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**Investigating links between Cognitive Function and Moderate-to-Vigorous Physical  
Activity in Elementary Physical Education**

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**Submitted in partial fulfillment of the requirements for the degree of  
Master of Arts in Applied Health Sciences  
(Health and Physical Education)**

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### **Dedication**

As with many things in life, to fully achieve your goals it requires strength and encouragement from others – this endeavour was no different. I'd like to dedicate this thesis to my friends and family who supported me throughout this project, even when deadlines were tight and times were less than pleasant.





### Abstract

Research has noted both physical and psychosocial benefits when children participate in regular physical activity. Recent studies are indicating that there may also be academic benefits and that students may be more efficient learners with participation in physical activity. This study investigated the influence of acute moderate-to-vigorous physical activity on four cognitive functions: planning, attention, simultaneous processing, and successive processing. Three classes (59 students) were each tested twice using a balanced design (intervention, balance, and control groups). It was found that the intervention group had a large increase in planning ability ( $ES = 1.67$ ) when compared to the balance ( $ES = .80$ ) and control ( $ES = -.89$ ) groups. On the three remaining cognitive functions, the intervention group showed effect sizes similar to that of the balance and control groups. These results indicate that improved planning after physical activity may play a role in improving student performance.



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## Table of Contents

Dedication .....	ii
Abstract .....	iii
Acknowledgements .....	iv
Table of Contents .....	v
List of Tables .....	vii
Introduction .....	1
Literature Review .....	1
Obesity and Physical Activity .....	1
School-based Physical Activity Programs .....	4
Physical Activity and Cognitive Performance in Children .....	6
Longitudinal Studies of Physical Activity and Academic Achievement .....	12
Cognitive Function .....	15
Planning, Attention, Simultaneous, and Successive Theory .....	17
PASS Theory and Academic Achievement .....	20
Gender Differences in Cognitive Function .....	22
Physiology of Physical Activity and Cognitive Function .....	23
Conclusion .....	25
Research Objectives .....	26
Methods .....	27
General Procedure .....	27
Participants .....	27
Measures .....	28





Procedures .....	32
Data Analysis .....	33
Results .....	34
Descriptive Analysis .....	34
Contextual Factors .....	35
Physical Activity and Cognitive Function .....	37
Gender, Physical Activity, and Cognitive Function .....	39
Discussion .....	42
References .....	50
Appendices .....	64
Appendix A: Letters of Introduction and Consent/Assent Forms .....	65
Appendix B: Demographic Questionnaire.....	75
Appendix C: Activ8 Lesson Plan .....	76
Appendix D: Examiner's Instructions .....	79
Appendix E: Standard Response Sheet .....	85
Appendix F: Sample CAS Subtests .....	86



### List of Tables

Table 1 Testing Schedule .....	32
Table 2 Correlations between the cognitive test scores and academic grade .....	37
Table 3 Cognitive function test scores and effect sizes between weeks one and two ..	38
Table 4 Effect size (Hedge's <i>g</i> ) of differences in test scores between genders .....	40
Table 5 Cognitive function test scores for males and effect sizes between weeks one and two .....	41
Table 6 Cognitive function test scores for females and effect sizes between weeks one and two.....	42



Research has suggested many physical and psychosocial benefits when children participate in regular physical activity (Biddle, Gorely, & Stensel, 2004; Sothorn, Loftin, Suskind, Udall, & Blecker, 1999; Williamson, Dewey, & Steinberg, 2001). Recent research has also indicated that spending more time in physical education (PE) and less time sitting in a classroom is not detrimental to academic achievement (Dwyer, Coonan, Leitch, Hetzel, & Baghurst, 1983; Shephard, 1997; Sibley & Etnier, 2003). Some studies have noted improvements in cognitive function (and specifically attention) when children are physically active during the school day (Caterino & Polak, 1999; Gabbard & Barton, 1979; Mahar et al., 2006; McNaughten & Gabbard, 1993). These findings indicate that physical activity may enhance the student's ability to perform academically; however few studies have investigated this relationship.

It is apparent that daily physical activity can be integrated into schools while maintaining a strong academic focus (Welk, Eisenmann, & Dollman, 2006, p. 675). The main objective of this thesis is to further investigate the relationship between acute physical activity and cognitive function in a school setting by evaluating the students' working memory, short-term memory, selective attention, and planning ability following moderate-to-vigorous physical activity (MVPA). The implications of these findings on both physical activity programs and academic achievement will be discussed.

## Literature Review

### *Obesity and Physical Activity*

Childhood obesity rates have been steadily increasing in recent years and have become a prominent focus of health educators. In 1998 to 1999, 37% of Canadian children aged 3 to 11 years were overweight and 16% were obese (Statistics Canada,





2002). In addition, 57% of Canadian children and youth aged 5 to 17 years were not sufficiently active to meet international guidelines for optimal growth and development (Craig, Cameron, Storm, Russell, & Beaulieu, 2001). Chronic health issues linked to being overweight are appearing more frequently in children, these include: asthma (Gilliland et al., 2003), sleep apnea (Tauman & Gozal, 2006), Type II diabetes (Sinha, 2002), cardiovascular disease (Freedman, Dietz, Srinivasan, & Bereson, 1999), and poor psychosocial well-being (Parfitt & Eston, 2005). These obesity-related ailments place a substantial economic burden on Canadian society (Birmingham, Muller, Palepu, Spinelli, & Anis, 1999) and can have negative effects on student academic performance (Taras & Potts-Dema, 2005). Meanwhile, low levels of physical activity have been linked to the “epidemic” of overweight children in Canada (Tremblay & Willms, 2003). In comparison, adequate physical activity has been associated with numerous health benefits in children, including reduced risk of cardiovascular disease, overweight, Type II diabetes, and improved skeletal health (Biddle et al., 2004; Sothorn et al., 1999). Physical activity can also have positive effects on a child’s psychosocial well-being, improving self-esteem, body image, and mood (Biddle et al., 2004; Williamson et al., 2001).

It would seem logical that some societal modifications need to take place, but we have yet to see suitable changes in the Canadian education system. The Ontario Ministry of Education (2005) responded to this need by mandating that “elementary students... have a minimum of 20 minutes of sustained moderate to vigorous physical activity each school day” (para. 3). The Alberta government mandated a similar program requiring every student in grades one through nine to be physically active for 30 minutes per day. Between 2001 and 2006, 71% of Canadian schools reported that they had policies to



provide daily PE (Canadian Fitness and Lifestyle Research Institute, 2006); however the Canadian Association for Health, Physical Education, Recreation and Dance (2005) has reported that only 57% of these schools meet their provincial guidelines for minutes spent in PE. Despite this lack of consistent programming, more than half of Canadian parents believe that their child receives sufficient daily physical activity at school to provide health benefits (Canadian Institute for Health Information, 2004). Children spend several of their daily hours at school and for some it is their only opportunity to be physically active (Allison & Adlaf, 2000). As such, many have deemed it the social responsibility of schools to provide adequate opportunities to be physically active (Allsion & Adlaf, 2000; Lee, 2006; Macdonald, Ziviani, & Abbott, 2006). Meanwhile, a number of school administrators believe that it is not their prerogative to address health problems during school time when they are under pressure to meet academic standards (Dwyer et al., 2003). In a report to the General Council, the Canadian Medical Association (2006) called on school boards and the government to, “introduce at least 30 minutes of active physical education daily, led by trained instructors, for all primary and secondary students” (p. A-24). There is a need for the Canadian education system to step-up and provide quality daily physical activity that will meet the health requirements of its students.

Dwyer et al. (2003) surveyed elementary school teachers in the Toronto area, finding that from the teachers’ perspectives there are significant barriers to implementing physical activity guidelines. The most common barriers cited were lack of infrastructure, low priority compared to academic subjects, and lack of guidance and lesson resource support from the provincial government (Dwyer et al., 2003). A systematic review by



Khan et al. (2002), also found that a major barrier to implementing physical activity programs comes from the pressure to increase academic performance. Further, according to Bandura's (1998) Social Cognitive Theory, the individual's behaviour and their environment interact reciprocally. If the environment is not perceived to be supportive of a behaviour, then the individual is less likely to perform the desired behaviour. Therefore, in order to improve the quality of physical activity acquired by children in Ontario schools, it appears necessary to address the barriers to implementing physical activity guidelines, as perceived by PE teachers, and to provide evidence that supports the cognitive benefits of physical activity in a primarily academic institution.

#### *School-based Physical Activity Programs*

School-based interventions have been effective in increasing the physical activity of elementary school students (Khan et al., 2002). In a systematic review of school-based studies, Khan et al. (2002) found the net minutes spent in MVPA during PE class increased by 50.3% and the percentage of PE class time spent in MVPA increased by 10%. Although BMI and skin-fold measurements were inconsistent, there were noted improvements in flexibility, muscular endurance, and self-efficacy to be physically active.

One of the largest and most widely adopted school-based programs that targeted physical activity was the Coordinated Approach to Child Health (CATCH) (Hoelscher et al., 2001). The objective of CATCH was to increase the cardiovascular health of children through improving nutrition (reduced sodium, saturated fat, and total fat intakes), improving physical activity (greater than 50% of PE class time spent in MVPA), and reducing tobacco use (Hoelscher et al., 2001). After the three-year trial period, it was





found that the program was successful in meeting its goals for improved school lunches and increased MVPA in PE class (Luepker et al., 1996). However, despite these successes, long-term adherence has been less than spectacular. Hoelscher et al. (2001) reported that when returning to the former intervention schools three years after the initial trial, there were no differences observed in the PE classes, in relation to the CATCH goals, when compared to a control school that had not been exposed to the CATCH program. Therefore, although school-based programs can be effective, it is relevant to consider the long-term maintenance and institutionalization of the program to continue meeting its objectives after the initial intervention.

When Barroso, McCullum-Gomez, Hoelscher, Kelder, and Murray (2005) surveyed teachers and principals involved in the CATCH trials, they found that physical activity often took a back seat to academics. This is the same outlook found by Dwyer et al. (2003) when surveying PE teachers in Toronto. The following is list of qualitative responses highlighted by Barroso et al. (2005) as representing common themes presented by PE specialists when asked to describe the barriers to providing quality PE: a) “Many times children are pulled out of my classes to fill an academic objective” (p. 317), b) “We need students in PE every day (sometimes teachers keep them in the classroom to catch up academically)” (p. 317), and c) “As a physical education teacher I am face [sic – faced] with teachers keeping students from my class as punishment for misbehavior, pulling them out for tutoring, ESL, or helping [sic – to] file papers” (p.317). These scenarios will ring true to anyone who has experience in an elementary classroom. Even though physical activity programs are successful, research shows that they experience difficulty when forced to compete with the importance placed on academics and



successful student performance on standardized academic tests (Barroso et al., 2005; Dwyer et al., 2003).

Although the Ontario and Alberta governments have mandated daily physical activity for elementary students, there has been little guidance as to how school participation will be ensured. The Ontario policy simply states, “School boards will monitor the implementation of the policy on daily physical activity to ensure that all elementary students are provided with the opportunity to be active for at least twenty minutes each day during instructional time” (Ontario Ministry of Education, 2005, para. 10). Alberta’s guidelines dictate that, “School authorities shall ensure that all students in grades one to nine are physically active for a minimum of 30 minutes daily...” (Alberta Ministry of Education, 2006, para. 3). If school principals and authorities are focused more on academic indicators that are publicly announced, then there is little incentive to effectively oversee the compliance of daily physical activity for all students. While the Education Quality and Accountability Office supervises and assesses academic achievement in Ontario, there is no venue through which school authorities are publicly held accountable for the quality of physical activity they provide. Thus, it is the aim of this thesis to further investigate the potential benefits that can be obtained through physical activity within schools and discuss how physical activity programs may help achieve academic objectives.

### *Physical Activity and Cognitive Performance in Children*

The concept that physical activity develops and preserves both physical and mental health is not novel. Early philosophers, such as Socrates and Plato, discussed the benefits of physical activity on maintaining a clear mind and demonstrated this belief by



walking with their scholars as they lectured. Academic studies examining the influence of physical activity on cognitive processes can be found dating over a century ago, however most published research has occurred within the last 30 years (Tomprowski & Beasman, 2005). In 1986, Tomporowski and Ellis conducted a narrative review of the research published on physical activity and cognitive function. They concluded that within the 27 studies reviewed there was no evidence to support the notion that exercising influences cognitive function. This finding was followed by a major criticism from the authors concerning the lack of convincing theoretical rationale in the studies. A review by Folkins and Sime (1981) addressed the effects of exercise on a broader mental health, including items such as cognition, perception, affect, and personality. Folkins and Sime (1981) echoed Tomporowski and Ellis (1986) in finding that studies of this period were riddled with methodological shortcomings that made it nearly impossible to make any conclusions concerning physical training and cognition.

Recent studies can be divided into two main categories: acute and chronic. Studies assessing the effects of acute exercise generally require short bouts of physical activity in order to activate the body and produce changes in physiological functions, such as body temperature, cardio-respiration, and endocrine functions (Tomprowski, 2006). Evaluation of cognitive performance takes place either throughout the exercise or shortly after terminating the exercise. On the other hand, chronic protocols are typically several months in length and aim to measure changes in both physiological and psychological functions comparing the results from a battery of tests completed sometime before and after the training program (Tomprowski & Beasman, 2005).





There have been a handful of reviews covering the research of physical activity and cognitive processes over the last decade; however I am aware of only three that relate to children. The first, by Sibley and Etnier (2003), was a review and meta-analysis of 44 published and unpublished studies. The cognitive assessments used in these studies varied considerably including intelligent quotient, perceptual skills, verbal tests, mathematics tests, memory, academic readiness and concentration. Physical activity ranged from 15 minutes of walking to six years of PE classes. Overall, the authors found a moderate effect size of 0.32. This is slightly larger than the effect size of 0.25 found in a previous review by Etnier et al. (1997), which included adults, suggesting a greater effect for children (Sibley & Etnier, 2003). Also, their review indicated that the largest effect sizes were obtained in studies using elementary and middle school students. Activity design (chronic, acute, cross-sectional) and type (resistance, aerobic, PE program, perceptual-motor training) were not found to be moderator variables, suggesting that any activity can be used. From the published studies analysed, nine had used an experimental design, of which eight used chronic exercise conditions and only one directly tested the acute effects of physical activity (Sibley & Etnier, 2003). This acute study was carried out by Caterino and Polak (1999) and assessed concentration in second-, third-, and fourth-grade students. Students from each grade were divided into two groups; one group was tested after 15 minutes of aerobic walking and compared to the second group who did not participate in any activity. Using the Pair Cancellation subtest of the Woodcock-Johnson III Cognitive Abilities Battery, it was found that significant ( $p = 0.05$ ) differences in concentration were observed only between the fourth-grade activity ( $n = 25$ ) and no-activity groups ( $n = 27$ ) (Caterino & Polak, 1999). The authors did not



indicate if they measured activity intensity during the aerobic walking. Although the authors did not provide an effect size, Sibley and Etnier (2003) calculated it to be 0.42 in their review. Overall, Sibley and Etnier (2003) reported consistent findings of the positive influence that physical activity has on cognitive function, yet caution that the research methods used in the studies they reviewed were highly variable with many different assessments and physical activity protocols. The authors suggest that statistically powerful studies that control for confounding variables and use valid and reliable dependent measures are needed to establish whether a causal relationship does exist and the underlying mechanisms that may be involved.

Tomporowski (2003) focused his review on acute exercise in children and youth in a school setting. This perspective was approached in response to anecdotal evidence that recess and PE cause children to be overly excited and are detrimental to classroom and academic performance. The four studies he presented all indicate that physical activity improved rather than impaired student performance. The first study by Caterino & Polak (1999) was described earlier. The second study by Gabbard & Barton (1979) showed improved mathematical computation in 106 second-grade students following relay activities lasting, 20, 30, 40, and 50 minutes. Computation scores improved at each time point and there was a significant ( $p < 0.05$ ) difference between all time points on a one-way repeated measures ANOVA; although, post-hoc analysis showed the only time point significantly different from baseline (no exertion) occurred after 50 minutes. The third study in Tomporowski's (2003) review also assessed mathematical computation, but the sample was 120 sixth-grade students. The study found that paced walking showed improvements after 30 and 40 minutes of activity, but not after 20 minutes (McNaughten



& Gabbard, 1993). The fourth and final study, by Raviv and Low (1990), demonstrated that students performed better on tests of concentration at the end of a class taught at 2 p.m. compared to a class taught at 8 a.m., regardless of whether it was science or PE. Thus, time of day may affect any studies measuring concentration. In the second half of his review, Tomporowski (2003) also describes a trend in studies sampling students who have learning and behavioural disorders characterized by poor impulse control and attention. These students showed improvements in both behaviour and performance post-exercise. However, the author cautions that the number of studies was small and thus the results should not be taken as conclusive evidence.

Taras (2005) reviewed 14 published articles since 1984 that examined physical activity and school performance. The most common dependant variable used was academic grades, followed by two measuring concentration, and one study measuring school-readiness. This review indicated that there was little or no correlation between physical activity and school performance, however many of the studies were not experimental. For example, Daley and Ryan (2000) surveyed 232 students, aged 13-16 years, to determine how participation in sports-based activities was correlated with academic achievement. As such, there were many confounding variables that made it difficult to make any direct connections between physical activity and student performance.

Since these three reviews were conducted, there have been two major studies of note. The first study by Coe, Pivarnik, Womack, Reeves, and Malina (2006) examined the relationship between the enrollment of 214 sixth-grade students in PE and their academic test scores. While no significant difference in scores was observed between





those enrolled in PE and those who spent that period in the classroom, this finding suggests that spending one hour less per day in a classroom did not cause a decline in academic achievement. Also, Coe et al. (2006) reported that students who performed MVPA at a level that met the Healthy People 2010 guidelines (30 minutes per day at least five days a week of moderate activity and 20 minutes at least three times a week of vigorous activity; US Department of Health and Human Service, 2000) had significantly ( $p < 0.05$ ) higher grades than those who did not meet the guidelines. This trend suggests that there may be a threshold level of activity required to obtain the desired academic benefits (Coe et al., 2006).

Mahar et al. (2006) assessed the effects of a 10-minute classroom-based physical activity program (Energizers) on students' on-task behaviour during the academic instruction that followed. Behaviour was observed and rated for 30 minutes pre- and post-activity in 37 third-grade and 25 fourth-grade students. A control group of 108 students did not receive the physical activity program. Students in the intervention group took significantly ( $p < 0.05$ ) more steps than the control group during the school day, and on-task behaviour improved systematically as the Energizers program was implemented. Overall, on-task behaviour improved by 8% after the Energizers compared to pre-Energizers ( $p < 0.02$ ,  $ES = .60$ ). The authors also found that the students who had the least on-task behaviour during baseline improved the most, showing a 20% improvement and statistical significance ( $p < 0.001$ ,  $ES = 2.20$ ). Physical activity having the greatest effect on students who are the least attentive may be beneficial for teachers trying to maintain classroom control and overall student performance (Mahar et al., 2006).





While there are many other studies investigating acute exercise and cognitive function, they are in the context of playing sports. They analyze the effects of short duration maximal and sub-maximal exercise on attention, decision-making, and reaction time (Tomprowski, 2006). Measurements are conducted throughout the exercise to assess how well the athlete can respond in a game-time situation and also to monitor the effects of fatigue and dehydration as the duration or intensity increases. These studies elicit conditions that are not consistent with what would be expected in an elementary PE class situation and do not give a reasonable indication to the cognitive effects that would be seen during an academic period following PE. Therefore, these studies have been excluded from this review.

It is apparent that very little is known about the effects of acute physical activity on the cognitive function of children and thus, all three reviewers call for further research in the area. Five experimental studies have investigated acute physical activity in children, two measuring concentration, two measuring mathematical computation (representing simultaneous processing and working memory), and one measuring on-task behaviour. Reviewers have noted their amazement at the lack of research in an area that would have beneficial and practical implications on education and curriculum (Taras, 2005; Tomporoski & Beasman, 2005).

#### *Longitudinal Studies of Physical Activity and Academic Achievement*

While the focus of this thesis is on acute physical activity, some perspective can be gained by analyzing two well-documented large-scale chronic, longitudinal studies. Shephard and Trudeau (2005) provide a retrospective review of the Trois-Rivières PE study that they conducted with Jéquier, LaBarre, Rajic, Volle, and Beaucage. The study



initially took place between 1970 and 1977, and participants were followed up between 1997 and 1999. Originally, 526 Canadian students were provided with PE classes for one hour a day (5 hours a week) and taught by a qualified PE instructor. The lessons were designed to keep each child participating in vigorous activity. Students in the intervention group were tested each year within two weeks of their birthday as they progressed from grade one to grade six. Students in the same schools who were in the immediately preceding and succeeding classes were used as the control group. The research team collected data on both physical function and academic achievement (using grades and provincial standardized test scores). In general, the program was effective in enhancing the students' aerobic function, muscle strength, and physical performance (Shephard & Trudeau, 2005). Despite students in the intervention group receiving 14% less academic teaching time, they had higher average scores and performed better in mathematics and English language classes from the second through sixth grades, when compared to the control group. In first-grade, the control group initially had better marks than the intervention group. While this study did not explore the mechanism behind the improved academic performance, the authors suggest that it may have been due to better behaviour and increased arousal from the activity (Shephard & Trudeau, 2005). When the participants were traced and re-evaluated 25 years later, the authors were encouraged to find that the intervention group had higher ratings of their own health, greater intentions to exercise, and were more likely to exercise at least three times a week (Shephard & Trudeau, 2005).

Salis et al. (1999) also completed a longitudinal study called Project Sports, Play, and Active Recreation for Kids (SPARK) to evaluate the effects of a health-related PE



curriculum on academic performance. Seven schools participated in the study and were divided into three groups. Two schools were taught PE by specialists who implemented the SPARK program. Another two schools were taught the SPARK program but by the usual classroom teachers who were trained to use the SPARK curriculum for the purpose of this study. Three schools were used as a control and classes were taught as usual by the classroom teachers. None of the classroom teachers were trained PE specialists, and prior to the study neither of them had a specific PE program. Grade four students were recruited over two years, providing two cohorts that were evaluated in grades four, five, and six. Results indicated that although the experimental schools spent twice as many minutes in PE than the control school, there were favourable effects on academic achievement (Salis et al., 1999). Compared to the control schools, students in the teacher-trained classes performed better on a basic battery of academic achievement, language, and reading and those in the specialist-taught classes showed enhanced reading scores, but lower language scores (Salis et al., 1999). Salis et al. (1999) suggest a possible explanation for these results is that the specialist-taught classes had the lowest baseline achievement test scores.

These two studies and the aforementioned study by Coe et al. (2006) indicate that spending more time in PE and away from the classroom does not appear to reduce academic achievement. Although the mechanisms are unknown, Taras (2005) suggests that that devoting time to PE can increase the “rate of academic learning per unit of class time” (p. 217). That is to say, although participation in PE may not improve overall academic achievement, it can function to enhance the efficiency of learning during the





rest of the school day, compensating for the additional time spent away from the classroom.

### *Cognitive Function*

To discuss cognitive function, it is important to have a clear understanding of its meaning. Definitions of cognitive function vary widely, possibly due to a lack of agreement on what constitutes cognition. Merriam-Webster (2007) broadly defines cognition as, “cognitive mental processes” and cognitive as, “involving conscious intellectual activity (as thinking, reasoning, or remembering)”. Also, in the same dictionary, function is defined as, “a group of related actions contributing to a larger action.” In educational psychology, the field of cognition studies the “acquisition, representation and activation of knowledge” (Posner & Friedrich, 1986, p. 81). Cory-Slechta et al. (2001) remarks that, “cognitive function is often thought of as encompassing learning, memory, and attention processes” (p.84). This view is consistent with the assessment tools used in the reviewed studies, which measure memory, attention, decision-making, and academic achievement. Therefore, for the purpose of this thesis, cognitive function will be defined as the processes used in the acquisition, representation, and activation of knowledge, such as attention, memory, and problem solving. The term cognitive function will be used interchangeably with cognitive processes.

Attention is a vital cognitive function defined by Posner and Friedrich (1986) as, “The system that involves our ability to select among competing data so as to bias our memory, responses, or current thought toward some contents rather than others” (p. 81). Attention has more specifically been referred to as “directed arousal” (Naglieri, Prewett, & Bardos, 1989, p. 349), which can require vigilance over a period of time (sustained



attention) or selective signal detection (selective attention) (Naglieri et al., 1989). In relation to other cognitive processes, attention serves as an internal regulator that maintains arousal for proper information processing (Naglieri et al., 1989; Posner & Friedrich, 1986).

Memory is one of the more complex cognitive processes, as there are multiple forms. Working memory and short-term memory are similar in having limited capacities, unlike long-term memory (Linden, 2007). Working memory is “a central cognitive function at the interface of perception and action” (Linden, 2007, p. 257). This type of memory is used when an individual requires holding and manipulating information for a short period of time. It has been described as a “flexible mental workspace” (Gathercole & Alloway, 2004, p. 2) that stores information throughout complex cognitive activities. An example of using working memory is multiplying two numbers mentally (without writing anything down or use of a calculator). In order to accomplish this task one must apply the learned multiplication rules and temporarily store the intermediate products that occur during calculation. Any distraction such as an unrelated thought or stimulus can cause this information to be completely lost. Hence, working memory is dependent on attention to be effective and efficient (Gathercole & Alloway, 2004). In children, working memory plays an important role in their ability to learn and is typically measured using tasks that require the child to store and process information simultaneously (Gathercole & Alloway, 2004). Working memory span continues to increase from age five until age 15, at which point it levels off and remains at that level into adulthood. Working memory has been linked to reading comprehension (Perfetti & Goldman, 1976), mathematical



computation (Ashcraft & Kirk, 2001; Wilson & Swanson, 2001), and problem solving in mathematics (Logie, Gilhooly, & Wynn, 1994),

Short-term memory describes the “mere maintenance of information” (Linden, 2007, p. 257). While it is similar to working memory, the two serve distinct functions. Working memory allows the person to temporarily hold and manipulate information while complex cognitive tasks are occurring, such as learning and reasoning. In comparison, short-term memory holds a small amount of information (approximately seven chunks in adults) until new information is presented, at which time it either stores or loses the original information (Mather & Wendlin, 2005). Hence, it is commonly referred to as the “‘use it or lose it’ memory” (Mather & Wendling, 2005, p. 278). Short-term memory is often tested through sentence repetition tasks and the repetition of numbers in a specific order. Information in the short-term memory can be moved into long-term memory (lasting longer, any time between 30 seconds and decades) through rehearsal or association (Mather & Wendlin, 2005). While children who have better working memory tend to perform better on both reading and mathematics tests (Gathercole & Alloway, 2004), short-term memory has not shown these links to academic performance (Swanson, 1994).

#### *Planning, Attention, Simultaneous, and Successive Theory*

To fully investigate the relationship between physical activity and academic performance, it is important to have a theoretical framework on which to base the cognitive functions being explored. Naglieri and Das (2005), the developers of the Planning, Attention, Simultaneous, and Successive (PASS) theory of cognitive function, describe it to be the first theory of human intelligence rooted in “a specific researched





neuropsychological theory”(p. 120). The neuropsychological theory they are referring to is Luria’s blueprint of the three functional units of the brain that provide these four basic psychological processes of cognitive function (Das, Naglieri, & Kirby, 1994). While other theories measure “writing, reading, and arithmetic...as isolated or even indivisible ‘faculties’” (Luria, 1973, p. 29), Luria remarks that there is no spot in the brain specific to the writing ability. Instead, the brain must be conceptualized as containing units that perform separate functions but work together to complete the desired mental activity (Luria, 1973). Although cognitive tasks require all three units in some capacity, one task may rely more heavily on attention (regulated by the first unit), while another may rely more heavily on strategy development (occurring in the third unit). Naglieri and Das (2005) expanded on Luria’s functional units in the PASS theory (see Figure 1) by further describing the processes that these units provide and their relation to cognition and knowledge.

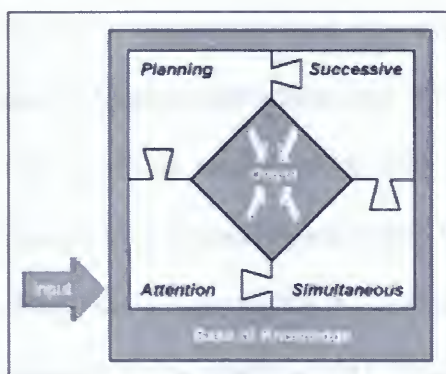


Figure 1. PASS Theory Diagram (Naglieri, 1999, p. 11)

*Attention.* The first functional unit described by Luria (1973) occurs in the brain stem, diencephalon and medial cortical regions (see Figure 2). These regions are responsible for providing cortical arousal, allowing an individual to focus and direct their attention (Naglieri & Das, 1990). Luria (1973) states that an optimal level of arousal must





be achieved before other forms of attention (i.e. selective), and the processes of the second and third functional units can effectively occur. This unit is also important for allowing the person to inhibit a response to another stimulus when multiple stimuli are presented, such as reading a book in a noisy room (Naglieri & Das, 1990).

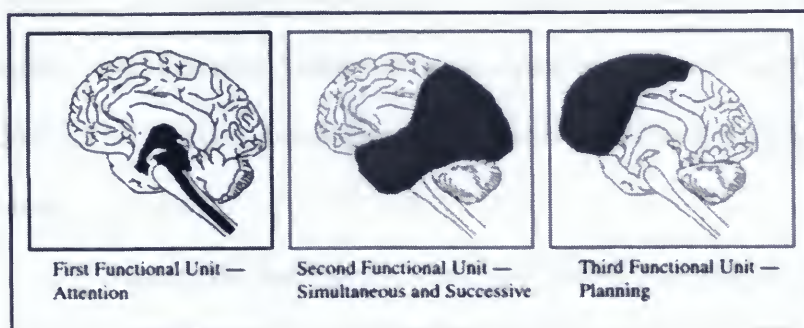


Figure 2. Luria's functional units (Naglieri, 1999, p. 10)

*Simultaneous and successive processing.* The second functional unit is associated with the occipital, parietal, and temporal lobes of the brain (Naglieri & Das, 1990; see Figure 2). These regions are responsible for receiving, processing, and retaining externally presented information, through both simultaneous and successive processes (Das, Kirby, & Jarman, 1979). Both memory and attention facilitate these information-processing activities (Floyd, 2005). Simultaneous processing involves “integrating stimuli into groups so that the interrelationships among the components are understood” (Naglieri & Das, 2005, p. 121). This type of processing uses working memory and is important for organizing information and putting pieces together to make a reasoned whole. Simultaneous processing is commonly associated with visual-spatial activities, but can also be used in the grammatical understanding of language and comprehension of word context, for example, “Draw a triangle above a square that is to the left of a circle



under a cross” (Naglieri & Das, 2005, p.121).

Successive processing is employed when working with information that is linearly organized (Naglieri & Das, 1990). Learning to write or follow the order of operations in a math problem are common examples of successive processing where each step must be done in a specific order to successfully complete the task. Also, when information must be stored in short term memory successive processing is involved (Naglieri & Das, 2005). This function is an important component of working with sequential sounds and learning to read.

*Planning.* The last functional unit is planning, regulated by the frontal lobes (Naglieri & Das, 1990; see Figure 2). This unit is responsible for the control of cognitive activity and is involved in the programming, verification, and regulation of behaviour (Naglieri & Das, 2005). These skills are important in problem solving and self-monitoring. When faced with a problem, children must determine the possible solutions, select one, apply it, and evaluate the results. Planning allows for strategies to be formed, interacts with the first and second unit processes, and uses the individual’s skill and knowledge base (Naslieri & Das, 2005). Planning moderates an individual’s voluntary activity, impulse control, and spontaneous conversations (Naglieri & Das, 2005). The relationship between planning and attention is particularly strong. Arousal influences the ability for planning to occur and attentional resources are under the conscious control of planning (Luria, 1973).

#### *PASS Theory and Academic Achievement*

Researchers have demonstrated that attention, simultaneous, successive, and planning processes are correlated to achievement. Das, Kirby, and Jarman (1979)



reviewed initial studies that showed both simultaneous and successive abilities to be superior in high achievers versus low achievers. Simultaneous and successive processing tasks have correlated significantly with measures of reading comprehension (Das & Cummins, 1982; Kirby, 1982; Kirby & Robinson, 1987), reading decoding (Das & Cummins, 1982; Das), performance in English courses (Wachs & Harris, 1986), and mathematics (Garofalo, 1986; Naglieri & Das, 1987). Das and Heemsbergen (1983), and Garofalo (1986) reported that success in mathematics computation and written composition has correlated significantly with planning tasks. Planning has correlated significantly with reading decoding and reading comprehension in studies with elementary school aged students (Das, 1984; Leong, Cheng, & Das, 1985). Since attention and sufficient arousal is important for the other cognitive processes to effectively occur, this function has also been correlated with mathematics, reading, spelling, and written language (Zentall, 1993). Although the correlations between planning, simultaneous, and successive processing with achievement were all significant, planning correlated with reading and math as well as or better than information coding (simultaneous and successive processing combined) (Naglieri & Das, 1990). This suggests that planning being overlooked in current intelligence tests is an important omission to consider.

A major strength of the PASS theory of human intelligence is that it places emphasis on cognitive function as opposed to traditional verbal-nonverbal models of human intelligence. The PASS theory has been operationalized and tested using the Cognitive Assessment System (CAS), a battery of psychoeducational tests built strictly on the PASS theory (Naglieri, 2005). Unlike common tests of intelligence quotient, the





CAS subtests are not dependent on previously acquired knowledge, such as vocabulary and arithmetic skills (Naglieri, 2005). This feature is important since it helps to provide a common measurement for children who may have a history of academic failure or may come from disadvantaged backgrounds. When compared to other tests of ability (i.e. Differential Ability Scales, Woodcock-Johnson Psycho-Educational Battery Broad Cognitive Ability Score, Wechsler Intelligence Scale for Children Third Edition), the CAS had substantially higher correlations with achievement (Naglieri, 2005). The validity of the PASS theory has been continually demonstrated through correlation with academic achievement scores, comparison to other measures of ability, and demonstration of the test's ability to differentiate between students with various learning disabilities (Naglieri, 1999).

### *Gender Differences in Cognitive Function*

Studying differences in cognitive ability based on gender has long been a controversial topic (Halpern, 2000). It has been argued from various perspectives, nature versus nurture, evolutionary paths, and psychobiological differences; however, from all directions, the research indicates that there are indeed variances between males and females. Common intelligence tests are specifically designed to balance these differences so that the average score is similar for both genders (Halpern, 2000).

From a young age each gender tends to exhibit strengths in different cognitive functions (Halpern, 2000). Males on average have a greater ability to perceive visual-spatial information and perform mental rotations (rotating the mental image of a two-dimensional or three-dimensional figure, usually to compare with another figure; Linn & Petersen, 1986). Simultaneous processing and working memory are abilities for which



males are inclined to have a greater aptitude (Halpern & Wright, 1996) and, as such, tend to use mental imagery when attempting to solve problems (Richardson, 1991). On the other hand, females tend to have stronger verbal abilities, excelling in reading, spelling, grammar, and oral comprehension (Gazzaniga, Ivry, & Mangun, 1998). On average females perform better on tasks that require recalling words from a list (Geffen, Moar, O'Hanlon, Clark, & Geffen, 1990). Since gender differences in these cognitive processes are apparent, it is prudent to consider this while analysing the results from the CAS subtests.

### *Physiology of Physical Activity and Cognitive Function*

There is strong evidence that physical activity causes physiological changes within the human body (Marieb, 2002), however the extent of change occurring in the brain and in relation to cognitive function is still in question. Significant advances in our understanding of how the body responds to exercise has allowed further study into how physical activity can affect cognitive function from a biological perspective (Tomprowski & Beasman, 2005). Recent studies suggest that exercise induced changes in the central nervous system also impact the brain systems that are connected to cognitive function (Tomprowski & Beasman, 2005).

When the human body is activated, the muscular activity signals the sympathetic division of the autonomic nervous system to release stress hormones. The adrenal gland releases both epinephrine (EPI) and norepinephrine (NE) into the blood stream. These hormones are very similar in function, however EPI is more potent and the ratio of hormones released is uneven with approximately 80% being EPI (Marieb, 2002). The concentrations of EPI and NE found in the blood plasma increase rapidly at the beginning



of exercise and are released in proportion to the intensity of activity. When a consistent workload is maintained levels continue to increase but at a slower pace. NE levels have been found to be ten times greater immediately following exercise when compared to pre-exercise measurements (Krum, Conway, & Howes, 1991). A key difference between the two hormones is the length of time required to recover to baseline levels. While EPI is processed quickly, NE can last in the body for much longer depending on the intensity of exercise; elevated levels have been detected in marathon runners 24 hours after a long distance run (Sagnol et al., 1989). In a study by Eliakim et al. (2006), it was found that NE levels were still above baseline two hours after 25 children participated in a 30 minute physical activity session. Therefore, in a school situation, participation in MVPA can have lasting effects into the proceeding class periods.

As described in the PASS theory, the prefrontal cortex of the brain is responsible for a child's ability to self-regulate, inhibit impulsiveness, problem solve, organize, and plan. When individuals lack optimal levels of NE in the prefrontal cortex their behaviour mimics the symptoms of Attention-Deficit/Hyperactivity Disorder (ADHD). Thus, treatments for ADHD involve facilitating the transmission of catecholamines, predominantly NE, in the prefrontal cortex (Arnsten & Li, 2005). The known benefits of improving NE levels in children with ADHD have inspired some researchers to evaluate the impact of exercise on these children (Wigal et al., 2003). While studies have been conducted to examine the effects of physical activity on plasma NE concentrations (i.e. Sagnol et al., 1989) and on both observed and reported classroom behaviour (Tomprowski, 2003), there is no known study examining the impact of physical activity on planning ability assessed using a standardized test.





## *Conclusion*

It is apparent that physical activity is very beneficial for the health and well-being of students (Biddle, Gorely, & Stensel, 2004; Sothorn, Loftin, Suskind, Udall, & Blecker, 1999; Williamson, Dewey, & Steinberg, 2001). Despite this knowledge, PE teachers perceive barriers to providing daily physical activity within Canadian schools, as academics are given a higher priority (Dwyer et al., 2003). With the ever increasing rate of childhood obesity and the numerous hours that students spend at school, many have deemed it the social responsibility of the education system to provide daily physical activity (Allsion & Adlaf, 2000; Lee, 2006; Macdonald, Ziviani, & Abbott, 2006). Recent studies have suggested that physical activity may positively influence a student's academic performance, possibly due to improved attention (Caterino & Polak, 1999) or behaviour regulation (Mahar et al., 2006).

The purpose of this thesis was to further investigate the link between physical activity and cognitive function through an acute quasi-experimental study. A criticism of previous studies was the lack of theoretical framework guiding the studies in this area (Tomprowski, 2003). For the present study a biological perspective was adopted, based on physiological principles of physical activity and Das and Naglieri's PASS theory of intelligence. Another criticism was the lack of experimental studies and the number of confounding variables in correlational studies (Taras, 2005). Attempts were made in this study to control for confounding factors by testing students immediately following the physical activity lesson, at the same time of day, and comparing against their own measures. It also follows a quasi-experimental design by including both a control and a balance group, although students were not randomly assigned to their group (since they





were already subdivided by class). By addressing these issues, this study might provide a better insight into the relationship between physical activity and cognitive function.

Through examining the acute effects of physical activity on multiple cognitive functions we can gain a more holistic understanding of how the students' cognitive ability changes (or remains the same) when classroom teaching resumes post-activity. Also, investigating the acute changes may help to partially explain the positive results found in longitudinal chronic studies. It is anticipated that the results from this study will have both theoretical and practical implications for education.

### Research Objectives

This thesis had four objectives and two hypotheses. The first objective was to perform a descriptive analysis of the demographic data and each of the components of cognitive function (attention, simultaneous processing, successive processing, and planning). The second objective was to develop an appropriate context for analysis. Time spent in moderate-to-vigorous physical activity (MVPA) was compared between the groups to ensure that similar conditions were achieved. Also, baseline cognitive function scores were correlated with academic achievement to ensure that the relationship observed in the literature (Naglieri & Das, 1990) holds true for this sample population. The third objective was to determine the change in each cognitive process (attention, successive processing, simultaneous processing, planning) following MVPA. It was expected that attention (Caterino & Polak, 1999; Mahar et al., 2006) and simultaneous processing (Gabbard & Barton, 1979) would be enhanced following an acute bout of physical activity. Since successive processing and planning have not been specifically measured post-activity, speculation was not made and the findings will be reported. The



fourth and final objective was to compare the change in each cognitive process for each gender. While it is known that gender differences commonly occur during standard testing situations (Halpern, 2000), it was unknown what would be observed for each gender when comparing scores with and without physical activity.

## Methods

### *General Procedure*

Fourth-grade students were recruited to participate in a PE lesson during school time. Intensity of physical activity was monitored throughout each PE lesson using heart rate monitors. Measures of cognitive function were assessed using four subtests from the Das-Naglieri Cognitive Assessment System (CAS) that targeted attention, simultaneous processing, successive processing, and planning. Testing took place immediately after the PE lesson, as well as on a separate day when the students had no PE class. The control group completed the CAS tests without participating in physical activity both times; while they maintained PE in their curriculum, it was not scheduled for days when testing occurred.

### *Participants*

*Recruitment.* Independent schools in the Niagara region were mailed information packages including a request to study fourth-grade students attending their school. Since we did not receive a response from any schools containing three fourth-grade classes, two volunteering schools that had sufficient class sizes were selected to fulfill the requirement. After receiving principal approval, meetings were scheduled with the classroom teachers to review the study requirements and obtain consent. The teachers



sent information packages home with their students; the packages included a letter of introduction, a parental consent form, and a student assent form (see Appendix A).

*Sample population.* The sample consisted of 60 fourth-grade students (30 males, and 30 females). In the first class, 22 of 23 students (96%) participated, in the second class 19 of 22 students (86%) participated, and in the third class 19 of 22 (86%) participated. This grade has been used in similar studies (Caterino & Polak, 1999; Mahar et al., 2006) and in testing the PASS theory (Naglieri, Prewett, & Bardos, 1989) and the validity of the CAS (Naglieri, 1999). Since physical exertion is required, one student who was physically incapable of attaining MVPA during PE class was excluded from the study.

*Ethics.* The Brock University Research Ethics Board reviewed the research methods and evaluation tools to be used in the study. Also, the board reviewed the letters of introduction to the schools, parents, and students, as well as the consent/assent forms. Clearance was obtained from the board. Participation was voluntary and participants were free to leave the study at any time. All personal data has been kept anonymous and strictly confidential, with information to be shredded one year after completion of the study.

### *Measures*

*Demographic information.* Participants were asked to complete a short demographic questionnaire reporting their age, gender, and ethnicity (see Appendix B). To maintain anonymity, students were assigned numbers and their names were not used on any of the documentation. School administrators were asked to provide each student's





grades based on the most recent report card period. Specifically, grades for mathematics, science, reading, and language arts were requested.

*Moderate-to-vigorous physical activity.* Heart rate monitors were used to measure the intensity of physical activity throughout the PE lesson. A review by Kohl, Fulton, and Caspersen (2000) has shown that heart rate is a valid measure of energy expenditure through comparison with other physiological measurements such as doubly-labeled water. Treiber et al. (1989) found that heart rate monitors are a valid instrument to take readings of children's heart rates while completing various upper and lower body exercises, in both laboratory and field settings. Finally, heart rate monitors have been found to be reliable monitoring devices for children through various test-retest conditions (Kohl et al., 2000).

The researcher tested each monitor for proper function before use in the study, ensuring that the batteries were functioning and each wrist watch was receiving information from its respective chest strap. The Polar S810 monitors were pre-set to record minutes spent in three target zones: moderate (65-74% of maximum heart rate), vigorous (75-90% of maximum heart rate), and above vigorous (91%+), using a maximum heart rate of 210 beats/minute (based on 10 years of age; Physical Activity Resource Centre, 2003). No data was recorded from the other monitors since they did not have the capability to store information. Prior to the PE lessons, each monitor was numbered and the student's assigned case number was also recorded. Every student wore their monitor for the duration of the PE session and they were collected immediately after the lesson.



*Cognitive function.* The Das-Naglieri Cognitive Assessment System (CAS) was used to measure attention, simultaneous processing, successive processing, and planning. Sixteen university students and one professor were trained to administer the tests using the materials prepared for this study (selected tests from the CAS). Also, directions for administering and scoring the subtests were used directly from the CAS manual (Naglieri & Das, 2005; see Appendix D for the examiners instruction manual). The CAS was standardized using 2,200 children aged 5 – 17 in a stratified random sampling across the United States and the subtests and scales have internal consistency reliability coefficients with the full scale ranging from 0.84 to 0.90 (Naglieri, 2005). The CAS has been shown to be valid for diverse students across differences in race, achievement, learning disabilities, and attention-deficit/hyperactivity disorder (Naglieri, 2005). In order to maintain the integrity of the subtests, the planning test was administered first, since it allows for the most flexibility. The attention subtest was administered later since it contains more constraints (Naglieri & Das, 2005). All tasks were administered individually with an examiner and the results for each student were recorded on a standard response sheet (see Appendix E).

Planning was assessed using the Planned Connections subtest. Planned Connections is a trail-making test that contains five items. The first three items require the student to draw a line connecting the numbers in sequential order (similar to “connect the dots”). The last two items require the student to connect numbers and letters, alternating between them (i.e. 1 to A, A to 2, 2 to B, B to 3, 3 to C). The score is based on the amount of time required to complete all five items. See Appendix F for a sample item.



Attention was evaluated using the Expressive Attention subtest, which is a brief version of the Stroop Test. The test is conducted individually with an examiner and consists of three pages but only the third page is scored. On the first page the student is asked to read aloud 40 colour words (BLUE, GREEN, RED, YELLOW) from the stimulus page. The next page asks the students to name the colours of a series of rectangles. Page three presents the same colour words as on page one except this time each word is in a different colour of ink. The child must inhibit their immediate response to read the word. The score is calculated as the ratio of correct responses and the time to complete the third page. See Appendix F for an example of this subtest.

Simultaneous Processing was examined using the Non-verbal Matrices subtest. The Non-Verbal Matrices test was selected, instead of the common Verbal-Spatial relations test, since it does not depend on language skills or the student's ability to differentiate between right and left, making it most suitable for populations that may not speak English as their first language. There are 33 items, each of which contains a matrix of geometric figures with a missing segment. The child must choose the piece that completes the diagram; see Appendix F for a sample item. The score for this test is total number of correct responses over the 33 items.

Successive Processing was assessed using the Sentence Repetition subtest. The examiner read 20 sentences of colour words (e.g., "The red is yellowing") to the student one at a time. The students were asked to repeat each sentence verbatim. The score was the total number of correct responses.





### *Procedures*

Each participating class completed the CAS tests on two days (approximately one week apart). Class One (herein referred to as the intervention group) completed their initial testing after no-activity on week one. On week two they were followed up with a second test after their PE lesson. Class Two (the balance group) was tested using the opposite schedule of Class One (after PE first and with no PE for the second test). Class Three completed both tests with no activity during the preceding periods, providing a control group (see Table 1).

Table 1

#### *Testing schedule*

	Week One	Week Two
Class One (Intervention)	No Activity	Post Activity
Class Two (Balance)	Post Activity	No Activity
Class Three (Control)	No Activity	No Activity

The conditions for each class were randomly assigned before meeting with the teachers. Each group was tested at the same time of day on both occasions and testing for all three classes took place in the afternoon since it has been suggested by Raviv and Low (1990) that time of day can influence student attention. Given that school schedules tend to be consistent, it was expected that the classes would have their PE scheduled at the same time each week. Therefore, tests on week two were completed between six and eight days after the first week's tests.

The PE sessions were conducted by the same PE teacher that typically teaches each class. The same lesson plan was used for both classes and inquiries were made to



make sure the teachers understood the lesson and had everything prepared. The lesson was adapted from the Activ8 physical activity program (Active Healthy Kids Canada, n.d.), since the goal of the lesson was to maintain MVPA for at least 20 minutes. This has been the standard set by the Ontario Ministry of Education (2005) for daily physical activity. Teachers used the Heart Smart lesson of the Activ8 program (see Appendix C) as the main activity, including warm-up and cool-down. Prior to each PE lesson, five male and five female students were randomly selected to wear the ten Polar S810 heart rate monitors that were available. The remaining students wore another model of Polar or a Minder heart rate monitor as a placebo to be inclusive (everyone experienced wearing the monitor and seeing their heart rate readout on the wrist watch).

#### *Data Analysis*

In examining the data, an analysis was conducted using chi-square and ANOVA tests to determine the demographic similarity of the three sample classes to allow further comparison. Descriptive analysis was also used to ensure that the data conformed to the statistical assumptions required to perform parametric statistical procedures. A *t*-test was used to compare time spent at each level of intensity (moderate, vigorous, above vigorous) between the intervention and balance groups. Academic grades were correlated with the student's baseline scores (for students who had no physical activity prior their first testing) in order to confirm that the cognitive tasks used were indicators for academic success. Student scores on the cognitive function tasks were then analysed using paired samples *t*-tests to determine the changes that occurred between week one and week two for each condition; this analysis was repeated with each class divided by gender.



Since sample sizes were small, effect sizes were also calculated for all relevant analyses. For chi-square tests, the phi coefficient was used to determine effect size. Comparisons investigated using ANOVA and *t*-tests had the effect size calculated using Hedge's *g*. While Cohen's *d* describes effect size at the population level, Hedge's *g* is calculated as a sample effect size and is better suited for small samples (Cohen & Lea, 2004). As sample size increases, Hedge's *g* approaches Cohen's *d*. Although arbitrary, Cohen (1988) proposed that an effect size (*ES*) of 0.2 is considered to be a small difference, 0.5 is a moderate difference, and 0.8 is a large difference; these distinctions remain commonly used and will be adhered to in reporting the results of this study. Finally, correlations for Pearson's *r* represent the relative effect of the condition, ranging from -1 to +1, with 0.1 being a small effect, 0.3 moderate, and 0.5 large (Cohen, 1988)

## Results

### *Descriptive Analysis*

All continuous data were analysed for normality using skew and kurtosis and were found to be within an acceptable range (absolute value less than 2.00; Tabachnick & Fidell, 2001). Two cases were missing results for the Sentence Repetition test, due to a lack of time at the school, so these cases were omitted from analysis for that test only. One student was caught looking at an answer key, so her case was removed completely from the study.

*Demographics.* Overall, the sample population had a mean age of 9.72 years (*SD* = 0.36). An ANOVA (using the Bonferroni correction) indicated that mean age was not significantly different between the three classes,  $F(2, 56) = 1.55, p > .05$ . The means for each class were 9.67 years, (*SD* = 0.30), 9.84 years (*SD* = 0.40), and 9.67 years (*SD* =





0.36). Although the effect sizes (Hedge's  $g$ ) between classes one and two and between classes two and three were 0.47 and 0.44, respectively, an age range of 0.17 years (or 2.04 months), is an acceptable range for the cognitive function tests (Das & Naglieri, 1997). According to Das and Naglieri (1997), the norm range of raw test scores for students between 9.33 years and 9.99 years is the same; therefore students within this age range are comparable. The majority of the students were Caucasian ( $n = 56$ ), two were Asian-Canadians and one participant's ethnicity was listed as "Other." The ethnic composition between classes was compared using a 3x3 chi-square analysis and no significant difference was observed,  $\chi^2(4, N = 59) = 2.86, p > .10$  and  $\phi$  (phi coefficient) = 0.22. Comparing class gender, a 2x3 chi-square analysis revealed that there was no significant difference between the three classes,  $\chi^2(2, N = 59) = 3.81, p > .10$  and  $\phi = 0.25$ , although a 2x2 chi-square between the intervention and control class,  $\chi^2(1, N = 40) = 3.68, p = .06$  and  $\phi = 0.30$ , suggests that gender differences should be an area of caution when comparing between these two classes.

*Cognitive function.* The scores for each cognitive function task and condition were evaluated for outliers using box plots. No extreme outliers were found to exceed the limit of three times the inter-quartile range ( $3 \times \text{IQR}$ ) or the "outer fence," however some values were greater than one and a half times the inter-quartile range or the "inner fence." These values, referred to as mild outliers, were not removed since they were within the  $3 \times \text{IQR}$  boundary for extreme values (Frigge, Hoaglin, & Iglewicz, 1989) and they represent the diversity of student aptitude that is expected in a typical class. Removing these values would limit the results and would not represent a standard class.

*Contextual Factors*



*Heart rate.* Data from one heart rate monitor could not be used since the device had slipped out of place on the participant and did not record that individual's heart rate for several minutes. From the remaining monitors, it was found that the intervention group ( $n = 9$ ) spent an average of 5.09 ( $SD = 1.33$ ) minutes in moderate activity, compared to 4.88 ( $SD = 1.09$ ) minutes in the balance group ( $n = 10$ ). Vigorous activity was achieved for 15.46 ( $SD = 2.81$ ) minutes and 14.15 ( $SD = 1.32$ ) minutes in the intervention and balance group, respectively. The students spent some time above the specified vigorous activity zone, specifically 10.45 ( $SD = 3.95$ ) minutes for the intervention class and 8.86 ( $SD = 3.16$ ) minutes for the balance class. A one-way ANOVA resulted in no significant differences between the two groups for all three intensities ( $p > .05$ ). The effect sizes (Hedge's  $g$ ) between the two groups was small for time spent in moderate intensity ( $ES = 0.17$ ) and moderate for both time spent in vigorous intensity ( $ES = 0.58$ ), and time spent above vigorous intensity ( $ES = 0.43$ ). Therefore, the difference in time spent in MVPA is a caution to note when interpreting the results, as the level of physical activity (intensity and time) may influence the changes observed.

*Cognitive function and academic achievement.* A Pearson's  $r$  correlation was conducted between the grades of each academic subject and the four cognitive function tests (see Table 2). Grades were used from the intervention and control group since the balance class had physical activity as a confounding factor for their first time completing the cognitive function tests and a test-retest effect on their second administration of the tests. Marks for science were combined with social science on all of the report cards, due to the standard reporting procedures for fourth-grade students.



Table 2

*Correlations between the cognitive test scores and academic grades*

	Planning	Attention	Simultaneous	Successive
Mathematics	-.28*	.21	.53**	.23
Science/ Social Science	-.37*	.32*	.26	.27
Language Arts	-.02	.19	.34*	.17
Reading	-.04	.19	.36*	.14

\*  $p < .05$ , \*\*  $p < .001$

Planning had a negative relationship with all subjects, which is expected since the Planned Connections task is scored based on time to completion, making a lower score more desirable. Both mathematics and science showed moderate relationships with the planning test scores ( $r = -.28$  and  $r = -.37$ , respectively,  $p < .05$ ). Attention scores were moderately correlated with science ( $r = .32$ ,  $p < .05$ ), but overall showed insignificant correlation values for the other subjects ( $r = .19$  to  $.21$ ,  $p > .05$ ). The students' performance on the simultaneous test was moderately correlated with all four subjects, significantly with language arts and reading ( $r = .34$ ,  $p < .05$ ; and  $r = .36$ ,  $p < .05$ ) and highly significantly with mathematics ( $r = .53$ ,  $p < .001$ ). Lastly, the successive test did not show significant correlations with any of the academic subjects, but there were small correlations found with all four ( $r = 0.14$  to  $r = 0.27$ ). These results indicate that improved performance on specific cognitive function tests was associated with higher academic performance in the related subjects, as assessed using academic grades.

#### *Physical Activity and Cognitive Function*

Paired  $t$ -tests were conducted using the scores from weeks one and two. The changes that were significant in the intervention group (Planned Connections,  $t(20) =$





8.96,  $p < .001$ ; and Expressive Attention,  $t(20) = -4.84$ ,  $p < .001$ ) were also significant in the control group (Planned Connections,  $t(18) = 6.99$ ,  $p < .001$ ; and Expressive Attention,  $t(18) = -2.68$ ,  $p < .05$ ), indicating a possible test-retest effect. Since the group sizes were small ( $n = 17$  to  $21$ ), there was a risk of Type II error (Vincent, 1999); therefore, effect sizes have also been reported. See Table 3 for group mean scores on the cognitive function tests and effect sizes between weeks one and two.

Table 3

*Cognitive function test scores and effect sizes between weeks one and two*

	Planned Connections	Nonverbal Matrices	Expressive Attention	Sentence Repetition
<b>Intervention Group (<math>n = 21</math>)</b>				
Week One Score	252.80 (47.94)	18.33 (3.72)	34.57 (9.89)	9.76 (2.28)
Week Two Score	182.35 (33.79)	19.00 (4.72)	39.86 (10.79)	10.29 (2.17)
Effect Size	1.67***	0.15	0.50***	0.23
<b>Balance Group (<math>n = 19</math>)</b>				
Week One Score	154.05 (38.06)	16.58 (4.43)	42.95 (7.43)	8.79 (1.81)
Week Two Score	124.84 (33.59)	18.00 (4.46)	49.11 (11.98)	9.32 (1.96)
Effect Size	0.80***	0.31	0.61**	0.28
<b>Control Group (<math>n = 19</math>)</b>				
Week One Score	197.47 (46.16)	16.47 (3.45)	46.74 (11.43)	10.06 (2.70) <sup>a</sup>
Week Two Score	156.63 (43.18)	17.74 (3.74)	53.00 (13.84)	10.12 (1.80) <sup>a</sup>
Effect Size	0.89***	0.36	0.48*	0.03

Note: Test scores reported as  $M(SD)$

<sup>a</sup>  $n = 17$

\*  $p < .05$  \*\*  $p < .01$  \*\*\*  $p < .001$  (paired  $t$ -test)

*Planned connections.* The paired  $t$ -test indicated that all three groups had statistically significant improvement ( $p < .001$ ). The balance and control groups showed similar gains in their test scores ( $ES = 0.80$  and  $ES = 0.89$ , respectively), while the intervention group had an even greater improvement with an effect size of 1.67. Since the



intervention group scores improved after participation in physical activity by an effect size greater than the two other groups, this suggests that MVPA may have influenced the students' planning ability and the improved test scores were possibly not due to test-retest effects alone.

*Nonverbal matrices.* None of the groups showed statistically significant differences on the paired  $t$ -test ( $p > .05$ ), however both the balance and control groups showed small to moderate effect sizes ( $ES = 0.31$  and  $ES = 0.36$ , respectively). These similar effect sizes suggest that any improvement in nonverbal matrices on the second testing was potentially due to test-retest effects and not MVPA.

*Expressive attention.* While all groups showed statistically significant improvements (intervention group,  $t(20) = -4.84$ ,  $p < .001$ ; balance group,  $t(18) = -3.85$ ,  $p < .01$ ; control group,  $t(18) = -2.68$ ,  $p < .05$ ), the effect sizes were all moderate ( $ES = 0.48$  to  $ES = 0.61$ ), indicating that the higher scores on week two were possibly due to test-retest effects and not MVPA.

*Sentence repetition.* The control group had very similar scores on both weeks ( $ES = 0.03$ ). The intervention and balance groups had small effect sizes ( $ES = 0.23$  and  $ES = 0.28$ , respectively); however none of the groups showed significant improvement ( $p > .05$ ) when analysed with a paired  $t$ -test. Overall, the results indicate that MVPA did not influence the sentence repetition task.

#### *Gender, Physical Activity, and Cognitive Function*

There was no statistical difference found in cognitive function scores by gender when conducting an ANOVA for all three groups ( $p > .05$ ). Due to small sample sizes ( $n = 6$  to  $13$ ), there was low statistical power and a high probability of Type II error (false



negative; Vincent, 1999). Thus, Hedge's  $g$  was decidedly the best measure to compare test scores. Comparing scores between genders (see Table 4) the effect sizes were at least moderate ( $ES = .50$  or greater) for seven of the 24 comparisons. In five of these seven comparisons, the females had higher scores than the males. The two comparisons for which the males had higher scores were both for the Nonverbal Matrices test; this is consistent with the literature (Halpern & Wright, 1996). Also, see Table 5 for the means, standard deviations, effect sizes and noted significance for each test for males, and Table 6 for the same results for females.

Table 4

*Effect size (Hedge's  $g$ ) of differences in test scores between genders*

	Class One (Intervention)	Class Two (Balance)	Class Three (Control)
<b>Week One</b>			
Planned Connections	0.07	0.55 <sup>b</sup>	0.21
Nonverbal Matrices	0.51 <sup>a</sup>	0.30	0.21
Expressive Attention	0.08	0.25	0.85 <sup>b</sup>
Sentence Repetition	0.51 <sup>b</sup>	0.13	0.14
<b>Week Two</b>			
Planned Connections	0.27	0.01	0.36
Nonverbal Matrices	0.59 <sup>a</sup>	0.44	0.28
Expressive Attention	0.29	0.13	0.79 <sup>b</sup>
Sentence Repetition	0.11	0.06	0.53 <sup>b</sup>

<sup>a</sup> males had higher scores than females

<sup>b</sup> females had higher scores than males

*Planned connections.* All three conditions showed an average decrease in time to complete this task (a lower score is desirable). While the control group did show a large improvement (decreased time to completion) on the second test ( $ES = 0.99$  for males and  $0.80$  for females), the intervention showed even greater improvements ( $ES = 1.42$  for males and  $1.90$  for females). The balance group was split with the females improving by





approximately the same effect size as the control and the males showing moderate improvement. The larger increase by the intervention females indicates that the test-retest effect was not the only factor in their improvement and suggests that MVPA had a positive influence on their planning ability. The intervention males showed a similar result as the intervention females but to a lesser degree. Interestingly, the balance males had a smaller improvement across the two weeks when compared to the control group, suggesting that participating in MVPA on the first week may have resulted in superior baseline test scores.

Table 5

*Cognitive function test scores for males and effect sizes between weeks one and two*

	Planned Connections	Nonverbal Matrices	Expressive Attention	Sentence Repetition
<b>Intervention Group (<math>n = 13</math>)</b>				
Week One Score	252.67 (53.11)	19.08 (4.54)	34.23 (10.83)	9.31 (2.36)
Week Two Score	186.25 (35.37)	20.08 (5.19)	38.62 (9.89)	10.38 (2.26)
Effect Size	1.42 ***	0.20*	0.41**	0.45
<b>Balance Group (<math>n = 10</math>)</b>				
Week One Score	149.60 (42.34)	17.10 (4.98)	41.30 (8.22)	8.70 (2.06)
Week Two Score	125.80 (35.66)	18.90 (4.01)	47.50 (9.02)	9.20 (1.55)
Effect Size	0.58*	0.38	0.69*	0.26
<b>Control Group (<math>n = 6</math>)</b>				
Week One Score	190.33 (50.56)	17.00 (2.83)	40.17 (8.38)	10.50 (3.89)
Week Two Score	145.50 (29.48)	18.50 (4.23)	45.50 (10.52)	9.50 (2.17)
Effect Size	0.99**	0.38	0.51	-0.29

Note: Test scores reported as  $M(SD)$

\*  $p < .05$  \*\*  $p < .01$  \*\*\*  $p < .001$  (paired  $t$ -test)

*Nonverbal matrices.* All groups showed a small improvement ( $ES = 0.21$  to  $0.38$ ) on this task from week one to week two, except for the intervention females who did not



show any increase in test score ( $ES = 0.04$ ). Since the intervention and balance groups did not differ from the control, it seems that all changes in nonverbal matrices scores were due to the test-retest effect and that MVPA did not influence the scores.

*Expressive attention.* The three conditions all showed a moderate increase in attention scores, ranging from an effect size of 0.41 to 0.69. As was found with the nonverbal matrices test, the effect sizes for expressive attention were very similar across all conditions and genders, suggesting that improvement was due to a test-retest effect and that MVPA was not a factor.

Table 6

*Cognitive function test scores for females and effect sizes between weeks one and two*

	Planned Connections	Nonverbal Matrices	Expressive Attention	Sentence Repetition
<b>Intervention Group (<math>n = 8</math>)</b>				
Week One Score	253.00 (42.47)	17.13 (1.25)	35.13 (8.81)	10.50 (2.07)
Week Two Score	176.50 (32.69)	17.25 (3.45)	41.88 (12.55)	10.13 (2.17)
Effect Size	1.90***	0.04	0.59**	-0.17
<b>Balance Group (<math>n = 9</math>)</b>				
Week One Score	159.00 (34.51)	16.00 (3.94)	44.78 (6.40)	8.89 (1.62)
Week Two Score	123.78 (33.24)	17.00 (4.95)	50.89 (14.99)	9.44 (2.24)
Effect Size	0.99**	0.21	0.51	0.27
<b>Control Group (<math>n = 13</math>)</b>				
Week One Score	200.77 (45.75)	16.23 (3.79)	49.77 (11.63)	9.82 (1.99) <sup>a</sup>
Week Two Score	161.77 (48.42)	17.38 (3.62)	56.46 (14.14)	10.45 (1.57) <sup>a</sup>
Effect Size	0.80***	0.30	0.50*	0.34

Note: Test scores reported as  $M(SD)$

<sup>a</sup>  $n = 11$

\*  $p < .05$  \*\*  $p < .01$  \*\*\*  $p < .001$  (paired  $t$ -test)



*Sentence repetition.* Unlike the other tests, there did not seem to be any trend in these results. The scores of the control males and intervention females both decreased, while the intervention males showed a moderate increase. The remaining groups showed small rises in test score. While the lack of trend indicates that there was not the same test-retest effect observed with the other tasks, it also suggests that MVPA was not a factor for this cognitive function.

### Discussion

The main objective of this study was to investigate how acute physical activity might affect cognitive function in the period following PE and to observe the change (or lack of change) for each gender. Each of the four research objectives will be addressed and specifically the cognitive function test scores with and without physical activity between the three classes (intervention, balance, and control), will be discussed. Potential applications of these findings, limitations, and suggestions for future research will also be presented.

The first research objective was to perform a descriptive analysis of the data, ensuring that it met the assumptions required for using statistical parametric procedures. The analysis showed that all of the data did meet these assumptions and thus could be analysed using the chosen statistical procedures. The demographic variables were also compared between classes, and it was found that there were no statistical differences between the groups, suggesting that the groups were similar.

The second research objective was to develop the study context by measuring physical activity intensity and comparing the covalidity of the test scores. Using the heart rate monitors, time spent in each of the intensity ranges (moderate, vigorous, and above





vigorous), was not statistically significant between the intervention and the balance groups. The specific times have been reported in the results section for comparison with future research. In the correlational analysis, attention was significantly correlated with science, but showed low correlations with the other subjects. This result did not seem to follow the same positive correlations found by Zentall (1993) between attention and mathematics, reading, and language arts. Simultaneous processing did show a moderately positive correlation with all four academic subjects, significant ( $p < .05$ ) for all subjects except for science, and highly significant with mathematics ( $p < .001$ ). This finding supports the previous research that students in the current sample with better simultaneous processing skills also perform better in mathematical problem solving, as well as grammar and reading comprehension (Das & Cummins, 1982; Logie, Gillhooly, & Wynn, 1994). Also, Pearson's  $r$  correlation showed successive processing had no significant correlations with any of the academic subjects, which is consistent with the findings of Swanson (1994). However, based on the PASS theory, it would be expected that successive processing would have some correlation with reading (Das & Naglieri, 1997). Academically, planning has been correlated with problem solving skills (Naglieri & Das, 1990); thus it was not surprising to see that planning was moderately correlated with the mathematics grades and science. While these findings do not emulate exactly what has been found in previous literature, the positive correlations that were found do support the tasks as measures of potential academic performance.

The last two objectives were to analyse the differences between each of the groups, comparing the cognitive function test scores with and without physical activity, and also stratified by gender. First, it was hypothesized that improvements in attention



would be observed after physical activity. Interestingly, the positive changes measured in the intervention and balance groups did not seem any greater than that of the control groups, indicating the physical activity did not improve attention for the class as a whole or for either gender. However, not seeing a decrease in attention is a useful finding, as some believe that PE can be detrimental to a student's attention (Tomprowski, 2003). While Caterino and Polak (1999) found that student's attention increased by an effect size of 0.42, a direct measurement of the intensity of the physical activity was not provided and the students were active for 15 minutes, as opposed to 30 minutes in the current study. Caterino and Polak (1999) also did not use the same students as their own baseline. The variance in activity time, between-participant comparisons, and possibly effort, may have influenced this result. It should be noted that the attention test administered to the students specifically measured selective attention, which does not cover the full spectrum of attention. For example, sustained attention may show different results than selective attention, however, the Das-Naglieri Cognitive Assessment System (based on the PASS theory of intelligence) uses selective attention as its measure of the attention component.

Second, based on previous studies using mathematical computations to test working memory (Gabbard & Barton, 1979; McNaughten & Gabbard, 1993), it had been hypothesized that simultaneous processing would improve following physical activity. As was found with attention, the intervention and balance groups showed similar changes to the control groups, indicating that physical activity did not improve (or diminish) simultaneous processing. Students in the previous studies had participated in paced walking (Gabbard & Barton, 1979; McNaughten & Gabbard, 1993), so the intensity of physical activity may have varied. Both studies did report that length of activity time was



a factor in whether or not the students showed improved mathematical computation skills; one study (McNaughten & Gabbard, 1993) found that students needed to be active for 50 minutes in order to measure significant changes. The length of time that the students were active in the current study may have limited the beneficial influence on simultaneous processing.

The greatest difference observed in this study was between the Planned Connection subtest scores. While the intervention group effect sizes improved more than the control (1.67 versus 0.89 overall, 1.42 versus 0.99 for the males, and 1.90 versus 0.80 for the females), the balance group males showed less improvement ( $ES = 0.58$ ). This group did have the best week one score (after physical activity) and therefore may not have had as large of a test-retest effect. According to Luria's theory, the planning process is responsible for a student's ability to self-monitor and regulate his or her own behaviour. This finding may be a step in discovering how students who spend less time in the classroom and more time in PE can increase the "rate of learning per unit of class time" (Taras, 2005, p. 117). It also supports the study by Mahar et al. (2006) that found students were more on-task in the classroom after physical activity. While this connection between physical activity and student self-regulation has been suggested as a possible mechanism (Shephard & Trudeau, 2005), until now it had not been directly evaluated post-activity using a standardized test. Tomporowski (2003) noted in his review that students who have learning and behavioural disorders were reported to show improved on-task behaviour and performance after physical activity. In general, these results suggest that students who have difficulty with self-regulating their behaviour may benefit from having time to be physically active throughout the day. If the class is having





difficulty focusing one day, the teacher may want to rearrange the schedule to provide a physical activity break, which might help regain student focus. It is apparent that there are some potential applications of this finding in education, however caution should be used since the design of this study does not allow for causal links to be made and other confounding variables may have played a role in these improvements (other than the test-retest effect). For example, the students may have had lunch at a different time or have acquired more sleep the night before. No abnormalities in schedule were known (school trips, special lunch days, etc.), so the risk of many students having these confounding factors was reduced.

Lastly, no hypothesis had been made as to how successive processing changes in response to physical activity because of a lack of research on which to base such a prediction. The results seem to be inconclusive of any trend as some scores increased and others decreased, regardless of condition or gender. Therefore, based on the current study and previous research, successive processing ability does not seem to be influenced by physical activity.

In the collection of this data there were some limitations that should be noted. The first item to be considered was the control of environment during the PE classes. The measure of MVPA (heart rate) was included to give an indication of the environment in which the study took place, for comparison with daily physical activity guidelines, and to allow comparison with future studies. Although the heart rate information did show that the intervention group spent an average of 21-91 seconds longer in each zone, some variation was expected due to differences in teachers. Given that the environment was left as undisturbed as possible to provide realistic circumstances, while still attempting to



maintain some consistency between PE lessons, this small variation was not regarded as a major concern. It was surprising to see the number of minutes spent above the vigorous activity zone. It would be interesting to compare these results to other PE classes to ascertain if these figures are typical or may have been a result of known monitoring.

Another limitation was the gender differences between the classes. One class had a disproportionate number of males, while another had a greater number of females. Since the groups were subdivided by gender, sample sizes were smaller and therefore statistical power was low and there was a high chance of Type II error (Vincent, 1999). In light of this, effect sizes and correlations were reported whenever possible. Future research with larger sample sizes would be appropriate to verify that the same observations are made on a larger scale. The results from this study also need to be tested with children in different grades. As Caterino and Polak (1999) found in their study on attention, the results of students in grade four were not the same for students in grades two and three. Therefore, generalizations should not be made to students in other grades.

Finally, since this study was focused on the acute effects of physical activity and the potential physiological changes, it was important that testing was completed immediately following PE and in a timely fashion. As such, testing required up to eight assistants per session. The assistants were volunteers, so it was not possible for everyone to be at every session. In total there were 17 assistants that worked one-on-one with the students to complete the tasks and it was not possible for the same assistant to evaluate the same student both times, possibly introducing some minor inconsistencies between testing sessions. Every attempt was made to reduce this factor by preparing the standardized script for test administration.



This study has attempted to answer the question of how cognitive function may be affected by physical activity. Through a careful study plan, the goal was to reduce the number of possible confounding variables while maintaining a realistic environment within a school. The measure of cognitive function is based on a sound neurobiological theory of human intelligence and has been tested numerous times for validity (Naglieri, 2005). Using this measure, this study has suggested a positive connection between a student's participation in physical activity and their ability to plan, self-regulate, and problem solve. This conclusion was supported by the physiological responses to physical activity that are hypothesized to improved function in the prefrontal cortex. No other study has been found that investigated this link using a standardized test. The connection between physical activity and planning ability may shed some light on the results of past studies, and suggests that future endeavours should be adopted to further explore the benefits of physical activity on student's cognitive abilities. Educators can also take this knowledge and apply it to how they schedule classroom activities.

It is interesting to note that some of the earliest research in this area was being conducted under the notion that physical activity was hypothesized to impair student function (Tomporowski, 2003). Advances, such as the results of this study, are slowly working against those preconceptions. The results presented give rise to many questions to be explored through future research. While the focus of this thesis was on the effect sizes for each group, future analysis may include using more sophisticated statistical procedures, such as ANCOVAs to compare between the groups. In the current study the students were active for a full PE period, but the mandated daily physical activity in Ontario is 20 minutes. It would be very informative to observe what influence of shorter





and longer physical activity times would have on the results. Also, the type of program used for the physical activity session may be important. Perhaps lessons that require team work, for example, will show different results than a lesson designed to improve individual sports skills. Lastly, the sample population examined was only a small representation of students in the Ontario education system. In order to fully understand the impact of physical activity on cognitive function in children, further studies are required to expand our knowledge to other grade levels, compare urban versus rural settings, and provide a better cross-section of the ethnic diversity found in Canada. Answering these questions would build on the foundation provided by this study, providing useful knowledge to educators and school administrators and helping to break down the perceived barriers to providing more effective physical activity programming in schools.



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## Appendix A: Assessment of Environmental and Financial Feasibility

### Appendix A: Assessment of Environmental and Financial Feasibility

#### Appendix A: Assessment of Environmental and Financial Feasibility

Table A.1

#### Table A.1

The following table provides a summary of the environmental and financial feasibility assessment for the proposed project. The assessment was conducted in accordance with the requirements of the Environmental Impact Assessment Act (EIAA) and the Financial Feasibility Assessment Act (FFAA).

### Appendices

The assessment was conducted in accordance with the requirements of the Environmental Impact Assessment Act (EIAA) and the Financial Feasibility Assessment Act (FFAA). The assessment was conducted by a team of experts in the field of environmental and financial feasibility assessment.

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Table A.1

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## Appendix A – Letters of Introduction and Consent Form

### Letter of Invitation for Schools

Principal and HPE Department Head  
School Board

Dear Sir/Madam,

Enclosed please find the materials for a study cleared by Brock University (see attached documentation) entitled *Investigating links between Cognitive Function and Moderate-to-Vigorous Physical Activity in Elementary Physical Education* that I would like to conduct with the grade 4 classes in your school. I am a Masters graduate student within the Department of Physical Education and Kinesiology at Brock University, under the supervision of Dr. Ken Lodewyk. Prior to this, I obtained an Honours Bachelor of Science in Kinesiology from McMaster University and a Bachelor of Education from the University of Western Ontario. The aim of this research is to investigate how physical activity affects cognitive function and may improve academic performance. In the study, students who provide consent will be asked to complete a quick demographic questionnaire that asks them to report their age, gender, and ethnicity. Also, students will be asked to complete four 5-minute cognitive function tasks on two typical school days; one day will be after no physical activity and the other will be after either a prescribed physical education lesson or no physical activity (control group). Physical activity intensity during the physical education lesson will be assessed using heart rate monitors. As part of the study, I would also like to request that participating students' most current academic grades be provided by your school's administrative assistant in order to compare the relationship between their cognitive performance scores and prior academic success.

Participation in the research project will be strictly voluntary and any data collected will remain anonymous. Any data collected as part of the research study will not be viewed by the participant's teacher nor will they be used as part of students' grades. Participating schools will receive a final written report with the anonymous results of the study and the results of the study may also be shared with teachers in the local school district through professional development workshops and publications.

If you have any questions or concerns about this study please contact me at (905) 529-1794 or [melissa.pirrie@brocku.ca](mailto:melissa.pirrie@brocku.ca), or my supervisor, Ken Lodewyk, at (905) 688-5550 ext. 5220 or [klodewyk@brocku.ca](mailto:klodewyk@brocku.ca). I will contact you by phone in the following days to discuss my request. Thank you *very much* for considering it.

Sincerely,

Melissa Pirrie, B.Sc, B.Ed  
Brock University

Ken Lodewyk, Ph.D  
Brock University



### Informed Consent Form (School)

STUDY TITLE: Investigating links between Cognitive Function and Moderate-to-Vigorous Physical Activity in Elementary Physical Education

Principal Investigator: Melissa Pirrie      Faculty Supervisor: Dr. Ken Lodewyk

- Volunteering schools are agreeing to allow the research to contact the grade four classroom and physical education teachers to request participation in this study.
- Volunteering classroom teachers will be asked to provide two periods of class time divided between two separate days for the cognitive tasks to be completed. One of these classes must be in the time slot immediately following the students' physical education period and the second must at approximately the same time of day when the student does not have physical education. Also, I would be requesting that the teacher prepare an alternate activity for any students who do not provide a completed consent form.
- Volunteering physical education teachers will be requested to follow the prescribed Activ8 Heart Smart lesson during the period preceding the cognitive testing. This lesson has been developed by the Ontario Physical and Health Education Association. Also, the teacher will be required to meet with myself prior to the lesson to ensure that everything has been prepared and to answer any questions that you may have.
- Participation in this study is voluntary and you may withdraw from the study at any time and for any reason without penalty.
- There will be no payment for your participation although participating schools will also be able to request professional development workshops for their teachers based upon the methods and results of the study. The results may be published in or presented at various professional and scholarly journals or conferences. The scientific community/society will also benefit since the information gathered from this study should help to fill a "gap" in the theoretical and research literature about physical activity affects students' cognitive function.
- This study has been reviewed and obtained clearance by the Brock Research Ethics Board (File #07-097).
- If you have any questions or concerns about your participation in the study, you may contact Melissa Pirrie (905-529-1794 or [melissa.pirrie@brocku.ca](mailto:melissa.pirrie@brocku.ca)), Ken Lodewyk (905-688-5550 ext. 5220 or [klodewyk@brocku.ca](mailto:klodewyk@brocku.ca)), or the Brock University's Research Ethics Officer (905-688-5550 ext. 3035 or [reb@brocku.ca](mailto:reb@brocku.ca)).
- If requested, feedback about the use of the data collected will be sent to you during the Fall of 2008. Please provide your name and mailing address on the back of this page if you wish to have the information sent to you.
- Please keep the top portion of this consent form, but complete, detach, and submit the bottom portion to the researcher as soon as is convenient.
- Thank you for considering your participation in this important initiative!

#### CONSENT FORM

School Authority's Name: \_\_\_\_\_ School: \_\_\_\_\_

☐ I have read and understood all relevant information pertaining to this study

☐ I understand that I may ask questions in the future

☐ I will voluntarily participate in the Brock University study as described herein and conducted by Melissa Pirrie.

☐ I will not participate in the Brock University study as described herein and conducted by Melissa Pirrie

Signature of School Authority: \_\_\_\_\_ Date: \_\_\_\_\_

Signature of Researcher: \_\_\_\_\_ Date: \_\_\_\_\_





### Letter of Invitation for Teachers

Date \_\_\_\_\_

Dear Classroom and Physical Education Teacher:

I am writing to ask you to participate in a research study entitled *Investigating links between Cognitive Function and Moderate-to-Vigorous Physical Activity in Elementary Physical Education* that I would like to conduct with the grade 4 classes at your school. The aim of this research is to investigate how physical activity affects cognitive function and may improve academic performance.

Please let me introduce myself, my name is Melissa Pirrie and I am a Masters graduate student within the Department of Physical Education and Kinesiology at Brock University, under the supervision of Dr. Ken Lodewyk. Prior to this, I obtained an Honours Bachelor of Science in Kinesiology from McMaster University and a Bachelor of Education from the University of Western Ontario. The study that I would like to conduct will help to fill a “gap” in our knowledge of how physical activity affects the cognitive function of students in a school atmosphere. As part of this study, I will be asking students in your class to complete a short, anonymous demographic questionnaire asking the student their age, gender, and ethnicity. This will help me to know how similar the classes are for comparison of the data. Also, on two typical school days I will be asking the students to conduct four 5-minute tasks of cognitive function, conducted by individuals from the university. One day of testing will occur after the students have had no physical activity and the other will occur either after a prescribed physical education lesson or after no physical activity (control group). The control group will have the option to participate in the physical education lesson on a non-testing day. Students will wear heart rate monitors during the physical education lesson to monitor the intensity of physical activity.

As a classroom teacher, I will be requesting that you provide two periods of class time divided between two separate days for the cognitive tasks to be completed. One of these classes must be in the time slot immediately following the students' physical education period and the second at approximately the same time on a day when the student does not have physical education. During each testing period the students will be asked to complete four tasks one-on-one with an examiner. It is expected to take approximately 40 minutes to test the entire class. During this time the teacher will be asked to provide an activity that the students can work on while it is not their turn to complete the tasks and for those who have not provided consent. This activity should not require a lesson or presentation of material as there will be some disruption with students coming and going. For example, the students may be assigned an individual reading activity. Lastly, I will be asking for your assistance in collecting the parent and student consent forms.

As a physical education teacher, I will be requesting that you follow the prescribed Activ8 Heart Smart lesson during the period preceeding the cognitive testing. This lesson has been developed by the Ontario Physical and Health Education Association. Also, you will be required to meet with myself prior to the lesson to ensure that everything has been prepared and to answer any questions that you may have.





*Participation in the research project will be strictly voluntary and any data collected will remain anonymous. Participating schools will receive a final written report with the anonymous results of the overall study. The overall results of the study may also be shared with teachers in the local school district through professional development workshops and the results may be published in or presented at various professional and scholarly journals or conferences. Any presentation, report, or publication resulting from this study will not contain any identifiable information regarding you, the class, the school, or the school district.*

*This study has been reviewed and received clearance from the Ethics Review Committee of Brock University (File #07-097), the school board and the school's principal. Should you participate, you will have the option of withdrawing from the study at any time for any reason without consequence. There are no known risks associated with this study. A copy of the questionnaire, cognitive tasks, and physical education lesson we are asking your students to complete will be available for review in the principal's office should you desire to do so.*

If you have any questions or concerns about this request, please contact Melissa Pirrie (905-529-1794 or [melissa.pirrie@brocku.ca](mailto:melissa.pirrie@brocku.ca)), Ken Lodewyk (905-688-5550 ext. 5220 or [klodewyk@brocku.ca](mailto:klodewyk@brocku.ca)), or the Brock University's Research Ethics Officer (905-688-5550 ext. 3035 or [reb@brocku.ca](mailto:reb@brocku.ca)). Thank you *very much* for enhancing the experience of physical education through your involvement in this study.

Sincerely,

Melissa Pirrie, B.Sc, B.Ed  
Brock University

Ken Lodewyk, Ph.D  
Brock University



### Informed Consent Form (Teachers)

STUDY TITLE: Investigating links between Cognitive Function and Moderate-to-Vigorous Physical Activity in Elementary Physical Education

Principal Investigator: Melissa Pirrie      Faculty Supervisor: Dr. Ken Lodewyk

- Volunteering classroom teachers will be asked to provide two periods of class time divided between two separate days for the cognitive tasks to be completed. One of these classes must be in the time slot immediately following the students' physical education period and the second at approximately the same time of day when the student does not have physical education. Also, I would be requesting that you prepare activity for students to work on for those who do not provide a completed consent form and for those who are waiting their turn or who have already completed the tasks.
- Classroom teachers will be asked to assist in the collection of student consent forms.
- Volunteering physical education teachers will be requested to follow the prescribed Activ8 Heart Smart lesson during the period preceding the cognitive testing. This lesson has been developed by the Ontario Physical and Health Education Association. Also, you will be required to meet with myself prior to the lesson to ensure that everything has been prepared and to answer any questions that you may have.
- Participation in this study is voluntary and you may withdraw from the study at any time and for any reason without penalty.
- There will be no payment for your participation although participating schools will also be able to request professional development workshops for their teachers based upon the methods and results of the study. The results may be published in or presented at various professional and scholarly journals or conferences. The scientific community/society will also benefit since the information gathered from this study should help to fill a "gap" in the theoretical and research literature about physical activity affects students' cognitive function.
- This study has been reviewed and obtained clearance by the Brock Research Ethics Board (File #07-097), the school board and the school's Principal.
- If you have any questions or concerns about your participation in the study, please contact Melissa Pirrie (905-529-1794 or [melissa.pirrie@brocku.ca](mailto:melissa.pirrie@brocku.ca)), Ken Lodewyk (905-688-5550 ext. 5220 or [klodewyk@brocku.ca](mailto:klodewyk@brocku.ca)), or the Brock University's Research Ethics Officer (905-688-5550 ext. 3035 or [reb@brocku.ca](mailto:reb@brocku.ca)).
- If requested, feedback about the use of the data collected will be sent to you during the Fall of 2008. Please provide your name and mailing address on the back of this page if you wish to have the information sent to you.
- Please keep the top portion of this consent form, but complete, detach, and submit the bottom portion to the researcher as soon as is convenient.
- Thank you for considering your participation in this important initiative!

#### CONSENT FORM

Teacher's Name: \_\_\_\_\_

- ☐ I have read and understood all relevant information pertaining to this study
- ☐ I understand that I may ask questions in the future
- ☐ I will voluntarily participate in the Brock University study as described herein and conducted by Melissa Pirrie.
- ☐ I will not participate in the Brock University study as described herein and conducted by Melissa Pirrie

Signature of Teacher: \_\_\_\_\_ Date: \_\_\_\_\_

Signature of Researcher: \_\_\_\_\_ Date: \_\_\_\_\_





### Letter of Invitation for Parent/Guardian

Date \_\_\_\_\_

Dear Parent(s) or Guardian(s):

The following letter and consent form are to inform you of a study I wish to conduct within your son/daughter's class and to ask your permission for him or her to participate in the study. The title for this study is called: *Investigating links between Cognitive Function and Moderate-to-Vigorous Physical Activity in Elementary Physical Education*.

I am a Masters graduate student within the Department of Physical Education and Kinesiology at Brock University, under the supervision of Dr. Ken Lodewyk. Prior to this, I obtained an Honours Bachelor of Science in Kinesiology from McMaster University and a Bachelor of Education from the University of Western Ontario. This research investigates how physical activity can affect cognitive function and possibly improve academic performance. I would like your son and/or daughter to participate.

Students who provide informed consent will be asked to complete a short anonymous demographic questionnaire (age, gender, and ethnicity) to provide an overview of the class' characteristics. Also, students will complete four 5-minute tasks of cognitive function (such as attention) on two typical school days; once after no physical activity and again on another day either after a physical education lesson or after no activity. Two of the four tasks will be completed simultaneously as a class and two will be completed individually (one-on-one). As a result of individual testing, there will be some disruption to the normal classroom activities. Students who are waiting their turn to complete the tasks or who have already completed the tasks will be provided with an activity to work on by the teacher that does not require new material to be taught in front of the class. During the physical education lesson, heart rate monitors will be worn to monitor physical activity intensity. Participants also agree to allow their most recent course grades to be provided to the researcher by the school administration. Any student choosing not to participate will work quietly in the same classroom on the activity provided by the teacher, however they will not complete the cognitive tasks and will not wear a heart rate monitor during the physical education lesson.

*Participation in the research project will be strictly voluntary and any data collected will remain anonymous. Students do not have to participate in the research project if they choose not to. Any data collected as part of the research study will not be viewed by the participant's teacher nor will they be used to determine student grades. Participating schools will receive a final written report with the anonymous results of the overall study. The overall results of the study may also be shared with teachers in the local school district through professional development workshops and the results may be published in or presented at various professional and scholarly journals or conferences. Any presentation, report, or publication resulting from this study will not contain any identifiable information regarding your son/daughter or their school or school district.*

*This study has been reviewed and received clearance from the Ethics Review Committee of Brock University (File #07-097), the school board and the school's principal. Should*





*you allow your son/daughter to participate, you and/or your son/daughter will have the option of withdrawing from the study at any time for any reason without consequence. Simply inform one of the researchers, teachers, or principal that you wish to withdraw from the study and your information will be removed upon your request. As well, you and your son/daughter have the right to not answer any question that you or your son/daughter consider inappropriate. There are no known risks associated with this study. A copy of the questionnaire, cognitive tasks, and physical education lesson we are asking the participants to complete will be available for review in the principal's office should you desire to do so.*

If you have any questions or concerns about this request, please contact Melissa Pirrie (905-529-1794 or [melissa.pirrie@brocku.ca](mailto:melissa.pirrie@brocku.ca)), Ken Lodewyk (905-688-5550 ext. 5220 or [klodewyk@brocku.ca](mailto:klodewyk@brocku.ca)), or the Brock University's Research Ethics Officer (905-688-5550 ext. 3035 or [reb@brocku.ca](mailto:reb@brocku.ca)). Your written consent is needed to allow your son/daughter to participate. To indicate your consent, please complete the enclosed CONSENT FORM and return it to your son/daughter's classroom teacher as soon as possible. As well, if you wish to receive a summary of the results, please provide your contact information on the back of the informed consent form. Thank you *very much* for enhancing the experience of physical education through your involvement in this study.

Sincerely,

Melissa Pirrie, B.Sc, B.Ed  
Brock University

Ken Lodewyk, Ph.D  
Brock University



### Informed Consent Form (Parents)

**STUDY TITLE:** Investigating links between Cognitive Function and Moderate-to-Vigorous Physical Activity in Elementary Physical Education

Principal Investigator: Melissa Pirrie      Supervisor: Dr. Ken Lodewyk, Brock University

- Volunteering students will be asked to complete a short demographic questionnaire. They will also be asked to complete four 5-minute tasks of cognitive function (such as attention) on two occasions: after no physical activity and after a physical education lesson. Participants agree to wear a physical activity monitor (i.e. Heart rate monitor) during the physical education lesson. Participants also agree to allow their most recent course grades to be provided to the researcher by the school administration.
- There are no known risks associated with this study. Completing the tasks will likely be a fun activity for the students. Students who choose not to participate will work quietly in the same classroom on an activity designed by the classroom teacher.
- All personal data will be kept strictly confidential and anonymous (the students' names will not be requested on the questionnaire) so your son/daughter's name will not be associated with his/her answers and scores. Only the researchers will have access to the data, which will be stored in a locked office. All data will be shredded one year after the completion of the study.
- Your son/daughter's participation in this study is voluntary and you and/or your son/daughter may withdraw from the study at any time and for any reason without penalty. Your son/daughter's teacher will not have any access to the completed questionnaires or tasks and their responses and scores will not influence their grades. There will be no payment for your son/daughter's participation.
- Participating schools will also be able to request professional development workshops for their teachers based upon the methods and results of the study. Results of the study may be published in or presented at various professional and scholarly journals or conferences.
- There is no obligation for your son/daughter to answer any question that you or your son/daughter consider inappropriate. Before deciding to participate or anytime during or after the study, parents and participants are also welcome to view a copy of the tests, which are available in the principal's office at the school.
- This study has been reviewed and cleared by the Brock Research Ethics Board (File #07-097), and the school's Principal. If you have any questions or concerns about your participation in the study, please contact Melissa Pirrie (905-529-1794 or [melissa.pirrie@brocku.ca](mailto:melissa.pirrie@brocku.ca)), Ken Lodewyk (905-688-5550 ext. 5220 or [klodewyk@brocku.ca](mailto:klodewyk@brocku.ca)), or the Brock University's Research Ethics Officer (905-688-5550 ext. 3035 or [reb@brocku.ca](mailto:reb@brocku.ca)).
- If requested, feedback about the use of the data collected will be sent to you during the Fall of 2008. Please provide your name and mailing address on the back of this page if you wish to have the information sent to you.
- Please complete the bottom portion of this consent form and then detach it (keep the top portion for your information) and return it to your son/daughter's physical education teacher as soon as possible. Thank you for considering your participation in this study!

#### CONSENT FORM

Student's Name: \_\_\_\_\_

☐ I have read and understood all relevant information pertaining to this study

☐ I understand that I may ask questions in the future

☐ I will voluntarily participate in the Brock University study as described herein and conducted by Melissa Pirrie.

☐ I will not participate in the Brock University study as described herein and conducted by Melissa Pirrie

Signature of Parent: \_\_\_\_\_ Date: \_\_\_\_\_

Signature of Researcher: \_\_\_\_\_ Date: \_\_\_\_\_





## Child Assent Form

Welcome! We would like you to participate in our research program.

### What is it?

A research study to help us understand more about how being physically active might help you perform in school.

### What do I have to do?

- You may be asked to participate in a physical education lesson that is designed to keep you active, working your heart and getting your blood pumping.
- During the physical education lesson, you may be asked to wear a heart rate monitor. The monitor is like a belt that goes around your rib cage and has a watch that goes on your wrist.
- On one day you will be asked to complete four tasks that will take about five minutes each to complete. The tasks will be completed one-on-one with an individual helping with the study. Your teacher will not be shown any of your results and they will not affect your grades in any way.
- You will also be asked to complete the same four tasks on another day, possibly after physical education.
- When you complete the tasks, you will also be asked to complete a very quick questionnaire listing your age, gender, and ethnicity.
- Your grades will be requested from the office to compare with your results on the study tasks.
- If you would like to participate, you will need to have a consent form signed by a parent/guardian and the bottom of this form needs to be formed by yourself. These forms should be returned to your home room teacher as soon as possible.

### Who can I talk to if I have questions?

1. Brock Ethics Officer – This person is responsible for making sure that you are comfortable with your participation in the study. They are not involved in the study and can help you with any concerns. You can contact them at 905-688-5550 ext. 3035 or [reb@brocku.ca](mailto:reb@brocku.ca).
2. Melissa Pirrie – I'm the main researcher working on this study. You can talk to me while I'm at the school or I can be contacted at 905-529-1794 or [melissa.pirrie@brocku.ca](mailto:melissa.pirrie@brocku.ca).
3. Ken Lodewyk – The supervisor of the research study. He can be contacted at 905-688-5550 ext. 5220 or [klodwyk@brocku.ca](mailto:klodwyk@brocku.ca).
4. School counsellor or teacher (names provided here)

### What if I don't want to participate?

If you do not want to participate, then this can be marked on the consent form and returned to the school. By doing this, you will not be asked to complete the questionnaire or any tasks and you will not be asked to wear the heart rate monitor during the physical education lesson. Also, if you decide at any time that you do not want to participate in any part of the study, you can let your teacher or the researcher know and you will not have to participate.





**ASSENT FORM**

Student's Name: \_\_\_\_\_

- ☐ I have read and understood the information about this study
- ☐ I understand that I may ask questions in the future
- ☐ I will voluntarily participate in the Brock University study as described here.
- ☐ I will not participate in the Brock University study as described here.

Signature of Student: \_\_\_\_\_

Date: \_\_\_\_\_

Signature of Researcher: \_\_\_\_\_

Date: \_\_\_\_\_



## Appendix B – Demographic Questionnaire

General Information

1. Your Date of Birth: Day \_\_\_\_ Month \_\_\_\_ Year \_\_\_\_

2. Gender (circle one): Male Female

2. Your Ethnic Background (circle one):

Afro-Canadian or Black

Asian-Canadian

Caucasian or White

Hispanic/Spanish Speaking

Other: \_\_\_\_\_



## Appendix C – Activ8



activ8 is a curriculum-based physical activity challenge program intended to help students, particularly those who are less active, develop a positive attitude about participating in physical activity.

activ8 emphasizes personal development and the recognition of that personal development.

Core to the program are eight developmentally appropriate and modifiable physical activity challenges for each grade that are designed to motivate students to be physically active.

activ8 is comprised of eight flexible and easy-to-use lessons, that culminate in a "Challenge Day" - a celebration of individual student achievement.







## Heart Smart

### Description

Ten minutes of mixed aerobic activities.

### Student Learning

1. Physical Fitness - endurance
2. Movement Concepts - body awareness

### Materials

- Music
- Aerobic activities posted on wall charts

### Challenge Check and Reflect

Consider strategies to determine if student learning occurred. See the Challenge Check and Reflect in the Appendix.

## Learning Strategies

### Warm-Up

#### Leader of the Pack

- Divide students into four groups.
- Each group forms a single line. The first student in line is the leader.
- When the music begins, the leader moves, and the group follows: hopping, twisting, rolling, moving forward, backwards, sideways, diagonally or in a zigzag.
- When the music stops or on a signal, the leader moves to the end of the line, and the next student becomes the new leader.

### Challenge Development

#### Changing Homes

- Maintain groups from previous activity.
- Assign each group a "home" (corner) of the gym and ask groups to choose a name related to a theme. For example, if the theme is 'The Flintstones', the groups might be called, Fred, Barney, Bam Bam, and Pebbles.
- Each group stands in their corner of the gym to begin.
- Call out two group names (e.g., Fred and Barney), and the two groups switch homes.
- Ask groups to run, jog, walk, hop, or skip as they move.
- Each group moves to the new corner as quickly as possible.
- Establish a safe zone so students stop well before the wall.
- To increase the challenge, add a time element. Challenge students to get to their new home as quickly as possible and hold a pose there.



### Challenge #2

#### HEART SMART

- Maintain same four groups and position in four corners of the gym.
- Play music while each group chooses two aerobic activities to present to the class, such as knee lifts, running on the spot, hip hop dance moves.
- Each group prepares to lead the class in this activity for two and a half minutes.
- After five minutes of preparation, start the activity. Point to a group to begin the first activity. The rest of the class follows their lead.
- Students jog or step-touch on the spot between activities.
- Point to the next group to lead an activity.
- Students complete 10 minutes of continuous aerobic activity.





## Challenge Application

### Keep Smiling

- Students work as a group to complete all of the activities listed on a wall chart that is posted in their corner of the gym. Students develop a strategy to complete the activities as quickly as possible with all group members working together.



Sample activity list:

1. Touch the middle of each sideline and endline of the gymnasium - these lines should be away from the wall. Otherwise, provide a slow down zone.
2. Perform eight knee lifts in each corner.
3. Jog around the boundaries twice. Jog forward on the sideline and backwards on the endlines.
4. Touch every circle in the gym with one knee and opposite hand.
5. Do eight tuck jumps in your corner.
6. Perform eight curl-ups in another corner of the gym.
7. Jump over and back on 10 different lines.
8. Side step around the boundaries.
9. Give a high five to eight different people.
10. Perform a balance with a partner.
11. Do four half jump-turns on the spot, then do two full jump-turns. Jump first in one direction, then in the opposite.

## Cool-Down/Wrap-Up

### Stretch Wave

- Students stand in a circle.
- Begin by holding a stretch.
- Students copy the stretch one at a time, moving into the stretch position in sequence around the circle (the wave).
- Students hold that stretch position until the leader introduces a new stretch.
- The person beside the leader copies the stretch, then one at a time, moving around the circle, each person moves into the new stretch position.
- Challenge students to focus on holding the stretch and only moving into the new stretch when the person beside them moves into that stretch.

### Notes to Teacher

- Remind students to use proper form (see Appendix) when stretching.
- It's recommended that you experiment with creative ways of forming groups; e.g., birth month, colour of printing on T-shirt, or sock colour.
- While students are stretching, discuss the importance of developing endurance. Students can share examples of activities they do that help to build their endurance, e.g., biking, swimming, jogging, in-line skating.
- Discuss what components of fitness were addressed by the activities in the Keep Smiling activity. See [www.poguide.ca](http://www.poguide.ca) for further information related to children's physical activity guidelines.

#### Increasing the Challenges

- Increase the intensity by playing faster music.
- Increase the complexity of the moves/activities.

#### Decreasing the Challenges

- Decrease the intensity but continue to move, such as step-touching or marching on the spot.
- Decrease the complexity of the move or allow students to substitute.
- Use smaller actions.







## Appendix D – Examiner's Instructions

**Test #1 Planned Connections**

Materials: Student Workbook, Stopwatch (Maximum Time: 180 seconds/item)

1 – Expose Sample A

2 – **“Look at this page”** (Point to page)

3 – **“Draw a line from the number 1 to the number 2, 2 to 3, 3 to 4, and 4 to 5”** (Hand them the pen and provide assistance if necessary).

4 – **“I’m going to give you more of these to do. You should always start from the number 1 (point to the number 1) and draw a line from one number to the next until you get to the last number (point to the number 5). Work as quickly as you can without making a mistake, and tell me when you’re finished. Ready?”** Explain again if necessary.

6 – Expose each item (4-6) and say, **“Now do this one. Begin here.”** (Point to the number 1 and start timing)

7 – Stop timing when the child reaches the last number. Record times on the student's score sheet.

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8 – **“Put down the pen for now.”** Expose Sample B.

9 – **“Look at this page. There are numbers and letters. This time you are to draw a line from the number to the letter and then to the next number, like this.”** Using your finger, trace over the sequence and say, **“1 to the letter A, A to the number 2, 2 to the letter B, B to the number 3, 3 to the letter C, and so on.”**

10 – **“Now you do it with the pen.”** If the student needs help, repeat #9 while they draw it.

11 – **“I’m going to give you more of these to do. You should always start from the number 1 (Point to number 1.) Draw a line from the number to the letter, then from the letter to the number, and so on until you get to the last letter (Point to D.) Work as quickly as possible without making a mistake, and tell me when you’re finished. Ready?”**

12 – Expose each item (7-8) and say, **“Now do this one. Begin here.”** (Point to the number 1 and start timing).

13 – Stop timing when the child reaches the last letter. Record time.





Additional Instructions:

- If the child makes a mistake, keep timing and immediately say, **"Wait, you made a mistake. Begin again from here"** (and point to the last correct location)." Do not allow the child to erase an error.
- If the child reaches the time limit, say **"Stop,"** record 181, and continue with the next item.

## Test #2 Nonverbal Matrices

Materials: Diagrams

1 – Expose Item 7 and say, **"Look at this page. There is a piece missing here** (Point to the question mark.) **Which one of these** (point to the five options in a sweeping motion) **goes here?** (Point to the question mark)"

- If response is correct (option 1), say: **"Yes, that's the right one because it is all yellow,"** and record on the student score sheet.
- If response is incorrect, say: **"This is the right one because it is all yellow."** (Point to option 1). Provide an explanation if necessary and continue.

2 – For each item (8-33) say as needed, **"There is a piece missing here** (Point to the question mark.) **Which one of these** (point to the five options in a sweeping motion) **goes here?** (Point to the question mark)"

3 – When the complete question is no longer necessary, say **"Now do this one."**

4 – If the student does not provide a response after about 60 seconds, encourage the child to choose one of the options. If they still do not offer a response, say, **"Let's try the next one"** and expose the next item.

5 – Discontinue after 4 consecutive items are failed.



## Test #3 Expressive Attention

Materials: Diagrams, Stopwatch

Additional Instructions:

- Only correct errors on the samples, not on the test items. The students are permitted to make self-corrections.

1 – Expose Sample D. **“Look at this page. It has the words BLUE, YELLOW, GREEN, and RED on it. Read all the words on this page as fast as you can. Begin here (point to the top row) and go this way (sweep along the row). When you finish this row, go on to the next one. (Point to the second row in a sweeping motion) Ready? Begin.”**

2 – Correct the child immediately, if necessary. Record incorrect responses on student score sheet.

3 – **“I’ll show you another page with the words BLUE, YELLOW, GREEN, and RED on it. Read all the words without skipping any. Begin as soon as I turn the page, and do it as fast as you can. Ready?”**

4 – Expose Item 4 and say, **“Begin”**. Start timing as the child says the first word. Record incorrect responses and completion time. If the child is still working after 180 seconds, say: **“Stop”** and record 181 seconds.

5 – Expose Sample E. **“Look at this page. Tell me the colours on this page as fast as you can. Begin here (point to the top row) and go this way (sweep along the row). When you finish this row, go on to the next one. (Point to the second row in a sweeping motion) Ready? Begin.”**

6 – Correct the child immediately, if necessary. Record incorrect responses on student score sheet.

7 – **“I’ll show you another page with the colours BLUE, YELLOW, GREEN, and RED on it. Tell me all the colours on the page without skipping any. Begin as soon as I turn the page, and do it as fast as you can. Ready?”**

8 – Expose Item 5 and say, **“Begin”**. Start timing as the child says the first colour. Record incorrect responses and completion time. If the child is still working after 180 seconds, say: **“Stop”** and record 181 seconds.

9 – Expose Sample F. **“Look at this page. It has the words BLUE, YELLOW, GREEN, and RED on it, and they are printed in different colours. Tell me the**



colour each word is printed in. Do it as fast as you can. What do you say for this one? (Point to the first row)"

- If the child says "red", say: **Good. You said "Red" because the color the word is printed in is red.**
- If the child does not say "red," say: **You should have said "red" because the colour the word is printed in is red.**

10 – **"Now do the rest of these. Begin here** (point to the second word on the top row) **and go this way** (sweep along the row). **When you finish this row, go to the next one. Remember, tell me the colour the word is printed in. Ready? Begin."**

11 – Correct the child immediately, if necessary. Record incorrect responses on student score sheet.

12 – **"I'll show you another page. Tell me the colour each word is printed in without skipping any. Begin as soon as I turn the page, and do it as fast as you can. Ready?"**

8 – Expose Item 6 and say, **"Begin"**. Start timing as the child says the first colour. Record incorrect responses and completion time. If the child is still working after 180 seconds, say: **"Stop"** and record 181 seconds.





## Test #4 Sentence Repetition

Materials: None

Comments:

- Read each sentence in a very clear manner, in a normal reading voice, and drop your voice when the last word of the sentence is spoken.
- In the larger sentences, commas indicate how the words should be grouped.

1 – “I’m going to say a sentence, and when I’m through, I want you to say it just as I did. The sentences are not real ones, so listen carefully and be sure to wait until I’ve finished before you repeat what I said. Ready?”

2 – Sample A, say, “**The blue is yellowing**”. If necessary, say: “**Say what I said**”.

- If the response is correct, say: **Good**.
- If the response is incorrect, say: **Listen again and say what I say. The blue is yellowing.** (Encourage the child to say the sentence).

3 – Sample B, say, “**The red browned**”. If necessary, say: “**Say what I said**”.

- If the response is correct, say: **Good**.
- If the response is incorrect, say: **Listen again and say what I say. The red browned.** (Encourage the child to say the sentence).

4 – Continue for items 1 through 20, but reading each sentence only once, until the child has failed 4 consecutive items.

Item 1:       **The white is blue.**

Item 2:       **The reds are black.**

Item 3:       **The yellow greened the blue.**

Item 4:       **The yellow and green brown the purple.**

Item 5:       **The yellows have pinked a blue brown.**

Item 6:       **The purple is blacking to tan the gray.**

Item 7:       **The blue whites the gray with red.**

Item 8:       **The red blued the green with a yellow.**

Item 9:       **The purple yellows are green and the reds are white.**



- Item 10: The green reds the blue and yellows the brown.
- Item 11: The red who blues yellow, browned on the green.
- Item 12: The tan greened to the black, and the purple grayed to the white.
- Item 13: The purple blued at the green, when the gray yellowed at the pink.
- Item 14: Red blues to pink the green purple, but not the brown purple.
- Item 15: The white that greened a yellow pink, blacked a tan that browned the red.
- Item 16: The brown that grayed the blue white, pinked the green to black a red.
- Item 17: The red that tanned the blue to the black, greened before pink yellowed gray.
- Item 18: Brown blues green, but green blues the pink who reds in the purple white.
- Item 19: The purple blacked the gray with a pink, when the tan greened the yellow to brown.
- Item 20: The blue reds a green yellow of pinks, that are purple in the brown, and then grays the tan.



# Appendix E: Standard Response Sheet

## Student Score Sheet

Student ID: \_\_\_\_\_

Planned Connections (Time in seconds):

Item 4: \_\_\_\_\_ Item 5: \_\_\_\_\_ Item 6: \_\_\_\_\_ Item 7: \_\_\_\_\_ Item 8: \_\_\_\_\_

Nonverbal Matrices (Circle Correct)

7(1) 8(4) 9(2) 10(4) 11(5) 12(2) 13(4) 14(2) 15(1) 16(3) 17(2) 18(3) 19(5) 20(4)  
 21(4) 22(2) 23(6) 24(2) 25(3) 26(6) 27(3) 28(1) 29(1) 30(2) 31(5) 32(6) 33(4)

Expressive Attention (Mark incorrect answers and enter time, in seconds, below):

Sample D

blue	yellow	green	red
green	red	yellow	blue

Sample E

red	green	blue	yellow
yellow	blue	green	red

Sample F

red	green	blue	yellow
yellow	blue	green	red

Item 4

red	blue	green	yellow	red
yellow	green	red	blue	yellow
red	yellow	yellow	green	blue
green	blue	green	red	blue
green	yellow	red	yellow	green
red	blue	red	green	yellow
blue	green	yellow	red	blue
yellow	blue	red	green	blue

Item 5

blue	green	yellow	green	yellow
red	yellow	blue	yellow	blue
yellow	red	green	red	green
red	green	red	blue	green
red	green	yellow	green	red
blue	yellow	blue	red	blue
yellow	red	red	blue	yellow
blue	green	blue	yellow	green

Item 6

blue	green	yellow	green	yellow
red	yellow	blue	yellow	blue
yellow	red	green	red	green
red	green	red	blue	green
red	green	yellow	green	red
blue	yellow	blue	red	blue
yellow	red	red	blue	yellow
blue	green	blue	yellow	green

Time: Item 4: \_\_\_\_\_

Item 5: \_\_\_\_\_

Item 6: \_\_\_\_\_

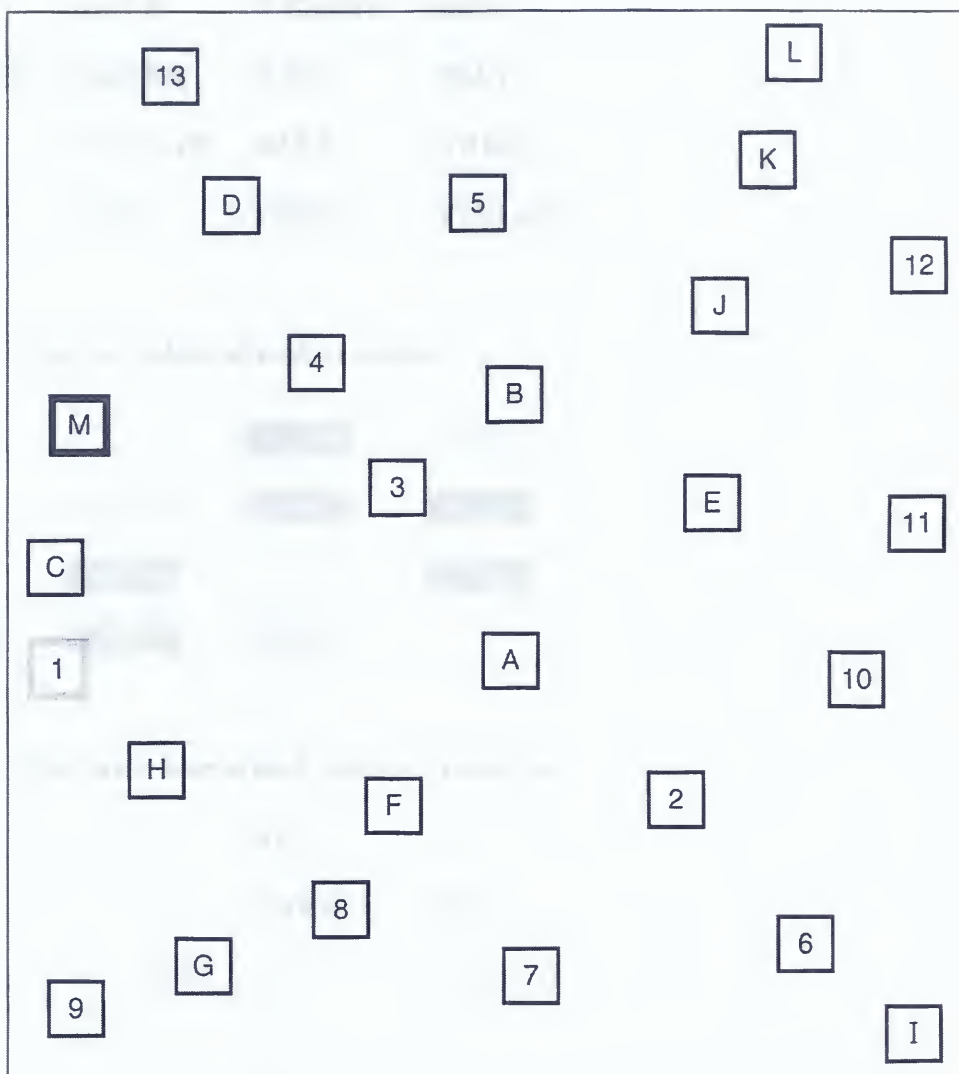
Sentence Repetition (Circle Correct)

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20





Appendix F: Sample CAS subtests  
**Planning Subtest**





### Expressive Attention Subtest

Page 1 – Read each of the following words:

GREEN	BLUE	YELLOW	RED
YELLOW	GREEN	RED	BLUE
RED	YELLOW	BLUE	GREEN
BLUE	RED	GREEN	YELLOW

Page 2 – State the colour of each rectangle:



Page 3 – State the colour of each word is printed in:

YELLOW	GREEN	RED	BLUE
RED	YELLOW	GREEN	RED
RED	YELLOW	BLUE	YELLOW
GREEN	BLUE	RED	GREEN



**Simultaneous: Non-Verbal Matrices Subtest**

?



a



b



c



d



e













