarily true for the second. When the subject is given positive feedback for a match during the test (therefore being rewarded for finding the solution to the sorting problem) and the required series of correct trials is achieved, the subject is expected to find a new sorting criterion based on the feedback from the examiner, therefore facing again a new sorting problem. In order to successfully complete the test, the subject needs to observe patterns and use these observations to make generalizations. The test, therefore, is equally a measure of analogy and inductive reasoning.

Inductive reasoning in general is broadly constrained by the nature of the knowledge to be learned, the existing state of the child’s conceptual system, and the context in which the new concept is first encountered. For example, there are contexts

promoting cognitive flexibility, such as experiencing a multitude of uses for a tool or experiencing a multitude of exemplars for a new concept (Goswami, 2003). Traditionally, developmental approaches have separated problem solving ability from concept formation: problem solving was about the acquisition of logical rules while conceptual development was about the growth of real word knowledge. Goswami has researched and supported the idea that problem solving is a tool in children's ability to transfer knowledge and develop. However, in the absence of the requisite knowledge, it is difficult to reason, and thus, novice learners are likely to fall back on simpler solution strategies such as associative reasoning and matching on the basis of surface similarity. Ability for inductive reasoning and problem solving are key requirements for successful completion of the WCST, but may be insufficient for young children who have a less sophisticated and poorer pool of required knowledge. The lack of sustainability in experiencing new concepts in as many uses and contexts as possible, can lead to apparent "functional fixedness" or "cognitive embeddedness", when potential solutions to a problem are not recognized because the action is too embedded in a familiar context (Goswami, 2003). From a gestaltist perspective, experts also display a functional fixedness in their problem-solving strategies, but research has proven that the experts will eventually surpass the novices (Sternberg, 2004). This idea is supported by the behavioral observations of normal adolescent and adults who do make a series of errors in sorting the WCST cards, but are able to adjust their behaviors and conceptualization of the test, and perform within the normal limits (Barcelo & Knights, 2002). Normal adolescents and adults will find the necessary knowledge and use the appropriate skills sooner rather than later, and conquer the demands of the WCST (Dunbar & Sussman, 1995). Their abilities

to organize information in pre-existing schemas and to find and build interconnections between units of knowledge are ultimately helpful. Additionally, their experience with more efficient problem-solving strategies and their self-monitoring of the strategies and processes prove in the end to help against “functional fixedness” (Goswami, 2003).

Purposes of Current Study

Theories of cognitive development provide a context for understanding of the difficulties encountered by young children in tasks that focus specifically on flexibility in thought, strategic planning, and organized search. From the multiple definitions of executive function discussed previously, it appears that executive function is a very complex phenomenon, which depends to a higher degree on cognitive development, namely abstract reasoning, concept formation, working memory, ability to inhibit behavior, etc. Complex tests such as the WCST or other measures of executive function are likely to require certain levels of cognitive skills which may not yet be available to six-years-old children. As a result, the measure of their executive functioning is likely to appear deficient when compared with task performance of older children or adults. Furthermore, the review of the literature reveals incongruous WCST performance for six year old children across different studies and cautions about the test’s lack of developmental sensitivity to children’s cognitive abilities. This dissertation assessed the extent to which particular cognitive skills are tied to and lead to difficulties in performing the WCST task for children across three age groups, and support developmental trends in test efficiency through initial conceptualization of the sorting criteria.

It was hypothesized that young children’s performance on the test would be affected by the presence of number as a sorting criterion, since number is a concept of a

higher abstract level when compared to color or shape, presumably involving higher neurological and cognitive structures that may not yet be available for children at younger ages. Thus, children's performance on the WCST may not be an exclusive reflection of executive functioning, but also of overall cognitive skills and knowledge. Consequently, the use of the test with young children and the clinical implications of such assessment need to be understood in a complex developmental context. The study examined (1) the ability to learn the task and become more efficient in solving it; (2) the ease in achieving the number sorting principle in the WCST for three age levels; and (3) the type of sorting criterion chosen by each participant for his or her first choice as a reflection of their initial conceptualization of object characteristics.

The choice of age-groups of participants was based on factors such as well known qualitative and quantitative developmental differences amongst the three age groups; the relative correspondence of the study ages with known cognitive development stages characterized by well defined skills and abilities; and the neuroanatomical changes due to known brain growth around the proposed ages.

Research Hypotheses

Participants in this study will be identified according to their age groups: young(er) children (6 years old), older children (11 or 12 years old), and adolescents (18 or 19 years old).

The hypotheses of the proposed study are:

1. Efficiency in the WCST task improves with age.

2. Six-year-old participants have more difficulty sorting by the number criterion regardless of its position in the test sequence, when compared with older children and adolescents.
3. The initial conceptualization of the first sorting criterion varies across the three age groups, in a developmentally predictable manner.

CHAPTER II: METHODS

Participants

Participants included 196 children and adolescents, distributed across three age groups: younger children (6 years old), older children (11 to 12 years old), and adolescents (ages 18 to 19). An additional 13 children were tested but the data could not be used in the analyses. In most cases this was because of experimenter error. Two participants had to be eliminated from the analysis due to either inability to complete the task (one 6-year-old) or to an irreparable recording error (one 12-year-old).

All participants were volunteers recruited either from regular elementary classes or from the freshmen class at a large state university. The young children were attending kindergarten or first grade classes in either a private Catholic school or urban public schools. Given the nature of the tasks and its proven sensitivity to neurological problems, all participants were screened prior to testing for a history of neurological dysfunctions, learning disabilities, mood disorders, attention disorders, and pharmacological treatment addressing cognitive and mood conditions. In addition, given that color perception is an important aspect in correctly performing on the WCST, male participants were screened for color blindness.

A priori power calculations indicated that $N=198$ was needed for an alpha level of 0.05, based on 80% power and a small effect size of 0.10, and after accounting for follow-up tests in the data analysis. This effect size was chosen based on Cohen's small d (1988) and based on correlational results in the Paniak study (1996). Moreover, the addition in this proposed study of a new WCST variable made it important to adopt a conservative position and assume a similar small effect size for this new variable. The

sample of 198 participants accounted for equal distribution of 66 participants per each age group, comprising 22 participants in each of the three conditions of sorting-criterion order. The even number within each cell allowed also for counterbalancing the sorting-criteria proceeding number.

Findings of Paniak and his colleagues (1996) suggest that age distinctions finer than one year were not necessary in studying the WCST performance of children ages 9 to 14. Their analysis revealed few statistically significant correlations within each age between the number of months of age and the WCST variables. Consequently, this dissertation study also grouped the participants in the older children and adolescent groups based only on their age in years. The same decision was made for the younger children's group, as it is beyond the scope of this dissertation to provide an analysis of the performance on the WCST on month-based age intervals.

The decision to not include any additional accounts of achievement or intelligence for the study participants was based on findings from previous research. In the Rosselli and Ardilla study (1993), academic achievement accounted for very little variance in the WCST performance of children and the few WCST scores that did correlate significantly with the academic measures were not of specific interest to this dissertation. Paniak and colleagues (1996) similarly found very little variance in the WCST performance of children as accounted by the WISC-III Vocabulary scores. In the same way, Chelune and Baer (1986) found that while some WCST scores correlated with the Peabody Picture Vocabulary Test, it was seen only as an indicator of the covariance of the WCST performance with cognitive growth in children. Finally, Heaton's 1981 version of the

WCST manual also indicates only modest correlations between the WCST variables and the WAIS Full Scale IQ.

Demographic information for each age group is provided in Table 1.

Table 1

Demographic Variables for the Study Participants

	Age	Grade	Gender	Ethnicity
Total sample (N=196)	6-19 years		40.8% Male 59.2% Female	58.2% Caucasian 5.1% African American 23.5% Hispanic 4.1% Asian 7.2% Other: Biracial 1.5% Other: Cape Verdean, Native Indian
Younger children (N=65)	6 years (average age 6.45)	58.46% Kindergarten 41.53% First grade	47.7% Male 52.3% Female	43.1% Caucasian 4.6% African American 38.5% Hispanic 1.5% Asian 12.3% Other: Biracial
Older children (N=65)	11-12 years (average age 11.46)	100% Sixth grade	47.7% Male 52.3% Female	47.7% Caucasian 4.6% African American 26.2% Hispanic 6.2% Asian 9.2% Other: Biracial 4.6% Other: Cape Verdean, Native Indian
Adolescents (N=66)	18-19 years (average age 18.19)	100% Freshman year	23.3% Male 72.7% Female	81.8% Caucasian 6.1% African American 6.1% Hispanic 4.5% Asian

Measures

Along with the informed consent form and a letter describing the study, parents of the child participants and freshmen were asked to complete a demographic questionnaire containing several questions regarding the participant (age, ethnicity, educational

level/grade, educational history, social skills, health history) and the participant's family (parental occupation, income, family members living with the participant). For the purpose of this study, only the information pertaining to participant's age (years and months), ethnicity, and educational level/grade were considered. Information gleaned from the questionnaire regarding prior special education services and diagnosis, as well as current medication affecting school performance were all considered as study exclusion criteria.

Prior to the administration of the test, male participants were screened for color blindness with Ishihara's Test for red-green color blindness (Atkins, 1998). Prevalence studies in the US reveal that about 10% of males have red-green blindness (National Health Interview Survey, 1995). The test of color blindness required the subject to find a series of numbers printed with red paint on green painted backgrounds.

All participants were administered the WCST task, individually, by the researcher. The assessment was performed in a quiet room in the school, with adequate furniture and illumination, in order to allow for good viewing the WCST stimuli. As recommended in the instruction manual, a desk was used to arrange the stimuli cards, with the examiner and the participant seated facing each other (Heaton et al., 1993).

The test consisted of four stimulus cards that display figures of one of four forms (triangles, stars, crosses, or circles), four colors (red, green, yellow, or blue), and four quantities/numbers (one, two, three, or four). The stimulus cards were arranged at the top of the desk in the following order from participant's left to the right: one red triangle, two green stars, three yellow crosses, and four blue circles. One deck of cards containing 64 cards was placed in front of the participant, followed by another deck of 64 cards, starting

with the 65th card in the test order. The cards in the decks display all the possible combinations of forms, colors, and numbers. The participant was instructed to place each consecutive card in the deck in front of one of the four stimulus cards, wherever he or she thought it should go. Correct matches were based on one of the three sorting principles such as color, form, or number, which respondents had to induce from the feedback given by the examiner. The examiner provided feedback in the form an oral presentation, by saying “right” or “wrong” depending on the accuracy of the participant’s answer. When the respondent correctly categorized ten cards in a row, the matching principle was changed without indication or warning, leaving the respondent to realize the change in response to examiner feedback. The test proceeded in this manner until the three possible sorting principles were repeated twice in the same order (e.g. color, form, number, color, form, number), for a total of six categories completed. Once a card was placed and feedback was provided, the respondent was not allowed to undo his or her choice.

Given the goal of this proposed study, the research design veered from the standard administration of the WCST only in that the order of the three sorting criteria inside the test sequence (color, form, and number) were modified from the original test. More information is provided in the procedure section below.

Of the available WCST scores, the following scores were highlighted for the purpose of this study: Number of Categories Achieved (NCA) and Learning to Learn (L2L). The NCA score involved a simple accounting of the number of categories (i.e. sequence of 10 consecutive correct matches to the criterion sorting category) that the participant successfully completed during the test. The L2L score could not be calculated for all participants, as the necessary condition required the completion of at least three

categories in the test or completion of two categories and attempting a third. A category is said to have been attempted when “there are at least 10 trials in the category, even if the category is not successfully completed, for example at the end of the test” (Heaton et al., 1993, p. 13). The first step for preparing a L2L score is calculating a Percent-Errors Score (%ES, see description below) for each completed or attempted category. Next, percent errors difference scores for each consecutive pair of adjacent categories or stages were computed (%ES for category 1 - %ES for category 2; %ES for category 2 - %ES for category 3, etc.). Finally, the percent errors difference scores were summed and averaged to yield an average difference as the final L2L score (Heaton et al., 1993). In order to show increased efficiency on the WCST, it is ideal that the %ES for consecutive categories achieved/attempted have smaller values, in the hope that it reflects participants’ ability to achieve the categories faster and faster, and indicate the increasing facility for the task as the test progresses.

Another score given special consideration in this study was Percent Errors Score (%ES) for each category achieved or attempted, as it captured the total number of errors made by each participant in their transition from one sorting principle to the next. The calculation of the %ES was made as a step for the computation of the L2L score. The calculation of %ES involved dividing the total number of errors made within each category by the total number of trials composing that category, multiplied by 100 (Heaton et al., 1993). The %ES was conceptualized as the degree of difficulty that each category posed for the participant and was used for the analysis of a possible developmental trend of cognitive skills in children and adolescents. A small value for this score could imply that the participant displayed involvement in the shifting of the mental set and had insight

into the timing of the shift and the next possible criteria to shift to (Berg, 1948). The score could reflect participants' ability to be aware of what the remaining two possibilities were and to test them systematically when the sorting category was shifted.

After the first card was placed and the feedback was provided, the examiner asked each participant to provide information about the first sorting criterion used ("What did you sort by?"). Additional information was gathered through direct questioning of each participant after the test administration (the end-of-test interview). Upon the completion of the test, participants were asked to report the criteria used for sorting the cards along the test ("What did you sort by in the test/What were the things you sorted by in the test?"). Finally, each participant was asked to hypothesize about the timing of the shift between the sorting principles during the test ("Every now and again the sorting criterion was switched without warning; do you have any idea what determined that change?").

Procedures

Data for the study was gathered through the use of the examiner-administered version of the test, in accordance with the 1993 WCST manual by Heaton and his colleagues. The reason for choosing the examiner-administered version was the need to alter the standard order of the sorting criteria in the test. While retaining the same order of the cards in the deck and in the four stimulus cards, the number sorting criterion was presented either as the first, the second or the third criterion in the test, by randomly assigning age-matched participants to each of the test conditions. The order of applied sorting criteria for each test administration was randomly generated with using a computer program to control for possible teacher-confounds when children were tested from the same classroom.

At the time of data collection, the examiner had been extensively trained in the use of the WCST with children and adults, and had already administered and scored under supervision approximately 50 WCST protocols. This qualification assured standardized administration and maximized the accuracy of test recording.

The following instructions were given to each participant:

“This test is a little unusual because I am not allowed to tell you very much about how to do it. You will be asked to match each of the cards that appear here (point to the response card decks) to one of these four key cards (point to each of the stimulus cards at the top of the table, in succession, beginning with the red triangle). You must always take the top card from the deck and place it below the key card you think it matches. I cannot tell you how to match the cards, but I will tell you each time whether you are right or wrong. If you are wrong, simply leave the card where you have placed it and try to get the next card correct. There is no time limit on this test. Are you ready? Let’s begin.” (Heaton et al., 1993, p. 5).

During the testing procedure, no guidance was given to the participants; the examiner was allowed to only to clarify the meaning of the stimulus cards and the manner in which the participant was to respond.

Each participant was asked a series of questions at the same point in the test administration, in order to assess additional aspects, such as conceptualization of the task. Each participant’s choices were documented exactly on the recording sheet.

The ethical aspects of informed assent from children coupled with the need to perform research in schools were considered in designing the research procedure. This

dissertation study used active parental consent and child assent, as described below (Graue & Walsh, 1998). Issues such as children not being capable of giving informed assent (Abramovitch, Freedman, Henry, & Van Brunschot, 1995) and children being afraid that there will be negative consequences for stopping once involved in the session (Nannis, 1991) were addressed by this study's procedures. The involvement of the teacher as an adult that children may find more easily accessible to express their refusal and the child assent before the testing session were strategies to help children feel free to refuse their participation after parental consent was obtained.

Written agreement was obtained from the school principal in order to recruit children in the schools (Appendix A). Following this step, teachers were informed about the study, its goals, and the test during Teacher Training or team meeting times, at the discretion of and on advice from the school principal. Teacher cooperation was requested in order to send the consent letters home with the children and for the collection of the signed consents. Also, teachers' cooperation was needed for allowing children to leave the classroom for a one time, 20-minute interval for data collection.

A letter for parents or legal guardians was sent home via the teachers for all children ages 6, 11, and 12 years (independent of the number of months in their age). The letter introduced the study and its implications, briefly explained the task, and requested that the child be allowed to volunteer for the 20 minutes testing session. Parents also received a consent form and a demographic questionnaire, and were asked to return the forms to the child's teacher (Appendix B).

Children were notified about the study by means of teacher and classroom announcements. A short class visit was scheduled prior to the initiation of the study in

which the researcher explained the study, gave out samples of the assent form to the children, and discussed each point in the document with the class. Questions following the short visit were answered. In order to eliminate any possibility of coercion in children's decision to participate in the study such as peer or examiner pressure, each child in the selected classrooms was given a piece of paper. Children were prompted indicate their desire to participate in the study or not, by signing their name next to one of the two available options. This way, each child had to return to the teacher their decision paper, rather than single out only the children who would have liked to be excluded from the study. The examiner also clarified during the class visit that only if the parents gave their consent was the child able to participate in the study. Following the parents' consent and the child's refusal/acceptance, one child at a time was invited to take the test in a room provided by the school. Once the child and the examiner arrived in the testing room, prior to beginning the data collection, the assent form was presented and explained. After reading/having been read the assent form, each child was asked to indicate his or her agreement by signing the form (Appendix C).

Adolescents were recruited from an introductory class in the Psychology Department, a class generally offered in the fall semester to incoming freshmen. A short lecture visit was scheduled during which the researcher presented the study. The consent form was discussed with the class and questions were answered. Students that fit the age requirements and agreed to participate in the study were asked to sign-up by providing their email in order to set up an appointment for the data collection session. The test was administered in a room provided by the school. Once the participant arrived in the testing

room, he or she was required to read and sign the informed consent and to complete the demographic information questionnaire (Appendix D).

After the administration of the WCST and the end-of-test interview about the task, child participants were offered the opportunity to play a game of Checkers, if so desired, to assure that the overall experience of participating in the study was a positive one. In addition, a reward was offered at the end of the meeting for all children, as an immediate gratification for their participation. The reward (a small rubber bouncy ball) was offered independent of the child's performance or completion of the task. All participants had the option of being compensated for their time and effort in the study. Prior to leaving the testing room, all participants were invited to write their name and contact information (teacher and school or email for adolescents) on a ticket and insert it in a sealed box, in order to participate in a raffle as a token of appreciation for their participation in the study. Once data collection was complete, a raffle was held and a total of ten participants were randomly selected to receive a \$15 gift certificate at a local bookstore. All rewards and gift compensation were provided from examiner's personal funds.

In order to guarantee correctness in data entry, scoring, and calculation of the WCST results for all the participants, as well as to prepare the data for computerized statistical analysis, a computer software program was designed (Martin, 2006) to automate the process. The program was written using the Microsoft Access 2003 database package and Microsoft Visual Basic. The software was divided into two parts, the first of which made available forms for the entry of demographic and test data for each subject. Each card chosen during every test was recorded in chronological order into

a database table unique to that participant along with the sorting criterion order. This recording used an on-screen entry form that provided visual feedback regarding the possible matches based on the position in the card deck, taking into account the appropriate sorting criterion. This visual feedback was used to provide a reliability check for the correctness of the handwritten values recorded during each test administration. As a consequence of this on-going check, data from a total of 11 participants had to be eliminated from the study as they had been incorrectly marked, and new participants were recruited during the data collection phase. The program also made it easy to re-check the entries in the database against the original recording sheet for each test; this check was carried out for more than 80% of the tests and found to be virtually error free. Despite this thorough process, two protocols still had to be eliminated after the data collection phase of the study ended. The remaining 196 completed test database tables were then batch loaded into the second part of the program which calculated the scores for each individual participant by simulating perfectly each test, card for card, while applying the appropriate rules for calculating the matches and resulting scores as indicated in the WCST manual. This part of the program was carefully validated by using all the training examples in the manual as well as by a random selection of 20 tests that were scored manually by the examiner as a cross-check. It is worth noting that in every case where the program scores did not initially match the examiner-obtained scores, on recalculation, it turned out to be an error in the examiner's manual calculations. The literature (Axelrod et al., 1992; Bowden et al., 1998; Flashman et al., 1991) supports the notion that the WCST scoring procedure is complex and involves multiple rules and calculations that leave a lot of room for human error if one does not apply a validated automated process such as the

one described above. The summary results for each participant were added to a database table that was then imported into the SPSS 11.0 software program for statistical analysis.

CHAPTER III: RESULTS

Descriptive Statistics for Overall Sample

In order to analyze the impact of age and position of number as a sorting criterion in the order of the test, participants in three different age groups were administered either the standard or modified versions of the WCST. Children and adolescents were randomly assigned to the testing groups according to their age (6 years, 11-12 years, and 18-19 years old). Two basic WCST scores were measured: Number of Categories Achieved (NCA) and Learning to Learn (L2L), as well as one additional score specifically considered for this study: Percent Errors Score (%ES) in attempting to achieve a category when it appears in the test.

A between-subjects Multivariate Analysis of Variance (MANOVA) method was used given the characteristics of the variables and the research questions (Tabachnik & Fidell, 2001). Both independent variables (IVs) in the study were categorical and had three manipulated levels, and all dependent variables (DVs) were continuous. For the third research question of the study, a study of frequency of the initial sorting criterion across the age groups was employed.

Descriptive statistics for the DVs as seen in Table 2, revealed that overall study participants completed a medium to high number of categories (mean=4.22, scale 0 to 6, where 0 stands for “no categories completed” and 6 stands for “six categories completed”), displayed relatively good efficiency in sorting across successive categories (mean=-5.55, minimum value -39.24 and maximum value 4.44, where big negative scores reflect poorer performance), and made several errors in attempting to sort by the number criterion the first time it appeared in the test (mean=30.90, minimum value 0 and

maximum value obtained 78.48). Based on the values of the standard deviations in the context of continuous values for the DV, it appears that the variability in the study is within acceptable limits. All variables are within the accepted ranges for skewness and kurtosis, suggesting normal distributions. Additional measures of normality were assessed with Q-Q plots for residuals, histograms with superimposed normal curve, stem and leaf plots, box plots, and z-scores.

Table 2

Descriptive Statistics for Dependent Variables in the Overall Sample

DV	M	SD	Skewness	Kurtosis
NCA	4.22	2.03	-.65	-1.07
L2L	-5.55	9.50	-1.84	2.76
%ES	30.90	23.46	0.64	-.88

Descriptive Statistics for Each Age Group

Given the big discrepancies in the WCST performance across ages as reflected throughout the literature, it was considered important to present and discuss separately the descriptive statistics for each age group. Six-year old children completed a medium to low number of categories (mean=2.42, scale 0 to 6), displayed poor efficiency in sorting across successive categories (mean=-9.29, minimum value -39.24 and maximum value 4.44), and made numerous errors in attempting to sort by the number criterion the first time it appears in the test (mean=49.58, minimum value 8.33 and maximum value 78.48). The variability for the six-year-old group is low overall and all three measured variables are within the accepted ranges for skewness and kurtosis, suggesting normal distributions (Table 3).

For the older children, it was found that the group completed a high number of categories (mean=4.88, scale 2 to 6), displayed relatively medium efficiency in sorting across successive categories (mean=-4.94, minimum value -18.33 and maximum value 1.89), and made relatively few errors in attempting to sort by the number criterion the first time it appeared in the test (mean=24.71, minimum value 0 and maximum value obtained 59.57). The variability in the responses for this age group is low and all measured variables are within accepted ranges for skewness and kurtosis, suggesting normal distributions (Table 4).

Finally, 18-19 years old adolescents completed a high number of categories (mean=5.42, scale 1 to 6), displayed good efficiency in sorting across successive categories (mean=-2.31, minimum value -14.39 and maximum value 3.08), and made few errors in attempting to sort by the number criterion the first time it appeared in the test (mean=19.09, minimum value 0 and maximum value obtained 63.04). The variability is low, but two of the three variables are outside the accepted ranges for skewness and kurtosis. The skewed distributions could be a reflection of the ceiling effect for this age group, as the tendency to perform well is expected and anticipated for this age (Table 5).

Table 3

Descriptive Statistics for Dependent Variables in the Six-Year-Old Group

DV	M	SD	Skwn.	Kurts.	Min	Max	Heaton norms	Chelune norms	Roselli norms
NCA	2.42	1.81	.64	-.60	0	6	2-6	2.73 (2.10)	4.2 (2.0)
L2L	-9.29	13.45	-1.03	.46	-39.24	12.34	$\geq$ 11.34		
%ES	49.58	24.64	-.51	-1.25	0	77.27			

Table 4

Descriptive Statistics for Dependent Variables in the 11 to 12-year Old Group

DV	M	SD	Skwn.	Kurts.	Min	Max	Heaton norms	Chelune norms	Roselli norms
NCA	4.88	1.42	-.86	.73	0	6	3-6	5.65 (.80)	5.7 (.80)
L2L	-4.88	6.46	-.99	-.32	-30.46	4.3	$\geq$ 14.25		
%ES	24.71	17.45	.61	.49	0	79.13			

Table 5

Descriptive Statistics for Dependent Variables in the 18 to 19-year Old Group

DV	M	SD	Skewness	Kurtosis	Min	Max	Heaton norms
NCA	5.42	1.29	-2.18	3.72	1	6	4-6
L2L	-2.31	4.49	-1.75	2.48	-22.83	15.14	$\geq$ 5.39
%ES	19.09	14.82	1.21	1.37	0	73.73	

The correlation coefficients for each age group indicated low correlations between the DVs (Table 6). Finally, the close to equal distribution of subjects across the three levels of the two IVs (21 or 22 participants for each level), is likely to have supported the a priori calculation of power in MANOVA.

Table 6

Correlations Between Dependent Variables for Each Group

Age Group	NCA	L2L	%ES
6	NCA -	0.03	0.61
	L2L	-	0.16
	%ES		-
11-12	NCA -	0.52	-0.38
	L2L	-	-0.12
	%ES		-
18-19	NCA -	0.65	-0.06
	L2L	-	-0.13
	%ES		-

Significant Statistical Findings for Overall Sample

Macro-level analysis in MANOVA revealed that the two IVs significantly influenced the WCST performance of the participants. Similarly, the interaction between age and position of number did prove to be significant (see Figures 1-3 for detailed representation of the significant interactions). As reflected in Table 7, both age and position of number showed large effect sizes (Cohen, 1992).

Table 7

Multivariate Analysis of Variance for the WCST

Source	df	F	η^2	p
Age (A)	6	23.01**	.48	.000
Position of number (P)	6	13.53 **	.34	.000
AxP	12	1.87*	.12	.035

*p<.05, **p<.001.

Figure 1

Number of Categories Completed Based on Age and Position of Number

Figure 2

Learning to Learn Scores Based on Age and Position of Number

Figure 3

Percent Error Score for Number Based on Age and Position of Number

Micro-level analyses have been performed using Analyses of Variance (ANOVA) for all DVs, as seen in the table below:

Table 8

Analysis of Variance for the WCST

IV	DV	F	MS _{error}	p
Age (A)	NCA	69.75**	144.78	.000
	L2L	11.95**	976.86	.000
	%ES	49.62**	16505.72	.000
Position of Number (P)	NCA	3.19*	6.61	.044
	%ES	13.73**	4565.69	.000

*p<.05, **p<.001.

Planned post hoc tests of differences between groups were performed in order to assess which age or position of number show significant differences in the test performance. The analysis for age using Tukey HSD indicated that younger children achieve significantly ($p<.000$) less categories than older children or adolescents. Younger children become significantly ($p<.000$) less efficient on consecutive stages of the test than older children and adolescents. Finally, younger children made significantly more errors than older children or adolescents ($p<.000$) in attempting to sort by number the first time this sorting criterion appears in the test (Table 9). The post hoc analysis of the data for the position of number indicated that when number was the first sorting criterion in the test, participants achieved significantly ($p<.016$) less categories than when number was the third category to sort by in the test. Similarly, participants made significantly ($p<.000$) less errors in attempting to sort by number the first time, than when number was in the second or third positions in the order of the test (Table 10).

Table 9

Tukey HSD for Age

DV	Age group		Mean Difference	SE	p
NCA	6	11-12	-2.40**	.26	.000
		18-19	-2.97**	.26	.000
L2L	6	11-12	-4.92*	1.62	.008
		18-19	-7.55**	1.73	.000
%ES	6	11-12	24.87**	3.27	.000
		18-19	30.49**	3.25	.000

*p<.05, **p<.001.

Table 10

Tukey HSD for Position of Number

DV	Position of Number		Mean Difference	SE	p
NCA	First in series	Third in series	-.73*	.26	.016
%ES	First in series	Second in series	-14.82**	3.18	.000
		Third in series	-13.09**	3.28	.000

*p<.05, **p<.001

ANOVA was performed further in order to better assess the effect of position of number on the DVs (Table 11) and it was found that it had a significant influence on the DVs only in the younger children group: when number as a sorting criterion appears later in the test (third criterion), six-year-old children achieved significantly ($p<.014$) more categories than when number was the first criterion in the test (Table 12).

Table 11

Analysis of Variance for Position of Number in the Younger Children Group

IV	DV	F	MS _{error}	p
Position of N	NCA	4.61*	13.53	.014

*p<.05.

Table 12

Tukey HSD for Position of Number in the Younger Children Group

DV	Position of N		Mean Difference	SE	p
NCA	First in series	Third in series	-1.67*	.553	.011

**p<.05

Findings revealed that position of number significantly influenced the amount of errors made in attempting to sort by number the first time it appeared in the test for 11-12 years old children ($p<.000$) and for adolescents ($p<.002$). Specifically, when number was in the second or third position in the sequence of categories in the test, there were more errors made than when number was the first category in the test (Tables 13 and 14).

Table 13

ANOVA for Position of Number in the Older Children and Adolescent Groups

Age group	IV	DV	F	MS _{error}	p
11-12	Position of N	%ES	9.14**	2211.87	.000
18-19	Position of N	%ES	6.93*	1290.79	.002

*p<.05, **p<.000

Table 14

Tukey HSD for Position of Number in the Older Children and Adolescent Groups

Age group	DV	Position of N		Mean Difference	SE	p
11-12	%ES	First in series	Second in series	-16.27*	4.69	.003
			Third in series	-18.62**	4.81	.001
18-19	%ES	First in series	Second in series	-14.64*	4.10	.002
			Third in series	-11.30*	4.15	.023

* $p < .05$, ** $p < .000$

In an effort to clarify the nature of such reflected difficulty in sorting by number, further ANOVAs were pursued for all age groups on the transitions to shape and to color (Tables 15 and 16). The results of these follow-up analyses lead to the conclusion that participants have difficulty with switching to sorting criteria for the second and third categories, not only when the criterion is number as shown above, but also when the criteria is color ($p < .000$) or shape ($p < .000$). However, the shift from the second to the third category proved significantly easier ($p < .003$) for color, at the overall group level (Table 17).

Table 15

Analysis of Variance for Position of Shape and Color

IV	DV	F	MS _{error}	p
Position of F	%ES	58.59**	9790.22	.000
Position of C	%ES	34.41**	8905.47	.000

** $p < .001$.

Table 16

Tukey HSD for Position of Shape

DV	Position of F		Mean Difference	SE	p
%ES	First in series	Second in series	-22.13**	2.34	.000
		Third in series	-21.13**	2.34	.000

**p<.001

Table 17

Tukey HSD for Position of Color

DV	Position of C		Mean Difference	SE	p
%ES	First in series	Second in series	-23.57**	2.85	.000
		Third in series	-13.51**	3.03	.000
	Second in series	Third in series	10.07*	3.03	.003

*p<.05, **p<.001

Finally, an ANOVA was also performed for all age groups in order to assess specifically the difficulty of sorting by number when compared with the difficulty of sorting by color or shape the first time these criteria appear in the test (Table 18). It was found that the first criterion (number, shape, or color) had an influence on the number of errors made in sorting by it the first time it appeared in the test. However, this finding was significant only for the 6-year old group, as the type of criterion had no influence on the older children' or adolescents' error scores. Follow-up analyses revealed that number was significantly harder to use as a sorting criterion than color ($p<.016$) and than shape ($p<.000$). Also, color was proven to be significantly harder ($p<.030$) than shape for younger children (Table 19).

Table 18

Analysis of Variance for First Criterion in the Younger Children Group

IV	DV	F	MS _{error}	p
First Criterion	%ES	15.08**	7342.075	.000

**p<.001.

Table 19

Tukey HSD for First Criterion in the Younger Children Group

DV	First Criterion		Mean Difference	SE	p
%ES	Number	Color	11.74*	4.19	.016
		Shape	22.94**	4.19	.000
	Color	Shape	11.21*	4.37	.030

**p<.05, p<.001.

Interview Analysis for Each Age Group

After the completion of the first match in the test, all participants were asked to name the criteria by which they sorted the card in order to assess participants' conceptualization of the initial sorting criteria. A study of frequency of the first sorting criterion chosen was employed and, as shown in Table 20, shape was the most frequent answer across ages.

Table 20

Initial Sorting Criterion Offered by Participants

Age group	Color	Shape	Number	Other
6	21.5%	70.8%	1.5%	6.2%
11-12	30.8%	66.2%	3.1%	-
18-19	33.3%	66.7%	-	-

Frequency analyses were also calculated for the answers provided in the end-of-test interview. When asked to reveal the sorting criteria used during the test, 21 young children (32.31%) could not provide an answer (“don’t know” group). Inside the “don’t know” group, 33.33% were administered the test with number as the first sorting criterion to sort by, 42.85% had number as the second sorting criterion, and 23.81% had to sort by number as the third category in the test. More than half of the children in the “don’t know” group mentioned “shape” (55%), followed by “color” (35%) as criteria used for their match of the first card at the beginning of the test.

In addition to the “don’t know” group, three other young children responded that they sorted their first card “by how they looked”. This answer was considered ambiguous; given that these three children could not elaborate their response further, they were excluded from the general 6-year old sample analysis of final-test answers. Similarly, one child responded to have sorted by “size”, therefore warranting the exclusion of the answer from the analysis, as well. From the 40 (61.53%) remaining children that did provide their first criteria to sort in the test, 13 (32.5%) reported sorting only by one criterion, while 27 (67.5%) children provided multiple (at least two) criteria in their answer.

Table 21

Answers Offered by All Six-Year-Old Participants

Don’t know	One criterion	Two criteria	Three criteria	Other responses
32.31% (21)	20% (13)	27.69% (18)	13.85% (9)	6.15% (4)

Notes: Parentheses contain the actual number of participants.

Table 22 provides a more detailed analysis of the responses provided by the youngest group of participants, with a differentiation between answers that were concrete

(e.g. triangles, circles, stars, yellow, blue, four stars with four stars, etc.) and abstract/conceptual/categorical answers (e.g. color, shape, or number).

Table 22

Sorting Criteria Offered by Six-Year-Old Participants That Did Provide an Answer

Type of response	Color	Shape	Number
Conceptual level responses	61.9% (26)	52.38% (22)	2.38% (1)
Concrete response of each criterion	11.9% (5)	26.19% (11)	11.9% (5)
No mention of the C/F/N criterion	26.19% (11)	21.42% (9)	47.61% (19)

Notes: Calculations are made on the 40 young children that did provide an answer to this question; It is possible that children provided both concrete and categorical level responses for different criteria; Parentheses contain the actual number of participants.

Finally, in the 63.08% of young children that named their sorting criteria, 26.19% omitted to mention color, 21.42% did not mention shape, and 47.61% did not mention number as a sorting criterion used in the test.

In the 11-12-year old age group, all but one participant provided answers on the sorting criteria used along the test: this child displayed a very complicate thinking process in his or her response, making it impossible to consider it in the analysis: *It got too complicated to think of the pattern...for example, three crosses go with one red triangle*. In this sample, 87.69% of the older children provided all three sorting criteria as part of the ones used in the test and 93.84% offered conceptual level answers (e.g. color, shape, number). Specific analysis of the number answers, revealed that 18 older children reported having sorted by “how many shapes were on the card” instead of naming the “number” concept, and four older children reported concrete examples (e.g. *I sorted by twos, threes*, etc.). The table below provides more detailed analysis of the responses provided by the sample of older children:

Table 23

Sorting Criteria Offered by 11-12 Years Old Participants

Type of response	Color	Shape	Number
Conceptual level responses	95.4% (62)	87.69% (57)	80% (52)
Concrete responses of each criterion	-	1.53% (1)	7.69% (5)
No mention of the C/F/N criterion	1.53% (1)	6.15% (4)	7.69% (5)

Notes: Parentheses contain the actual number of participants;
It is possible that participants provided both concrete and categorical level responses for different criteria.

As expected, all 18-19-year-old participants provided answers on the criteria they used to sort by in the test and were able to mention all three sorting criteria used; one adolescent displayed a very complicate thinking process in his or her response, making it impossible to consider the response in the analysis: *I matched green of two different shapes and three times by color*. In the sample, 93.93% adolescents offered conceptual level answers (e.g. color, shape or number). Specific analysis of the number answers, revealed that 20 adolescents named having sorted by “how many shapes were on the card” or “amount of objects on the card” instead of naming the “number” concept, three adolescents reported concrete examples (e.g. *I sorted by twos, threes*, etc.), and five participants reported that they sorted by position on the card/pattern/placement of objects in the card. Below is a detailed analysis of the responses provided by the adolescent participants.

Table 24

Sorting Criteria Offered by 18-19 Years Old Participants

Type of response	Color	Shape	Number
Conceptual level responses	100% (66)	91% (60)	96.92% (63)
Concrete responses of each criterion	-	-	1.51% (1)
No mention of the C/F/N criterion	-	9.06% (6)	3.02% (2)

Notes: Parentheses contain the actual number of participants;
It is possible that participants provided both concrete and categorical level responses for different criteria.

The end-of-test interview attempted to address participants' insight into the mechanism by which the sorting criteria were switched by the examiner during the test: "Every now and again the sorting criterion was switched without warning; do you have any idea what determined that change?" None of the 6-year old children were able to respond this second question, which required an understanding of the task at an abstract level.

Eighteen of the older children (27.69%) did not know what to respond this question. Sixteen 11-12 years old children (24.61%) realized that the test involved a sequential switch of the sorting criterion triggered by a certain number of cards matched, even if they did not guess the exact number of correct sequences (e.g. *You switched after I got so many right: between 8 to 10; After eight numbers in a row; Once I got a couple right...three or four; When I got too many right... about 10?; When I was getting used with the pattern – every 10 cards or so*). The majority of the participants in the 11-12 years old age group (40.01%) had responded in what appeared to be a self-centered manner, based on an assumption that the examiner was playing a trick on them; this majority was not able to offer a conceptual formulation of the test (e.g. *To see if I had*

already figured out... you tried to trick me; To see how quick I can catch on; To see if I got it and I know what I am doing; See if I can figure out your thinking). The five remaining older children (7.69%) provided nonsensical answers that did not reflect any understanding of the task or the question, such as: *Fours should go with twos and twos should go with fours, etc.*, or *To do with me the same thing*.

Surprisingly, 19 adolescents (28.78%) could not provide their conceptualization of the task while a smaller subgroup of adolescents (22.04%) provided random answers, such as: *I don't know... it was confusing... you kept changing; By match from simple to difficult; When focusing too much on one thing, you switched on me...; When I was getting the pattern too well*. Twenty seven adolescents (40.09%) understood that what determined the criterion switch was a certain number of correct responses (e.g. *There was a certain number; Every 10 cards; By a certain number... I wasn't counting; After I got it right for a while; By how many I got right... 10, I think*) and 6 participants (9.09%) replied that they only relied on the feedback received to switch and that they had gone, each time the feedback changed, through a trial and error type of approach until they got the right response.

Summary of Major Findings

A between-subjects multivariate analysis of variance was performed on three dependent variables: Number of Categories Achieved (NCA), Learning to Learn (L2L), and Percent Error Scores for achieving number category the first time it appears in the test (%ES). The two independent variables had three levels each: age (6, 11-12, and 18-19 year old participants) and position of number as a sorting criterion in the order of test administration (number as the first, second, or third sorting criterion).

The SPSS 11.0 General Linear Model/Multivariate was used for a MANOVA analysis. The assumptions of normality, linearity, and homogeneity of variance were satisfactory for all variables. With the use of Wilks' criterion, the combined dependent variables were significantly affected by both age $F(6, 358)=23.01, p<.000$ and position of number as the first sorting criterion in the order of test administration $F(6, 358)=13.53, p<.000$. The interaction between age and position of number significantly affected the combined dependent variables $F(12, 473)=1.87, p<.035$ (see Table 7 and Figures 1, 2, and 3). The results reflected a strong association between age levels and the combined dependent variables, $\eta^2=0.48$, as well as between the position of number and the dependent variables, $\eta^2=0.34$. The association was medium for the interaction of age and position of numbers had an average effect on the measured WCST performance, $\eta^2=0.12$.

To investigate the impact of each main effect on the individual dependent variables, further analyses were performed through ANOVA tests (Table 8). All three dependent variables obtained statistically significant F-test values for the age groups, as follows: NCA, $F(2,194)=69.75, p<.000, MS_{\text{error}}=144.78, \eta^2=0.20$ (large effect size); L2L, $F(2,194)=11.95, p<.000, MS_{\text{error}}=976.86, \eta^2=0.05$ (small to medium effect size); and %ES, $F(2,194)=46.62, p<.000, MS_{\text{error}}=16505.18, \eta^2=0.16$ (large effect size). There were two significant F-test values for the position of number as a sorting criterion: NCA, $F(2,194)=3.19, p<.044, MS_{\text{error}}=6.61, \eta^2=0.01$ (small effect size) and %ES, $F(2,194)=13.73, p<.000, MS_{\text{error}}=4565.69, \eta^2=0.04$ (small effect size). For the interaction of the independent variables, no significant F-test values were obtained.

Based on the significant ANOVA analyses, it was considered meaningful to continue with Tukey HSD tests for finding the significant differences between pairs of

groups. The analysis focused on noting which ages and positions of number show significant differences in the three dependent variables. Planned comparisons revealed that younger children achieve the least number of categories ($p<.000$) when compared with older children or adolescents. Younger children are also significantly less efficient on consecutive stages of the test than older children ($p<.008$) and adolescents ($p<.000$). Finally, younger children make significantly ($p<.000$) more errors than older children or adolescents in attempting to sort by number the first time this sorting criterion appears in the test (Table 9). The post hoc analysis of the data for the position of number indicated that when number was the first sorting criterion in the test, participants achieved significantly ($p<.016$) less categories than when number was the third category to sort by in the test. When number held the second or third positions in the order of the test, participants made significantly ($p<.000$) more errors in attempting to sort by number than the first time they attempted to sort by this criterion (Table 10).

In order to better assess the effect of position of number on the WCST performance, ANOVAs were further performed for each age group. A significant finding for the number of categories completed was observed in the younger children group, $F(2,59)=4.61$, $p<.014$, $MS_{\text{error}}=13.53$, $\eta^2=.07$ (medium effect size). Post hoc analyses revealed that when number appears later in the test (as the third criterion), six-year-old children achieve significantly ($p<.011$) more categories than when number is the first criterion in the test (Tables 11, 12).

Position of number was also found to significantly influence the amount of errors made in attempting to sort by number the first time it appears in the test for the two older age groups, but not for the 6-year-old children: for older children, $F(2,62)=9.14$, $p<.000$,

$MS_{\text{error}}=2211.87$, $\eta^2=.12$ (large effect size) and for adolescents, $F(2,63)=6.97$, $p<.002$, $MS_{\text{error}}=1290.89$, $\eta^2=.09$ (medium effect size). Post hoc tests showed that older children and adolescents make more errors in attempting to sort by number when number is the second or the third criterion in the sequence of the test (Tables 13 and 14). For younger children there were no significant findings for the values of the percent error scores determined by various positions of number in the test; however, they made significantly more errors than any other age groups when attempting to sort by number, as presented above.

In an effort to clarify the nature of such reflected difficulty in sorting by number, further analysis focused on the transitions to the other sorting criteria of the test, color and shape, when appearing as second or third criteria in the sequence of the test for all ages (Table 15). The results lead to two conclusions: that participants have significant ($p<.000$) difficulty with switching to sorting criteria for the second and third categories independent of which type the criterion was. This is a phenomenon observed across ages, with the already noted exception of number sorting criterion for six-year-old children (Tables 16 and 17).

For an even deeper understating of the measured WCST performances, the relation between the type of the sorting criteria and the difficulty attaining it the first time it appears in the test was pursued. The ANOVA analysis revealed that there is a significant relationship between the amount of errors made in attaining the first category and the type of sorting criterion, but only for the six-year-old children: $F(2,161)=15.08$, $p<.000$, $MS_{\text{error}}=7342.08$, $\eta^2=.08$ (medium effect size). Post hoc analyses showed that for six-year-old children number was significantly harder to sort by than color ($p<.016$) and

than shape ($p < .000$) when they first appeared in the test, and that color is significantly harder to achieve ($p < .030$) than shape (Tables 18, 19). The difficulty in sorting triggered by the type of sorting criteria was not observed for the older children and adolescent groups, leading to the conclusion that for these age groups, color, shape, and number share the same degree of salience as criteria in the test.

CHAPTER IV: DISCUSSION

Discussion of Major Findings

It was hypothesized in this study that efficiency in the WCST improves with age: the two WCST indicators that were considered in assessing this hypothesis were the number of categories achieved and the learning to learn score across different age groups.

Several of this study's findings supported this hypothesis. A developmental trend in the number of categories achieved has been observed across ages, with as much as 48% on the variance in the performance on the WCST being accounted for by participants' age. The finding that six-year-old children achieved significantly less categories than older children and adolescents is in agreement with all previous studies of the WCST performance in children across different developmental levels and ages (Chelune & Baer, 1986; Heaton et al., 1991; Roselli & Ardilla, 1993; Shu et al., 2000).

In the literature, cognitive development has frequently been attributed directly to brain maturation. It is important to acknowledge that the environment and life experience bear equally on children's increased cognitive skills, however, for the purposes of this dissertation, only the connection between behaviors, cognition, and neuropsychological aspects were considered and discussed. The explanations offered in the above mentioned studies have been most frequently linked to aspects of neuroanatomical and brain development as well as to aspects of cognitive development across life span. Many authors paralleled the episodes of formation of neural pathways, synaptogenesis, or intense myelination in various brain areas in childhood with models of cognitive development. While the match is not exact between observable and measurable behaviors and underlying brain organization, a considerable amount of experimental work supports

the contemporary understanding of cognitive functioning and brain development. For the purposes of this current study, a constructivist approach toward development has been adopted. This study used Piaget's framework where qualitative and quantitative changes in cognitive abilities were thought to result from the hierarchical integrations of knowledge. From a cognitive developmental perspective, the behavior of six-year-old children is characterized by an explosion of vocabulary and language functioning, therefore showing an involvement of the left brain hemisphere. At this age, children's thinking becomes more logical, although there are still faulty thinking processes such as their inability to grasp the principles of conservation, difficulty understanding classification, or difficulty viewing the world through other people's eyes. Of interest to the WCTS performance is also the fact that children of this age cannot think back to the initial stage of an action to answer a question pertaining to it. Despite these apparent cognitive limitations, this age is one of rapid growth, especially in vocabulary achievement and use, reflecting the increasingly complex knowledge of the young child (Piaget & Inhelder, 1967).

Once children enter school, tasks such as hierarchical structuring, conservation, and de-centering are exercised and ultimately achieved. Children in this stage can think systematically and quantitatively, their reasoning processes become logical, they can conserve and classify, and are no longer bound by egocentrism or perceptual centration. Integration of information is ultimately the essential cognitive ability that allows the child to perform the steps necessary to understanding the complexity of the world. All these newly achieved skills are reflected in the much improved the WCST performance of the 11-12 years old age group. One brain structure that has been seen as directly responsible

for connecting all major subdivisions of the cerebellum is the corpus callosum. The observation that corpus callosum develops the most around this age, underlines the relevance of this particular brain structure to such cognitive abilities (Pujol, Vendrell, Junque, Marti-Vilalta, & Capdevila, 1993 in Giedd et al., 1996). From approximately 12-13 years of age, the neurodevelopmental literature describes increased anatomical development of the frontal brain systems. The thinking processes in the adolescent ages are characterized by hypothetico-deductive reasoning, scientific-inductive reasoning (the ability to draw conclusions by going from specific observations to generalizations), and reflective abstraction (the presence of internal thought and reflection based on available knowledge) (Piaget, 1985). All these behaviors are manifestations of ongoing maturation of prefrontal cortex (Powell & Voeller, 2004) The prefrontal cortex has been found to be responsible for much of the discussed higher cognitive abilities of adolescence and adulthood, such as judgment, reasoning, or planning (Anderson, 2002; Mahone, 2004; Riccio, 2006).

In summary, there is developmental evidence (cognitive and neuroanatomical) that supports the prediction that the WCST is a harder task to complete for young children: they are less well equipped biologically and cognitively to respond to several WCST task demands, such as shifting set/reversibility, selectively attending to relevant stimulus dimensions, and integrating feedback when compared to older children and adolescents.

Another finding supporting the study prediction that age positively affects the WCST efficiency is that younger children become significantly less efficient on consecutive stages of the WCST when compared with older children and adolescents.

Being efficient on the task, as measured by the L2L score (see Chapter II for detailed explanation of the calculations involved for this score), involves several aspects: the participant understands that the task is about sorting the cards by certain criteria; has a good grasp on which are the right sorting criteria; has an idea of the task coordinates (i.e. the changes in the sorting criterion happen after a certain amount of correct responses); and has the ability to quickly switch between the sorting criteria by integrating the feedback from the examiner. One relevant addition to this particular finding of age influence on WCST performance is brought by the results of the end-of-test interview. The question “What did you sort by in the test?” tapped into participants’ understanding that this test was, in essence, a sorting task where multiple sorting criteria were likely to be used for successful completion. According to Inhelder and Piaget (1967), in order for an act of sorting to be a classification, abstraction is required; in other words, the action needs to be mediated by the awareness of the sorting criteria, in order for the behavior to become a classification. Similarly, from Wieg’s perspective, the author who introduced categorization tasks in the study of conceptual behaviors, the active and planned search for characteristics of the given material in a categorization task involves the “realization of the possibilities” (Wieg, 1927, cited in Rioch, Landis, & Goldstein, 1941). Zelazo and his colleagues also spoke of the importance of an accurate representation of the problem as a first step in the process of efficient problem-solving (Zelazo, Carter, et al., 1997; Zelazo, Müller et al., 2003). Within the six-year-old group, a third of the participants could not answer the question about any sorting criterion used, despite the fact that all but one child had achieved at least one category in the test; only 41.54% of the younger children sample was able to specify more than one criterion by which they sorted in the

test. This situation could be interpreted as a reflection of younger children's difficulty in understanding the sorting criteria at an abstract level. In contrast, both the older children and the adolescent participants were able to provide, as an overwhelming majority, all three criteria used in the test, therefore displaying abstract knowledge of the criteria and at least a basic understanding of the task. As an interesting observation, participants' responses to this first question show that only 40% of all six-year-old children offered conceptual level responses, in contrast to 93.8% of all older children and 93.94% of all adolescents (Tables 22, 23, and 24).

The second question in the end-of-test interview, "Every now and again the sorting criterion was switched without warning; do you have any idea what determined that change?" attempted to address participants' insight into the mechanism by which the sorting criteria were switched by the examiner during the test. The answer to this question was thought to involve the understanding of the WCST task demands at an abstract level, beyond the identification of the sorting criteria and the concrete step-by-step reliance on examiner's feedback. None of the six-year-old children were able to respond to this second question. Less than one third of the 11-12 years old children realized that the test involved a sequential switch of the sorting criterion triggered by a certain number of cards matched, even if they did not guess the exact number of correct sequences. Despite age expectations based on Piaget's theory of cognitive development, 18-19 years old participants also had difficulty providing coherent answers for the conceptualization of the task. Fewer than half, namely 41% of the adolescents understood that what determined the criterion switch was a certain number of correct responses, therefore revealing a full understanding of the task at an abstract level. This particular

finding is, however less surprising when one considers the research showing that even in the most developed countries, less than 100% of the adults manifest the skills described by the Piagetian stage of concrete operations, while only approximately 30% of the adults manifest the formal cognitive abilities of Piaget's final developmental period (Dasen, 1972). The finding of this study seems to replicate these conclusions (with a slight overestimation), despite the fact that the participants in this age group were part of a population of college freshmen students.

In discussing further this finding of poor conceptualization of the WCST task for young children, it is helpful to refer to the multi-factorial model of executive function proposed by Anderson (2002). In the model, Anderson discussed the existence of a cognitive flexibility domain which refers to the ability to shift between response sets, learn from mistakes, devise alternative strategies, and process multiple sources of information simultaneously. Anderson points out that there is a qualitative improvement of such behaviors which can be observed when adopting a developmental perspective on behavioral performances: the capacity to switch between two response sets in problem solving emerges around the age of three to four years and continues to develop in a manner contingent on the simplicity of the behavioral rules. However, by seven years of age, children still struggle when the switching behaviors are conditioned by more than one dimension and rule (Espy, Kaufman, Glisky, & McDiarmid, 1987). Theory and research reflect the fact that in general, young children have difficulty switching mental set (Goswami, 2003; Piaget, 1963; Zelazo et al., 1997). A closer look at participants' WCST performances reveals that young children were overall able to switch set, but needed more trials than the other age groups to make the switch, therefore leaving a

smaller number of available cards to build additional categories in the test. Consequently, the low numbers of categories completed by young children affected the calculation of the L2L score used to demonstrate their ability to learn the task; even when three or more categories were achieved by young children (35.4% of this age group), it became clear that the six-year-old group was not efficient in performing the task, as there were high numbers of errors in trying to achieve each category (only 9.23% young children achieved six categories, when compared with 53.8% of older children and 80.3% adolescents). Such behaviors are not surprising, as six-year-olds are in general drawn to the concrete aspects of the objects with which they interact and therefore are less able to make the conceptual leap to an abstract formulation of the task (Piaget & Inhelder, 1967). Based on Piaget's theory and observations, young children do not have a consistent sorting strategy in which to fully coordinate the intension (the criterion that defines the class) and extension (the sum of objects that meet that criterion) properties of the class (Phillips, 1981). Specifically for the WCST, the combination between a limited ability to classify and the concrete thinking of six-year-olds is a likely explanation for the observed struggle in learning the task and the lack of generalizability of the learned skill. The improved performance of older children is likely to be supported by the new cognitive ability to decenter, specifically, to return to the initial collection of objects, to look for, and to find additional classification criteria (intensions). According to Piaget and Inhelder, not only are 11-12 year old children able to see the intension and work towards different intension of a class (concretely or in thought), but they can also compare extensions, making their classifications stable and permanent, in that their classes do not disintegrate under any external, physical pressures (1987).

For additional support of the prediction of increased test efficiency with increasing age, another outcome of this study becomes noticeable. This finding mainly addresses the second hypothesis of the study about the developmental trend in the ability to sort by number the first time it appears in the test. Indeed, younger children make significantly ($p < .000$) more errors than older children and adolescents in attempting to sort by number the first time this sorting criterion appears in the test. The struggle to find number as a sorting criterion is very likely to have impeded children's ability to progress in the test and to allow enough trials/categories to understand and adjust to the demands of the test. Similarly, when discussing previously the "realization of possibilities" (Wiegl, 1927, cited in Rioch et al., 1941) and the need to gain insight in the multiple possibilities of choice in order to perform on a sorting task, younger children were found to be at a disadvantage when compared with the rest of the participants in the study, as number was proven to lack salience in comparison with color and shape. Number does not stand-out for young children as a relatively distinct, prominent or obvious sorting criterion when compared with the other matching possibilities (Gelman et al., 1986). Only six young children (14.28%) named number as a criterion they sorted by when asked to enumerate the sorting criteria they used during the whole test.

This particular conclusion was examined further in the study, and two significant results were found. Depending of the type of the first sorting criterion in the test (color, shape, or number) the number of errors made in sorting by that criterion was significantly different for the youngest participants. For the older children and adolescents, there were no significant differences between the %ES values calculated for the first sorting criterion, no matter if the criterion was color, or shape, or number. Number was the

hardest sorting criterion to sort by for six-year-old children when compared with color and with shape (Tables 18 and 19). Finally, as mentioned previously, the position held by number in the test sequence was found to significantly affect the number of categories completed by six-year-old participants: when number was in the third position, participants achieved more categories than when number was the first criterion to sort by (Table 10). These conclusions are supportive of the prediction that six-year-old participants have more difficulty identifying and sorting by the number criterion regardless of its position in the test sequence when compared with older children and adolescents, as it is a developmentally less salient criterion for a sorting task.

One explanation for the noted complexity of number as a harder concept for young children to sort by comes from neurodevelopmental research comparing brain areas involved in perception of color, shape, and numerosity (judging the relative quantity of items), and from the normal development of these brain regions across childhood and early adolescence. The lateral occipital complex (lateral and ventral occipital cortex) has been found to be the brain part involved in the extraction and/or representation of object shape independent of the image cues that define that structure, such as lines, shading, texture, or monocular depth cues (Kourtzi & Kanwisher, 2000). The lingual and fusiform gyri of the occipital lobe are considered the areas responsible for color perception (Chao & Martin, 1999). In studying the brain structures activated by the perception of number, two brain systems have been consistently found to be involved in representing approximate numerical magnitudes: the prefrontal cortex and the intraparietal sulcus (Nieder, Freedman, & Miller, 2002; Nieder & Miller, 2004). In the effort to explain how and why perception of numerosity is a skill that appears less

available for younger children, it is important to add that the neurosciences state that trajectories of development for the human brain have a vertical (subcortical-cortical) and horizontal (anterior-posterior) progression during infancy and childhood (Satz, et al., 1990, cited in Spreen et al., 1995).

At a behavioral level, research has shown that children prefer shape over color or size in the array of object characteristics evoked for matching tasks (Brown & Campione, 1971; Kagan & Lemkin, 1961; Prevor & Diamond, 2005). While children as young as 30 months were found to be able to conceptualize changes in numerosity, this result has been found to be task-specific, therefore measurable only through a task carefully designed for that goal (Gelman et al., 1986; Gelman 2006). For the purpose of this dissertation, it is important to clarify that the coordinates of Gelman's task do not correspond with the WCST demands. Consequently, it would be unrealistic to expect that six-year-old children would be able to automatically react to the changes in numerosity as depicted on the sorting cards and use that knowledge in solving the task. From a neuropsychological perspective, the observed developmental trends in the WCST performance could be reflective of the gradual maturation of executive function, as it is "inextricably connected with the gradual emergence of other cognitive capacities" (Anderson, 2002, p. 71). The interconnection between executive functioning and cognitive development can, once more, be discussed using Piaget's theory, as he claimed that, based on the tasks he used, children are not usually able to conserve number until the age of six or seven, and that children must grasp the principle of conservation of quantity before they can develop the concept of number (1967). Accordingly, for young children, thoughts and behaviors are triggered by the appearance of objects, and

children's decisions are dominated mostly by their perceptions. Goswami's work also supports the idea that in the absence of the requisite knowledge it is difficult to reason and thus, novice learners are likely to fall back on simpler solution strategies such as associative reasoning and matching on the basis of surface similarity. This difficulty in experiencing new concepts can be observed as a "functional fixedness" or "cognitive embeddedness", when potential solutions to a problem are not recognized because the action is too embedded in a familiar context (Goswami, 2003). Understanding children's cognitive skills in this perspective, it is quite easy to accept that six-year-old children may relate to the stimuli on the cards in many ways other than through their color, shape, or numerosity, therefore, affecting their performance at the WCST as measured by these specific test's scores. An example of such possible cognitive embeddedness comes from Grant's study, where one third of the sample of college students reported sorting the WCST cards by configuration and not by the amount of symbols on the card, therefore "misperceiving" the number of objects on the cards as configurations and reacting to perceptual (not abstract) information (1951). Given the small number of children in this current study that reported having used number as a sorting criteria (14.28%) and given the measured difficulty in sorting by number across this age group, it is feasible to see a connection with a lack of salience for number in young children's cognitive repertoire. When adding to the explanatory equation the neurological data already discussed above by which the involvement of the prefrontal cortex is required for perceiving and judging number quantity, it becomes even more apparent that number (as represented in the WCST) may not be a developmentally relevant dimension for young children to use in their problem-solving approach, therefore negatively affecting their WCST performance.

Related to the first study prediction of efficiency on the WCST as dependent on age, supplementary follow-up analyses led to a new conclusion that across all ages there is a general difficulty in shifting mental set from one sorting criterion to another, independent of the type of criterion. Mental inflexibility has been recognized as an obstacle to problem solving since the 1940s, when Gestalt psychologists focused on problem solving as a central topic of research. In Dunker's (1945) classic experiments on functional fixedness, for example, participants rigidly represented objects only in terms of their canonical functions (Zelazo et al., 2003). The measured difficulties with finding the next sorting criterion independent of the type of criterion (color, shape, etc.) for older children and adolescents lost its relevance when coupled with the previously discussed finding of increased efficiency on the test for these groups. However, this finding remains true for younger children. Again, a developmental explanation for understanding the inability to shift set was proposed. Zelazo and his colleagues suggested that inflexibility can occur at the level of representations (e.g. problem-solving sets) "when performance fails because of difficulty inhibiting an incorrect problem representation and establishing a correct one", therefore making it "an error based on representational inflexibility" (2003, pg. 4). They further suggested that the inability to shift mental set could be also due to "failures in response control, which occur when one fails to inhibit an incorrect response despite establishing and maintaining a correct intention to act" (Zelazo et al., 2003, pg. 4). While the observed difficulty in this study for young children could be explained by either of Zelazo's suggestions, the results of the end-of-test interview tend to support the first explanation. Young children in this study were unable to name number as a sorting criterion in the test. Therefore, it is likely that they did not represent

number as a possible solution, rather than having thought of it as an option but having difficulties inhibiting their behavior in matching cards by number. In conclusion, the WCST is a less than a desirable fit with young children's cognitive repertoire because of its focus on number as a sorting criterion and because of its subsequent negative influence on young children's mental flexibility. Clearly, the coordinates of the test demands are not leading the majority of six-year-old children to perceiving numerosity or changes in numerosity in the sorting cards and to represent this as a possible solution to the WCST problem.

The third hypothesis of the study, anticipating a developmentally predictable variation in the initial sorting criterion chosen for the first move in the test, was not founded. Analysis revealed that shape was, with overwhelming majority, the most common criterion reported/used by all three age groups, followed by color, as the second most frequent criterion in the sorting of the first card of the test (Table 20). It is interesting to mention that the first card of the test depicting one green triangle is an ambiguous-type of stimulus: when matched to the first card in the deck (one red triangle), it could appear to the observer to be matched either by shape (triangle) or by number (one object on the card). For this reason, each participant was asked to report right after the match the criterion used in their placement of the first test card. Based on the conceptualization of developmental significance of the sorting criteria in this study (the percent error score obtained in the attempt to discover and sort by each criterion), a hierarchy of relevance for the three criteria was found, but only for six-year-old children. Shape was still found to be the easiest sorting criterion, followed by color, and then by number (Table 19). This conclusion of shape bias stands in contrast to a previous study

by Grant, Jones, and Tallantis in which college students were found to have “selected most easily for number, next easily for form, and most difficult for color” (1949, p. 556). However, the shape bias finding is in agreement with the developmental literature discussed earlier. Prevor and Diamond provide an excellent summary of developmental research about the source of the shape bias in their 2005 article.

Implications of the Study and Future Directions

This study proves to be informative to child neuropsychologists as well as other professionals or families who are the agents of change in the child’s life because it addressed significant aspects of assessment and, indirectly, of diagnosis for children with neuropsychological difficulties. As discussed throughout this paper, children’s performance on the WCST has often been compared to adult performance and age-related test weaknesses have been attributed directly to deficits in executive functioning and brain maturation, leaving the possible developmental and cognitive explanations aside (Zelazo et al., 1997). The findings of this study are a first step in the attempt to revise the attitudes of child clinical neuropsychologists in the use and interpretation of the WCST, especially in the context of use with children at the younger end of the age range of applicability. Specifically, it has been found that age, position of number in the test, and the interaction of these two factors significantly affect the performance on the WCST as seen in the measured DVs. These findings are reasons to reconsider the theoretical support for the WCST as well as the usage of the WCST with young children. In reviewing the work of the WCST pioneers, such as Grant, Jones, Tallantis, or Curran (1949, 1952), there is no supporting information or theoretical reason for placing the test’s sorting criteria in the order in which they are introduced (color, shape, number).

Based on the current study, it is shown for the first time in the history of the test that, in actuality, having number as the third sorting criterion in the sequence is the best approach as far as the performance of young children on the WCST is concerned. Within the coordinates of the WCST as a measure of executive function and within the available test scores and calculations, having number as the third sorting criterion in the test has been shown in this study to improve young children's test performance through increasing the number of categories completed. While the other two indicators of interest to this study did not appear to have been affected by the position of number, it is quite likely that further analyses of the rest of the WCST scores would be fruitful in deepening the understanding of the test's use with young children (i.e. Perseverative Responses and Errors, Trials to Complete the First Category, Conceptual Level Responses, and Failure to Maintain Set). It is likely that WCST use with young children will continue in the field of neuropsychological assessment until a more appropriate measure of executive function is established as more appropriate for and sensitive to cognitive development in younger children. It is therefore important to acknowledge that, at a minimum, the fact that number is the third category to be sorted by in the test is advantageous for young children's performance. This choice of sorting order gives the young child the best chance to make progress in the test since the other two sorting criteria appear to be more developmentally salient (color and shape). Achieving a sequence of two completed categories and managing one switch of set before having to sort by number increases the chances that the child understands the task demands and will be able to abstract its rules before facing number, as it appears to be developmentally less salient as a matching criterion.

Similarly, age is a crucial aspect to consider in interpreting the WCST performances, as it proved to affect all indicators considered in this study. One of the implications of this study relates to the indiscriminate use of the WCST on young children. Given the difficulties of younger children with the test demands and the cognitive skills required, as observed in this study, it will be important to ask what exact meaning can be inferred from the finding that a six-year-old child could not succeed past the third category in the test sequence or has barely managed to achieve the number category before running out of cards, if number is the first criterion in the test. Is the test measuring an inability to switch mental set or is it measuring the child's cognitive sophistication that allows him/her to use number as a sorting criterion? Perhaps other assessment measures could provide information to better answer this question. Diamond and Espy provide excellent examples for the adaptation of old tests or development of new measures to suit the level of cognitive skills in young children (Diamond et al., 2005; Espy, 1997; Espy, et al., 2006; Gerstadt, et al., 1994; Gerstadt, et al., 1994; Kirkham et al., 2003). In the same way, maybe replacing number as a sorting criterion in the WCST with some other criterion, such as size, may benefit the use of the WCST as a measure of executive function in young children (Brown & Campione, 1971; Kagan & Lemkin, 1961). Further studies will have to clarify the feasibility of this suggestion. A follow-up study from the available data may be that of analyzing the psycho-social profiles of six-year-old children by including more of the variables collected with the demographic questionnaire. By the use of cluster analysis, it will be interesting to evaluate if there is a profile of the young child who performs well at the WCST (based on academic performance, social skills, family composition, extracurricular activities, etc.).

Another contribution of this study, given its developmental perspective on assessment and cognitive functioning, pertains to the developmental input of the test results to the process of reaching and interpreting diagnoses. Rather than seeing a diagnosis as a summary of particular deficits, this study attempts to provide a context for reframing diagnoses into delays of skill acquisition (Mahone, 2004). Perhaps the WCST test should be seen as a “zone of proximal development” (Vygotsky, 1978) for a cognitive skill or an area of intervention where the child would need further support and guidance to fully master some cognitive milestone. A particular theory of cognitive development referring to knowledge of numbers in toddlers and preschoolers proposed by Gelman and colleagues, warns that when new informational inputs do not map readily or are inconsistent with available mental structures, the risk is high that data will be misinterpreted as examples of what is already known (Hartnett & Gelman, 1998). This is a likely explanation of the behaviors observed in the WCST performance for young children when confronted with number as a sorting criterion (they continue to sort by color or shape). Also, according to research cited by Zelazo, preschool children cannot switch their sorting behaviors even when told the new sorting criterion they are expected to use (Zelazo, Jacques, Burack, & Frye, 1996, cited in Zelazo et al., 1997). Along these lines, it would be interesting to pursue the study of the WCST performance of young children when the test administration procedure is slightly altered. It would be meaningful to assess the effects on WCST performance of young children when the administration of the WCST to six-year-old children would start with the introduction of the three sorting criteria to be used in the test, in order to make them readily available to the child. The focus of such a study would be to establish if there would still be a

measured difficulty with number as a sorting criterion. Also, by offering the child the information which appears to be affecting the ability to efficiently perform on the WCST, based on the findings of this current study, WCST would possibly become a better account of executive function behaviors in young children (ability to shift set, regulate activity, and integrate feedback).

A foremost implication and future direction of study derived from this current research is the need for theory driven test development and theory driven assessment approaches. In the study of executive function in young children, one such model comes from Zelazo and colleagues (Zelazo, Carter, et al., 1997; Zelazo, Müller et al., 2003). Their proposed conceptualization of executive functioning as a macroconstruct spanning four phases of problem-solving (representation, planning, execution, and evaluation) has proven to provide a framework in which the authors were able to integrate temporally and functionally distinct aspects of executive function as a single overarching structure. Their work was focused on executive function development in preschool ages and it started by examining the literature on specific and relevant skills of problem solving within this age group. By providing a theoretical structure to their work, the authors were able to integrate in meaningful ways aspects that constitute, collectively, the higher order ability of executive functioning. Their review of research in cognitive development revealed a convergence of findings that was bound to be overlooked in the absence of a broad framework like the one they advance, that of executive functioning as a problem-solving process. In light of their literature review, the authors were able to evaluate several theories of executive function and conceptualize its development between the ages of three to five years (Zelazo et al., 1997). A future direction of study pertaining to the

WCST could lead to the adoption of such a theoretical framework and could further pursue the understanding of the WCST as a problem-solving task. For example, a more in-depth analysis of mental inflexibility could be pursued through the use of other scores from the WCST such as Perseverative Responses, Perseverative Errors or Failure to Maintain Set. As Zelazo and his colleagues suggest in their model of executive function in children, “by determining the circumstances in which children are susceptible to inflexibility, it should be possible to describe the development of executive function more precisely and reveal the way in which basic cognitive processes are orchestrated in order to fulfill the higher order functioning of problem solving” (2003, p. 6).

Another key conclusion to be drawn from this study has implications for the neuropsychological assessment of the young child. Before the WCST can be replaced from the repertoire of executive function measures for children under a certain age, it would be important to evaluate what current alternative assessment instruments are available for child neuropsychologist to administer. One way to address this development is to defer to current authorities in the field of child neuropsychological assessment. In an effort to compile a summary of normative data for individual child neuropsychology tests, Baron clustered several tests generally accepted as measures of executive function by the cognitive functions they engage (Baron, 2004). Baron’s grouping points out the following tests, based on the focus on the ability to plan, organize, reason, and shift as part of the ability to problem-solve: Children’s Category Test (CCT; Boll, 1993), Wisconsin Card Sorting Test, Delis-Kaplan Executive Function System, Sorting Test and Tower Test (D-KEFS; Delis, Kaplan, Kramer, 2001), and NEPSY Tower Test (Korkman, Kirk, & Kemp, 1998). The CCT is thought of as requiring “modification of problem-

solving hypotheses in response to feedback” (Mitrushina, Boone, Razani, & D’Elia, 2005), while the remaining tests are traditionally considered to measure the child’s ability to maintain response set, plan, and display flexibility in thinking. All but one of these tests are available for children ages 5-12 years old, which covers the lower age range chosen for this study; the D-KEFS has norms only for ages eight and up.

The conclusions about the psychometric properties and quality of these alternative neuropsychological tests measuring problem-solving abilities in children 5 to 12 years old are disheartening. Of the four neuropsychological tests analyzed, the CCT seems to stand out for its reasonable psychometric properties, but there are caveats in using this test: there is a known effect of high IQ on performance and a need to analyze the pattern of errors for certain subtests, as the test can be invalidated. The psychometric statuses of the Sorting or Tower tests from the D-KEFS set and of the Tower Test from NEPSY are poor. At their core, all these tests have some clinical value as shown through acceptable reliability and validity coefficients; however, the values of the indicators came either from the use with adult population or with specific clinical populations of children. It is quite possible that one reason the tests fail in measuring reliably and in a valid manner the problem-solving abilities in children is because of a lack of developmental fine-tuning to the cognitive and emotional coordinates of early ages, when skills are in the process of being achieved. The explanation could be that, while the tasks of these tests are developmentally accessible to children 5 to 12 years old, the coordinates of the tasks might not be (e.g. not only planning three steps ahead, but using visually complex images; or sorting cards, but by abstract concepts such as how many objects are on each card). A direct consequence of this situation could be the poor internal consistency of the

tests; test-retest reliability could also be affected as no developmental knowledge had been involved in deciding, for example, the appropriate interval between the two testing sessions, to assure the attribution of change only to true score variance. Therefore, it would be important to turn to the literature focused on executive function in preschoolers, such as the work of Diamond and Espy cited throughout this dissertation, and learn from those reputable authors about ways in which to assess executive function in developmentally appropriate manners, based on theory, and with well designed and well suited instruments.

Study Limitations

The final implication of this study, which is also its first limitation, relates to the minutiae of the WCST administration, recording, scoring, and interpretation. Particularly, it is noteworthy to reflect on the weaknesses of the WCST, some which became relevant given the focus of this study. One such limitation of the WCST experienced within the coordinates of this study was related to the Learning to Learn score. It was noted in the data from the adolescent group that significant ceiling effects appear for the NCA and the L2L scores, hence the skewness and over inflated kurtosis mentioned in the descriptive statistics section (Table 5). This observation raises questions about the clinical utility of the WCST use with normal adolescents and adults. Secondly, the inability to measure the L2L when there are less than three categories completed or two categories completed and one attempted defeats the existence of the L2L as a measure of cognitive efficiency alongside executive function skills. This score could be very informative, especially in the use of the WCST with younger children or patients with brain impairments, as it measures aspects of cognitive function (planning, short term memory, etc.) related more

or less directly with executive function features (mental flexibility, working memory, etc.). A future direction of study may be, therefore, to explore the addition of cards to the test in order to allow young children to continue with the task (rather than stop as they run out of cards) with the goal of facilitating more trials to exercise the cognitive skills available, to learn the task, and to generalize it across sorting criteria. This approach could be beneficial if one would be invested in pursuing measurement of executive function in young children and not have it be affected by specific cognitive abilities which can limit, as proven in this study, the conceptualization of the task.

A specific limitation of this particular research design could be the attempt to measure the “difficulty” of the sorting criteria through the %ES. Up until this point in the existence of the WCST, there has been no research discussing the properties of this intermediate score and its clinical significance. However, based on the findings in this study, it appears that this score has offered meaningful information for the particular research questions. One could argue that Perseverative Responses or Perseverative Errors scores could be better indicators for the level of difficulty one sorting criterion poses in comparison with the others in the test. For example, Grant and his colleagues determined the relative difficulty of the three sorting categories in the WCST through the amount of reinforcement and reminders required to confirm or establish a consistent response and to acquire the correct sorting response for each category. Further, they measured the tendency to perseverate in one sorting response versus the other two criteria. They found that the number was the easiest sorting criterion to find as it needed less reinforcement and the most perseverative in the test, independent of its order in the series (Grant et al., 1949). Similarly, in the current study’s quest for a conceptual hierarchy of relevance for

the three sorting criteria (color, shape, and number) through the initial match, a case could be made that a better way to measure the performance would have been achieved through the analysis of scores such as Perseverative Responses. Further studies will have to pursue these directions and elucidate on the correctness and appropriateness of each method, considering this study a first step.

One weakness of this study could also be found in the lack of accounting for participants' context of development and for their fund of knowledge. These aspects could be thought as influencing young children's ability to consider number as a sorting criterion. Previous research (Chelune & Baer, 1986; Paniak et al., 1996) reports that levels of intellectual functioning (measured through vocabulary tests or verbal IQ) were not correlated with performance on the WCST, beyond reflecting age improvement in cognitive functioning. Therefore, the attempt to find appropriate measurements of life context and experience for the account of ability to recognize number and use it in tasks such as sorting or matching may prove futile.

Summary and Conclusions

The WCST is a commonly used neuropsychological test of executive function in both clinical and research settings, with use across wide age ranges from 6 years, 6 months to 89 years of age. Although it was initially developed for use with adult population, for the last two decades the test has been frequently used with children as young as five years old.

The current study aimed to assess the developmental appropriateness of the test in measuring executive function with six-year-old children, starting from the premise that number as a sorting criterion is lacking the necessary developmental salience for this age

group, therefore, impeding the WCST performance of young children. Further, the study looked at the developmental trend in test performance improvement across three age groups, concurrent with the increase of cognitive abilities and overall availability of the cognitive skills required to successfully complete the WCST.

Overall, the results have been supportive of the study predictions. The findings revealed that both age and position of number in the test sequence, as well as their interaction, account for differences in the WCST performance, as measured through purposely chosen scores. Specifically, there was one finding across age groups which reflected the overall difficulty in switching mental set between sorting criteria. Most importantly, for the main focus of this study, that of the use of the WCST with six-year-old children, number as a sorting criterion was found to be the hardest criterion to sort by, and to have an influence on and inhibit young children's ability to achieve a sufficient number of categories in the test. The findings raised a number of questions with implications for theory and practice in the field of neuropsychological assessment of children, such as the use of adult measures in the neuropsychological assessment of young children. Furthermore, this study is an inspirational starting point for further research addressing the need for developmentally appropriate tests in the context of child neuropsychological assessment.

APPENDICES

Appendix A: Letter to the Principals of the Participant Schools

MM/DD/2005

Dear Principal XXX,

This fall, I am working on my Doctoral Dissertation in Child Psychology. I am planning to look at the Wisconsin Card Sorting Test (WCST), a test of mental flexibility and problem solving. The goal of my research is to see how children of three different age groups respond to this test.

I would like to ask children of ages 6 and 11 to 12 years old in your school to participate in a 20- to 30-minute task. This test is very similar to a sorting game and is performed with me by one child at a time. No risks are associated with participating in this task. Rather, most children enjoy the experience, as they find the task challenging and interesting and they enjoy the interaction. While there are no direct benefits to the children, they will have an opportunity to contribute to psychological science by participating in this research. The study will only look at group outcomes based on age and not children's individual responses.

The children's responses will be kept anonymous. Children will not be asked to provide their name or any other identifying information. All collected data will be encrypted and kept secure in accord with the standards of the University, Federal regulations, and the American Psychological Association.

The children will have the option to decline to participate before or even during the task. Whatever the decision, there will be no penalization. A raffle for 10 gift certificates at a bookstore will be held for the participants at the end of the data collection.

I appreciate your consideration of my request. If you have any questions about this research you may contact Dr. Berman at aberman@uri.edu, (401) 874-4257 or Ms. Bujoreanu at ibuj0442@postoffice.uri.edu, (917) 497-9808.

Respectfully,

I. Simona Bujoreanu, MA
University of Rhode Island
Doctoral Research Study

Research Project Developmental and Neuropsychological Perspectives in the Wisconsin
Card Sorting Test in Normal Children

School Participation Agreement Form

I have read the statements above, have had my questions answered, and do agree that the school will participate in this study.

____ I do agree for the school to participate in the research study.

Principal's signature _____

Principal's name _____

School name _____

Date _____

Appendix B: Parent/Legal Guardian Letter, Consent Form, and Demographic Information

Questionnaire

MM/DD/2006

To: All Parents/Guardians
From: I. Simona Bujoreanu, MA
Re: Participation in Research Project Developmental and Neuropsychological Perspectives in the Wisconsin Card Sorting Test in Normal Children

Dear Parents/Legal Guardians,

With the approval of Principal XXX, I am initiating a research study the XXX School and I am asking for the participation of children and their parents. This project is focused on children's performance at the Wisconsin Card Sorting Test, a task of mental flexibility and problem solving. The goal of the research is to see how well this task works with children and adolescents of three different age groups.

Your child will be asked to participate in a 20-minute individually administered task, very similar to a sorting game. No risks are associated with participating. Slight frustration may be experienced at times, given that the focus of the research is to test the task in a young population. Overall, reports from children who have taken this task tell that they enjoyed the experience, as they found the task challenging and interesting. If your child does experience frustration, he or she will be reassured. You will be asked to fill in a demographic information sheet that should not take you more than 5 minutes to complete. After your consent, your child will be asked to give his or her assent for participating in the study, as well.

While there are no direct benefits to you or your child, your child will have an opportunity to contribute to psychological science by participating in this research. The study will only look at group outcomes based on age and not at children's individual responses. Both you and your child can refuse to participate or withdraw from the study without any consequences. At the end of the task, your child can choose to enter his or her name in a sealed raffle box for the option to win one of the ten \$15 gift certificates at a local book store. The raffle will take place at the end of all research data collection.

Your and your child's responses will be kept anonymous. Children will not be asked to provide their name or any other identifying information. All collected data will be kept secure in accord with the standards of the University, Federal regulations, and the American Psychological Association.

This research is part of the doctoral program in which I am enrolled at the University of Rhode Island. This research has received the approval of the university's internal review board and a dissertation committee, both of which consider your and your child's rights as study participants.

If you have any questions about this research or if you are not satisfied with the way this study is performed, you may discuss it anonymously with to Dr. Berman at aberman@uri.edu; (401) 874-4257 or myself at ibuj0442@postoffice.uri.edu; (917) 497-9808. In addition, you may contact the office of the Vice Provost for Graduate Studies, Research and Outreach, 70 Lower College Rd, Suite 2, University of Rhode Island, Kingston, RI; (401) 874-4328.

Thank you in advance for your and your child's cooperation in the project.

XXX, Principal

I. Simona Bujoreanu, MA
Doctoral Candidate in Clinical Psychology

Research Project Developmental and Neuropsychological Perspectives in the Wisconsin
Card Sorting Test in Normal Children

Participation Consent Form

I have read the statements above, have had my questions answered, and do agree that my
child and I should participate in this study.

____ I do give permission for my child to participate in the research study.

Child's name

Signature of Parent/Guardian

Signature of Researcher

Typed/printed Name

I. Simona Bujoreanu
Typed/printed name

Date

Date

Please sign both consent-forms and return one copy to your child's teacher.

ID#: _____

Demographic Information Questionnaire

ID #: _____

Please fill out this questionnaire. Your answers will help better understand general aspects that may influence children's responses on the task. The information will be used for age group outcomes and not at individual level. Thank you for your cooperation.

1. Your child's age (in years and months): _____

2. Your child's grade: _____

3. Occupation Mother: _____

Father: _____

4. Family income:

- ___ 0-\$ 10,000
- ___ \$ 10,000 - \$ 29,000
- ___ \$ 30,000 - \$ 39,000
- ___ \$ 40,000 - \$ 49,000
- ___ \$ 50,000 - \$ 59,000
- ___ Over \$60,000

6. Who lives in the home with your child (choose all that apply):

- ___ Mother
- ___ Father
- ___ Older children (siblings or not)
- ___ Younger (siblings or not)
- ___ Other adults, such as: _____

7. Your child's ethnicity:

- ___ White
- ___ Hispanic
- ___ African American
- ___ Asian
- ___ Other (please specify) _____

8. Has your child repeated any grade(s):

- ___ Yes, grade(s) _____
- ___ No

9. Is your child receiving any special services at school:

- ___ Yes
- ___ No

If yes, please describe the nature of the services: _____

10. How well is your child performing in:

	N/A	Below Average	Average	Above Average
Math	_____	_____	_____	_____
Reading	_____	_____	_____	_____
Writing	_____	_____	_____	_____
Physical Ed.	_____	_____	_____	_____

11. How well is your child getting along with:

	N/A	Below Average	Average	Above Average
Siblings	_____	_____	_____	_____
Other children	_____	_____	_____	_____

12. About how many close friends does your child have? _____

13. Does your child belong to any organizations or clubs:

____ Yes
____ No

14. Has your child had any:

	Yes	No
Head injury	_____	_____
Illnesses	_____	_____
Hospitalizations	_____	_____

15. Is your child currently taking any medication:

____ Yes
____ No

If yes, what medication: _____

16. Does your child have any diagnoses that affect his/her school performance:

____ Yes
____ No

If yes, what diagnosis: _____

Appendix C: Children Assent Form

My name is Ms. Simona. I am doing a study about how children and adolescents respond to a sorting task.

If you agree to be in this study, here is what will happen: you will be asked to sort cards that have different pictures on them. The task will take about 20 minutes and we will be working together in my office. The things you would do should be easy and fun for you.

There is no risk for being in this study and there will be no direct benefit to you. You will help me learn more about how children of different ages solve this task.

Your responses will be kept secret. No one else will know that you were part of this study and no one can find out your responses to the task.

You might want to talk this over with your parents before you decide to be in this study. You do not have to participate. No one will be upset if you don't want to be part of the study. You can change your mind later if you want to stop. I also asked your parents to give their permission for you to take part in this study and they said yes. Even though they said yes, you can still decide not to do this.

You can ask me any questions you may have about this study. Would you like to read or hear about this study a second time?

Signing your name at the bottom of this form means that you have read or listened to what it says and you understand it. Signing this form also means that you agree to participate in this study and your questions have been answered. You and your parents will be given a copy of this form after you have signed it.

Signature of participant: _____ Date: _____

Signature of Investigator: _____ Date: _____

ID# _____

Appendix D: College Student Letter, Consent Form, and Demographic Information

Questionnaire

MM/DD/2005

University of Rhode Island
Department of Psychology
Kingston, RI 02881

Title of Project: Developmental and Neuropsychological Perspectives in the Wisconsin Card Sorting Test in Normal Children

I am requesting your participation in a research study focused on children's performance at the Wisconsin Card Sorting Test, a task of mental flexibility and problem solving. The goal of the research is to see how children and adolescents of three different age groups respond to this test.

You are asked to participate in a 20-minute individually administered task, very similar to a sorting game. No risks are associated with participating in this task. Rather, most people enjoy the experience, as they find the task challenging and interesting. While there are no direct benefits to you, you will have an opportunity to contribute to psychological science by participating in this research. The study will only look at group outcomes based on age and not at individual responses.

Your responses will be kept anonymous. You will not be asked to provide your name or any other identifying information. Also, you will be asked to fill in a demographic information sheet that should not take you more than 5 minutes to complete. All collected data will be encrypted and kept secure in accord with the standards of the University, Federal regulations, and the American Psychological Association.

This research is part of the doctoral program in which I am enrolled at the University of Rhode Island. This research has received the approval of the university's internal review board and a dissertation committee, both of which consider the rights of participants in such studies.

If you have any questions about this research or if you are not satisfied with the way this study is performed, you may discuss it anonymously with Dr. Berman at aberman@uri.edu; (401) 874-4257 or myself at ibuj0442@postoffice.uri.edu; (917) 497-9808. In addition, you may contact the office of the Vice Provost for Graduate Studies, Research and Outreach, 70 Lower College Rd, Suite 2, University of Rhode Island, Kingston, RI; (401) 874-4328.

Thank you in advance for your cooperation in the project.

I. Simona Bujoreanu, MA
Doctoral Student in Clinical Psychology, URI

Research Project Developmental and Neuropsychological Perspectives in the Wisconsin
Card Sorting Test in Normal Children

Participation Consent Form

I have read the statements above, have had my questions answered, and do agree to
participate in this study.

Signature of Participant

Typed/printed Name

Date

Signature of Researcher

I. Simona Bujoreanu

Typed/printed name

Date

Please sign both consent forms and keep one copy for yourself.

Demographic Information Questionnaire

ID #: _____

Please fill out this questionnaire. Your answers will help better understand general aspects that may influence people's responses on the task.

The information will be used for age group outcomes and not at individual responses.

Thank you for your cooperation.

1. Your age (in years and months): _____

2. Your educational level:

____ Freshman in college

____ Sophomore in college

3. Your parents' occupation

Mother: _____

Father: _____

4. Your family's income:

____ 0-\$ 10,000

____ \$ 10,000 - \$ 29,000

____ \$ 30,000 - \$ 39,000

____ \$ 40,000 - \$ 49,000

____ \$ 50,000 - \$ 59,000

____ Over \$60,000

6. Who lives in the home with you? or Who lived in the family with you before you left for college? (*choose all that apply*)

____ Mother

____ Father

____ Older children (siblings or not)

____ Younger (siblings or not)

____ Other adults, such as: _____

7. Your ethnicity:

____ White

____ Hispanic

____ African American

____ Asian

____ Other (please specify) _____

8. Have you ever repeated any grade(s):

____ Yes, grade(s) _____

____ No

9. Have you received any special services at school:

☐ Yes

☐ No

If yes, please describe the nature of the services:

10. How well did you perform in:

	N/A	Below Average	Average	Above Average
Math	☐	☐	☐	☐
Reading	☐	☐	☐	☐
Writing	☐	☐	☐	☐
Physical Ed.	☐	☐	☐	☐

11. How well did you get along with:

	N/A	Below Average	Average	Above Average
Siblings	☐	☐	☐	☐
Other children	☐	☐	☐	☐

12. Approximately how many close friends to you have? _____

13. Do you belong to any organizations or clubs:

☐ Yes

☐ No

14. Did you have any:

	Yes	No
Head injury	☐	☐
Illnesses	☐	☐
Hospitalizations	☐	☐

15. Are you currently taking any medication:

☐ Yes

☐ No

If yes, what medication: _____

16. Do you have any diagnoses that affect your school performance:

☐ Yes

☐ No

If yes, what diagnosis: _____

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