THE DEVELOPMENT OF EXECUTIVE FUNCTIONING SKILLS IN CHILDREN FROM LOW-INCOME FAMILIES: A PRELIMINARY INVESTIGATION

BY

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To my husband Sam, you have given up so much so that I may follow my dreams and I am so honored to be your wife. Your constant support carries me when I think I just can’t do it. You are my endless love. To my Mom, for always encouraging me to chase after my dreams and for giving me “roots and wings”. To Kim who has provided immeasurable support in every way imaginable throughout this process. I could not survive graduate school without you. I am so thankful for all of the many memories we’ve created, you are simply the best.
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THE DEVELOPMENT OF EXECUTIVE FUNCTIONING SKILLS IN CHILDREN FROM LOW-INCOME FAMILIES: A PRELIMINARY INVESTIGATION

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Children from lower-income families are at an increased risk for delays in academic achievement and cognitive development. This goal of this study was to examine differences in the executive functioning skills of children from lower-income families compared to their more affluent peers. Executive functions underlie cognitive skills that are necessary for learning in academic development. Performance on the Tower of London (TOL) was measured in 170 kindergartners (76 lower-income, 46 average-income, & 48 higher-income). In general lower-income had poorer performance than the higher-income children. Lower-income children solved fewer problems correctly and of the problems solved correctly they used more time and problems were solved less efficiently than higher-income children. These results indicate that children from lower-income families may benefit from executive skills training to better prepare them for school entry, thus results were discussed in terms of implications for early intervention programs.
CHAPTER 1
INTRODUCTION

One educational challenge that faces our nation today is the gap in achievement that exists between economically disadvantaged children and their majority peers. Children from lower-income families have more academic problems when compared to children from middle to higher-income families (Brooks-Gunn, Kelbanov, & Duncan, 1996). This gap in achievement increases with each grade level. Children raised in low-income families have been found to have delayed cognitive development and deficits in skills such as language, memory, and attentional capacities (Corcoran & Chaudry, 1997; Lupien et al., 2001; Craig, Connor, & Washington, 2003). Delays in cognitive development may place children from low-income families at an increased risk for academic failure and high school drop out which limit their successes later in life (Stevenson & Newman, 1986; Buckner, Mezzacappa, Beardslee, 2003). Thus, it is important to understand the role that family income level plays in cognitive development, particularly the skills critical for learning. The primary goal of this paper is to examine the effect of income level on the executive functioning skills of children.

Academic success is dependent on the development of underlying cognitive skills that are involved in aspects of self-regulation. Cognitive tasks require skills such as inhibition, working memory, planning, the use of strategies, and cognitive flexibility. This broad set of skills, referred to as executive functions, serve as the foundational skills needed for learning in academic environments. In order to learn basic literacy and math skills, it is necessary for children to inhibit inappropriate behaviors, hold instructions in working memory, use strategies to reach goals, and plan exactly how they will accomplish their goals. Variations in the early learning experiences provided in home environments place children from lower-income families at an increased risk for delayed development of executive functioning skills (Waber, Gerber,
Turcios, Wagner, and Forbes, 2006). Numerous studies have shown that low socioeconomic status is highly correlated with suboptimal development, particularly delayed cognitive development (Ryan, Fauth, & Brooks-Gunn, 2006; Bendersky & Lewis, 1994; Donahue, Finnegan, Lutkus, Allen, & Campbell, 2001). Given the critical role that executive functions play in cognitive functioning, it seems likely that delayed cognitive development may result from an underdeveloped set of basic executive functioning skills. Given this, the primary goal of this study was to investigate whether differences in the development of executive functioning skills will be observed in children of varying socioeconomic levels through children’s performance on a planning task. The study is of necessity exploratory in nature since so little specific research on this topic is available.

**Development of Executive Functions**

The term executive function encompasses multiple higher order brain functions that are interrelated and functionally dependent. These skills are important in emotional control, cognitive functioning, and goal directed behavior. Planning, in some ways, may be considered a unifying aspect of executive functioning in that the ability to plan effectively involves several aspects of executive functioning. Complex cognitive skills such as recognizing differences between start and goal contexts, creating effective strategies to accomplish goals, the use of working memory to remember rules of tasks, monitoring actions taken to reach goals, and correcting any errors made are all aspects of planning (NICHD, 2005). Competence in planning therefore requires sufficient development of working memory, cognitive flexibility or set shifting, inhibition of irrelevant information or behaviors, and sustained attention (Bull & Scerif, 2001).

Executive functions begin to develop in early childhood and continue through early adulthood. The development of executive functions is preceded by the development of motor
inhibition and selective attention after which the development of more complex skills such as complex working memory and the use of strategies emerge (Klenberg et al., 2001). Welsh, Pennington, and Grossier (1991) found that basic executive functions such as planning and search behaviors can be observed by six years of age and complex executive functions such as higher level planning skills, verbal fluency, and complex working memory can be observed after twelve years of age. Other evidence suggests an earlier onset, however. For example, children between the ages of three to six years of age exhibit early forms of executive functioning skills when given developmentally appropriate tasks (Welsh & Pennington, 1988). Further, younger children are able often to verbalize the correct response yet continue to make an incorrect motor response, which indicates that their impaired performance on executive functioning tasks is not due to a lack of understanding of the rules but rather immature development of the skills required to perform the task correctly. More recently, research from our laboratory has shown that preschoolers are far better problem solvers than previously reported. They are able to solve surprisingly difficult problems, problems that are also challenging to adults. But preschoolers solve fewer of such difficult problems and when they solve them do so with less efficiency (Berg & Byrd, 2002). Preschoolers show a great deal of variability in their use of strategies when solving problems both within individual sessions and within problems (Byrd, Van der Veen, McNamara, Berg, 2004). These age related effects on children’s executive functioning performance suggests immaturity of the brain regions associated with executive functioning skills (Rennie, Bull, & Diamond, 2004; Dowsett & Livesey, 2000; Diamond & Taylor, 1996).

The difficulties that young children show with executive functioning tasks are similar to the cognitive deficits found in adults and animals with frontal lobe damage, which provides support for an underlying neurological component of executive functions (Dowsett & Livesey,
Evidence from neuroimaging studies of adults and children indicate that executive functions are predominately influenced by the frontal lobes of the brain. Adults with frontal lobe lesions demonstrate deficits in planning, goal setting, cognitive flexibility, inhibition, and self-monitoring. In studies of damage to the frontal lobes in rats and rhesus monkeys, lesions in the prefrontal cortex resulted in deficits in inhibition and working memory on response tasks (Dowsett & Livesey, 2000).

The development of executive functions is related to neuropsychological changes that occur in normal development. From birth to five years, progressive myelinization results in rapid and more efficient neuronal connections. The maturation of frontal lobe circuitry results in increased information processing. Increases in neuronal connections and myelinization allow for the integration of cognitive processes or, in other words, enhanced executive control (Anderson, 2002). Repeated exposure to novel tasks increases information processing efficiency and speed as learning occurs. It has been suggested that experience plays a role in the executive functioning abilities of young children (Zelazo, Reznick, & Piñon, 1995; Zelazo & Reznick, 1991, Dowsett & Livesey, 2000). Repeated exposure to novel tasks requiring the use of executive functions likely accelerates the acquisition of executive functioning skills (Dowsett & Livesey, 2000). It would seem that children exposed to tasks within their environments that require the use of executive functions would likely be more advanced in their development of these skills when compared to children who have not been exposed to such tasks.

**Differences in Cognitive Development of Low-income Children**

Although there is minimal data on the effects of income specific to executive functioning, a variety of evidence points to the effects of income on many basic cognitive functions, including some that overlap with executive functioning. For example, in most studies of children from lower-income families, socioeconomic status is the most consistent predictor of IQ, cognitive
functioning, and school readiness, even more so than parent education level or occupation (Stipek & Ryan, 1997; Davis & Ginsburg, 1993). Large differences in cognitive skills have been found in kindergarteners’ performance on tasks that involve basic reading and numeric skills, problem solving, creativity, memory, and language skills (Stipek & Ryan, 1997). Family income level has been found to account for 20% of the variance associated with children’s IQ scores (Gottfreid, Bathurst, Guerin, & Parramore, 2003). Similarly, family income level at age three is a powerful predictor of IQ at age five, even when IQ at age three is controlled for (Duncan et al., 1994). This relationship between income and children’s intelligence is typically mediated by the degree of cognitive stimulation available to children in the environment provided by families (Yeung, Linver, & Brooks-Gunn, 2002). For example, Yeung, Linver, and Brooks-Gunn (2002) found that the association between family income level and children’s scores on the Woodcock Johnson Achievement Test was mediated by the family’s ability to provide a stimulating learning environment. These and other data would make it reasonable to expect that income would also impact specific executive functions, and the very few studies conducted in this area address the question of whether children from lower-income families are at an increased risk for delayed development of executive functions.

Davis and Ginsburg (1993) found that children from lower-income families developed problem-solving skills slower than children from middle class families. The lower-income children performed more poorly than middle class children in both formal and informal mathematic cognition at all age levels in the study (from 3 to 8 years old). Behavioral research on the executive attention and inhibition skills of children from lower-income families revealed that these children made more errors and performed significantly worse than their affluent peers on tasks related to executive skills (Mezzacappa, 2004). Similarly, when five developing
neurocognitive systems in children were examined, socioeconomic status was disproportionately associated with the left perisylvian (language) and the prefrontal (executive) systems, with lower-income children performing more poorly than middle-income children on measures of go/no go tasks, spatial working memory tasks, false alarms, card sorting, and the PPVT (Noble, Norman, Farah, 2005). Physiological research on the EEG maturation of young children raised in poverty revealed less activation of the frontal lobes when compared to children in the control group (Otero, Pliego-Rivero, Fernandez, and Ricardo, 2003). Furthermore, data from the NICHD Study of Early Child Care (2003) revealed that the quality of the home environment, which is highly correlated with socioeconomic status, predicted children’s performance on tasks of sustained attention and inhibition. Sustained attention and inhibition, in turn, mediated the relationship between the home environment and school readiness.

Although research is lacking on the development of executive functioning skills in lower-income children, the existing physiological and behavioral research is consistent with the proposition that lower-income children are more susceptible to delays in the development of executive functioning skills when compared to their affluent peers. The data available have only examined a few of the various aspects of executive functions that have been identified. In particular, one of the major features of executive functioning, planning and problem solving, appears not to have been examined much from the perspective of income effects.

**Planning, Problem Solving, and the Tower of London**

The Tower of London (TOL) is an executive functioning task that is used to examine complex problem solving skills in children and adults (Shallice, 1982). It is one of the most widely used tasks to assess planning and problem solving in adults and children in the last decade, and could prove to be a valuable tool to explore the effects of SES. Perhaps one of the largest advantages of the TOL is that the task is minimally dependent on language proficiency or
knowledge, so the language environment of the home or school is unlikely to be reflected in task performance. Children’s performance on the TOL has been correlated with academic achievement (Sikora, Haley, Edwards, Butler, 2002). Children with reading difficulties, mathematical difficulties, and a control group with no academic difficulties demonstrated significant differences in performance on the TOL. Children with mathematical difficulties struggled the most, getting the fewest number of correct solves. Children with reading difficulties and those in the control group performed similarly (Sikora et al., 2002). The children with mathematical difficulties appeared to experience the greatest impairment in planning abilities, which is a necessary skill in mathematical abilities. Given the relationship between income level and mathematical abilities and the correlation between mathematical abilities and executive functions, it would seem reasonable to propose that children from lower-income families would be more likely to perform worse on the TOL than children from middle class and affluent families. Executive functions have been correlated with children’s mathematical abilities on other measures of executive functions (e.g., working memory tasks, Stroop tasks, and visual-spatial working memory tasks) (Shi-jie, La-yan, Juan, 2005). Children with lower math abilities demonstrated a lack of inhibition and poor working memory skills on tasks of executive functions. Children with mathematical difficulties were also less likely to switch and develop new strategies (Bull & Scerif, 2001). Interestingly, a study of differences in the math skills of several ethnic and social class groups found that children from lower-income families in the US demonstrated the greatest number of mathematical difficulties and typically lagged two years behind children from other countries and middle class US children (Davis & Ginsburg, 1993). The relationship between academic skills, specifically mathematical skills, and performance on
executive function tasks suggests a need to examine planning and problem solving skills directly as a means of assessing the effects of income on children’s cognition.

In summary, the environment that a child grows up in influences cognitive development. Early childhood is the developmental period when the effects of family income are most influential in development. Family income is more strongly correlated with early childhood achievement and abilities than are measures of health and behaviors in part because of the effects of income on experiences provided within the home (Duncan, Yeung, Brooks-Gunn, Smith, 1998). Variations in the learning experiences provided in the home environment results in differential cognitive stimulation. Although research on the development of executive functions in lower-income children is lacking, existing data suggests that income might specifically affect at least some aspects of executive functioning. Similarly, there is no specific data on the effects of income on planning, though the work on reading and math abilities suggests this is an important and fruitful area to explore. Thus, the current study examined the effects of income on children’s executive functioning skills using the TOL.

The focus of the current research was to examine whether differences exist in the development of executive functioning skills in children from lower, middle, and higher income level families. Specifically, this study examined multiple aspects of the planning abilities of kindergartners from their performance on the TOL. It was predicted that lower-income children would solve proportionately fewer problems and perform more poorly on difficult problems when compared to children from middle class and affluent families. Lower-income children were expected to benefit from repeated exposure to problems and possibly perform comparably to higher-income children at the end of the task. In addition, it was predicted that lower-income
children would perform more poorly overall on multiple components of executive functions reflected in the TOL task, such as accuracy, speed, and efficiency.
CHAPTER 2
METHODS

Participants

The data included in this study represent the first year of data for a larger longitudinal study. More lower-income children were tested than average or higher-income children given that lower-income children typically have high attrition rates. One hundred and eighty-one kindergarten children (testing conducted in the summer months included children who were entering kindergarten or those who had just completed kindergarten) were tested. The sample included a total of 170 children (76 lower-income, 46 average-income, & 48 higher-income) which consisted of 78 girls and 96 boys. Six children were excluded from the study because computer program failure during the testing session resulted in a loss of data, three children were excluded based on low Peabody Picture Vocabulary Test (PPVT) scores (see criteria below), one child was excluded because of age outside the limits set, and one child was fearful of the electrodes. The mean age of children was five years, ten months, and four days old. The higher-income children consisted of three African American, three Asian, thirty-nine Caucasian, and three Latino children. The average-income children consisted of four African American, one Asian, thirty-six Caucasian, and five Latino children. The lower-income children consisted of sixty-two African American, one Asian, eleven Caucasian, and two Latino children. All participants were English speaking. Participants were recruited from preschools and elementary schools that were considered lower-income, average-income, or higher-income based on the percentage of children on free and reduced lunches. Schools which were considered lower-income schools were Head Start programs or schools in which ninety percent or more of children were enrolled in the free or reduced lunch program, average-income schools were schools in which thirty to thirty-six percent of children were enrolled in the free and reduced lunch
program, and higher-income schools were private schools or those in which thirty percent or less of children were enrolled in the free and reduced lunch program. Children were recruited with an ice cream incentive in that any child who returned the consent form got an ice cream cup, regardless of whether consent was given. Some schools also received one hundred dollars for the kindergarten teachers to use at their discretion if more than fifty percent of the consent forms were returned.

Although the Hollingshead Four Factor Index of Social Status was used to collect demographic data, participants were grouped according to income on the basis of school criteria. The Hollingshead data was not available for all participants (data collection is ongoing) and thus comparisons were made to verify the accuracy of groupings according to school. Hollingshead data was available for 86 of the participants. When the Hollingshead score was compared to the groupings by school, ninety-two percent of participants were labeled correctly as lower-income, average-income, or higher-income children.

**Measures**

**Verbal IQ Assessment**

The Peabody Picture Vocabulary Test III (PPVT) was used to assess children’s verbal IQ abilities and their receptive language skills. Any children with a verbal IQ score of 60 or less on the PPVT were excluded from the study. The standard PPVT was modified so that it could be administered on a laptop computer (see figure 1 for example of presentation screen). All other aspects followed the standardized instructions and procedures for this task (Dunn and Dunn, 1997). Four pictures were presented on the screen. The researcher read a word aloud and the child was instructed to use the computer mouse to click on the picture that best represented the word. For example, the researcher said "show me ball" and the child pointed to the picture of a ball. Words were presented in a sequence which became progressively more challenging as the
child continued with the task. The program ended and calculated a final score after children answered seven out of thirteen problems incorrectly in the sequence.

Figure 2-1. Peabody Picture Vocabulary Test III (PPVT) presentation screen

**The Tower of London**

The Tower of London (TOL) was used to assess children's problem-solving skills. The TOL was presented on a laptop computer (see figure 2 for an example of the presentation screen). The basic task in the TOL required children to move a set of three colored balls from their initial positions to their predetermined goal positions. All participants were given sixty seconds to arrange the three colored balls (red, blue, and green) on their own board to match the three colored balls on a cartoon character's (Sesame Street’s “Ernie”) goal board. Each board had three pegs arranged in decreasing size order. The small peg could hold one ball, the middle peg could hold two balls, and the tall peg could hold three balls. Children were allowed to move only one ball at a time and they were not allowed to move a ball if it had another ball on top of it until they moved the ball(s) on top to a different peg. In essence, the child was required to
recognize a difference in their board and the goal board and then plan how to move the balls so that their board matched the goal board.

Figure 2-2. Tower of London (TOL) presentation screen

TOL problems were presented in a sequence of increasing difficulty levels which allowed children to become more experienced with the task and allowed for them to build familiarity and confidence before the more difficult problems were presented. More difficult problems are defined here to mean problems that require more moves to complete an optimal solution. Children were given three sets of 10 TOL problems. Each set contained two problems of each difficulty level; three-move, four-move, five-move, six-move, and seven-move. After each problem children received feedback on their performance from an animated cartoon figure. Feedback was given according to the number of moves the child used to solve the problem. Children received a "high five guy" (solved the problem in the fewest number of moves), a "dancing guy" (solved the problem quickly, but in an extra move or two), "good job" (solved
problem, but took two or more extra moves to solve), or "the clock" (tried really hard but ran out of time).

TOL data was available on move by move basis which allowed the following measures of performance to be analyzed. Overall performance or success with the task was analyzed in terms of the proportion of correctly solved problems. Efficiency in solving problems and developing strategies was analyzed in terms of the relative number of optimal moves versus non-optimal moves made. This generated a scale that goes from -1 to +1, with more positive numbers indicating more optimal move selections. A score of 1 indicates every move was optimal and would translate into a problem solved in the fewest possible moves. Timing or speed of solving a problem which is related to planning abilities and inhibition was analyzed in terms of the time used to initiate the first move and then the solution time used to correctly solve problems after the first move was made.

**Heart Rate**

Given the previous evidence of income effects on physiological responses, children’s heart rate was measured during their TOL performance as a means of assessing their sustained attention during the task. This was used as an ancillary, more exploratory measure for the study although the data will not be presented in this paper. An electrocardiogram (EKG) was recorded using a Biopac MP3500 system in an effort to better understand cognitive events that occurred during the task through comparisons of the time between the r-r intervals of heart beats. This data was not included as part of the thesis, thus details will not be provided here.

**Hollingshead Index-Revised**

A revised version of the Hollingshead Four Factor Index (Hollingshead, 1975) was used to obtain a more accurate estimate of the child’s socioeconomic status. The revised Hollingshead index included all of the original questions (e.g., “what is your current household
income; what is your occupation”) as well as additional questions that were added to provide a more detailed description of families’ income levels (e.g., “did the child receive any type of formal preliminary education such as preschool, mother’s day out program, or early head start program”). This revised Hollingshead index was given to primary care takers during a phone interview that was conducted after the testing session. Primary care takers received twenty-five dollars for their participation in the study and children received a five dollar gift card to Walmart stores.

**Procedure**

Children were tested at their school or home and were video taped. Testing sessions lasted approximately one hour for each child and included four cartoon breaks to help maintain the child’s interest and involvement. Cartoons were shown after the child completed the PPVT and then following each set of TOL problems. Cartoons consisted of short five minute clips from popular children’s cartoons (Toy Story2, Shrek, Chicken Little, etc.). Two researchers were present at each testing session. The testing session begin with the researcher asking the child to draw a picture of a "smiley face" as a warm up task and to determine handedness. The researcher first explained the procedure to the child and asked if the child needed to use the restroom. The child completed the PPVT and was given a sticker for their effort. The researcher then explained how the "special stickers" (electrodes) were used for the EKG and asked the child's permission to adhere them. Electrodes were placed on child as they watched the first cartoon break in an attempt to distract the child. It was expected that such distraction may prevent children from moving and result in children feeling less fearful of the electrodes. The researcher then explained the TOL "game" to the child and the child was given four practice problems to ensure that they understood the rules. Practice problems consisted of one move problems that the child solved on their own. After the first practice problem was presented, the
researcher reminded the child which game board was theirs and which was Ernie’s and that the goal was to match their game board to Ernie’s goal board. If the child appeared to not understand the directions or rules, the researcher reiterated the rules of the game. The child was required to solve all four practice problems correctly and without help from the researcher to proceed to the experimental TOL. If the child was unable to solve the practice problems, the problems were repeated up to three times. The child then played all three sets of the TOL game. After each set of 10 problems children were given a sticker and a five-minute cartoon break to accommodate their short attention spans. During the last cartoon the researchers removed the electrodes. The researcher then thanked the child for helping them learn about "how kids think" and walked the child back to class.

The children’s primary care takers were then contacted after the testing session was completed and asked to participate in a phone interview. The phone interview consisted of the revised Hollingshead index.
CHAPTER 3
RESULTS

MANOVA results that include multiple dependent variables will be presented as will mixed between-within univariate analysis of variance (ANOVA) results for each of the dependent variables (proportion solved, solution time, first move time, and optimal move score). For all analyses independent variables were Income (low, average, and high), Difficulty (3 move, 4 move, 5 move, 6 move, and 7 move problems), and Set (first, second, and third). MANOVA analyses as well as analyses of each dependent variable will be presented with age as a covariate\(^1\). Solution time was excluded from the MANOVA analysis given that so few six and seven move problems were solved, especially in the first set. Since solution time is not meaningful when the problem is not completed, this variable is analyzed only for solved problems. Therefore, the univariate ANOVA of solution time was limited to 3 through 5 move problems where sufficient numbers of problems were solved. Levine’s homogeneity of variance test was conducted for each analysis. The homogeneity of variance assumption was typically not universally met in that at least one of the 15 repeated measure variables had a significant F value. Regular F tests were reported, however, given that the large majority of the variables met the homogeneity test and ANOVA is relatively robust to heterogeneity violations. Lastly, since the primary focus of this paper is the effects of income on executive functions, follow up tests of main effects and interactions will be limited to the effects of income rather than including effects of sets and difficulty as well.

\(^1\) Analyses were also conducted with age and PPVT as covariates; however, with the exception of optimal move score, the addition of the PPVT only slightly altered results. Therefore, only results with age as a covariate are presented.
Omnibus results

As noted above, repeated measures MANOVA analysis included three of the four outcome variables. Wilks’ Lambda was selected as the multivariate effect estimation. Mauchly’s test indicated the sphericity assumption was not met for a two of the variables, thus Greenhouse-Geisser degrees of freedom corrections will be used to account for the departure from sphericity. Not surprisingly, overall performance shows evidence of a very consistent effect of income as well as substantial multivariate effects of sets and difficulty. Each of these overall effects and the related statistical support from the Manova will be considered in turn.

In general, income showed a clear effect as low and average-income children performed more poorly for two of the variables, proportion correct and optimal move score, but this was not so for the first move time measure. These differences in performance were confirmed by the multivariate main effect of income, $(F(6,312)= 2.766, p < .012, \eta^2= .051)$. As expected, when collapsed across sets, lower-income children generally performed more poorly than average and higher-income children on the more difficult problems, although this was not supported by a significant difficulty level by income interaction in this omnibus analysis. Similarly, although their performance improved in the second and third sets on proportion solved and optimal move score, lower-income children typically did not “catch up” to their more affluent peers by the third set. As noted above, income effects did vary depending on the outcome measure. For example, clear effects were found for the proportion solved and optimal move score variables, but there was no effect of income for the first move time variable. This issue will be discussed in more detail within the separate analysis of each variable provided below and in the discussion.

Improvements from the first set to the second set can be observed for each of the three performance variables for most children at most difficulty levels. For example, in regards to the first move time variable, children typically scored 20 percent faster on the first set when
compared to the second set. Changes from the second to the third set on all performance variables were far more variable and appeared to depend much more on the difficulty and income level. These changes in performance with each set were confirmed by the multivariate main effect of sets \((F(6,153)= 3.528, p < .003, \eta^2= .122)\), which remained strong regardless of the type of F approximation used. Examination of means confirmed improvements with each set for each of the three performance variables as each of the mean difference scores were significantly different from each other \((p's < .03)\), with the exception of the second and third set of the optimal move score measure, which did not show a significant difference though mean differences were in the expected direction.

Similarly, children’s performance generally declined as problems became more challenging and thus difficulty level effects were in the expected direction with the exception of the six move problems. The six move problems proved to be unusually difficult on all measures for each group of children, with the exception of lower-income and high-income children on the first move time measure. Possible explanations of this will be provided in the discussion. The multivariate test of the effect of difficulty level was extremely strong, \((F(12,147)= 3.078, p < .001, \eta^2= .201)\), regardless of the type of F approximation used.

Clearly, income has a strong effect on children’s performance abilities and the effect was rather consistent across performance variables. Effects of sets and difficulty were also evident. Inspection of the separate dependent variable data suggests that interactions will be more likely in univariate analyses. Follow up univariate tests which included orthogonal polynomial trends over income, sets, and difficulty were thus conducted for each outcome measure to further examine the unique aspects of each performance variable.
Proportion Solved

Results for the proportion solved variable are represented graphically in Figure 3. As expected, lower and average-income children in general solved fewer problems correctly when compared to higher-income children and all children performed more poorly on the first set. In the first set, the lower-income children performed more poorly than higher-income children on the two easiest problems, somewhat below them on the 5- and 7-move problems, but then all children performed similarly on the most challenging, six move problem. It appeared all children were performing poorly on these difficult problems in the first set. In the second set, average-income children began to perform more comparably to high-income children on the easier 3 and 4 move problems but still not equivalent for 5 and 7 move problems. Lower-income children continued to solve fewer problems on all but the four move problems. In the third set, lower- and average-income children did improve slightly; however their performance was never comparable to the higher-income children on any of the problems. Thus, overall it seems as if lower-income children can improve but the improvement does not reach the same performance levels of the average and higher-income children’s performance given the amount of experience provided by this study.

In addition to the clear effects of income, the effects across sets appeared as all children generally improved with successive sets, with the greatest improvement between sets 1 and 2. As noted above, this improvement varied somewhat with income levels. Similarly, the performance of all children appeared to change across difficulty level in that performance generally declined as problems became more difficult.

Most of the effects described above were confirmed in the overall ANOVA for proportion solved. The generally poorer performance by the lower-income children were confirmed by a strong main effect of income ($F(2,158)= 5.735, p < .004, \eta^2=.068$). This main
effect was qualified by several interactions with both sets and difficulty. The interaction with sets was indicated by the income by quadratic sets interaction ($F(2,158)= 3.400, p < .036, \eta^2 = .041$ ). The interaction was followed up with separate Anovas for each set. In the first set, an income by linear difficulty interaction emerged ($F(2,165)= 3.098, p < .048, \eta^2 = .036$ ), however this interaction did not appear in the second and third sets. The main effect of income was evident in each of the three sets of problems ($F$’s < 5.504, $p$’s < .021). Tukey’s post hoc analyses indicated that lower-income children’s performance differed only from higher-income children ($p$’s < .006) in the first and third sets in that they solved fewer problems correctly. In the second set, however, lower-income children’s performance differed from both average ($p < .016$) and higher-income children ($p < .009$) in that they solved fewer problems correctly.

In the overall Anova, the main effects of sets did not emerge. There was, however, a significant linear trend of difficulty ($F(1,158)= 9.363, p < .003, \eta^2 = .056$), and the effect of sets was seen in a quadratic sets by linear difficulty interaction ($F(1,158)= 5.023, p < .026, \eta^2 = .031$). Surprisingly, however, the difficulty by income interaction was not significant.

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**Figure 3-1.** Proportion solved with age as covariate over sets comparing performance on each difficulty level
Figure 3-1 Continued.

**First Move Time**

Results for the first move time variable are represented graphically in Figure 4, and appear quite different than those for Proportion Solved. The results for set 1 were rather unexpected in that a clear pattern for Income effects did not emerge. Looking across sets, lower-income children took more time than other children to initiate their first move in most instances. Income differences were rather variable in terms of difficulty level. It is important to note that none of these income differences appeared very large.

Generally speaking, all children showed differences in first move time from the first and second set, but differences between the second and third set were not apparent. Additionally, all children showed some differences on the first three and four move problems when compared to
the three and four move problems in the second & third set, but performance was rather comparable in regards to difficulty level on other sets with the exception of the 7 move problems.

These effects were somewhat confirmed in the overall ANOVA for first move time. Although the main effect of income was not supported, there was a strong linear trend across sets \( (F(1, 158)= 12.955, p < .000, \eta^2= .076) \). In contrast, a, the main effect of difficulty level was not present. The trend of sets was qualified by the three-way interactions of income by quadratic sets by cubic difficulty trend \( (F(2,158)= 3.214, p < .043, \eta^2= .039 ) \). Given the complexity of this result, and the lack of an obvious interpretation, follow-up analyses were not conducted. Even though there was not a main effect or simple interaction with income, the three way interaction does suggest that sets and difficulty may jointly play some role in income effects for first move time. This issue will be considered further in the discussion section.

![First Move Time Set 1](image.png)

**Figure 3-2.** First move time with age as covariates over sets comparing performance on each difficulty level
Figure 3-2 Continued

**Optimal Move Score**

Results for the optimal move score variable are represented graphically in Figure 5. The pattern of results for this variable is quite similar to those of the proportion solved variable. In the first set, lower and average-income children made moves that were less optimal when compared to higher-income. All children showed slight improvement in the second set. Lower and average-income children did have comparable performance to the higher-income children on the 3 and 4 move problems on set 2; however, lower-income children continued to solve problems less optimally than the average and higher-income children on the more difficult problems. This pattern remained in the third set. The lower and average-income children solved problems less optimally than the higher-income children. Thus, it appears lower-income children showed improvement across sets but did not catch up to the performance of other children in terms of optimal selection of moves.

Although performance differences for lower-income children were evident across sets, this improvement did not appear very marked. As expected, all children did appear to solve more difficult problems with a decreased proportion of optimal to non-optimal moves on the more difficult problems.
In general, the income effects were confirmed by the overall ANOVA for optimal move score as a strong main effect \( (F(2,158)= 6.312, p < .002, \eta^2= .074 ) \) of income emerged. Tukey’s post hoc analyses revealed that lower (M=.377, SE=.018) and average-income (M=.405, SE=.024), children were less efficient in their selection of optimal moves when compared to higher-income children (M=.475, SE=.022) \((p ‘s < .030)\). Additional follow up analyses of income effects which examined performance on each set individually were conducted so comparisons to the proportion solved results could be made. ANOVA results revealed main effects of income for each of the three sets \((F’ s < 5.155, \ p ‘ s < .020)\). Tukey’s post hoc analyses indicated in both the first and third set, lower \((M_s=3.05, .422; \ SE_s=.025, .023, \text{ respectively})\) and average-income children \((M_s=.294, .440; \ SE_s= .033, .030, \text{ respectively})\) used less optimal moves when compared to higher-income children \((M_s=.419, .519; \ SE_s= .031, .027 \text{ respectively})\). In the second set lower-income children \((M=.462, \ SE= .029)\), used less efficient strategies than both the average \((M=.462, \ SE= .029)\), and higher-income children \((M=.485, \ SE= .027)\).

Contrary to the strong effects of income, there were no significant main effects for sets and difficulty. There was, however, a linear effect of difficulty \( (F(1,162)= 7.188, p < .008, \eta^2= .042 ) \) that appeared only in the second set. Further, a quadratic sets by linear difficulty interaction was present \( (F(1,158)= 4.572, p < .034, \eta^2= .028 ) \).

![Optimal Move Score Set 1](image)

Figure 3-3. Optimal move score with age as covariate examining performance on five difficulty level over the three sets.
Figure 3-3 Continued.

Solution Time

The solution time measure only considers problems that were solved correctly. As noted above, most children solved few of the more difficult 6 and 7 move problems correctly, especially on the first set, so analysis of this variable only includes 3, 4, and 5 move problems. Results for the solution time variable are represented graphically in Figure 6. Children’s performance on this measure was quite similar to their performance on the Proportion Solved and Optimal Move Score variables. The effect of income was very consistent. Across first and second sets and each difficulty levels, lower-income children took longer to solve problems when compared to higher-income children, with average-income children usually performing somewhere between these. The lower-income children showed some improvement between the
second and third set. This solution time measure suggests that, with experience, the lower-income children were able to catch up to the average and higher-income children on the easiest problems, but not able to catch up to the average and higher-income children on the harder 5-move problems. The effect of sets was very evident between the first and second set, but more complex between the second and third.

As would be expected, children of all income levels improved and solved problems faster in the second set, and did so at all difficulty levels. Between the second third set, less overall improvement was evident, and the changes were less pronounced and varied considerably with income and difficulty level. Contrary to the effect of sets, the effect of difficulty was consistent as solution time increased steadily with increasing minimum number of moves.

These income effects were confirmed in the overall ANOVA for solution time as a strong main effect of income \((F(2,81)= 8.971, p < .001, \eta^2=.181)\) was present. Tukey’s post hoc analyses revealed lower-income children took longer to correctly solve problems \((M=16.316, SE=.507)\) when compared to average \((M=14.070, SE=.792)\) \((p < .022)\) and higher-income children \((M=13.229, SE=.525)\) \((p < .001)\). Average and higher-income children did not significantly differ. Additional follow up analyses which examined performance on each set individually so that comparisons could be made with proportion solved and optimal move score results indicated that the first set was the only set in which differences in any independent variable proved to be significant for this solution time measure. A main effect of income was very clear on this first set \((F(2,106)= 7.567, p < .001, \eta^2=.125)\), with lower \((M=19.601, SE=.741)\) and average-income children \((M=18.054, SE= 1.074)\) using more time as compared to higher-income children \((M=15.358, SE=.802)\) \((p’s < .045)\). In the first set there was also a linear effect of difficulty level \((F(1,106)= 5.486, p < .021, \eta^2=.049)\) in which children required more
time as problems became more difficult. Although it was rather unexpected, the second and third set showed no significant main effects of any of the variables or their interactions.

In addition to these income effects, in the overall ANOVA the main effect of sets was not present and, as expected, a moderately strong linear trend of difficulty \(F(1,81)= 5.050, p < .027, \eta^2= .059\) did appear.

![Solution Time Set 1](image1)

![Solution Time Set 2](image2)

![Solution Time Set 3](image3)

Figure 3-4. Solution time with age as covariates over sets comparing performance on each difficulty level
CHAPTER 4
DISCUSSION

To date, few studies have examined the role of executive functioning skills in lower-income children. Typically researchers include income as a covariate in statistical models and focus on other factors (Waber, Gerber, Turcios, Wagner, and Forbes, 2006). Of the few existing studies which investigate income effects on executive functions, research most often includes children’s performance on one specific subcomponent of executive function such as attention or inhibition and thus fails to account for multiple aspects of executive functioning (e.g., Mezzacappa, 2004; NICHD, 2003). In other words, a multifaceted approach has yet to be taken in the study of these skills in lower-income children. The current study thus expanded such results by looking at performance on multiple aspects of a complex executive functioning task, the Tower of London. These aspects include executive functions such as success, efficiency, and timing, as were identified by (Berg & Byrd, 2002).

The primary goal of this study was to examine the role of executive functioning skills in lower-income children as compared to average and higher-income children. It was expected that lower-income children in general would perform more poorly when compared to average and higher-income children. Results of the current study support existing research and do confirm that lower-income children have less developed executive functioning skills when compared to average and high-income children (Noble et al., 2005; Davis & Ginsburg, 1993). In general, lower-income children solved fewer problems correctly and the problems they did solve correctly were solved less efficiently and children needed longer to solve the problems when compared to average and high-income children. The results of the current study thus shed light on three aspects of performance in lower-income children; general success on an executive functioning task, efficiency when solving problems, and speed or timing needed to correctly
solve problems. The four performance variables will be discussed in turn to further examine lower-income children’s performance in comparison to their higher-income peers.

The proportion solved variable is considered a success measure in that it is a general indicator of children’s overall performance on the TOL (Berg & Byrd, 2002). This measure clearly indicated that lower-income children did solve fewer problems correctly when compared to the average and high-income children. Although lower-income children showed improvement with repeated exposure to the task, their performance was never fully comparable to their higher-income peers. Lower-income children began the task solving considerably fewer of the easier problems correctly and their performance remained behind the higher-income children initially, however with practice, their performance did improve. In fact, lower-income children were able to perform comparably to higher-income children on the easy problems but were unable to maintain the same level of performance on more difficult problems, even with repeated task exposure. Thus, generally speaking, lower-income children were able to improve their performance with repeated exposure but were not able to catch up to the same performance levels as the other children.

Lower-income children’s performance on the efficiency measure, optimal move score, was quite comparable to their performance on the general success measure. As with proportion solved, the optimal move score variable revealed that lower-income children began the task using a decreased number of optimal to non-optimal moves but their performance improved with repeated task exposure. With practice, lower-income children were able to perform comparably to the higher-income children on the easy problems; however they struggled on the more challenging problems and never reached the same performance levels as higher-income children.
As with the success measure, it is evident that lower-income children can improve with practice, however they remain unable to reach the same performance levels as their higher-income peers.

The pattern of results found for the success and efficiency measures may be explained by the literature which focuses on the self-regulatory aspects of executive functions. Self-regulation may be defined as regulation of emotion or as the regulation of attention and selective strategy use while performing a cognitive task (Blair, 2003). Existing research on sustained attention in lower-income children suggests that lower-income children have greater difficulty remaining focused on tasks and have less developed inhibitory skills (Chang & Burns, 2005; NICHD Early Child Care Research Network, 2003; Buckner, Mezzacappa, and Beardslee, 2003). For instance, in one study lower-income children were less able to regulate their attention on various cognitive tasks and their attention-regulation ability accurately predicted their achievement test scores (Howse, Lange, Farran, & Boyles, 2003). Similarly, studies with children in Head Start determined that children with lower levels of executive function displayed less on-task behavior and more problems with self-regulatory behaviors (Blair, 2003). With these facts in mind, it is reasonable to expect that lower-income children in the current study began the task with a lower level of executive functioning skills than higher-income children but with repeated task exposure were able to improve their performance. Lower-income children may have been less able to remain focused on the task and less able develop efficient strategies which would thus explain their inability to reach the same performance levels on difficult problems as higher-income children.

Physiological data from our lab would support this assertion. Heart rate variability is often used as a physiological indicator of children’s sustained attention during a task (Bornstein & Suess, 2000; Blair & Peters, 2003). Analyses of children’s heart rate variability during
performance on the TOL task indicate that lower-income children had higher heart rate variability power across all conditions, which suggests that these children have a more difficult time sustaining attention throughout the completion of the third set of problems when compared to higher-income children (DeLucca, McNamara, & Berg, 2006).

One of the two response time measures, solution time, clearly provides additional support to the conclusion that lower-income children have poorer executive functioning skills. The solution time is a measure of the time used to correctly solve problems once the first move has been made. Lower-income children showed a similar pattern on this variable as with the other performance measures. Lower-income children in general took longer to solve problems, especially the more challenging problems. These children initially took much longer to solve problems when compared to higher-income children, but lower-income children did improve and required less time to correctly solve problems with repeated task exposure. However, these children still continued to need more time than the higher-income children and by the end of the task, lower-income children actually regressed and began to need more time on the third set than the second. As with the other performance variables, lower-income children never caught up to higher-income children.

The other response time measure, first move time, is an indicator of the time children used before an initial first move was made. This measure is often interpreted as an indication of “planning time,” but can be difficult to interpret for a variety of reasons. For example, children with more advanced planning abilities may take longer to initiate their first move since they may plan a longer sequence of moves. But children with poorer planning abilities may also take more time since it may take much longer to plan each move. In contrast, children who are more impulsive may take much less time to initiate their first move, as might non-impulsive children.
who are exceptionally quick at formulating a good plan. Thus, it’s not always clear whether longer first move time indicates a better or worse planning unless some of these issues can be held constant or other information is available to help interpret the results.

Fortunately, the other information gathered in this study can aid in the interpretation of the first move time results. Thus, results of this variable may be considered in relation to the three other performance variables to better explain outcomes. Higher-income children performed better than lower-income children on each of the other performance variables which is indicative of better planning abilities than the lower-income children exhibited. This would suggest that the longer time that higher-income children used to make their first move indicates that their time was spent in effective planning (Berg & Byrd, 2002). In contrast, the lower-income children tended to have poorer performance on each of the other performance variables which is indicative of less developed planning abilities. The lack of an income effect for the first move time measure may suggest that lower-income children were either more impulsive than other children or, on the problems in which they did take longer to initiate their first move, they simply lacked the effective planning abilities that higher-income children displayed. This is a safe assumption when lower-income children’s performance on the other performance variables is considered.

Children’s performance on the two timing measures may be explained in terms of planning and inhibition abilities. Planning is a critical aspect of executive functioning skills that has yet to be explored in the literature. Although a few recent studies have began to explore executive functioning in lower-income children, a careful review of the literature revealed that research specific to lower-income children’s planning abilities is not yet available. The results of the current study however do strongly suggest that lower-income children have poorer planning
abilities than higher-income children. Effective planning and strategy use should translate to less time needed to correctly solve problems, which is exactly what was found for higher-income children. Conversely, children with well developed inhibitory skills should be able to inhibit the urge to move balls until they have developed an effective strategy for solving problems. Such skills would then be reflected in the optimal move score in that failure to inhibit a non optimal move which would take the child away from the goal position, which would result in a lower optimal move score. Thus, in addition to planning, inhibition may well have played a role in the pattern of results. Existing research on “set shifting” and inhibition tasks indicates that lower-income children typically make more errors and have less developed inhibitory skills when compared to their higher-income peers (Dowsett & Livesey, 2000; Waber et al., 2006; Diamond, Carlson, & Beck, 2005). In the current study, the results suggest that lower-income children have less developed inhibitory control when compared to higher-income children. Additionally, although inhibition is distinct from attention, it is evident that less inhibitory control may result in less task focus and thus the interaction of the two skills may also account for the varied performance of lower-income children (Bull, Espy, & Senn, 2004).

This study extends previous research and provides useful information on important aspects of executive functioning skills in lower-income children; however it is not without limitations. In particular, the participants in the study are grouped according to income on the basis of school criteria rather than on data gathered from the Hollingshead Four Factor Index of Social Status. Schools were selected based on the percentage of children enrolled in the free and reduced lunch program. As previously mentioned, however, the Hollingshead data was not available for all participants (data collection is ongoing) and thus comparisons were made to verify the accuracy of groupings and ninety-three percent of participants were grouped correctly.
Thus, it is not unreasonable to assert that the children are grouped correctly in this study. In addition, collection of specific income data from lower-income families can be difficult in that it is challenging to contact parents given the high rate at which phone numbers are disconnected, families move, varied work schedules, etc. Although it is not optimal, these challenging circumstances have prompted researchers to adopt this school lunch method of determining income status (Waber et al, 2006; Blair, 2003,).

Another limitation to this study is that the performance on the six move problems was, unexpectedly, substantially lower than for the seven move problems. It was expected that increasing numbers of moves required to correctly solve problems would produce more difficult problems, which would result in the seven move problem being the most challenging problem in the sets. This actually was not the case as six move problems proved to be the most challenging problems in all the sets.

Several reasons could contribute to this. Unpublished evidence from our laboratory with adults (Berg, Byrd, and McNamara, in preparation) as well as other published work (e.g., Kaller, Unterrainer, Rahm and Halsband, 2004) has shown that the minimum number of moves by itself is not always a good indicator of how challenging a problem will be. Several factors other than minimum moves contribute to this. For example, within each minimum move level required to solve problems, the difficulty can vary depending on the number of possible paths that may be taken to solve problems correctly. It clear that when the problems used in this study were originally selected during the design phase of the study, an unusually hard six move problem was inadvertently chosen. Although this was unexpected, this did not appear to have a negative effect on the results since problems were referenced collectively such as “easy” verses “challenging” rather than on a minimum move basis.
The present research could be further developed in a number of valuable ways with evidence our laboratory is currently gathering. Given that the data presented in the current study is the first year of data for a three year longitudinal study, future research will investigate how executive functioning skills develop over this period of time. It is widely known that the achievement gap between lower-income students and their higher-income peers increases with each grade level (Craig et al., 2003; Brooks-Gunn, 1996). It will be interesting to investigate how the gap in executive functioning performance found in this study will change with children’s development. Additionally, comparisons of children’s executive functioning skills to their academic performance would provide additional useful information. Future research will also include physiological data to provide additional support of behavioral findings. Although children’s performance may appear to be comparable, examination of physiological data can provide more comprehensive information which may indicate that although performance appeared to be equal, one child struggled much more than another to arrive at the end result. As noted above, heart rate variability or vagal tone is one common index of self-regulation and attention in children (Blair & Peters, 2003). Given that such data was collected for this study, additional analyses which examine the behavioral and physiological data together would provide valuable information related to lower-income children’s executive functioning skills.

In conclusion, the results of this study support the existing research on the delayed development of executive functioning skills in lower-income children. This study extended the existing research by adopting a multifaceted approach to executive functioning. The results indicate that lower-income children have poorer executive functioning skills and although they could improve their executive functioning performance, they were not able to perform at the same levels as higher-income children. It is important to note that these deficits were found on a
task in which the only language component involved the simple set of instructions at the start of the task. This means that the performance deficits reported in this study are not likely to be attributable to deficits in the lower income children’s vocabulary. However, income effects on brain systems have been found to be most pronounced in the language and executive systems (Noble et al., 2005). Lower-income children are at a greater risk than their more affluent peers for poor language abilities, however, research indicates that this risk is not based on their cognitive abilities but rather is a result of a lack of adequate language exposure in the home & childcare environments (Locke & Ginsborg, 2003). Similarly, recent research suggests that deficits in executive functions of lower-income children are not biological but rather a result of growing up in an economically disadvantaged environment (Waber et al., 2006). Thus it appears that one such way that economically disadvantaged environments affect school performance is through deficits in executive functioning skills. Given that these skills begin to develop rapidly in the preschool years and given the results of this study and existing research, lower-income children enter schools without the same school readiness skills. That is, a critical aspect of school readiness is likely the ability to plan effectively, and the present data suggest this and other executive functions are less developed for lower than for higher-income children (Welsh & Pennington, 1988).

These results have important implications for early intervention programs targeted at lower-income children. Such programs should consider school readiness as encompassing not only academic cognitive factors such as letter and number knowledge, but more basic cognitive skills, namely executive functions, which serve as foundational skills in academic environments. The early training of executive functioning skills could help lower-income children begin school at more comparable levels to higher-income children. Although few executive skills training
studies exist, those which have trained children in executive skills have reported marked improvement in children’s abilities (Dowsett & Livesey, 2000). Academic achievement has been related to levels of self-regulation independent of intelligence scores (Blair, 2002), as well as inhibitory control and planning abilities (Mezzacappa, 2004). Given that lower-income children are at an increased risk for deficits in these skills, it is important that programs incorporate early training. In fact, the early training of planning skills may prove effective in narrowing the achievement gap. Planning is a foundational cognitive skill necessary for academic success. Children with poor planning abilities typically complete easier problems on planning tasks, but struggle with more difficult, multi-step planning tasks (Byrd & Berg, 2002). Planning deficits would thus affect children’s abilities to plan strategies for completing assignments, their abilities to solve multi-step problems, and many other such academic tasks. The inclusion of training which would teach children how to inhibit initial responses and plan effective strategies towards reaching goals would not only improve attention regulation but perhaps improve lower-income children’s overall potential for academic success. Although there is still much work to be done, educational intervention programs geared towards these children have succeeded in narrowing the gap in achievement (Ramey & Ramey, 1998; Brooks Gunn et al., 1994). It is imperative that interventions focus on closing the gap in cognitive abilities that has been repeatedly observed in lower-income children. Interventions must target more specific cognitive abilities in order to be efficient. Given the results of this study and previous research, it is clear that the inclusion of executive skills training in early intervention programs would have far reaching implications for lower-income children. Such programs would give these children a better chance at academic success and thus improve their life opportunities.
LIST OF REFERENCES


BIOGRAPHICAL SKETCH

Teri DeLucca received her bachelor’s degree in psychology from the University of North Florida. Teri completed her undergraduate research in both a social psychology laboratory and developmental laboratory. She is currently enrolled in a dual degree doctoral program in both developmental and educational psychology at the University of Florida. Teri’s research is focused on the cognitive development of low-income children and the effects of socioeconomic status on their academic performance.