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The association between motor proficiency, cognitive tempo, academic skills, balance and visual efficiency in elementary school aged children.

Franklin R. Muntis
University of Louisville

THE ASSOCIATION BETWEEN MOTOR PROFICIENCY, COGNITIVE TEMPO, ACADEMIC SKILLS, BALANCE AND VISUAL EFFICIENCY IN ELEMENTARY SCHOOL AGED CHILDREN

By

Franklin R. Muntis

M.S.- University of Louisville, Louisville, KY, 3/13/17

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Franklin R. Muntis

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A Thesis Approved on

April 24, 2017

by the following Thesis Committee:

Daniela Terson de Paleville, Ph.D., Thesis Director

Jason Immekus, Ph.D.

John Caruso, Ph.D.

DEDICATION

To my beautiful wife, best friend and adventure partner, Shelby Muntis, who gives me the courage and confidence to be a better man than I ever knew I could be.

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ABSTRACT

THE ASSOCIATION BETWEEN MOTOR PROFICIENCY, COGNITIVE TEMPO, ACADEMIC SKILLS, BALANCE, AND VISUAL EFFICIENCY IN ELEMENTARY SCHOOL AGED CHILDREN

Franklin R. Muntis

April 26, 2017

The purpose of this study was to investigate the association between motor proficiency, cognitive tempo, academic skills, balance and visual efficiency in elementary aged children at a local Spanish immersion school. Forty-nine students and their parents provided consent to participate in the study. Motor proficiency was measured using the Bruininks-Oseretsky Test of Motor Proficiency Second Edition (BOT-2), cognitive tempo and academic skills were assessed using the Child and Adolescent Behavior Inventory, Visual Efficiency was measured using Visual Efficiency Rating (VERA) and Balance was measured using a Neurocom® platform function for stability evaluation test to determine limits of stability. Significant correlations were found between academic skills and cognitive tempo, motor proficiency and academic skills and visual efficiency and balance. The findings of the study suggest children with greater motor skills tend to have greater academic skills, possibly due to greater

development in regions of the brain that are highly active during both motor and cognitive skills, providing support for the inclusion of physical activity in programs aimed to improve cognitive development in children.

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CHAPTER 1

INTRODUCTION

The contribution of physical activity to child development, both physically and cognitively, has been an area of great interest in research. In one study, Raspberry et al found 251 associations between physical activity and academic performance (Rasberry et al., 2011). In one of the studies reviewed, a bilateral coordinative exercise intervention improved cognitive performance, concentration and attention in adolescents (Budde, Voelcker-Rehage, Pietraßyk-Kendziorra, Ribeiro, & Tidow, 2008). The researchers hypothesized coordinative exercise may pre-activate of parts of the brain responsible for mediating cognitive functions. In another intervention study spanning over 3 years, the inclusion of physical activity and motor training every day led to greater academic performance over the 3 years study than those who only participated in the normal two day per week physical education program included in the school curriculum (Ericsson, 2008). Furthermore, a strong association was found between physical activity and increased academic performance per unit of time (Trudeau & Shephard, 2008). The learning of new tasks, both motor and non-motor involve complex activation of several different regions of the brain including the basal ganglia (Middleton & Strick, 1994; Romo & Schultz, 1992), cerebellum (Leiner, Leiner, & Dow, 1986, 1991; Middleton & Strick, 1994) and dorsolateral prefrontal cortex (Raichle et al., 1994; Romo & Schultz, 1992; Schlosser et al., 1998). The dorsolateral prefrontal cortex is believed vital to some of the most complex cognitive tasks (Siddiqui, Chatterjee, Kumar, Siddiqui, & Goyal, 2008). The cerebellum is most noted for its role in the coordination of, and the learning of, novel motor skills (Thach, 1998). The basal ganglia refines, sequences and automates movement (Marsden & Obeso, 1994; Schwab, Chafetz, & Walker, 1954), inhibit competing movements (Hauber, 1998; Mink, 1996) and contributes to motor learning (Kimura, 1995). Recent research suggests all three regions may be more interrelated in motor and cognitive tasks than previously recognized (Diamond, 2000; Doya, 2000; Pelzer, Melzer, Timmermann, von Cramon, & Tittgemeyer, 2017).

Individuals with cognitive impairments may also experience delayed or impaired motor development (Barkley, DuPaul, & McMurray, 1990; Denckla & Rudel, 1978; Denckla, Rudel, Chapman, & Krieger, 1985; Hellgren, Gillberg, Gillberg, & Enerskog, 1993; Kadesjo & Gillberg, 1998). Berquin et al. (Berquin et al., 1998) studied 200 children with and without ADHD and found children with ADHD had smaller cerebellums and problems with motor tasks such as balance, rapid alternating movements and consistently coordinate movements of the proper distance to correct timing. Furthermore, it was found children with dyslexia have difficulties with fine motor tasks such as continuous tapping (Geuze & Kalverboer, 1994). Wolff et al. (Peter H. Wolff, Michel, Ovrut, & Drake, 1990) observed children with dyslexia have difficulty with bimanual tapping tasks that require moving fingers in an asynchronous pattern and that the deficit is rate dependent. Similar deficits, however, were not seen when the fingers moved in unison. Timing control has inputs from numerous neural processes distributed through the primary and supplementary motor area, the cerebellum, extrapyramidal system and midbrain structures that include the basal ganglia. Likewise, Manjiviona et al.

(Manjiviona & Prior, 1995) found children with autism have clinically significant levels of motor impairment. These findings suggest a connection between the regions of the brain affected by cognitive disorders and the motor impairments that accompany them.

In addition to motor impairments, individuals with cerebellar damage failed verbal fluency tasks (Appollonio, Grafman, Schwartz, & Massaquoi, 1993; Schmahmann & Sherman, 1998), verb generation (Fiez, 1996), planning (Leiner et al., 1986) and various learning and memory related tasks (Fiez, 1996; Schmahmann & Sherman, 1998; Tamagni et al., 2010). Not all cognitive measures were affected however, as individuals with cerebellar damage didn't exhibit similar deficits in tasks such as the Wisconsin card sorting test, a test of set-shifting in which participants were asked to match cards, but not how to match them, only if their match is right or wrong. Those associations indicate a link between the dorsolateral prefrontal cortex and the cerebellum in cognitive tasks.

Neuroimaging studies further indicate such a link between these brain structure(Bareš et al., 2014; Braver et al., 1997; Desmond, Gabrieli, Wagner, Ginier, & Glover, 1997; Durisko & Fiez, 2010). Those studies found when a cognitive task increases activation in the dorsolateral prefrontal cortex it also increases activation in the contralateral cerebellum (Raichle et al., 1994). This coactivation was demonstrated in tasks of verb generation (Raichle et al., 1994), verbal fluency (Schlosser et al., 1998), the Wisconsin card sorting test (Berman et al., 1995) and other non-motor working memory tasks (Desmond et al., 1997). Furthermore, when the memory load of a task is increased, activation of both brain regions shows a concomitant increase (Braver et al., 1997; Desmond et al., 1997; Rypma, Prabhakaran, Desmond, Glover, & Gabrieli, 1999). In addition, the most coactivation occurred when tasks were difficult or new, the conditions were changed, a quick response was required or when tasks required close attention (Braver et al., 1997; Desmond et al., 1997; Rypma et al., 1999). It was hypothesized by Fiez, Petersen, Cheney, and Rachiele that the cerebellum plays a role in detecting errors and learning from them (Fiez, Petersen, Cheney, & Raichle, 1992). The basal ganglia were also linked to the cerebellum during cognitive tasks (Albin, Young, & Penney, 1989; Alexander, DeLong, & Strick, 1986; Caligiore et al., 2017; Pelzer et al., 2017). The basal ganglia, associated with the refinement of movement and the inhibition of unwanted movements during motor tasks, is thought to be connected to the cerebellum via the thalamus and shows coactivity during both motor and non-motor tasks (Pelzer et al., 2017).

The basal ganglia and cerebellum play a role in fine motor control and performance. Kulp and Sorter found fine motor performance relies on both visual perception and motor coordination (Kulp & Sortor, 2003). Researchers identified the basal ganglia as having a role in memory-guided movement and more automated types of motor performance (Doya, 2000) and the cerebellum is associated with visual-guided movement and the integration of visual information and motor movements (Willingham, 1999). Cameron et al., suggest the ability to match motor movement with an external visual stimulus is more predictive of children's achievement than other motor skills (Cameron, Cottone, Murrah, & Grissmer, 2016). In addition, a study by Bouchard and Tetreault reported children with low vision have weaker gross motor skills, specifically balance (Bouchard & Tetreault, 2000).

Finally, fine motor performance was strongly associated with improved academic skills (Luo, Jose, Huntsinger, & Pigott, 2007; Son & Meisels, 2006). Children with strong fine motor skills had better mathematics performance at kindergarten entry and make greater mathematics gains over the year. Furthermore, by kindergarten, fine motor tasks are better predictors of reading achievement than gross motor tasks (P. H. Wolff, Gunnoe, & Cohen, 1985). Piaget et al. (Piaget, 1953) shared one theory on how movement contributes to cognitive development. The researchers postulated that, by placing increasingly more complex demands on the brain by increasing difficulty of the motor task, children develop the ability to combine multiple motor steps into a more organized framework. This same ability, they believe, allows for children to handle higher-order cognitive abilities.

A. Summary and Rationale

There is evidence the cerebellum, basal ganglia and dorsolateral prefrontal cortex are all interconnected in the development and practice of motor and non-motor skills. Furthermore, each of these brain regions plays a role in vision, cognition and academic achievement. It is possible characteristics such as motor proficiency, visual efficiency, cognitive tempo, academic skills and balance may be similarly interconnected.

B. Hypotheses and Specific Aims

1) Overall Aim:

To investigate the relationship between academic skills, cognitive tempo, motor proficiency, visual efficiency, and balance in elementary aged students.

a) **Specific Aim 1:** To determine if a correlation exists between motor proficiency (BOT-2), academic skills (CADBI Subset 9) and cognitive tempo (CADBI Subset 1.)

i) **Hypothesis 1.1**: Motor proficiency shows a positive correlation with cognitive tempo.

ii) **Hypothesis 1.2:** Motor proficiency shows a positive correlation with academic skills.

b) Specific Aim 2: To determine if a correlation exists between motor proficiency and visual efficiency.

i) Hypothesis 2: Motor proficiency scores show a positive correlation with visual efficiency scores.

c) **Specific Aim 3:** To determine if a correlation exists between balance and visual efficiency.

i) Hypothesis 3: Balance (as limit of stability scores) show a positive correlation with visual efficiency scores.

CHAPTER II

RESEARCH DESIGN AND METHODS

A. Ethical Approval for Human Studies

This study was formally approved by the University of Louisville Institutional Review Board (University of Louisville IRB: 16.0134) and Jefferson County Public Schools Institutional Review Board in compliance with all the institutional and federal regulations concerning the ethical use of human volunteers for research studies.

B. Experimental Procedures

a. Facilities/Resources

All testing was done at Hawthorne Elementary School, a Health Promotion School of Excellence and dual language school in Louisville, Kentucky that offers students the opportunity to be immersed in both the Spanish and English language.

Participants

Forty-nine children from Hawthorne Elementary School, a Spanish Immersion Public Elementary School in Louisville, Kentucky, participated in this study. Prior to consenting, parents and children were invited to several informational sessions held at Hawthorne elementary. In addition, they received written information via email and hard copies when they indicated interest in the research project. Parents provided consent and children were asked to sign an assent to participate in a unique eight week exercise intervention known as Minds in Motion (Meyer & Martin, 2005). All participants participated in pre-training testing for balance, visual efficiency, motor proficiency, cognitive tempo and academic skills, which were use to run correlations for this study. Of the 49 students who consented to participate, approximately 48% of participants are minority students (i.e. approximately 27% were African- American, 20% were students are Hispanic or Latino and 1% were Asian).

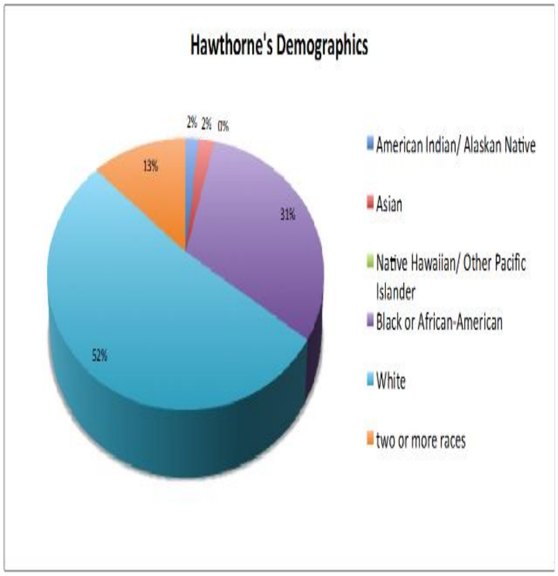

Figure 1: Student representation at Hawthorne Elementary School. Forty-eight percent (48%) are minority students. Thirty-one percent (31%) are African American.

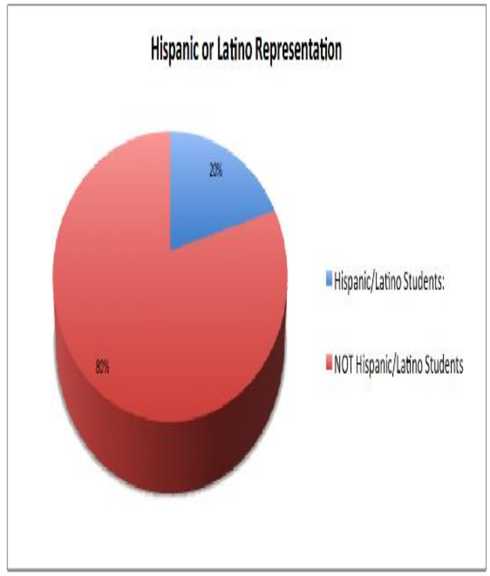

Figure 2: Twenty percent (20%) of the students at Hawthorne are Hispanic or Latino.

C. Equipment and Instrumentation

a) Motor Proficiency

The Bruinicks-Oseretsky Test of Motor Proficiency Second Edition (BOT-2) provided a measure of fine and gross motor control in subjects prior to the Minds in Motion Study. The BOT-2 test is a validated measure of motor proficiency utilizing a series of tasks designed to measure fine motor control and integration, coordination, balance, strength, running speed and agility of individuals between the ages of 4-21 years of age (Deitz, Kartin, & Kopp, 2007) . The assessment requires participants to (a) jump and hop in place; (b) tap their feet and fingers simultaneously, (c) walk forward in a line marked with tape on the floor; (d) maintain their balance in an approximately 5-inch tall balance bean; (e) dribble, drop and catch a tennis ball; and, (f) run a short distance and do push-ups and sit-ups for 30 seconds. The test is individually administered and requires approximately 30 minutes to complete.

b) Cognitive Tempo and Academic Skills

The Child and Adolescent Disruptive Behavior Index was given to parents and teachers of the elementary aged students to provide a series of measures of disruptive school and home behavior (G. L. Burns, Taylor, & Rusby, 2001a; G. L. Burns, Taylor, & Rusby, 2001b). Parents and teachers completed the CADBI before beginning the program. The CADBI assessment was validated in both English and Spanish and both options were provided to parents and students. CADBI Subset 1 provided a measure of cognitive tempo, which offered information about how parents and teachers would rate students amongst their age group on measures such as being easily confused, daydreaming, being easily tired or fatigued or losing train of thought among others. CADBI Subset 9 measured students academic skills. This portion of the assessment asks parents and teachers to rate students against their age group on their reading, writing and arithmetic abilities and their ability to complete and submit their homework on their own and in a timely manner.

c) Visual Efficiency

Visual acuity will be measured with the Visual Efficiency Rating (VERA) test, a software program designed for schools to detect routine vision and visual skill problems (Gallaway & Mitchell, 2010). The VERA consists of a saccadic test, two accommodative facility tests, and a variance facility test and was administered with a laptop computer. The instructional sets were standardized and appeared on the screen before each test. The assessment yields norm-referenced scores for each task based on a comparison of performance to an age-normed database of 1,500 children. Scores are reported as percentiles and cumulative percentiles with categories of pass, fail and borderline. Specifically, the saccadic test required students to examine 15 empty boxes arranged on the screen, with numbers presented sequentially in each box in a pattern that mimics reading. The student was instructed to report the last number exposed. The tester then entered the number reported by the student. After a practice screen (or screens), the test consisted of nine trials. The accommodative facility test is a two-part biocular task. The student holds a lens holder with 1 side having a red filter and a 11.50 lens and the other side having a green filter with a -2.00 lens. Each screen contains a box with three 20/50 size numbers that are only seen by 1 eye at a time. The child is instructed to make the numbers clear as quickly as possible and read the numbers out loud. The tester enters “0” or “1” for incorrect or correct, and the next screen presents three new numbers seen by the opposite eye. The child must alternately stimulate and relax accommodation to clear the numbers. The test lasts 60 seconds. For the second part of the test, the lens is reversed so that the child is stimulating or relaxing accommodation with the opposite eye. The vergence facility test consists of a random dot stereogram with a total vergence demand of eight base out or four base in. When the stereogram is fused, the child is able to perceive a number from one to four. The child reports the number that is seen and the tester enters this number. The test alternately presents base in and base out stereograms and lasts 90 seconds.

d) Balance

A Neurocom® platform was utilized to measures student’s balance and limit of stability using the function for stability evaluation test (SET) designed to assess functional balance control based on postural saw velocity during six testing conditions over a 2-5 minute period. Students were instructed to stand on the Neurocom platform and lean forward, back, left and right a couple of times. Student’s balance is recorded and results presented in graphical form, with traces of the center of gravity.

CHAPTER III

RESULTS

Motor Proficiency, Cognitive Tempo and Academic Skills

A moderate correlation of -.471** was found between cognitive tempo and academic skills as assessed by teachers and -.488** as assessed by parents. Furthermore, a strong correlation of .710** was found between academic skills as measured by teachers and academic skills as measured by parents. A moderate correlation of .412** was found between motor proficiency as measured by BOT-2 and teacher assessed academic skills. No significant correlation was found between motor proficiency score and parent assessed academic skills nor motor proficiency scores and cognitive tempo as measured by either teachers or parents.

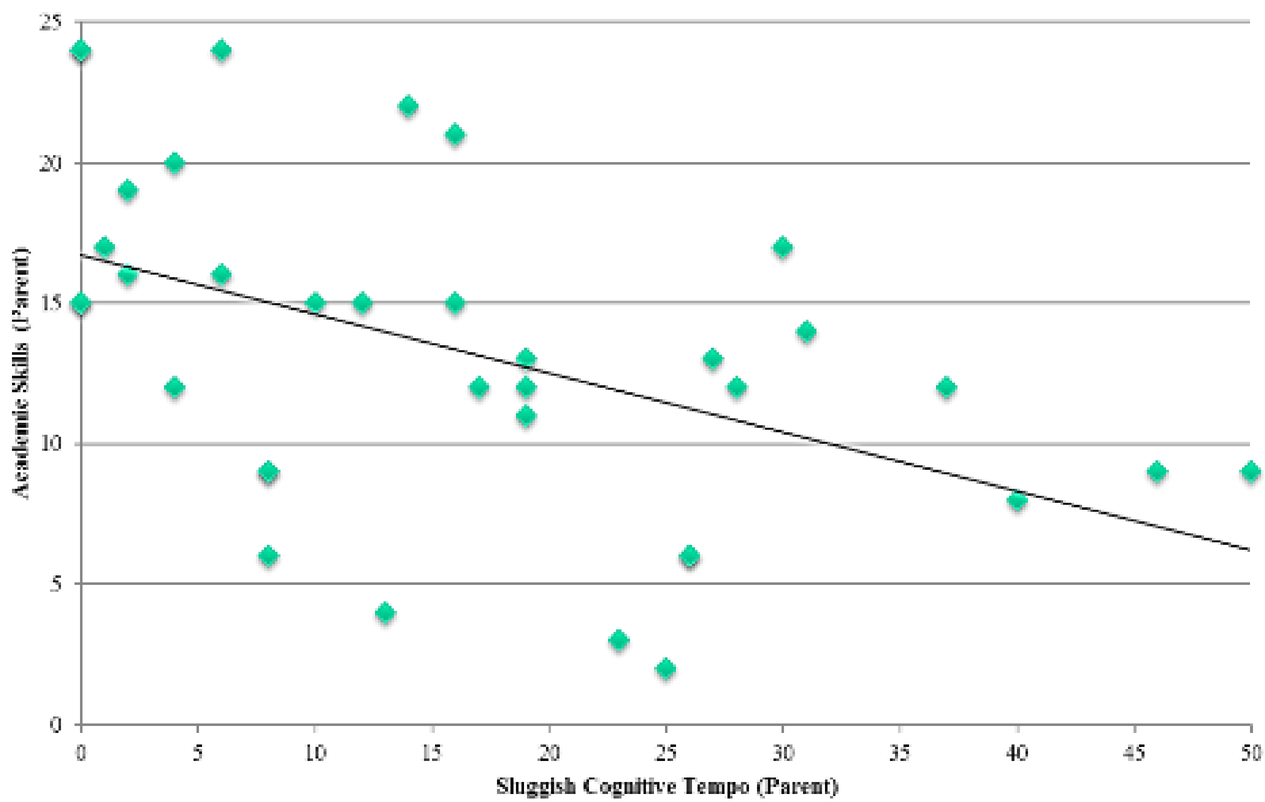

Figure 3: Correlation Between Academic Skills and Sluggish Cognitive Tempo as Assessed by Parents.

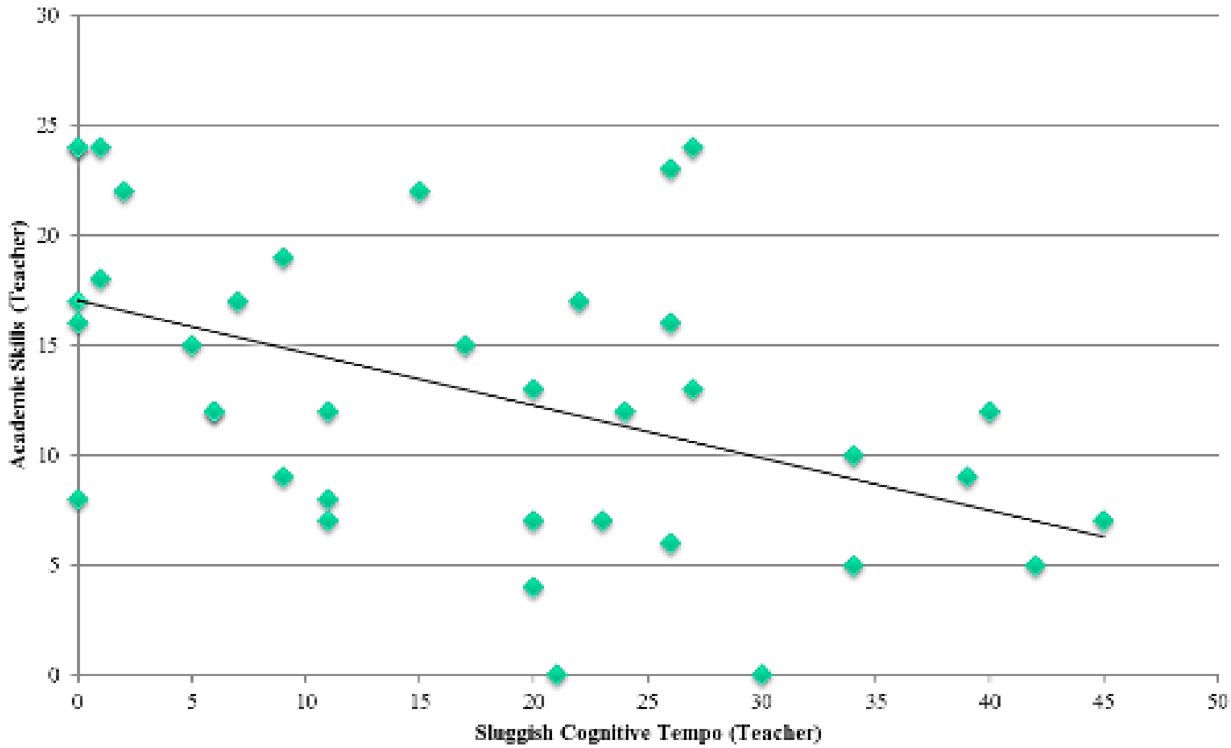

Figure 4: Correlation Between Academic Skills and Sluggish Cognitive Tempo as Assessed by Teachers

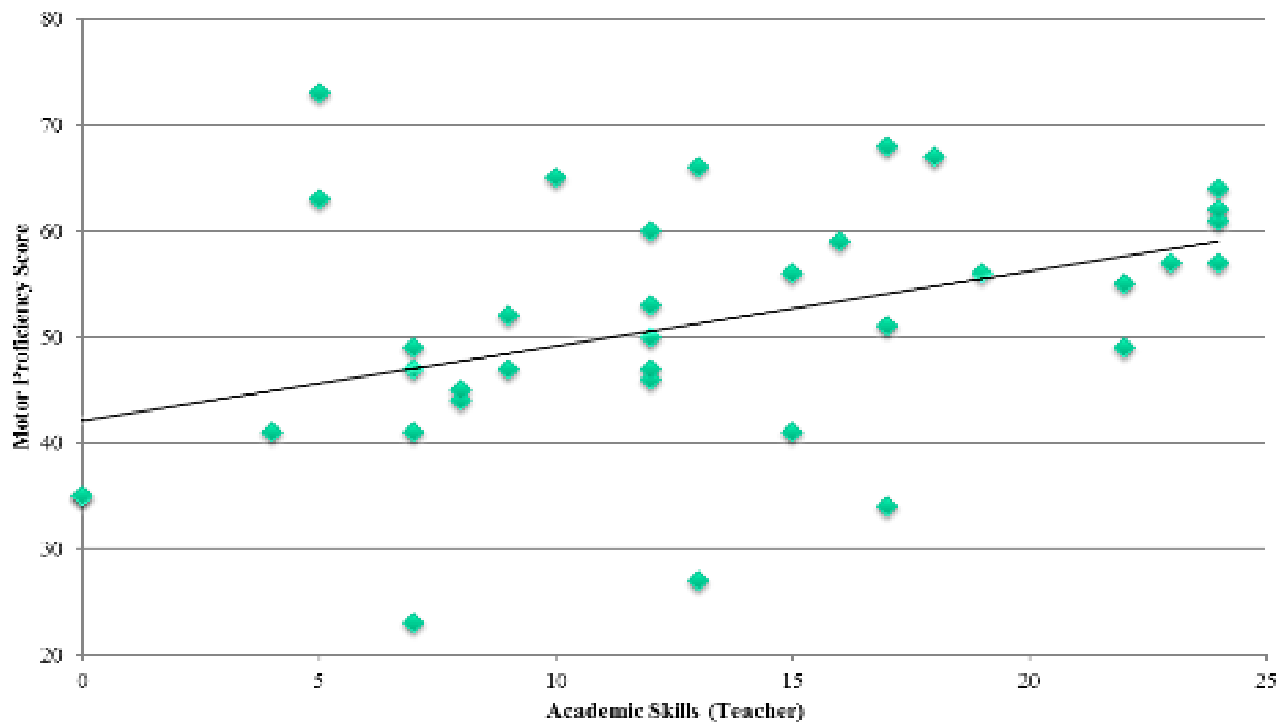

Figure 5: Correlation Between Motor Proficiency and Academic Skills as Assessed by Teachers

Motor Proficiency and Visual Efficiency

No significant correlation was found between motor proficiency, visual efficiency, reading eye pattern movement, focus flexibility part one, focus flexibility part two or binocular integration.

Visual Efficiency and Balance

A weak but statistically significant correlation of -.150* was found between visual efficiency and balance. A moderate correlation of .482* was found between visual efficiency and focus flexibility part two. A weak but statistically significant correlation of .085** between balance and binocular integration. No further significant correlations were found between visual efficiency. reading eye pattern movement, focus flexibility part one, focus flexibility part two, binocular integration and balance.

Further Correlations:

A moderate correlation of .382* was found between balance and academic skills as assessed by teachers. Weak correlations were found between focus flexibility part two and academic skills as assessed by teachers (-.087*), binocular integration and academic skills as assessed by teachers (-.05*), binocular integration and sluggish cognitive tempo as assessed by teachers (.074**). No further correlations were discovered between any of the measures collected.

	Sluggish Cognitive Tempo (Parents)	Sluggish Cognitive Tempo (Teacher)	Academic Skills (Parent)	Academic Skills (Teacher)	Motor Proficiency Percentile	Motor Proficiency Score	Visual Efficiency	Reading Pattern Eye Movement	Focus Flexibility Part 1	Focus Flexibility Part 2	Binocular Integration	Balance
Sluggish Cognitive Tempo (Parents)	1	0.187	-0.488**	-0.239	-0.02	0.075	-0.136	-0.263	-0.143	-0.213	0.27	-0.035
Sluggish Cognitive Tempo (Teacher)	0.187	1	-0.132	-0.471**	0.044	0.034	0.213	-0.083	0.288	0.128	0.074**	-0.164
Academic Skills (Parent)	-0.488**	0.132	1	0.71**	0.102	0.276	-0.003	0.066	-0.123	0.292	-0.041	0.382*
Academic Skills (Teacher)	0.239	-0.471**	0.71**	1	0.009	0.412**	-0.177	-0.028	-0.183	-0.087*	-0.05*	0.465
Motor Proficiency Percentile	-0.02	0.044	0.102	0.009	1	0.474	0.041	0.164	0.007	-0.104	-0.048	0.216
Motor Proficiency Score	0.075	0.034	0.276	0.412**	0.474	1	-0.251	0.017	-0.304	-0.127	-0.063	0.613
Visual Efficiency	-0.136	0.213	-0.003	-0.177	0.041	-0.251	1	0.557	0.682	0.482*	0.255	-0.15*
Reading Pattern Eye Movment	-0.263	-0.083	0.066	-0.028	0.164	0.017	0.557	1	0.035	0.237	-0.038	-0.032
Focus Flexibility Part 1	-0.143	0.288	-0.123	-0.183	0.007	-0.304	0.682	0.035	1	0.365	-0.245	-0.209
Focus Flexibility Part 2	-0.213	0.128	0.292	-0.087*	-0.104	-0.127	0.482*	0.237	0.365	1	-0.259	-0.135
Binocular Integration	0.27	0.074**	-0.041	-0.05*	-0.048	-0.063	0.255	-0.038	-0.245	-0.259	1	0.085**
Balance	-0.035	-0.164	0.382*	0.465	0.216	0.613	-0.15*	-0.032	-0.209	-0.135	0.085**	1

Table 1: Correlations between all of the variables evaluated during the study.
*P<.05
**P<.01

Descriptive Statistics

		Cognitive Tempo (Parents)	Cognitive Tempo (Teachers)	Academic Skills (Parents)	Academic Skills (Teacher)	Motor Proficiency Total Score	Motor Proficiency Percentile	Visual Efficiency	Reading Eye Pattern Movement	Focus Flexibility Part 1	Focus Flexibility Part 2	Binocular Integration	Balance
N	Valid	39	39	36	38	48	48	36	36	36	36	36	43
	Missing	12	12	15	13	3	3	15	15	15	15	15	8
Mean		15.692	16.846	13.25	12.921	51	29.583	23.361	17.528	32.583	11.472	32.472	57.936
Median		13	17	13	12	50.5	21	21	12.5	25.5	6.5	25.5	59.875
Std. Deviation		13.4049	13.5346	5.8767	6.8117	11.886	24.1642	10.0801	20.0649	28.1195	9.5483	20.4457	11.8924
Range		50	45	22	24	50	98	40	60	94	30	84	51
Minimum		0	0	2	0	23	1	5	0	3	1	13	27.4
Maximum		50	45	24	24	73	99	45	60	97	31	97	78.4

Table 2: Descriptive Statistics

Amount of Free Play and Screen Time Amongst Students								
	0-1 Hours	1-2 Hours	2-3 Hours	3-4 Hours	4-5 Hours	5-6 Hours	6-7 Hours	7+ Hours
Hours of Free Play				4		2	2	13
Hours of Screen Time (Weekdays)	10	6	2				1	
Hours of Screen Time (Weekends)		3	4	8	2	4		

Table 3: Reported Time Spent in Free Play and Screen Time (In Hours Per Day)

CHAPTER IV

CONCLUSION

Academic performance is a multidimensional measure influenced by many variables. In this study, it was hypothesized motor proficiency would correlate with both cognitive tempo and academic skills. While no correlation was identified between cognitive tempo and motor proficiency, the hypothesis that motor proficiency would correlate with academic skills was confirmed by the findings of this study. It was also hypothesized a correlation exists between visual efficiency and motor proficiency, however, no correlation was determined by this study, suggesting vision may not be a limiting factor to fine and gross motor performance, or that the sample size was too small to detect further associations. Finally, it was also hypothesized a positive correlation exists between visual efficiency and balance, however, the findings of this study indicate an inverse correlation between these variables. Though the correlation was not strong, it is possible that it indicates those with poorer visual efficiency may rely more heavily upon proprioception, or knowledge of their body in space, and therefore have greater balance. In addition to the hypothesized measures, a strong correlation was established between academic skills as measured by both parents and teachers indicating an agreement between teachers and parents as to the academic skills of the children being assessed. Furthermore, a moderate inverse correlation was found between academic skills and cognitive tempo as measured by both parents and teachers indicating children who have slower cognitive tempo, which is an indicator of being more easily fatigued, confused or forgetful, show decreased academic skills. In addition to the moderate correlation found between motor proficiency and academic skills, a moderate correlation was found between balance with academic skills that suggest a cognitive benefit to greater motor skills. It is possible these correlations may be due to interrelationships between the dorsolateral prefrontal cortex, the cerebellum and the basal ganglia in motor and cognitive tasks. Those who participate in greater amounts of physical activity may gain greater development in the dorsolateral prefrontal cortex, cerebellum and basal ganglia and therefore show greater aptitude in cognitive tasks associated with these areas, such as academic skills. In addition, a moderate correlation was found between visual efficiency and focus flexibility part two confirming the ability of children to exert and relax their visual focus will contribute to greater visual efficiency. Significance was not found in correlations between visual efficiency, reading eye pattern movement, focus flexibility part I and binocular integration as would be expected, however, this is likely due to a small sample size. Weak, but significant, correlations were also determined for binocular integration with cognitive tempo as assessed by teachers, balance and academic skills as assessed by teachers as well as between focus flexibility part two and academic skills. It is likely the small sample size of this study may have contributed to the lack of strength in the correlations between some of the variables assessed. The findings of this study provide seem to agree with previous findings of the benefits of the inclusion of physical activity into schools and programs aimed at improving the cognitive development of elementary aged children. Future studies should strive to investigate similar variables in different age groups and aim to incorporate larger sample sizes to better determine strength of correlations

REFERENCES

Albin, R. L., Young, A. B., & Penney, J. B. (1989). The functional anatomy of basal ganglia disorders. *Trends Neurosci, 12*(10), 366-375.

Alexander, G. E., DeLong, M. R., & Strick, P. L. (1986). Parallel Organization of Functionally Segregated Circuits Linking Basal Ganglia and Cortex. *Annual Review of Neuroscience, 9*, 357-381.

Appollonio, I. M., Grafman, J., Schwartz, V., & Massaquoi, S. (1993). Memory in patients with cerebellar degeneration. *NEUROLOGY -MINNEAPOLIS-, 43*(8), 1536.

Bareš, M., Husárová, I., Filip, P., Mareček, R., Mikl, M., & Lungu, O. V. (2014). 44. The cerebellum, basal ganglia and motor timing in movement disorders. Behavioral and fMRI study. *Clinical Neurophysiology, 125*(5), e39.

Barkley, R. A., DuPaul, G. J., & McMurray, M. B. (1990). Comprehensive evaluation of attention deficit disorder with and without hyperactivity as defined by research criteria. *J Consult Clin Psychol, 58*(6), 775-789.

Berman, K. F., Ostrem, J. L., Randolph, C., Gold, J., Goldberg, T. E., Coppola, R., . . . Weinberger, D. R. (1995). Physiological activation of a cortical network during performance of the Wisconsin Card Sorting Test: a positron emission tomography study. *Neuropsychologia, 33*(8), 1027-1046.

Berquin, P. C., Giedd, J. N., Jacobsen, L. K., Hamburger, S. D., Krain, A. L., Rapoport, J. L., & Castellanos, F. X. (1998). Cerebellum in attention-deficit hyperactivity disorder: a morphometric MRI study. *Neurology, 50*(4), 1087-1093.

Bouchard, D., & Tetreault, S. (2000). The Motor Development of Sighted Children and Children with Moderate Low Vision Aged 8-13. *Journal of Visual Impairment & Blindness, 94*(9), 564-573.

Braver, T. S., Cohen, J. D., Nystrom, L. E., Jonides, J., Smith, E. E., & Noll, D. C. (1997). A parametric study of prefrontal cortex involvement in human working memory. *Neuroimage, 5*(1), 49-62. doi:10.1006/nimg.1996.0247

Budde, H., Voelcker-Rehage, C., Pietraßyk-Kendziorra, S., Ribeiro, P., & Tidow, G. (2008). Acute coordinative exercise improves attentional performance in adolescents. *Neuroscience Letters, 441*(2), 219-223. doi:http://doi.org/10.1016/j.neulet.2008.06.024

Burns, G. L., Taylor, T. K., & Rusby, J. C. (2001a). Child and Adolescent Disruptive Behavior Inventory 2.3: Parent Version. *Pullman: Washington State University, Department of Psychology*.

Burns, G. L., Taylor, T. K., & Rusby, J. C. (2001b). Child and Adolescent Disruptive Behavior Inventory 2.3: Teacher Version. *Pullman: Washington State University, Department of Psychology*.

Caligiore, D., Pezzulo, G., Baldassarre, G., Bostan, A. C., Strick, P. L., Doya, K., . . . Herreros, I. (2017). Consensus Paper: Towards a Systems-Level View of

Cerebellar Function: the Interplay Between Cerebellum, Basal Ganglia, and Cortex. *The Cerebellum, 16*(1), 203-229.
Cameron, C. E., Cottone, E. A., Murrah, W. M., & Grissmer, D. W. (2016). How Are Motor Skills Linked to Children's School Performance and Academic Achievement? *Child Development Perspectives, 10*(2), 93-98.
Deitz, J. C., Kartin, D., & Kopp, K. (2007). Review of the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2). *Physical & occupational therapy in pediatrics, 27*(4), 87-102.
Denckla, M. B., & Rudel, R. G. (1978). Anomalies of motor development in hyperactive boys. *Ann Neurol, 3*(3), 231-233. doi:10.1002/ana.410030308
Denckla, M. B., Rudel, R. G., Chapman, C., & Krieger, J. (1985). Motor proficiency in dyslexic children with and without attentional disorders. *Arch Neurol, 42*(3), 228-231.
Desmond, J. E., Gabrieli, J. D., Wagner, A. D., Ginier, B. L., & Glover, G. H. (1997). Lobular patterns of cerebellar activation in verbal working-memory and finger-tapping tasks as revealed by functional MRI. *J Neurosci, 17*(24), 9675-9685.
Diamond, A. (2000). Close Interrelation of Motor Development and Cognitive Development and of the Cerebellum and Prefrontal Cortex. *Child Development, 71*(1), 44-56.
Doya, K. (2000). Complementary roles of basal ganglia and cerebellum in learning and motor control. *Curr Opin Neurobiol, 10*(6), 732-739.
Durisko, C., & Fiez, J. A. (2010). Functional activation in the cerebellum during working memory and simple speech tasks. *Cortex, 46*(7), 896-906. doi:10.1016/j.cortex.2009.09.009
Ericsson, I. (2008). Motor skills, attention and academic achievements. An intervention study in school years 1–3. *British Educational Research Journal, 34*(3), 301-313. doi:10.1080/01411920701609299
Fiez, J. A. (1996). Cerebellar contributions to cognition. *Neuron, 16*(1), 13-15.
Fiez, J. A., Petersen, S. E., Cheney, M. K., & Raichle, M. E. (1992). Impaired non-motor learning and error detection associated with cerebellar damage. A single case study. *Brain, 115 Pt 1*, 155-178.
Gallaway, M. O. D., & Mitchell, G. L. M. S. (2010). Validity of the VERA visual skills screening. *Optometry - Journal of the American Optometric Association, 81*(11), 571-579.
Geuze, R. H., & Kalverboer, A. F. (1994). Tapping a Rhythm: A Problem of Timing for Children Who Are Clumsy and Dyslexic? *ADAPTED PHYSICAL ACTIVITY QUARTERLY, 11*(2), 203.
Hauber, W. (1998). Involvement of basal ganglia transmitter systems in movement initiation. *Progress in neurobiology, 56*(5), 507-540.
Hellgren, L., Gillberg, C., Gillberg, I. C., & Enerskog, I. (1993). Children with deficits in attention, motor control and perception (DAMP) almost grown up: general health at 16 years. *Dev Med Child Neurol, 35*(10), 881-892.
Kadesjo, B., & Gillberg, C. (1998). Attention deficits and clumsiness in Swedish 7-year-old children. *Dev Med Child Neurol, 40*(12), 796-804.
Kimura, M. (1995). Role of basal ganglia in behavioral learning. *Neuroscience Research, 22*(4), 353-358. doi:http://doi.org/10.1016/0168-0102(95)00914-F

Kulp, M. T., & Sortor, J. M. (2003). Clinical Value of the Beery Visual-Motor Integration Supplemental Tests of Visual Perception and Motor Coordination. *Optometry and Vision Science, 80*(4), 312-315.

Leiner, H. C., Leiner, A. L., & Dow, R. S. (1986). Does the cerebellum contribute to mental skills? *Behavioral neuroscience, 100*(4), 443-454.

Leiner, H. C., Leiner, A. L., & Dow, R. S. (1991). The human cerebro-cerebellar system: its computing, cognitive, and language skills. *Behav Brain Res, 44*(2), 113-128.

Luo, Z., Jose, P. E., Huntsinger, C. S., & Pigott, T. D. (2007). Fine motor skills and mathematics achievement in East Asian American and European American kindergartners and first graders. *British Journal of Developmental Psychology, 25*(4), 595-614.

Manjiviona, J., & Prior, M. (1995). Comparison of Asperger syndrome and high-functioning autistic children on a test of motor impairment. *J Autism Dev Disord, 25*(1), 23-39.

Marsden, C. D., & Obeso, J. A. (1994). The functions of the basal ganglia and the paradox of stereotaxic surgery in Parkinson's disease. *Brain, 117 (Pt 4)*, 877-897.

Meyer, C., & Martin, M. (2005). *Handbook for Teachers and Parents-Minds in Motion*.

Middleton, F. A., & Strick, P. L. (1994). Anatomical evidence for cerebellar and basal ganglia involvement in higher cognitive function. *Science (New York, N.Y.), 266*(5184), 458-461.

Mink, J. W. (1996). THE BASAL GANGLIA: FOCUSED SELECTION AND INHIBITION OF COMPETING MOTOR PROGRAMS. *Progress in neurobiology, 50*(4), 381-425. doi:http://doi.org/10.1016/S0301-0082(96)00042-1

Pelzer, E. A., Melzer, C., Timmermann, L., von Cramon, D. Y., & Tittgemeyer, M. (2017). Basal ganglia and cerebellar interconnectivity within the human thalamus. *Brain Structure and Function, 222*(1), 381-392. doi:10.1007/s00429-016-1223-z

Piaget, J. (1953). *The origin of intelligence in the child*. London :: Routledge & Kegan Paul Ltd.

Raichle, M. E., Fiez, J. A., Videen, T. O., MacLeod, A. M., Pardo, J. V., Fox, P. T., & Petersen, S. E. (1994). Practice-related changes in human brain functional anatomy during nonmotor learning. *Cereb Cortex, 4*(1), 8-26.

Rasberry, C. N., Lee, S. M., Robin, L., Laris, B. A., Russell, L. A., Coyle, K. K., & Nihiser, A. J. (2011). The association between school-based physical activity, including physical education, and academic performance: a systematic review of the literature. *Preventive medicine, 52*(Suppl 1), S10-20.

Romo, R., & Schultz, W. (1992). Role of primate basal ganglia and frontal cortex in the internal generation of movements. III. Neuronal activity in the supplementary motor area. *Experimental brain research, 91*(3), 396-407.

Rypma, B., Prabhakaran, V., Desmond, J. E., Glover, G. H., & Gabrieli, J. D. (1999). Load-dependent roles of frontal brain regions in the maintenance of working memory. *Neuroimage, 9*(2), 216-226. doi:10.1006/nimg.1998.0404

Schlosser, R., Hutchinson, M., Joseffer, S., Rusinek, H., Saarimaki, A., Stevenson, J., . . . Brodie, J. D. (1998). Functional magnetic resonance imaging of human brain activity in a verbal fluency task. *J Neurol Neurosurg Psychiatry, 64*(4), 492-498.

Schmahmann, J. D., & Sherman, J. C. (1998). The cerebellar cognitive affective syndrome. *Brain, 121 (Pt 4)*, 561-579.

Schwab, R. S., Chafetz, M. E., & Walker, S. (1954). Control of two simultaneous voluntary motor acts in normals and in parkinsonism. *A.M.A. Archives of Neurology & Psychiatry, 72*(5), 591-598. doi:10.1001/archneurpsyc.1954.02330050061010

Siddiqui, S. V., Chatterjee, U., Kumar, D., Siddiqui, A., & Goyal, N. (2008). Neuropsychology of prefrontal cortex. *Indian Journal of Psychiatry, 50*(3), 202-208. doi:10.4103/0019-5545.43634

Son, S.-H., & Meisels, S. J. (2006). The Relationship of Young Children's Motor Skills to Later Reading and Math Achievement. *Merrill-Palmer Quarterly (1982-), 52*(4), 755-778.

Tamagni, C., Mondadori, C. R. A., Valko, P. O., Brugger, P., Schuknecht, B., & Linnebank, M. (2010). Cerebellum and Source Memory. *European Neurology, 63*(4), 234-236.

Thach, W. T. (1998). A role for the cerebellum in learning movement coordination. *Neurobiology of learning and memory, 70*(1-2), 177-188.

Trudeau, F., & Shephard, R. J. (2008). Physical education, school physical activity, school sports and academic performance. *The international journal of behavioral nutrition and physical activity, 5*, 10.

Willingham, D. B. (1999). The Neural Basis of Motor-Skill Learning. *Current Directions in Psychological Science, 8*(6), 178-182.

Wolff, P. H., Gunnoe, C., & Cohen, C. (1985). NEUROMOTOR MATURATION AND PSYCHOLOGICAL PERFORMANCE: A DEVELOPMENTAL STUDY. *Developmental Medicine & Child Neurology, 27*(3), 344-354.

Wolff, P. H., Michel, G. F., Ovrut, M., & Drake, C. (1990). Rate and timing precision of motor coordination in developmental dyslexia. *Developmental Psychology, 26*(3), 349-359.

CURRICULUM VITAE

Franklin R. Muntis
10629 Gleneagle Place
Louisville, KY, 40223
(859)992-7932
frmuntis45@gmail.com

Academics

MS Exercise Physiology w/ Thesis Option	May 2017
University of Louisville	GPA: 4.0
Concentration: Strength and Conditioning	

BS Health and Human Performance	May 2014
University of Louisville	GPA: 3.656
Concentration: Exercise Science	

Research:

Publications:

Perry, RA., Martin, JL., Vickers, SD., Cesarz, GM., Roberts, AH., Bai, L., Selimovic, EA., Muntis, F., Parmar, PJ., Caruso, JF. Lower Leg Anthropometry As A Correlate To Performance And Metabolism From Dynamic Exercise. *Gravitational and Space Research*. (In Review)

Swank, A., Muntis, F. Motivational Triggers For Lasting Change. *ACSM Health and Fitness Journal*: Clinical Applications Column. (In Preparation)

Symons, T., Muntis, F., Carter, K., & Caruso, J. Effect of High Molecular Weight Carbohydrates on Skeletal Muscle Performance and Fatigue During Resistance Training Exercise. (In Preparation)

Terson de Paleville, D., Immekus, J., Day, A., Vargas, L., Muntis, F., Cleary, N., Goodyear, C., Day, M., Mudd, E., and Little, T. Effects of a physical activity program called "Minds-in-Motion- the MAZE" on children's academic performance, perceptual and motor skills. (In Preparation)

Caruso, J., Ling, B., Muntis, F., Dawson, S., Selimovic, E., Greta, C., & White, E. Optimal Loads For High-Speed Resistive Exercise. (In Preparation)

Poster Presentations:

Muntis, F., Vargas, L., Immekus, J., Terson de Paleville, D. Association Between Motor Proficiency, Cognitive Tempo, Academic Skills and Balance Among Elementary Aged Children in a Local Spanish Immersion School. Poster Presented at the 27th Annual Neuroscience Day of the Society of Neuroscience. 2017 Apr 13; Louisville, KY.

Muntis F., Symons T.B., Bai L., Selimovic E., West J.O., Bouchet A., Dawson S., White E., and Caruso J.F. The addition of electrolytes to a carbohydrate-based sport drink: effect on aerobic exercise performance. Kentucky Chapter of The National Strength and Conditioning Association. Georgetown, Kentucky. April 22nd, 2017.

Dawson S., Bai L., Selimovic E., Muntis F., Symons T.B., White E., and Caruso J.F. Optimal load during high-speed high-impact exercise. Kentucky Chapter of The National Strength and Conditioning Association. Georgetown, Kentucky. April 22nd, 2017)

Work Experience:

Graduate Teaching Assistant for the Health and Sports Science Department at the University of Louisville (August 2015-May 2017)

Volunteer with the University of Louisville Department of Performance Nutrition (September 2015-May 2017)

Sports Nutrition Coach for NFL Combine Athletes (January 2016-Present)

Performance Coach Intern at Ignition Athletic Performance Group (April 2015-August 2015)

Practicum/Mentorship at Texas A&M University (August 2014-December 2014)

Graduate Assistant (August 2014-December 2014)

Certifications:

NSCA Certified Strength and Conditioning Specialist (February 9th, 2015)

Ignition Speed Systems Certified Coach (April 16th, 2015)

Precision Nutrition Level 1 Certified Nutrition Coach (January 2nd, 2016)

CPR/AED Certified through the American Heart Association (September 5, 2014)

Academic Honors:

University of Louisville Honors Program (2011-2014)

Deans List: Fall 2012, Spring 2013, and Spring 2014

Dean's Scholar: Fall 2013

Trustee's Scholarship: Fall 2011 – Spring 2014