

**The Impact of a Motor Skill Intervention on Executive Function in
Preschoolers from Low Socioeconomic Backgrounds**

by

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Abstract

Changes in motor abilities lead to changes in cognition including executive function, which may reduce the impact of poverty on cognitive outcomes. The first study examined changes in cognitive function in preschool children from a local Head Start program resulting from a motor skill intervention. Cognitive function was assessed before and after 13 sessions of the motor skill intervention, where the children participated in a mastery motivational climate with three different conditions and a control group ($n = 75$). The motor skill group showed consistent and greater improvement in cognitive flexibility, inhibitory control and attention compared to the other groups. The second study focused on the changes in executive function and consisted of 12 sessions, 151 children were assigned to either a mastery motivational climate motor skill intervention group or a comparison group. We verified that the intervention based on Mastery Motivational Climate showed consistent and greater improvement in attention and inhibitory control.

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List of Abbreviations

DCCS	Dimensional Change Card Sort
EF	Executive Function
HTKS	Head, Toes, Knees, shoulders
MMC	Mastery Motivational Climate
PV	Picture Vocabulary

Chapter 1: Study 1 - Cognitive Abilities in Preschool Children from Low Socioeconomic Backgrounds

Introduction

Reciprocal relationships exist between cognition, physical, social, and emotional health during early childhood and these relationships may be affected by adverse environmental conditions (Diamond, 2013). Poverty and neglect are considered critical environmental factors that negatively affect brain development and behavior in the first years of life (Loughan & Perna, 2012). Exposure to poverty and neglect result in atypical stress-responses, which may negatively impact cognitive functions (Suor et al., 2015). Moreover, greater stress associated with this type of environment is with associated impairments in executive function (EF) (Loughan & Perna, 2012). For example, exposure to neglect even before birth is associated with impairments in the development of the prefrontal cortex and high levels of disorganization and impulsivity (two components of EF). These deficits in executive function may affect how children respond to social interactions in class and on the playground (Olson et al., 1997).

Given the critical window of brain development the first six years of life, providing young children with the opportunity to develop EF may lead to long-lasting changes in brain and cognitive development that may compensate for adverse environmental conditions (Loughan & Perna, 2012). Diamond (2013) suggests that EF can be trained by creating an enriched environment where the children have opportunities for learning, developing peer relationships, and observing positive adult models. Beyond the development of cognitive and social abilities,

EF also plays an important role in skilled motor performance through the development of the prefrontal cortex and its connections with subcortical and cortical centers that are important for movement control (Diamond, 2000). Reciprocally, motor skill learning may affect EF via these same connections.

The relationship between motor and other cognitive abilities have been investigated by Haapala et al. (2014) who reported that lower motor performance was associated with lower academic skills in children, especially among boys. Similarly, Kantomma et al. (2013) reported that early childhood motor problems are linked to long-term academic achievement in adolescence, which is mediated by lower physical activity and greater obesity levels. Therefore, it is critical that children with low motor performance or at risk for movement problems are identified and provided opportunities to develop motor abilities, as this training may lead to improved academic performance.

Interventions employing a mastery motivational climate (MMC) have been used to promote motor skill learning, and have shown a positive impact in children's motor performance and physical activity levels (Robinson, 2011; Robinson et al., 2009; Valentini & Rudisill, 2004; Valentini et al., 2017). In this kind of intervention, instruction plays an important role in learning gross motor skills. MMC is guided by the TARGET framework, which consists of 6 principles: Task, Authority, Recognition, Grouping, Evaluation, and Time. Together, the aim of MMC is to increase children's autonomy, enjoyment, and performance when compared to traditional motivational climates (Theeboom et al., 1995; Valentini et al., 2017).

The current set of studies are part of a broader research program aimed at evaluating the relationships between perceived physical competence, motor performance, cognitive abilities, and physical activity in young children from low socioeconomic environments. The purpose of the set of studies examined in this thesis is to determine the impact of the mastery motor skill intervention on cognitive functions, particularly EF.

Methods

The interventions took place at a Head Start preschool program, which combines parent involvement, health, educational and social services to assist children between the ages of 3 to 5 years old from low-income families and children in the foster care system. The intervention for this first study consisted of a mastery motivational climate with three different conditions: one condition emphasized motor skill instruction, one emphasized physical activity and fitness, and one emphasized a combination of both. A fourth group served as a control in which the children participated in free play. Classrooms were randomly assigned to each condition. In the intervention groups, children were exposed to materials and activities easy to evaluate and determine success. These activities were divided into stations, varying in the level of difficulty. Children were given the opportunity to choose the stations they visited and how long they stayed at each station. They were involved in setting and adhering to playground safety rules. They were also given the opportunity to engage and play with whomever they chose while on the playground. In the motor skill group, children were provided with instruction and feedback regarding motor performance; in the 50/50 group children were provided with instruction and feedback regarding motor performance and in addition to that, the activities encouraged physical

activity; the third condition encouraged physical activity and fitness only, with no instruction or feedback given regarding motor performance.

1. Participants

A total of 75 children (37 girls; 38 boys) participated in the study. The racial distribution was as follows: African-American 77% ($n = 58$), Caucasian 8% ($n = 6$), Multiracial 7% ($n = 5$), Asian 3% ($n = 2$), other 4% ($n = 3$), and “not provided” 1% ($n = 1$).

Table 1 - *Number of participants and ages for each group.*

<i>Condition</i>	<i>N Total</i>	<i>n Boys</i>	<i>n Girls</i>	<i>Mean (Age Range)</i>
Control	21	10	11	4.74 (3.65 – 5.48)
Motor skill	15	6	9	4.66 (3.77 – 5.62)
50/50	19	9	10	4.86 (3.94 – 5.55)
Physical Activity and Fitness	20	12	8	4.90 (3.73 – 6.22)

2. Tasks

2.1. NIH Toolbox Early Childhood Cognition Battery

The NIH Toolbox is a set of neuro-behavioral measurements that assess four domains (cognitive, emotional, sensory and motor functions) and is validated for individuals ages 3 and 85 years old. The Early Childhood Cognition Battery is a subset of the cognitive assessment and recommended for children ages 3 – 6 years. The Early Childhood Cognition Battery consists of 5 tasks: picture vocabulary (language), list sorting working memory (working memory), picture sequence memory (episodic memory), flanker (attention), and dimensional change card sort

(cognitive flexibility). These tasks are described in more detail below. A Composite Score is computed based on the completion of all five tasks. Each participant was tested individually on an iPad by a trained research assistant (Weintraub et al., 2013).

2.1.1. Picture Vocabulary Test

For this task, four pictures were presented on the iPad screen. The child listened to an audio recording of a word presented on speakers. The child chose the picture that matched the meaning of the word presented on the speakers. The total time for this task was ~4 minutes.

2.1.2. List Sorting Working Memory test

For this task, simple pictures of animals and foods are presented on the screen with corresponding audio of the name of picture one at a time. The child must recall the pictures presented and say the items in size order from smallest to biggest. At first, only pictures of animals are presented, but if the child gets at least 1 point for two sets of 2-stimulus items (i.e., pig-mouse and bird -cow), and at least 1 point in the set of 3-stimulus items (dog-horse-rabbit), he/she goes to the next phase where both animals and food are presented. In this phase, the child needs to recall and first say the food in size order, and then the animals in size order from smallest to biggest. The total time task is ~7 minutes. This task assesses working memory, where the child needs to recall and sequence different stimuli.

2.1.3. Picture Sequence Memory Test

In this task, objects and/or activities are presented in a particular order in the screen, and the child is asked to reproduce the sequence of pictures that were presented on the screen. This task starts with three objects/activities and increases in the number of objects/activities. This task

assesses episodic memory, which includes cognitive processes involved in the acquisition, storage, and retrieval of new information. The time required for this task is ~7 minutes.

2.1.4. Flanker Inhibitory Control and Attention Test

For this task, five fish with arrows pointing in the same direction as the fish are presented on the screen. The child must choose the arrow that matches the direction that the middle fish is pointing. The test contains congruent trials, where all the fish point in the same direction, and incongruent trials, where the middle fish points in a different direction than the flanking fish. The time necessary for this task is ~3 minutes. If the child successfully completes the task with the fish, he/she will then move onto the next phase in which five arrows are presented (instead of fish). Again, congruent and incongruent trials are presented. This task measures inhibitory control and attention; it requires the participant to focus on one specific stimulus (the middle fish/arrow) and inhibit attention to the other stimuli (flanking fish/arrows).

2.1.5. Dimensional Change Card Sort Test

For this task, one picture is presented in the middle of the screen, and pictures at the bottom of the screen, the child is asked to choose the picture at the bottom of the screen that matches the picture in the middle based on one of two rules. For the color rule, the child must choose the picture that matches the color of the picture in the middle of the screen (e.g., blue ball matches the blue truck in the middle). For the shape rule, the child must choose the picture that matches the shape of the picture in the middle of the screen (e.g., blue ball matches the yellow ball). The time required for this task is ~4 minutes.

2.1.6. Early Childhood Battery Composite Score

The early childhood composite score is obtained by averaging the normalized scores of the five cognitive tasks (Picture Vocabulary, DCCS, Flanker, Picture Sequence and List Sorting). This assessment provides a reliable estimate of the child's general cognitive functioning; higher scores indicate higher levels of cognitive functioning.

The scores are computed in 4 ways: age-adjusted scale score, fully adjusted scale score, unadjusted scale score (mean = 100 and standard deviation = 15) and age-adjusted National Percentile. Scores 70 or below indicate significant impairments and 115 suggest above-average cognitive abilities.

We chose to use the unadjusted standard scores, rather than the age-adjusted or fully-adjusted standard scores. As the performance of the children in this study was significantly inferior to the performance expected from children in this age-range (3 to 6 years old), the unadjusted standard score was used so as not to deflate the performance of these children further. The unadjusted standard score is considered the appropriate measurement when monitoring performance over time and verifying the overall level of functioning, where higher unadjusted scores are indicative of better performance (Slotkin et al., 2012).

3. Statistical Approach

MATLAB (Version 9.2, R 2017a) was used to run stepwise linear regressions for each dependent measure with pre-test scores, age, and group and their interactions (i.e., pre-test x group, age x group, pre-test x age x group). Only significant factors were kept in the model using a backward selection approach (i.e., the full model is fit with all main effects and interaction, and then terms are removed based on their level of significance). A level of significance $p < 0.05$ was

used for all analyses. For each dependent measure, outliers were identified as any points with a large Cook's Distance (a measure of leverage) where $D = 4/n$. Normality was evaluated using Kolmogorov-Smirnov test. If the K-S test was significant, suggesting heterogeneity of residuals, a log-transformation was used to reduce non-normality. It is important to note that for some variables the log-transformation reduced non-normality but did not result in a non-significant K-S test (i.e., still evidence for non-normality).

Results

Table 2 presents the means and standard deviations for the post-test scores by group for all dependent measures.

Table 2 - *Post-test DV (means, standard deviations, and number of participants) by group*

<i>Group/ Task</i>	<i>Control</i>	<i>Motor Skill</i>	<i>50/50</i>	<i>Physical Activity</i>
Picture Vocabulary	52.25 (6.84) <i>n</i> = 20	54.28 (6.33) <i>n</i> = 14	54.44 (5.18) <i>n</i> = 4	55.95 (7.52) <i>n</i> = 19
Picture Sequence Memory	73.76 (9.79) <i>n</i> = 17	70.36 (10.19) <i>n</i> = 11	71.28 (8.83) <i>n</i> = 14	76.5 (12.95) <i>n</i> = 12
List Sorting Working Memory	61.14 (18.56) <i>n</i> = 7	56.25 (9.57) <i>n</i> = 4	52.44 (6.76) <i>n</i> = 9	62.16 (10.55) <i>n</i> = 6
Flanker	41.42 (12.37) <i>n</i> = 19	40.54 (18.58) <i>n</i> = 13	45.26 (16.19) <i>n</i> = 15	42.94 (19.60) <i>n</i> = 18
DCCS	47.45 (12.34) <i>n</i> = 20	46.36 (13.36) <i>n</i> = 14	45.66 (10.59) <i>n</i> = 15	51.66 (17.31) <i>n</i> = 18
Composite Score	38.19 (7.00) <i>n</i> = 16	42.66 (12.25) <i>n</i> = 9	38.5 (7.41) <i>n</i> = 10	41.36 (12.85) <i>n</i> = 14

Given the length of the testing, some children were unable to complete all five tasks. As such, a different number of participants were included in each analysis. Since the composite

score is based on successful completion of all five tasks, this analysis included the smallest number of participants.

No group main effect was observed for Picture Vocabulary (PV) scores. Age significantly predicted the post-test scores across all groups ($\beta = -20.738$, Standard Error = 7.3197, $T = -2.8332$, $p = 0.006$). There was a significant age x pre-test interaction ($\beta = 0.38933$, Standard Error = 0.14432, $T = 2.6977$, $p = 0.009$). Figure 1 depicts the age x pre-test interaction for PV task. Post-test scores are depicted with respect to pre-test scores for children based on a median split (children younger than 4.61 (left) and older than 4.61 years old right). For the children younger than 4.61, those with low pre-test scores showed greater improvement than those with high pre-test scores. In contrast, for the children older than 4.61 years, those with low pre-test scores showed less improvement than the older children with high pre-test scores.

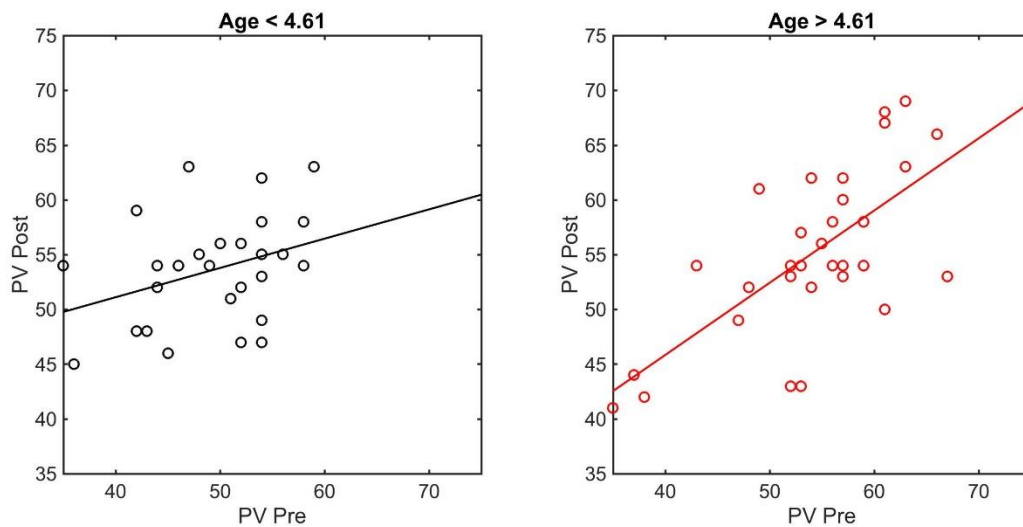


Figure 1.

PV post-test scores as a function of pre-test scores for children younger and older than 4.61 years old (median): Younger (black circles), Older (red circles).

For the Picture Sequence Memory Task there was no effect of pre-test scores, group, age, or a group x pre-test interaction ($p > 0.05$ for all).

Similar to what we found for PV, for List Sorting Working Memory (LS) there was a significant age x pre-test interaction ($\beta = 1.4968$, Standard Error = 0.53306, $T = 2.808$, $p = 0.048$). Figure 2 presents the LS post-test scores by the pre-test scores for children younger than 4.61 (left) and older than 4.61 years (right). The children younger than 4.61 years that had low pre-test scores showed less of an improvement in LS scores compared to those that had high pre-test scores. In contrast, the children older than 4.61 years that had high pre-test scores showed less of an improvement in LS scores at post-test. It is worthwhile to note that very few children were able to complete this task and as such, the results need to be interpreted cautiously.

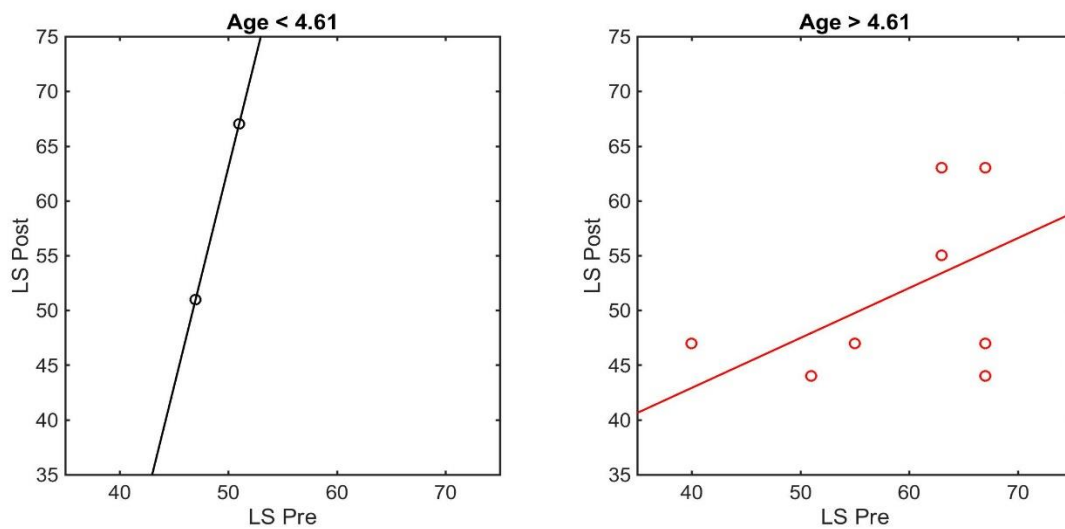


Figure 2.

LS post-test scores as a function of pre-test scores for children younger and older than 4.61 years old (median): Younger (black circles), Older (red circles).

For the Flanker tasks, no significant pre-test and age main effect were observed for the log-transformed post-test Flanker scores ($p > 0.05$). A significant group main effect such that the Motor Skill group ($\beta = -1.7314$, Standard Error = 0.57061, $T = -3.034$, $p = 0.003$) and Physical Activity Group ($\beta = -0.6949$, Standard Error = 0.28534, $T = -2.435$, $p = 0.018$) showed overall lower log-transformed post-test Flanker scores compared to the control group. However, a significant group x pretest interaction was observed in these groups. Figure 3 presents the log-transformed Flanker (inhibitory control and attention) post-test scores by pre-test scores for each group. The Motor Skill Group exhibited a greater slope compared to the controls ($\beta = 0.055548$, Standard Error = 0.019647, $T = 2.8272$, $p = 0.006$) and the Physical Activity group also showed a greater slope compared to controls ($\beta = 0.014309$, Standard Error = 0.0068183, $T = 2.0986$, $p = 0.041$). These results suggest that although the Motor Skill and Physical Activity groups exhibited overall lower post-test scores, these groups showed greater improvements for those with higher pre-test scores, compared to controls.

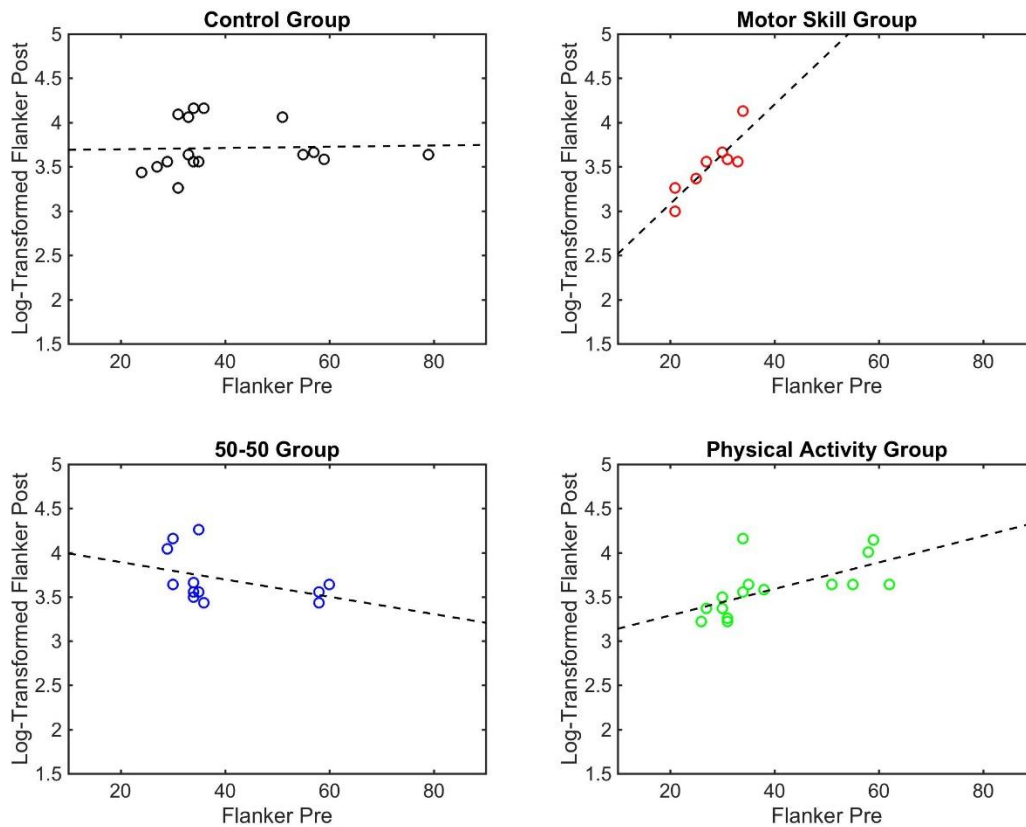


Figure 3.

Log-Transformed Flanker post-test scores as a function of pre-test scores for the four groups: Controls (black circles), Motor Skill Group (red circles), 50-50 Group (blue circles), and Physical Activity Group (green circles).

Significant pre-test ($\beta = 0.016895$, Standard Error = 0.0023581, $T = 7.1646$, $p < 0.001$) and age ($\beta = 0.27354$, Standard Error = 0.089982, $T = 3.04$, $p < 0.01$) and group main effect was observed for log-transformed Dimensional Change Card Sort (DCCS) scores. The Motor Skill group ($\beta = 1.1427$, Standard Error = 0.55696, $T = 2.0517$, $p = 0.046$) and the 50/50 group ($\beta =$

2.33, Standard Error = 0.60637, $T = 3.8425$, $p < 0.001$) showed significantly greater log-transformed DCCS post-test scores compared to controls. A significant group x age interaction was observed for the DCCS task in those same groups. Figure 4 presents the log-transformed Dimensional Change Card Sort post-test scores by age for each group. While the control group showed a greater increase in log-transformed post-test DCCS scores with age, the Motor Skill group exhibited a slightly less positive increase in log-transformed DCCS post-test scores with age ($\beta = -0.25945$, Standard Error = 0.1222, $T = -2.1232$, $p = 0.039$). The 50/50 group showed a slightly negative relationship between DCCS post-test scores and age ($\beta = -0.51703$, Standard Error = 0.13038, $T = -3.9657$, $p < 0.001$), which was significantly different than the control group. These results suggest that although the Motor Skill and 50-50 groups showed greater overall log-transformed post-test DCCS, control group showed a greater improvement with age compared to the other two groups.

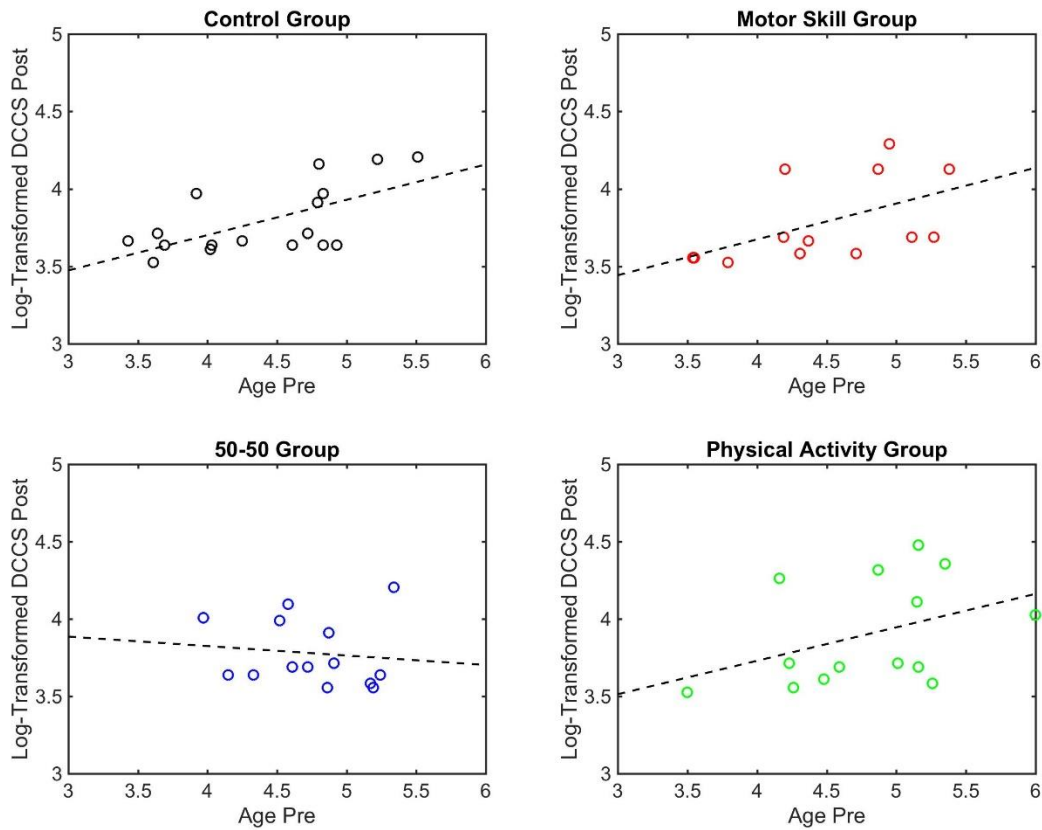


Figure 4.

Log-Transformed Dimensional Change Card Sort post-test scores as a function of ages for the four groups: Controls (black circles), Motor Skill Group (red circles), 50-50 Group (blue circles), and Physical Activity Group (green circles).

For the composite score, there was no effect of pre-test scores, group, age, or a group x pre-test interaction ($p > 0.05$ for all).

Discussion

This study provides new evidence regarding the impact of mastery climate movement interventions on cognitive abilities. We found that children with high baseline inhibitory control/attention skills showed greater improvements following a motor skill or physical activity intervention compared to children in the control group. With respect to cognitive flexibility, children in the motor skill and 50-50 groups showed a greater overall improvement compared to controls, but this effect depends on the age of the participant. Specifically, older children in the intervention groups show less improvement compared to controls. No group differences were observed for other measures of cognitive function, suggesting that the impact of motor skill interventions selectively affect EF skills.

Based on motor skill data acquired at the same time (Johnson et al., 2017), we observed that the mastery motivational climates are associated with improvement in motor skills which is also consistent with previous studies in other pre-school populations (Valentini & Rudisill, 2004; Rudisill et al., 2003; Martin et al., 2009; Goodway & Amui, 2007; Robinson & Goodway, 2009), but there is a lack of studies investigating the possible cognitive benefits from motor interventions based on mastery motivational climates, especially with high-risk populations. The current findings provide new support for the impact of a motor skill intervention on cognitive abilities, especially EF. Indeed, the mastery motivation intervention provided the time and tools to promote learning and practice executive skills. The children in all of the intervention groups were able to autonomously interact in the environment and engage in activities of their choice; they had to regulate their behavior, learn how to share the equipment with each other, adhere to

playground rules. These skills can all contribute to executive function. However, not all groups in the intervention showed similar improvement in EF, and there were subtle differences in the magnitude of effects across the different aspects of EF (i.e., inhibitory control vs. cognitive flexibility). Only children in the Motor Skill group showed improvement on both executive function tasks (Flanker and DCCS), suggesting that there is something unique that is conferred when the intervention targets motor skill development. These findings are consistent with Aadland et al. (2017) who found that motor skills, compared to general physical activity, were strongly associated with cognitive functions and academic performance. Moreover, Diamond & Lee (2011) reviewed several interventions aimed at improving executive function and suggested that interventions aimed at promoting physical development (i.e., motor skills via karate or yoga) may confer a greater benefit on executive function than those that target executive skills directly. The current study found that an intervention focused on motor skill development lead to greater change in executive function, particularly for higher performing children at baseline, compared to controls.

Limitations

The study was performed outside on 2 playgrounds of the Head Start preschool. The control group engaged in free play on one playground and the intervention groups participated in the other playground. So, it was not possible to directly observe the control group or determine any differences in the motivational climate. Future studies should directly assess the impact of motivational climate during free play (i.e., observe the control group and measure the impact of the climate).

The intervention was planned to take place over 16 sessions, but due to the weather and unanticipated activities from the school, we were only able to complete 13 sessions of intervention. Also, two makeup days were held inside, the equipment was set up at the gym, which was not the ideal setting and limited some of the activities. Future research should replicate and extend this study over a longer duration and account for potential changes in activities due to weather.

Lastly, we used the full Early Childhood Cognition Battery from the NIH Toolbox. This set of assessments took a long time to administer, particularly for the higher-performing children (i.e., it took longer to reach stopping criteria). Because the test was long, it was hard for children to pay attention and be fully engaged in all tasks, which might have affected their performance. Also, the Flanker and Dimensional Change Card Sort were the last tasks to be administered, and as such, if the child's attention or behavior was problematic early during the testing, it was not likely that the child would complete these two executive function tasks. Therefore, the results for these two tasks reflect the performance of children that were able to complete the full battery and may inherently differ from those children that were unable to complete the full battery. In addition, to the difference in the number of participants for each of the cognitive tasks for each testing session, there were a number of participants that did not complete post-test assessments. These children might have moved out of the school or were absent and/or sick during the post-test period. Therefore, future studies should examine a shorter or limited number of assessments to determine the effects of mastery motivation movement interventions on executive function in this at-risk population.

Chapter 2: Study 2 - The Impact of a Motor Skill Intervention on the Executive Function in Preschoolers from Low Socioeconomic Backgrounds

Introduction

Adverse environments, such as poverty and neglect, are associated with impairments in cognitive development, especially executive functions (EF), during the first years of life (Loughan & Perna, 2012; Suor et al., 2015). EF is crucial for both cognitive and social capacities, and they are acquired during early childhood (Zelazo, 2004; Rueda et al., 2005). EF includes several domains including working memory, inhibitory control, and cognitive flexibility (Diamond, 2013). Working memory is the ability to maintain and manipulate information so that it is ready to use when it is needed. Working memory is necessary for resuming a game after a break or taking turns during group activities. Inhibitory control is the ability to filter impulses and thoughts. It helps to inhibit irrelevant stimuli and focus attention on one specific task. Cognitive flexibility is the capacity to apply different rules in different contexts. For example, trying different strategies to solve a problem (Zelazo et al. 1996; Zelazo, 2004). Although these domains may be considered individually, they also work together to complete different cognitive, social, and motor tasks. Indeed, many activities performed at school and at home require children to adhere to rules, select appropriate behaviors, inhibit inappropriate actions, shift their attention, and manipulate information in real time (Zelazo et al., 1996; Cameron et al., 2012; Cameron et al, 2016; Pagani & Messier, 2012).

Motor development and cognitive development develop together throughout childhood and adolescence (Diamond, 2000). Children that exhibit problems in executive function also commonly exhibit motor coordination impairments. Conversely, when tasks require complex motor skills, children that have good executive control (i.e., good working memory, cognitive function and strong focus of attention) can be more engaged on the task (Piek et al., 2012). Diamond and Lee (2011) suggest that EF skills can be trained in the early childhood and that interventions aimed at promoting physical development (i.e., motor skills via karate or yoga) may confer a greater benefit on executive function than those that target executive skills directly.

Mastery motivational climates (MMC) have been shown to promote motor skill learning and performance in young children from at-risk populations (Rudisill et al., 2003; Robinson et al., 2009; Robinson & Goodway, 2009). MMC are guided by the TARGET framework, which consists of 6 principles: task, authority, recognition, grouping, evaluation and time. By promoting children's autonomy, children express higher levels of enjoyment and better motor skill performance in mastery groups when compared to control groups (Valentini et al., 2017; Theeboom et al.; 1995). In addition to these improvements in motor skill learning, MMC also show psychological benefits related to motivation achievement in preschoolers (Robinson et al., 2009). Although most studies have focused on improved perceptions of competence resulting from MMC motor skill interventions in at-risk populations, few studies have examined the extent to which a motor skill intervention using a mastery motivational climate framework may impact EF.

Therefore, the purpose of this study was to examine the impact of an MMC motor skill intervention on EF in at-risk preschoolers. Specifically, we compared two climates – one in which motor skills were promoted using a mastery framework and the other in which free play was promoted using an autonomy supported framework. This study built upon the results from the previous study by determining the unique effects of motor instructions on EF by controlling for the degree of autonomy in the two groups.

Methods

The intervention took place at the same Head Start preschool program as the Spring intervention. The Flanker and Dimensional Change Card Sort Task from the NIH Toolbox Early Childhood Cognitive Battery (Weintraub et al., 2013) and the Head, Toes, Knees, and Shoulders task (Ponitz et al., 2008) were administered before and after 12 sessions.

The intervention consisted of a mastery motivational climate emphasizing motor skill instruction and autonomy, and a second group exposed to an autonomy support climate with no motor skill instruction. Children in the intervention group were provided with stations with activities that differ in the level of difficulty which encouraged the learning of different motor skills (i.e., locomotor and object control skills). In the comparison group, children could play with the playground equipment and were provided similar equipment to those in the mastery motivational climate group but the setting was not divided into stations, and the children did not receive any feedback specific to motor skill instruction. The children were encouraged to play and be physically active. The teachers in this setting played games and engaged in physical activity with the children. Both groups were given autonomy and encouraged to select activities

of interest and engage in those activities for as long as they wanted. The main difference between the two groups is that the motor skill group is provided with autonomy and given motor skill instruction, while the comparison group is provided with autonomy but is not given motor skill instruction.

1. Participants

A total of 151 children (75 girls; 76 boys) participated in the study. The racial distribution is as follows: African-American (77%, $n = 116$), Caucasian (9%, $n = 14$); Multiracial (8%, $n = 13$), Asian (1%, $n = 1$), other (3%, $n = 4$), and “not provided” (2%, $n = 3$). Table 3 presents the distribution within each group. It is important to note that 78 children completed consent but were unable to complete pre- or post-test for at least one of the tasks (Motor Skill group = 46, Comparison group = 32).

Table 3. *The number of participants and ages for each group.*

<i>Condition</i>	<i>N (total)</i>	<i>Mean Age (range)</i>	<i>n (boys)</i>	<i>n (girls)</i>
Motor skill	86	4.16 (3.1-5.2)	41	45
Comparison	65	4.24 (3.0-5.0)	35	30

2. Tasks

2.1. NIH Toolbox Early Childhood Cognition Battery

The NIH Toolbox Cognition Battery is a set of neuro-behavioral measurements that assess four domains (cognitive, emotional, sensory and motor functions) that are validated for individuals ages 3 and 85 years old. The Early Childhood Cognition Battery is a subset of the

cognitive assessment and recommended for children ages 3 – 6. The Early Childhood Cognition Battery consists of 5 tasks: picture vocabulary (language), list sorting working memory (working memory), picture sequence memory (episodic memory), flanker (attention), dimensional change card sort (cognitive flexibility). Based on the results of the first study, the full battery was too long for the children of the Head Start program to complete successfully. Therefore, two of the executive function tasks that showed improvement following the previous intervention were used (Flanker and Dimensional Change Card Sort). These tasks are described in more detail below. Each participant was tested individually on an iPad by a trained research assistant (Weintraub et al., 2013).

The scores are computed in 4 ways: age-adjusted scale score, fully adjusted scale score, unadjusted scale score (mean = 100 and standard deviation = 15) and age-adjusted National Percentile. Scores 70 or below indicate significant impairments and 115 suggest above-average cognitive abilities.

We chose to use the unadjusted standard scores, rather than the age-adjusted or fully-adjusted standard scores. As the performance of the children in this study was significantly inferior to the performance expected from children in this age-range (3 to 6 years old), the unadjusted standard score was used so as not to deflate the performance of these children further. The unadjusted standard score is considered the appropriate measurement when monitoring performance over time and verifying the overall level of functioning, where higher unadjusted scores are indicative of better performance (Slotkin et al., 2012).

2.1.1. Flanker Inhibitory Control and Attention Test

For this task, five fish with arrows pointed in the direction the fish is swimming are presented on the screen. The child must choose an arrow that matches the direction that the middle fish is pointing. The test contains congruent trials, where all the fish point in the same direction, and incongruent trials, where the middle fish points in a different direction from the others. The time necessary for this task is 3 minutes. If the child successfully completes the task with the fish, he/she will then move onto the next phase in which five arrows (instead of fish) are presented. Again, congruent and incongruent trials are presented. This task measures inhibitory control and attention; it requires the participant to focus in one specific stimulus (the middle fish/arrow) and inhibit the attention from the other stimuli (flanking fish/arrows).

2.1.2. Dimensional Change Card Sort Test (DCCS)

For this task, one picture is presented in the middle of the screen, and two pictures at the bottom of the screen. The child is asked to choose the picture that matches the picture in the middle based on one of two rules. For the color rule, the child must choose the picture that matches the color of the picture in the middle of the screen (e.g., blue ball matches the blue truck in the middle). For the shape rule, the child must choose the picture that matches the shape of the picture in the middle of the screen (e.g., blue ball matches the yellow ball). The time required for this task is 4 minutes.

2.2. Head, Toes, Knees, Shoulders (HTKS)

This assessment requires attention, inhibitory control (focus), and working memory. For the first set, the child is asked to do the same thing as the experimenter. For example, if the experimenter asks the child to touch his/her head, the child is supposed to touch his/her head. If

the experimenter asks the child to touch his/her toes, the child is supposed to touch his/her toes. For the second set, the child is asked to do the opposite of what the experimenter asks. For example, if the experimenter asks the child to touch his/her head, the child is supposed to touch his/her toes and vice versa. Depending on the performance of the child, he/she will advance to the third set with two more stimuli: knees and shoulders. Again, they must do the opposite of what is asked for the knees/shoulders set. For example, when the experimenter asks the child to touch his/her knees, the child should touch his/her shoulders and vice versa. During the last set, head, toes, knees, and shoulder are all included; again, the child must do the opposite of what is asked. For each set, the child is given six practice trials, followed by ten formal trials. Each item is scored between 0 and 2. If the child responds incorrectly, he/she receives 0 points. If there is any motion to the incorrect response, but the child self-corrected to finish with a correct response, he/she receives 1 point. If the child responds correctly, he/she receives 2 points. The final score is the sum of the first six practice trials and the 20 test trials, ranging from 0 to 52 points (Ponitz et al.; 2008).

3. Statistical Approach

MATLAB (Version 9.2, R 2017a) was used to run stepwise linear regressions for each dependent measure with pre-test scores, age, and group and their interactions (i.e., pre-test x group, age x group, pre-test x age x group). Only significant factors were kept in the model using a backward selection approach (i.e., the full model is fit with all main effects and interaction, and then terms are removed depending on their level of significance). A level of significance $p < 0.05$ was used for all analyses. For each dependent measure, outliers were identified as any points that

had a large Cook's Distance (a measure of leverage) where $D = 4/n$. Normality was evaluated using Kolmogorov-Smirnov test. If the K-S test was significant, suggesting heterogeneity of residuals, a log-transformation was used to reduce non-normality. It is important to note that for some variables the log-transformation reduced non-normality but did not result in a non-significant K-S test (i.e., still evidence for non-normality).

Results

Table 4 presents the means and standard deviations for the post-test scores by group for all dependent measures for the children that were able to complete the EF testing. Note that all of the children were able to complete all tasks successfully.

Table 4 - *Post-test DV (means, standard deviations, and the number of participants) by group.*

<i>Group/Task</i>	<i>Comparison</i>	<i>Motor Skill</i>
Flanker	40.37 (14.66) $n = 32$	37.45 (13.00) $n = 43$
DCCS	46.86 (10.89) $n = 22$	48.41 (14.03) $n = 44$
HTKS	7.41 (9.28) $n = 41$	8.53 (9.16) $n = 49$

A significant positive pre-test main effect was observed for log-transformed Flanker scores ($\beta = 0.048761$, Standard Error = 0.00086456, $T = 5.64$, $p < 0.001$). Also, a significant group main effect was observed such that the Motor Skill group exhibited greater post-test log-transformed Flanker score compared to the comparison group ($\beta = 0.64937$, Standard Error = 0.29147, $T = 2.2279$, $p = 0.029$). A significant group x pre-test interaction was observed for the Motor Skill group as well ($\beta = -0.023643$, Standard Error = 0.0091069, $T = -2.5961$, $p = 0.011$).

Figure 5 presents the Flanker (inhibitory control and attention) post-test scores by pre-test scores for each group. Despite the overall greater post-test scores obtained by the children in the Motor Skill group, a greater positive relationship between pre-test score and post-test score was observed for the children in the comparison group. These results may be driven by the larger number of children in the Motor Skill group that had high scores on the pre-test. These children did not show a large improvement in post-test scores, which may have reduced the relationship between pre- and post-test scores for the Motor Skill group

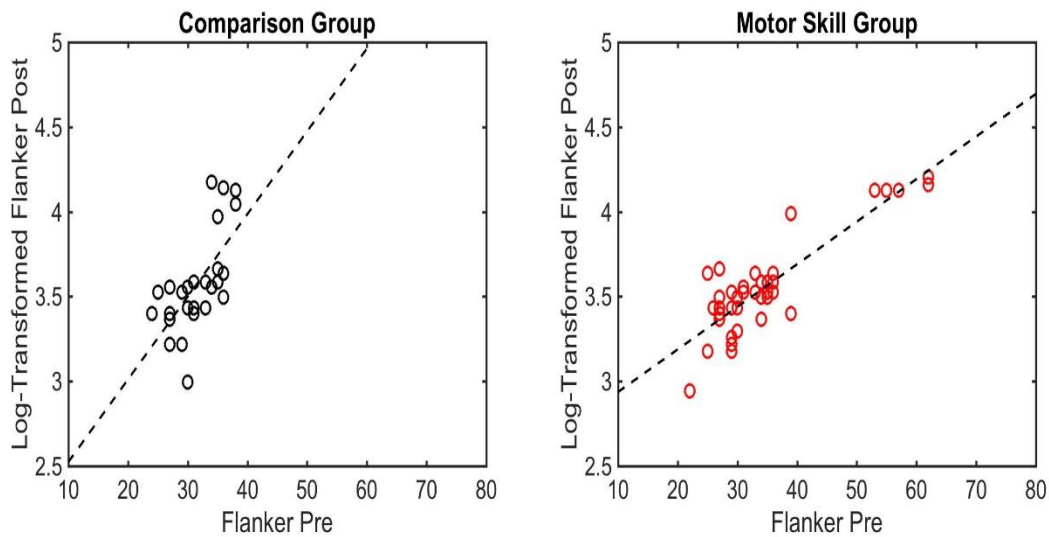


Figure 5.

Log-transformed Flanker post-test scores as a function of pre-test scores for the two groups: Comparison (black circles), Motor Skill Group (red circles).

For the log-transformed DCCS scores, age was the only significant predictor ($\beta = 0.20701$, Standard Error = 0.05988, $T = 3.4572$, $p = 0.001$). Figure 6 presents the log-transformed

Dimensional Change Card Sort post-test scores by age. The older children showed higher post-test scores compared to younger children, regardless the group.

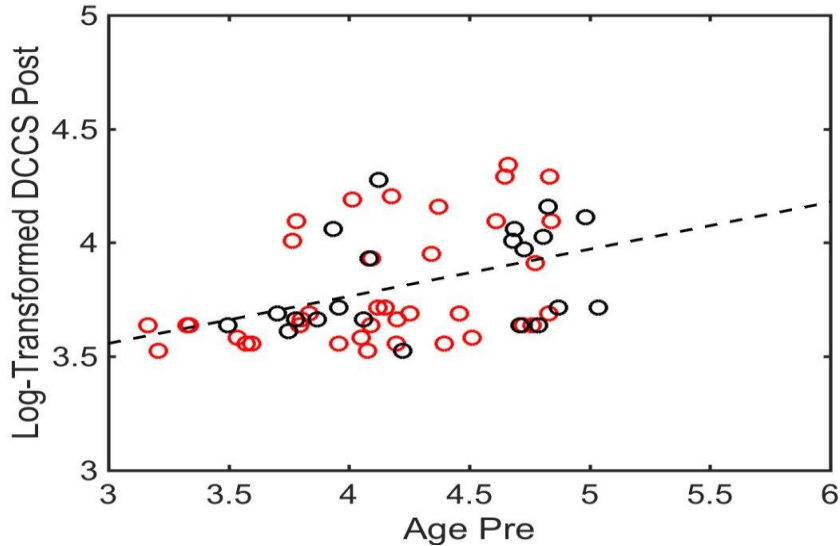


Figure 6.

Log-transformed DCCS post-test scores as a function of age for the two groups: Comparison (black circles), Motor Skill Group (red circles).

With respect to the log-transformed HTKS, no group or age main effects were observed. There were no significant interactions. Pre-test HTKS scores predicted the log-transformed post-test scores across the groups ($\beta = 0.050452$, Standard Error = 0.0092643, $T = 5.4458$, $p < 0.001$). Figure 7 presents the log-transformed HTKS task post-test scores by pre-test scores for both groups.

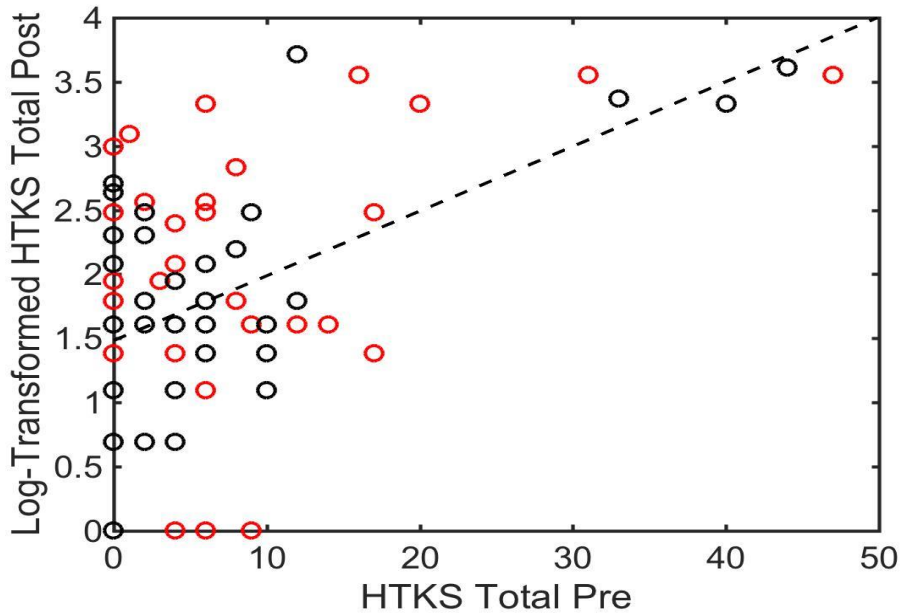


Figure 7.

Log-transformed *HTKS* post-test scores as a function of pre-test scores for the two groups: Comparison (black circles), Motor Skill Group (red circles).

Discussion

The structure of the mastery motivational climate provides children with a choice or autonomy over their behavior and has been shown to be very effective for motor learning. During the intervention, the children are encouraged to rehearse verbal cues and instructions during the activities and as a result recall more of these cues (Valentini et al., 2017). Based on our first study, mastery climate motor skill interventions appear to have a positive effect on EF, compared to children engaged in free play. However, the previous study did not examine how instruction within climates that provide autonomy may have influenced the results. Therefore, the present study compared two climates – one in which motor skill learning was promoted using

a mastery motivational framework, emphasizing motor skill instruction as well as autonomy, and the other consisted of free play with exposure to an autonomy support climate with no motor skill instruction.

We found a significant difference between the motor skill and comparison groups, where the motor skill groups exhibited a greater post-test score for the Flanker overall. However, a greater positive relationship between pre-test score and post-test score was observed for the children in the comparison group compared to those in the motor skill group. These results are different than what was observed in study 1, suggesting that the social interaction and engagement of the teachers may have influenced the post-test Flanker scores for the comparison group. Similarly, for the Dimensional Change Card sort task, we did not observe a group difference or any interactions with group. Rather, for both groups age was a significant predictor of post-test scores. These results also differ from study 1 and suggest that autonomy in both groups may have influenced post-test scores for cognitive flexibility. Lastly, we found that pre-test scores significantly predicted post-test HTKS for both groups. Again, these results suggest that the similarity in climate may have affected working memory, inhibitory control/attention, and cognitive flexibility needed for HTKS performance.

Previous studies have shown that motor and cognitive abilities are interconnected (Aadland et al., 2017; Houwen et al., 2017; Haapala et al., 2014). We expected to see a greater effect on post-test scores for the children in the motor skill group since motor skill development is associated with a greater impact on executive functions. The children in the motor skill group had to learn cognitive flexibility by applying the rules to the skills they learned. They also

trained their working memory (ability to maintain information) because they needed to remember the instructions to be able to perform the skill correctly. The children in the motor skill group also had to train their inhibitory control to be engaged in one activity at a time and inhibit their desired behavior if it was not appropriate to the specific activity.

Although motor skill interventions based on Motivational Climates are known to be effective for motor skill learning (Johnson et al., 2017), more evidence of its effectiveness in executive functions is needed. In this study, the intervention included two groups, one being the intervention group based on MMC, prioritizing instruction as well as autonomy, and a Comparison group prioritizing autonomy without motor skill instruction. In the Study 1, the intervention included four groups and a Control group, which consisted of free play without any instructional involvement and support. This difference between the Control group in Study 1 and the Comparison group in Study 2, might have contributed to the difference in the results between the two studies. The children in the Comparison group in Study 2 had similar opportunities to train the executive functions since they were able to interact with researchers throughout the intervention and encouraged to learn and apply rules in the playground.

Age played an important role in the findings from both studies. It is possible that in order to benefit from the intervention, the pre-school children need a baseline level of executive function skills. Although we could observe a change in cognition, more specifically in EF, it is possible that 12 sessions were not enough to see greater improvements, particularly for the very young children. Future interventions should be performed in a longer period to verify

improvements in a greater extent and may include a greater number of older children who may have some basic executive functions to build upon during the intervention.

The literature examining the relationship between motor skills and physical activity with executive function in preschoolers is limited. Few studies have employed interventions; the vast majority of studies employed cross-sectional designs to correlate motor skills, physical activity, and EF (Palmer et al., 2013; Becker et al., 2014). Even fewer studies have examined these relationships for preschoolers at-risk due to adverse environments. Therefore, the present studies add to the extant literature by examining the impact of motor skill interventions on cognition in children at risk.

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Appendix 1: IRB Approved Consent Form

The Auburn University Institutional
Review Board has approved this
Document for use from
08/02/2017 to 12/11/2017
Protocol # 06-262 EP 0701



Auburn University
SCHOOL OF KINESIOLOGY

**INFORMED CONSENT FOR DETERMINING THE EFFECTIVENESS OF THE
PRESCHOOL MOTOR DEVELOPMENT PROGRAM-
ACHR- DARDEN HEAD START CENTER**

We invite your child to participate in the Darden Head Start Center Motor Development Program. We are interested in determining the effects motor development programming has on the children's motor skill development, self-perceptions, physical activity and fitness level, mastery motivation, home environment, social and emotional behavior, and cognitive skills. The assessments measure actual motor skill performance (measured by the Test of Gross Motor Development), motor proficiency (measured by the Bruininks' Qseretsky Test of Motor Proficiency), and throwing speed (measured with a velocity speed radar detector), perceptions of physical competence and body image (measured by the Pictorial Scale of Perceived Competence and Acceptance), physical activity level (measured using the System of Observing Fitness Instruction Time, and accelerometers), mastery motivation (measured by the Dimensions of Mastery Questionnaire-17), home environment (measured with items from the National Children and Youth Fitness Study and the Youth Risk Behavior Survey), social and emotional skills to young children (by accessing and reviewing Head Start Devereux Assessment data and classroom videos) and cognitive skills (measured through the completion of a series of reasoning tasks). Additionally, descriptive information, including height, weight, Body Mass Index, sex, race, and date of birth, will be collected. The assessments will be used for future programming as it relates to Motor Development Programs as well as provide specific instructional information about the progress of your child. All lessons will be video recorded to code the time that children spend practicing. Following is an explanation of each assessment:

Self-perceptions will be assessed with two instruments. *The Pictorial Scale of Perceived Competence and Acceptance* for preschool children will be used to assess perceived competence and acceptance. This assessment consists of 26 items presented on pictorial plates each of which contains two separate pictures, side by side, one of which depicts a child who is skilled, and the other of which depicts a child who is not so skilled. The child's task is to first select the picture that is most like him/herself. Then, after making this choice, the child focuses on that picture and indicates whether he or she is just a little bit like that child or a lot like that child. *Body Perceptions* will also be assessed with black and white line drawing of body figures for children (boys or girls) and for mothers, respectively. Your child will be asked to point to the picture that they perceive "looks most like them, they like the most, and see as healthy for them and their mother".

The Dimensions of Mastery Questionnaire-17 is used to measure mastery motivation for children from infancy through elementary school-age. This assessment consists of 36 age-appropriate statements about how children perceive their behavior. Children verbally respond to questions regarding their behavior on a scale of 1 'not at all typical' to 4 'very typical'. Children answer questions related to their persistence on motor skills, cognitive tasks, interacting with other children, interacting with adults, and pleasure in learning/mastering skills. Motor skill program teachers will complete a pen and paper version of the Dimensions of Mastery Questionnaire-17.

The Test of Gross Motor Development is a measure of fundamental motor skill competence in children ages 3- to 10- years. The 12-item test includes 6 locomotor skills (running, jumping, hopping, leaping, galloping, and sliding) and 6 object-control skills (rolling, throwing, catching, striking, bouncing, and kicking).

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Parent/Guardian initials _____

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The *Bruininks-Oseretsky Test of Motor Proficiency* as an instrument used to measure children's gross and fine motor skills. Specifically the assessment measures: Fine Motor Precision - 7 items (e.g., cutting out a circle, connecting dots); Fine Motor Integration - 8 items (e.g., copying a star, copying a square); Manual Dexterity-5 items (e.g., transferring pennies, sorting cards, stringing blocks), Bilateral Coordination - 7 items (e.g., tapping foot and finger, jumping jacks); Balance-9 items (e.g., walking forward on a line, standing on one leg on a balance beam); Running Speed and Agility - 5 items (e.g., shuttle run, one-legged side hop); Upper-Limb Coordination - 7 items (e.g., throwing a ball at a target, catching a tossed ball); Strength - 5 items (e.g., standing long jump, sit-ups). In addition, children's overhand throwing speed will be measured using a *Velocity Speed Radar Detector*.

The *System of Observing Fitness Instruction Time* is an observational measure used to determine how intense a child is engaged in physical activity. Physical activity intensity level is recorded every 20 seconds. Child physical activity levels are coded on a scale of '1' to '5' corresponding to the student's body position: lying down, sitting, standing, walking, or very active.

Accelerometers will be used to assess children's physical activity throughout their day at the childcare center. accelerometers will be attached to the waistband of each child by an investigator prior to participation in the motor development program and/or start of the school day. These devices are small and lightweight (28 x 27 x 10 mm x 17 g). The accelerometers will measure the body's movement in both the vertical (i.e., up and down) and horizontal (i.e., side to side) direction.

Home environment will be measured using a series of single items designed to measure hypothesized social and physical environmental determinants of physical activity behavior. These will include access to sporting and/or fitness equipment at home (one question on a Likert type scale), access to play areas (two questions on a Likert type scale), and safety (one question on a Likert type scale). These items were modified from measures used in the National Children and Youth Fitness Study and the Youth Risk Behavior Survey.

Social and emotional behavior will be measured by accessing Head Start Devereux Assessment data and video-recorded classroom observations. The Devereux Childhood Assessment (DECA) Preschool Program, 2nd Edition is an assessment used by preschool educators to assist them in teaching social and emotional skills to young children. There are 37 items on the rating scale, each describing a specific behavior. For each child, the teacher indicates the frequency of the behavior's occurrence based on experience with the child. The DECA is currently used within Head Start as a screening tool to identify children who may need additional support in their social and emotional development. Also, the DECA is currently administered several times each year within all Head Start programs, including Darden Head Start in Opelika. The researchers intend to access existing DECA data collected by Darden Head Start over the course of a year for the purpose of monitoring children's social and emotional progress while being exposed to a movement/physical activity program. Accessing Head Start video-recorded classroom observations of instruction will be used to observe children within their classroom settings for the purpose of noting their academic and social behavior before and following the lessons. Currently, Head Start classrooms are equipped with recording devices and classroom activities are recorded for program purposes. The researcher will observe children's behaviors (from the video) before and after their participation in the program. The researchers will watch the recordings and note the frequency of behaviors associated with attention to task, compliance, accuracy of responses to questions, verbal aggression, and physical aggression.

Cognitive Skills will be measured both before and following your child's participation in the movement/physical activity program and will be assessed through a series of developmentally appropriate cognitive assessments (i.e., The NIH Toolbox cognitive assessments normed for children as young as 3). These include the following: (a) Flanker test takes 4 minutes to administer and measures inhibitory control (how well do children ignore irrelevant stimuli); (b) Processing Speed test takes 3 minutes to administer and measures how quickly can children identify if stimuli are similar or different;

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(c) Dimensional Change Card Sort test takes 4 minutes to complete and measures how well children shift from one category to another; (d) List Sorting Working Memory test takes 3 minutes to administer and measures how well children can organize a list of animals and food in size order from memory. Cognitive tests will also include: (e) Motor Skill Match test, that takes 4 minutes to complete and measures how quickly children can identify a specific movement skill out of other movements (e.g., kick vs. run, jump, throw); (f) Head, Shoulders, Knees, and Toes test takes 2 minutes to complete and measures how well children can do what they hear and inhibit what they see (e.g., hear head, see shoulders). Parents and teachers of participants will be asked to complete the Children's Independent Learning Development Checklist (5-10 minutes to complete) that will help provide information about the participants' cognitive development.

Descriptive Information including height, weight, Body Mass Index, sex, race, number of siblings, birth order, and date of birth will be gathered for your child. Height will be measured using a standard tape measure. Children will be asked to stand with their back against a wall and height will be measured to the nearest centimeter. Children will also stand on a standard scale to measure their weight to the nearest kilogram. Body Mass Index, a measure of overweight and obesity, will be calculated from the height and weight measures using the formula height divided by weight². Parents/guardians will be asked to report their child's sex, race, and date of birth.

There are no foreseeable risks or discomforts associated with completing the Test of Gross Motor Development, completing the Bruininks-Oseretsky Test of Motor Proficiency, reporting self-perceptions, observing physical activity with the System of Observing Fitness Instruction Time, reporting Dimensions of Mastery Questionnaire-17, wearing accelerometers, completing the home environment questionnaire, accessing the DECA data and observing social and emotional behavior, using the velocity speed radar detector to measure speed of throw, and completing the cognitive tasks.

Please note that any child who expresses a desire to quit the assessments will be allowed to stop immediately. Participants will also be told that they can remain in the Motor Development Intervention Program without completing the assessments. To preserve confidentiality, the children's performance and responses will be reported as group results only. I am informing you that any information obtained from the assessments may be used in any way thought best for education and publication. Unless otherwise notified by you, I plan to present the results of this program assessment at a scientific conference and publish the results in an appropriate journal. In any presentation or publication, the data will remain anonymous.

Your decision whether or not to allow your child to participate will not jeopardize his/her future relations with Auburn University, the School of Kinesiology, or Darden Head Start Center. Your child's performance or responses will in no way affect your child's standing in the childcare center. At the conclusion of the assessments, a summary of group results will be made available to all interested parents and educators. Should you have any questions or desire further information, please contact: Dr. Mary Rudisill at (334) 844-1458 (phone) rudisme@auburn.edu (email). You will be provided a copy of this form to keep.

For more information regarding your rights as a research participant you may contact the Auburn University Office of Human Subjects Research or the Institutional Review Board by phone (334)-844-5966 or e-mail at hsubjec@auburn.edu or IRBChair@auburn.edu

HAVING READ THE INFORMATION PROVIDED YOU MUST DECIDE WHETHER OR NOT TO ALLOW YOUR CHILD TO PARTICIPATE. YOUR SIGNATURE INDICATES YOUR WILLINGNESS TO ALLOW YOUR CHILD'S PARTICIPATION IN THE STUDY.

Child's Name _____

Parent/Guardian Signature _____ Date _____

Investigator Signature _____ Date _____