EFFECTS OF PHYSICAL FITNESS ON ATTENTION, MEMORY AND DECISION MAKING IN CHILDREN

by

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The aim of this study was to determine whether there was a relationship between level of fitness and the information processing components of attention, memory and decision making in children. Based on existing evidence from studies on adults, it was predicted that higher-fit children would perform better on attention, memory and decision making tasks than their low-fit counterparts. It was predicted that higher-fit subjects would perform better than their lower-fit counterparts on: i) attention (dual task-tracking and discrete simple reaction time tasks), ii) memory (numeric vigilance and probed memory tasks), iii) decision making (discrete-6 choice reaction time tasks, and iv) executive function (Tower of Hanoi). Forty-seven male children from a local middle school were selected for the study. Based upon a cycle ergometer test, the top twenty receiving the highest fitness scores and the twenty with the lowest scores were selected to complete the cognitive tests. Subjects were required to perform six cognitive tests on a computer. Fitness level (higher-fit and lower-fit) was the main independent variable while the dependent variables were VO^2 max, fat percentage, resting heart rate and the measures from the cognitive tests. First, a fitness level ANOVA with predicted VO^2 max indicated that the groups did differ on the level of fitness. A group x memory capacity (8, 10) with repeated measures on memory length and a group x duration (80,100) with repeated measures on time were computed. The remaining dependent variables were analyzed by a fitness group ANOVA. The fitness level did not differentiate the subjects on attention, memory or decision making. There was a trend for the higher-fit to perform better than the lower-fit on simple and choice

movement times, memory capacity and duration tests. Thus, the effects of aerobic fitness level on attention and memory capacity displayed a trend for higher-fit children to be slightly better than lower-fit children; however, these differences were not significant. Further studies need to continue to explore whether aerobic fitness levels have an impact on the components of children’s information processing.

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PREFACE

I am deeply indebted to people who have directly and indirectly played part in the successful completion of this study: My advisor, Dr. Jere Gallagher who has been a mentor, teacher, leader and editor throughout the years of my graduate career in the USA.

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1.0 INTRODUCTION

A physical fit and active lifestyle is not only being widely recognized but is also becoming one of the most vital health prescriptions for both young and old individuals. Research studies (Powell, Thompson, Casperson & Kendrick, 1987; Wei, Gibbons, Kampert, Nichaman, & Blair, 2000; Wei, Zanesco & Antunes, 2007) have convincingly shown that staying physically active and fit substantially reduces the risk of death due to heart related illnesses. Despite all these proven benefits, the CDC reports show that 60 % of American adults do not get enough physical activity to provide health benefits (Center for Disease Control and Prevention, 2001) The inadequate fitness level is however not limited to adults, the US Department of Health and Human Services indicate that more than thirty percent of young people in grades 9-12 do not engage in fitness related activities (US Department of Health and Human Services, 1996). Elsewhere, research studies have demonstrated a relationship between an active lifestyle and cognitive functioning in the elderly population (Bjorkland, 1991; Chodzko-Zacjko, 1991; Clarkson-Smith & Hartley, 1989; Spurdoso 1975). Since this phenomenon has not been extensively studied in children, this study focused on the relationship of aerobic fitness and the components of cognition in children. The relationship is of significant importance in the school system because a large portion of school time is spent in the cognitive/academic domain, thus examining the potential relationship between aerobic fitness and cognition is important to understand any effects on cognitive function.

Studies that have proposed to explain the relationship of physical activity and cognition have relied on physiological mechanisms and/or learning/developmental mechanisms. The physiological mechanism, such as structural change in the central nervous system, and increased cerebral blood flow are based on physical changes in the body that occur as a result of exercise while learning/developmental mechanisms explain the relationship via learning experiences that aid, and may even be necessary for, proper cognitive development (Sibley & Etnier, 2003).

While the objective of this study is not to address cognitive development in children, it is important to discuss how cognition develops and relates to information processing and decision making. In general terms, cognition is the act of knowing and knowledge is gained via mental process. Gabbard (2004) refers to cognition as "an integral part of perceiving, recognizing, conceiving, decision making, reasoning and varying any of the perceptual-conceptual processes" (p. 225). Cognition is also regarded as a major psychological determinant of the ability to program information (Gabbard, 2004). Programming helps individuals formulate thought which results in either verbal or physical expression. According to Gabbard, attention, perceptual awareness and information stored in working memory all influence programming. Therefore, in order for the individual to produce a thought or motor response, information is collected from the environment through any of the six senses, and through selective attention, that information is moved into working memory, where a decision as to effect a motor response is made; this process is known as information processing, (see Figure 1).

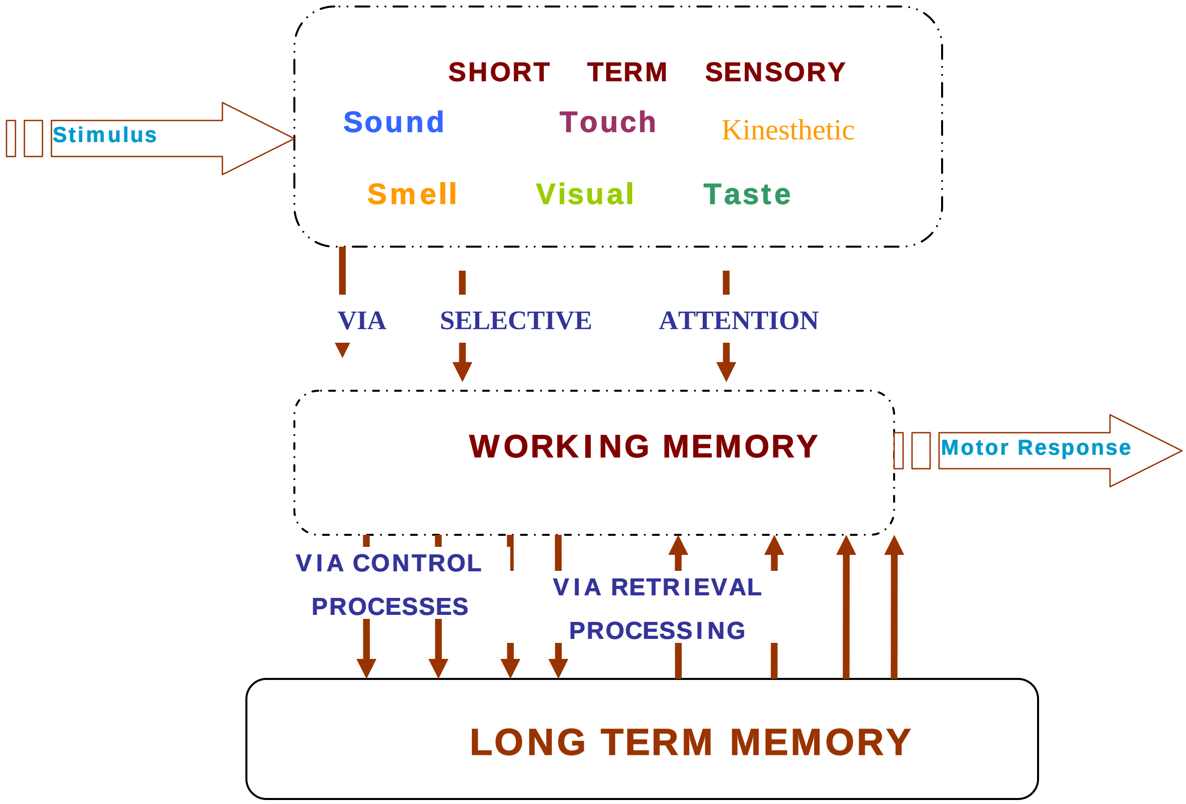

Figure 1: Information Processing Model

The information processing approach provides an understanding of how individuals handle internal and environmental information. When we process information, in addition to the cognitive and neural processing of the physical characteristics of the stimuli, allocation of attention, stimulus relevance and memories of past experience are important (Baddeley, 2000; Schmidt, 1988; Schmidt & Wrisberg, 2004). Based on the information-processing model, a framework for examining the characteristics of attention, memory and decision-making can be explained. Initially, all sensory information is maintained in sensory store and via attention and perception, information is moved into working memory or conscious thought. When the information is in working memory, prior experiences that are in long term memory can provide direction to the selection of the skill. For all actions, many alternatives exist from which the individual must select. Finally, the motor response is programmed and the muscular system is organized for the desired movement. Throughout the information processing cycle the individual must attend first to environmental information to select the important cues, selectively attend to the important information in memory, and then base the decision on the task criteria.

Various studies have investigated information processing differences between adults and children including speed of processing, attention, memory and decision making, all concluding that children process information differently from adults. This study investigated the various components of information processing to determine whether fitness level improved attention, memory, and decision making. In other words, were higher-fit children better than their lower-fit counterparts in attending to task appropriate cues, keeping more information in memory for a longer duration, and in making better decisions. The various components of information processing that were tested in this study were selective attention, memory capacity and duration and decision making.

Selective attention is an important factor in the achievement of motor tasks since it involves alertness and preparation of the motor system to affect a response. To successfully perform a motor task, the individual must select and attend to meaningful information. On the other hand, children are less efficient selectors than adults and have produce larger interference effects with irrelevant distracters when compared to adults, (Davies & Thomson, 1988; Ridderrinkhof, van der Molen, Band & Bashore, 1997; Ridderrinkhof, & van der Molen, 1995). Thus, selective attention abilities of adults are more efficient when compared to those of children. Adults appear to overcome distractions and produce accurate responses to the target in a wide variety of tasks.

Investigating selective attention of children with attention deficit hyperactivity disorder (ADHD), a recent study Brodeur and Pond (2001) examined the influence of age on a selective attention task in a sample of children with and without ADHD. Although the study included children with ADHD which is not specifically relevant to this study, older children without ADHD were more efficient in selective attention tasks than younger children without ADHD. Thirty-two children (6- to 8-years olds, 9- to 12-year olds) completed a visual attention task. The subjects were told that they would view pictures of clothing (tie, shirt etc) on the computer screen, and that they should indicate what they saw by depressing a corresponding button on the keyboard. They were also informed they would hear words in the headphones but they should ignore the words in the headphones and respond as quickly as possible in response to the pictures without making errors. Children were presented with a visual stimuli on the screen for 3000 ms or until a response was made. While all children experienced distraction, younger children were affected more by the headphones than were older children. Mean reaction times (RT) and accuracy scores for older children were significantly different from that of younger children (mean RT=137.01, mean accuracy 0.59 for younger group and mean RT =83.12 mean accuracy 1.04 for older group).

Similar to other reported studies on attention (Colombo, 2001; Enns & Cameron, 1987; Gallagher & Thomas, 1986; Guttentag & Ornstein, 1990) younger children are deficits in the use of selective attention strategies and consequently demonstrate larger deficits from irrelevant distracters when compared with older children (Ridderrinkhof, et al., 1997). Thus, the younger children’s ability to process relevant information and to selectively inhibit irrelevant information is affected by their inefficient strategy use. Furthermore, Wickens and Benel (1982) indicate that the ability to efficiently allocate attentional capacity improves with age and that developmental differences in attending to dual tasks may be due to lack of automation and how the individual deploys his/her attentional skills. Thus, as children grow older they become more adept at controlling the allocation of their attention and require fewer capacity resources.

Becoming more efficient at selectively attending has been found to be related to the fitness level of older adults. Physically fit older adults have demonstrated a less rapid decline in attentional capacity than their less-fit peers, and consequently perform better on tasks in which attentional resources are a limiting factor (Chodzko-Zacjko, 1991; Enns & Girgus, 1985). These studies suggest that cognitive tasks, which require effortful processing, should be more sensitive to the effects of fitness than tasks, which can be performed with minimal attention. The test of selective attention in this study was the dual task-tracking and Simple Reaction Time tasks. The dual task tracking involved attention to a primary task while performing a secondary task as appropriate. The individual was instructed to perform the main task and when prompted, respond to the second task as needed. The individual was not expected to reduce the performance on the main task. If there was no deficit in the primary task, the individual was selectively attending to the primary task. If there was a decrement in the secondary task, the individual was ignoring the irrelevant cues. If there was no decay in either the primary task or the secondary task, the individual had sufficient memory to complete both tasks. If the subject had a decrement in either the primary or the secondary task, the individual was distracted.

Memory is usually viewed as storage of material emanating from the activities of the various information processing stages. The memory capacity component of information processing is limited in its capacity to handle information (Miller, 1956; Schmidt & Wrisberg, 2004). Young children are also known to experience difficulty in the amount of information they can handle at any time (Gabbard, 2004) Thus, working memory is characterized by: *capacity* -

amount of information that will reside in working memory and *duration* - length of time information will remain in working memory. Working memory is thus used as a workspace to briefly store information presented in the immediate past before further processing and like attention it has limited capacity and duration for storing information.

One feature in processing of information that has strong implications for performance is the concept that memory is limited in its capacity to handle environmental information. Gabbard (2004) notes that if a specific movement activity requires attention, then some (or all) of an individual's limited capacity must be allocated to the performance. In this case, since capacity is believed to be limited, interference will occur if another activity requires these resources resulting in either loss of speed or quality of performance.

In a classical study, to quantify the capacity limit associated with working memory, Miller (1956) proposed that, for a remarkable number of different kinds of information, working memory capacity for young adults is at most around 7 ± 2 items, or chunks of information. The fact that we can easily recall seven digits justifies Miller's proposition.

As children age, they are quick to recognize relevant information and become more skilled at performing cognitive operations that are linked to motor operations. This notion is also supported by current research approaches with regards to working memory as emphasizing active processing as opposed to merely a memory store (Baddeley, 2000; Gallagher, French, Thomas, & Thomas, 1996). In order to process information in working memory, a memory strategy is adopted. Development of children's memory strategies as a process is viewed as analogous to the development of skill.

The most important characteristic of working memory is that, it retains information for a limited amount of time. An illustration of this limitation was a study by Adams and Dijkstra

(1966), who were among the first to show that, not only is information lost from working memory after about 20-30 s but most importantly that movement information has a short duration in working memory. In a classic study that became the standard pattern for what was termed motor short-term memory research, Adams and Dijkstra wanted to establish if motor or kinesthetic information is also lost as rapidly as verbal information in working memory. The authors had their subjects blindfolded, seated and asked to move to a stop on a linear positioning task, a free moving handle that slides along a metal rod. The task was to move the handle to a stop and then return the handle to a starting point. Following a specified time interval, with the stop removed, the subject repeated the task by moving the handle to a point where she or he estimated the location. The experimenter scored accuracy by recording how far the subject's estimate was from the criterion location. The authors' idea was that if verbal information in working memory has short duration, so does the motor information. The results of their study indicated that the motor or kinesthetic information suffers the same fate of short duration as verbal information in the working memory. Studies (Dempster, 1981; Kail, 1991; Miller & Vernon, 1996) that have been conducted after Adams and Dijkstra's investigations have generally supported the notion that duration of kinesthetic information in working memory is about 20-30 s.

Research studies reviewed on limitation of memory capacity and duration has always been that as children mature, so does their search strategy and memory capacity. The few studies that have looked into the relationship of physical fitness and information processing have however failed to address what aspects of information processing may be responsible for the differences found in how children process information. Therefore, this study examined the memory capacity and duration aspects of working memory, which is an important component of information processing. Young children are known to experience difficulty in the amount of information they can handle at any time. Probed memory was used to measure capacity of working memory.

The capacity of working memory was determined by presenting the subject with a sequence of either eight or ten consonants with for each series a new consonant being added every second. The consonants remained visible until the last consonant was displayed upon which all consonants were blanked. The subject was then presented with a consonant and asked whether or not it had been part of the prior list, the answer was given by clicking 'yes' or 'no' with the mouse on the computer screen. The list length of consonants was eight and ten and 50% of the probed consonants belonged to the original list. The test measured capacity since remembering whether the consonant was part of the original list involved the ability to store information in memory with the ability to retrieve it later.

Memory duration was measured by numeric vigilance. Information in working memory is known to last no more than 30 s, whereby if not rehearsed, or processed, it is lost or replaced by another stream of information. This test established if subjects are quicker and more efficient in recognizing relevant information (duplicates). The subject was asked to identify duplicates of three-digit numbers shown on a computer screen by pressing the spacebar as soon as a duplicate appeared. To measure the duration of memory, rate of presentation included 80 and 100 three-digit-numbers per minute. Each number differed randomly from the prior number in one digit. A sample might be 122, 172, 721, 721, 227, 274, and 874 containing a single duplicate 721. Correct responses, missed duplicates and incorrect duplication responses were recorded.

Decision making was the third component of information processing measured in this study. Studies showed that strategies employed by older children and adults are different from those used by younger children. Davidson (1991) examined the decision making strategies of second-, fifth-, and eighth-grade students using a decision board, a method used previously with adults. A decision board procedure involved a presentation of information about alternatives or choices, which allows subjects to open doors to examine information about different alternatives before making decisions. This procedure permitted the experimenter to record what information was examined as well as the order in which the information was uncovered.

The results showed that, compared with younger children, the older group searched significantly fewer alternatives as well as fewer dimensions of those alternatives. Older children searched information more efficiently and systematically resulting in better decisions than younger children. Younger children have difficulties distinguishing between relevant and irrelevant information. Similarly, other researchers found that younger children attend to irrelevant information more than older children in speeded classification tasks (Hagen & Hale, 1973) and display differences in attention to relevant information in memory tasks (Miller, DeMarie-Dreblow, & Woody-Ramsey, 1986).

Research studies on decision-making have focused on developmental differences across childhood. In particular studies have mostly focused either on when different age groups of children make decisions or how young children differ from adults in decision making. Having said this, it is possible that the young child's effective search strategy might simply be following a different, less adequate, strategy than that of older children. Unlike adults, few studies have looked at the effect of physical activity on decision making of young children of the same age group.

One way this study measured decision making was by subtracting simple reaction time from choice reaction time. Choice movement time compared to simple movement, which is the time required to complete the motor response either after a decision or a simple response, was used to determine whether they were continuing to think as they move. Decision making was measured by a combination of the discrete simple reaction time and Discrete 6-choice Reaction Time. The Discrete Simple Reaction Time initially measured alertness and preparedness using auditory and visual stimuli. The test assessed the subject's alertness by measuring the interval of time between stimulus onset (auditory beep, or appearance of moon) and the initiation of motor response (lifting finger from home key). The task required the subject to respond as quickly as possible to the visual, and the auditory stimuli, a task which involved reacting as quickly as possible to the stimuli. For Discrete 6-choice reaction time, it was expected that the decision reaction time would vary and decision movement time remain the same. If the decision movement time differed from the simple movement time, which indicated that the subject was continuing to decide what response to make.

The few studies that focused on the relationship of fitness and cognition in children have mostly focused on academic performance as a key measure of cognitive function. The studies have also used a wide variety of cognitive measures such as perceptual skills, IQ, academic achievements, arithmetic, reading, verbal tests and memory (Sibley & Etnier 2003), scholastic ratings (Dwyer, Sallis, Blizzard, Lazarus & Dean 2001), reading and math (Tremblay, Inman & Willms 2000), pre-SAT scores (Grissom, 2005), mathematics (Gabbard & Barton 1979; McNaughten & Gabbard 1993), and student perception of academic performance (Lindner, 1999).

What the reviewed studies on the relationship between cognition and aerobic fitness have not addressed was what component of the information processing continuum was related to level of physical fitness. In an initial attempt to separate the various components of information processing, Mokgothu (2000) investigated memory capacity and decision making of 7- and 9-year-old habitually active and sedentary children drawn from rural and urban areas of Botswana, Africa. The rural children were considered naturally fit (which was confirmed by a sub-maximal exercise test) by virtue of their habitually active lifestyle. All children completed anthropometric measures and sub-maximal cycle ergometer tests. Cognitive tests included simple and choice reaction time (SRT, CRT) and measured response time to stimulus and decision making time respectively. The ‘Simon’ game measured memory of a movement sequence. Results indicated that the rural fit group exhibited significantly faster SRT (287.00 ms, SD=52.73 ms) and CRT (381.00 ms SD=64.68) than their urban unfit group (SRT 322.20 ms, SD=34.35 ms) and (CRT 414.36 ms, SD=30.98 ms) respectively. The SRT test showed a trend a difference whereby the rural fit children being faster on simple reaction tasks and choice reaction tasks but groups were similar on CMT. The results implied that aerobic fitness was a factor in attention to a stimulus and decision making as measured by choice RT, thus physical fitness may be related to determining how children process information. The present study compared children’s fitness level based on their aerobic fitness.

So far, the validity and reliability of the various cognitive and physical measures used are questionable since many of the measures were created for the specific study and validity and reliability measures were not reported. The problems with the measures of physical fitness were the variety of measures used. For example, the measures included self-reported (Lindner, 1999), cycle ergometer, anaerobic measures such as and walking (Dwyer, et al., 2001). Given the few studies on each of the measures, conclusions are difficult to make. Despite all these varied measures of cognition, a meta-analysis (Silbey & Etnier, 2003) concluded that there was a positive relationship between fitness and cognition. The group that was physically fit scored better on the variety of cognitive measures.

The current study investigates the various components of information processing to determine whether fitness level improves attention, memory, and decision making in children. In other words, are fit children better able to attend to the task appropriate cues, or are they able to keep more in memory for a longer duration, or do they make better decisions. The difficulties with previous research on cognition have been addressed and how the measures used in this study address these problems are discussed below. The measure of aerobic fitness used in this study is aerobic performance as measured by a cycle ergometer test. Aerobic capacity is a measure that is felt to be the most important in relation to cognition and information processing.

The tests used in this study were part of the Psychomotor Evaluation test (PsychE). These psychomotor performance tests, especially the reaction time and movement time have been used by researchers to explore the various components of information processing. The PsychE is an integrated program that is used to assess psychomotor and cognitive tests using tasks and methodologies, derived from research in experimental psychology and ergonomics that assess memory, perception and attention (Hope, Woolman, Gray, Asbury, & Millar 1998). The tests in this battery were used to measure selective attention, memory capacity and duration and decision making.

1.1 HYPOTHESIS

In this study, it was hypothesized that the level of physical fitness will affect attention, memory and decision making differently. Based on existing evidence from studies on adults, it was predicted that physically fit children would perform better in attention, memory and decision making tasks than their less active counterparts. For attention, higher-fit subjects will perform better in Dual task-tracking and Discrete SRT tasks (RT, MT) than their lower-fit counterparts. For memory, higher-fit subjects were expected to perform better in Numeric Vigilance and Probed Memory tasks (hits, % correct responses) than their lower-fit counterparts. For Decision Making higher-fit subjects were expected to outperform their lower fit counterparts on Discrete-6 CRT tasks (RT) while Decision MT should remain the same. Lastly, higher-fit subjects were expected to score higher than their lower-fit counterparts in Tower of Hanoi test of executive function.

1.2 LIMITATIONS OF THE STUDY

The first limitation of the study is that while limited research on the effects of physical fitness on memory, attention and decision-making have been conducted on children, there is evidence that some studies have been done with adult population (Chodzko-Zacjko, 1991; Clarkson-Smith & Hartley, 1989; Spurdoso, 1975). Therefore, this study has relied on available studies of association between physical activity and general and selective benefits in cognitive function amongst an older adult population.

The second limitation is that cognitive measures using PsychE are estimates of the components of the information processing, however the instrument used in this study have been extensively used and is so far regarded as the best estimate of the information processing. Since the PsychE test usually consists of a task repeated a number of times, with results being averaged, the subject may develop familiarity with the test presentation and progressively devote more attention to the actual performance of the test.

It is important to mention that this study should be viewed as preliminary since no studies have looked at the effects of physical fitness on cognition using the elements of information processing.

2.0 METHODOLOGY

2.1 GENERAL CHARACTERISTICS

The participants were 47 male students (12-14 years, old, 144-167 months; SD= .69 months) from a middle school in western Pennsylvania. The study specifically examined male students since there was a companion study using girls attending the same school. The participants in this study were not selected based on ethnicity or race. The University of Pittsburgh Institutional Review Board approved the study and prior to participation in the study; the parents returned the IRB consent forms.

2.2 RECRUITMENT PROCEDURES

After approval by the University of Pittsburgh Institutional Review Board, a consent form along with a letter of explanation was sent to the parents of 100 middle school male students aged 12- to 14-years in a rural school in Western Pennsylvania. For a complete letter of recruitment, approval and University of Pittsburgh IRB form, see Appendix B. From the pool of children who returned their parental approval, and with the help of the physical education teacher, an initial screening of children was conducted using the Movement Assessment Battery for Children (M-ABC) checklist (Henderson & Sugden, 1992) to rule out Developmental Coordination Disorder (DCD). For complete M-ABC procedures see Appendix B. In addition, those children identified as having Individualized Education Plans were excluded from the study. The children who were not identified as having coordination problems using the M-ABC checklist were selected to continue participation in the study; forty-seven children were given a cycle ergometer exercise test. For classification purposes, two groups of 20 children (higher-fit and lower-unfit) were finally selected. Those in the top 20 were assigned to the higher-fit group and the lowest 20 children were assigned to the lower-unfit group, while the middle 7 was dropped.

2.3 INSTRUMENTS, VALIDITY AND RELIABILITY

The screening test was used to initially identify subjects for the study. The fitness test was used to classify subjects into higher-fit and lower-fit groups. The cognitive tests were used for both groups. The instruments used, their reliability and validity are described below.

2.3.1 Screening and Fitness Testing

The fitness testing included initial screening that exclude children with coordination problems and a second screening to select 20 children with a higher fitness level and 20 children with a lower fitness level. Anthropometric measures of height, weight and body composition were administered, followed by estimating the aerobic capacity using a cycle ergometer where the children wore a heart rate monitor.

2.3.1.1 Movement ABC Screening Test

The M-ABC test identifies and evaluates movement problems. The Movement ABC Checklist is an initial screening instrument that identifies children who might have movement problems in school situations and need to be assessed further. In a study to examine reliability of M-ABC checklist, Schoemaker, Smits-Engelsman, and Jongmans (2003) randomly selected 120 children (6- to 12 years) and screened 64 children using the four sections of M-ABC checklist (child moving- environment stationary, child moving-environment stable, child moving environment moving, child moving environment changing). The authors performed a reliability analysis of 48 items of M-ABC checklist to establish if the four sections measure the same construct. The results confirmed that the M-ABC measures the same construct (r = 0.96 for the 48 items). van Hartingsveldt, Cup and Oostendorp (2005) also examined test-retest reliability, inter-rater reliability, convergent validity and discriminant validity of M-ABC compared to Fine Motor Scale of Peabody Developmental Motor Scales (PDMS-FM-2). Scores of 36 children for the two test were compared, test-retest reliability and inter-rater reliability for the two tests varied from r = 0.89 to r = 0.99. Convergent validity was r = 0.69. The results indicated that M-ABC was reliable when compared with other developmental tests. The classroom PE teacher completed the M-ABC checklist for the children that returned their parental consent (Appendix A).

2.3.1.2 Anthropometric Measures

A Detecto- medic Scale and Bioelectrical Impedance scale was used for anthropometric measures. A Detecto - medic scale was used to measure the height (cm) and weight (kg) of the subject. A Bioelectrical Impedance Scale (Tanita TBF-305) an instrument the size of a bathroom scale was used to measure the child’s weight (kg) and calculate body fat percentage.

2.3.1.3 Polar Heart Monitor

The Polar Heart rate monitor, model E 600 was used to measure heart rate during exercise testing. The monitor used a watch and an elastic strap worn around the chest with a transmitter attached. The watch recorded the heart rate during exercise testing. Goodie, Larkin and Schauss, (2000) examined validity of the polar heart rate monitor as a measure of heart rate while exercising and resting. Thirty students' heart rates were measured at the same time, using a polar monitor and electrocardiography (ECG) during hand grip exercise and mental arithmetic. The correlations between the polar heart monitor and ECG were significant (mean $\underline{r} = 0.98$, $\underline{p} < .001$).

In another study, Treiber, Musante, Hartdagan, Davis, Levy and Strong (1989) assessed validity of the Sport Tester PE 3000 heart rate monitor on 10-year, 4- to 6- year and 7- to 9- year old children while performing cycle ergometer, treadmill and aerobic activity respectively. The heart rate readings for the three activities were correlated with ECG readings which were taken during the same periods of exercise. Correlations ranged from 0.94 to 0.99. The results indicate that heart monitors are valid for use in measuring heart rate during of children during physical activity. The heart rate monitor permitted the researcher to monitor current heart rate during cycle ergometer exercise.

2.3.1.4 Monark Cycle Ergometer (Model 824E)

Cycle ergometer tests are highly related to field measures and are regarded as valid measures of VO_2max. Patton, Vogel and Mellow (1982) examined reliability of a cycle ergometer as a predictor of maximal oxygen uptake (VO_2max) on 15 male and 12 female subjects. The maximal work rate of the cycle ergometer was compared with VO_2max measures of a treadmill test. The test-retest reliability of the two tests was 0.95 and 0.81 for males and females respectively. Andersen (1995) predicted VO_2max of 232-men and 303- women aged 15-28-years from maximal power output of a cycle ergometer test. The correlation coefficient of $\underline{r}$ = 0.88 was found between the two tests. These tests suggest that cycle ergometer test gave a reliable and valid estimate of VO_2max. The cycle ergometer was used in this study to assess cardiorespiratory fitness of participants in order to predict their VO_2max. The YMCA test was used to predict the subjects' cadiorespiratory fitness level. The test predicts maximal aerobic power on the steady rate heart response of an individual exercising at submaximal workloads. This test makes use of the direct linear relationships among heart rate, workload and oxygen consumption.

2.3.2 Cognitive Tests

Six tests were used to assess cognition. Five tests measure attention, decision making, selective attention, memory capacity and memory duration using the PsychE software package and the fifth test measured executive function using the Tower of Hanoi.

2.3.2.1 The Psychomotor Evaluation (PsychE)

This a self contained computer program for conducting psychomotor assessment that runs on a PC. Five of the PsychE tests were used in this research. The PsychE is an integrated program that purports to assess psychomotor and cognitive tests using tasks and methodologies, derived from research in experimental psychology and ergonomics that assess memory perception and attention (Hope, et al 1998).

In a study to assess practice effects of the Psych E, Hope et al (1998) administered six Psych E tests to 10 young fit healthy volunteers (mean age10.4 years), four test were selected based on large body of literature that show that divided attention, SRT, CRT and vigilance are highly sensitive (Miller, 1992) and the two memory test were selected in terms of their cognitive demand, which assess basic functions of memory (Miller, 1992). The SRT test showed practice effect until third trial. Performance measure of the other five tests showed no evidence of practice.

2.3.2.2 Reaction Time Board

The instrument consists of a response board; 23 x 13 inches long and the home key centered 1 inch from the lower edge of the board (see Figure 1). There are six movement keys located 10 inches from the home key. The six movement keys are located in a horseshoe shape 5 inches apart with the left key located at a 25 degree angle from the home key line to the left and the right key be 25 degree angle from the home key line to the right.

Figure 2: Reaction Time Board showing Cognitive test setup

2.3.2.3 Tower of Hanoi

A computer generated game that consisted of three pegs, and five disks of different sizes which were stacked on the middle peg and then are moved one disk at a time onto another peg such that a pyramid is created (see Appendix C). A test-retest reliability study of the Tower of Hanoi was examined with two groups of 7.7-years (N = 22) to 11.6-year (N=28) old children. Three versions of the Tower of Hanoi (3, 4, 5 disks) were administered to the two groups three times resulting in nine assessments over 18 months. The reliability of achieved scores for both groups on the ninth assessment was $\underline{r} = 0.67$, planning time was $\underline{r} = 0.81$, giving the test a satisfactory performance. This study used the Tower of Hanoi to test the subjects' executive functions.

2.4 PROCEDURES

The tests were conducted over five weeks in a quite area located in the school gym. The first two weeks consisted of screening tests of Movement ABC checklist and anthropometric measures administration. Based upon these measures, the top 20 higher fit and 20 lower fit subjects were selected for Physical Work Capacity Cycle Ergometer Test which was conducted on week three. During the last two weeks, cognitive measures were conducted in the following order in one test session lasting approximately 35 min: Simple/Choice RT (SRT, CRT), Discrete 6-choice RT (D6CRT), Dual task-tracking RT (DT-TSRT), Numeric Vigilance (NV), Probed Memory (PM) and Tower of Hanoi. Table 1 shows the different instruments, what they measure and the unit of measurement that was used in the study.

Table 1: Testing Instruments, and unit of measurement

Instrument	Measure	Unit
Detecto-medic scale	Height and weight	cm & kg
Bioelectrical Impedance	Body composition	% fat
Heart Rate Monitor	Heartbeat	Beats/min
Cycle Ergometer	Cardio-respiratory Fitness	VO2
Discrete Simple RT (PsychE)	Attention	ms
Discrete 6-CRT (PsychE)	Decision making	ms
DualTask-Tracking SRT (PsychE)	Selective Attention	ms
Probed Memory (PsychE)	Memory capacity	%correct responses
Numeric Vigilance (PsychE)	Memory duration	hits, misses
Tower of Hanoi	Executive Function	Min/s

2.4.1 Exercise Tests

The exercise screening tests included a Movement ABC checklist (see Appendix A) given to the classroom and PE teacher to prescreen for DCD. Children, whose scores exceeded 20 when added up, were excluded from the study. Anthropometric measures of height, weight and body composition were taken followed by physical work capacity measures of cardiorespiratory fitness.

2.4.1.1 Anthropometric Measures

Barefooted, the subject was asked to step on a Detecto-medic scale with an attached stadiometer to determine height and weight (***See Appendix B for instructions***). Height (cm) and body weight (kg) were recorded. Body fat percentage was measured using bioelectrical impedance (Tanita

TBF-305). The scale was attached to a small unit that displays the reading for each subject. The unit was calibrated for ‘child’ and the appropriate gender was selected. The subject removed his shoes and socks, stepped on the scale and remained motionless for 15 s. The unit displayed a reading of the subject’s weight in pounds and fat percentage.

2.4.1.2 Physical Work Capacity Cycle Ergometer Test

The Monark Cycle ergometer (Model 824E) was used to assess cardiorespiratory fitness of the subjects. Since subjects were children, the cycle will be set to an initial load of .25 kg with a pedal rate of 50- rev/min. The termination of cycling was when the subject reached a heart rate of 160- b/min. Before the test, a polar heart rate monitor (children’s size, Model E 600) was attached to the subject’s chest to record the heart rate throughout the test. Prior to test initiation, the subject was asked to climb on the bike and the height of the seat adjusted according to the subject’s leg length (95 % of leg length), with the ball of the foot on the pedal, the knee slightly flexed at maximal leg extension. The subject was asked to assume an upright, seated posture with hands positioned on the handlebars.

The test (See Appendix B for Instructions) began with a 2-min warm-up to orient the subject to the equipment and prepare for the first stage. In front of the subject was the Children’s OMNI scale of perceived exertion ratings chart for the child to indicate level of fatigue (Robertson , R., Goss, F., Boer, N., Peoples, J., Foreman A., Dabayebeh., Millich, N., Balasekaran, G., Riechman, S., Gallagher, J., & Thompkins, T. 2000)). At the end of the stage and prior to initiation of the next stage, the increase in resistance was communicated to the subject. The exercise intensity was increased gradually through the stages of the test which was recorded every minute (see Appendix D)**.** Work increments used resistance of .5, 1, 1.5, 2, 2.5, 3, and 3.5kg etc. The subject was encouraged to keep going throughout the test. The test continued until the subject's heart rate reached 160- b/min. or the subject request the test to be stopped due to fatigue. At the completion of the exercise, the subject cooled down by continuing to peddle for an additional 2 min at .30 rpm and HR was monitored during recovery.

To estimate the subjects' VO^2 max the YMCA's submaximal cycle test calculator was used. The program estimated the individual's aerobic fitness by calculating the VO^2 max based upon the subject's gender, age, weight, heart rate and exercise stages completed.

2.5 COGNITIVE AND INFORMATION PROCESSING TESTS

Six tests were used to measure the various components of information processing. Discrete Simple RT and dual task-tracking and SRT measured selective attention, Discrete 6-CRT measured decision making while Probed Memory and Numeric Vigilance measured memory capacity and duration respectively. Tower of Hanoi measured executive function. Complete instructions for the tests are in Appendix B.

2.5.1 Psychomotor Evaluation (Psych E)

Five tests were administered for a total time of about 30 min. For both simple and choice RT and MT, the response board was used. The task consisted of two components, the response board and the laptop monitor. The response board was positioned at a child-sized desk with the computer screen 5 inches behind the response board.

2.5.1.1 The Discrete Simple Reaction Time

This required the subject to respond as quickly as possible to the auditory beep. With the index finger of the dominant hand, the subject was asked to hold down the home key. After a random interval between 1 and 10 s, for the first test an auditory beep sounded, for the second test a small sun appeared on the screen, signaling the subject to lift his finger from the home key and press the number 6 response key. The subject was given three practice trials followed by 20 test trials. For correct responses, the RT and MT were recorded separately to within 1 millisecond, with means and standard deviations calculated and recorded.

2.5.1.2 Discrete 6-Choice Reaction Time

The subject required to make a decision quickly by responding to a visual stimulus. After a random interval (1-10 s) one of the keys in the computer screen was highlighted, prompting the subject to lift the index finger of the dominant hand from the home key to press the corresponding response key on the response board. The subject received three practice trials followed by randomly ordered trials to each of the 6 response keys. There were 20 test trials. For each trial, the reaction time and movement time were recorded. For correct responses, the RT, and MT were recorded separately to within 1 ms, with means and standard deviations calculated and recorded as in simple reaction time.

2.5.1.3 Dual Task-Tracking and Simple Reaction Time

This task requires the subject to use a computer mouse to follow a smooth but randomly moving target (primary task) on the computer screen as close as possible. At random intervals a stimulus in the form of an auditory beep (secondary task) was presented. The subject was asked to press the space bar of a computer keyboard as soon as s/he hears the auditory beep. Attending to tracking is the primary task while responding to the beep is the distracter. The subject was given three trials. The test lasted three minutes. The time taken for the subject to press the spacebar was measured, with total response time, reaction time and movement time being recorded separately.

2.5.1.4 Numeric Vigilance

This task required subject to identify duplicates of three-digit numbers shown on a computer screen by pressing the spacebar every time a duplicate appears. The three-digit numbers were presented on a computer screen at a rate of 100-three digit numbers per minute. Each of the three-digit number differed randomly from the previous pattern in one of the digits. Of the numbers presented during the test, 8% were duplicates of the previous number. The length of the test was three minutes. Correct responses (“hits”), missed duplicates (‘misses’), and incorrect duplication responses (‘false alarms’) were recorded. Test duration was three minutes.

2.5.1.5 Probed Memory

The subject was shown a sequence of eight consonants with a new consonant being added every second. The consonants remained visible until the last consonant was displayed. After an interval of one second the complete sequence of eight consonants were blanked out. The subject was then presented with a consonant and asked whether or not it had been part of the prior list, the answer was given by clicking ‘yes’ or ‘no’ with the mouse on the computer screen. Of the displayed consonants 50% of the probe consonant belonged to the original list. The percentage of correct responses was recorded. Three practice trials were followed by 20 test trials.

2.5.1.6 Tower of Hanoi

The subject was instructed to use a computer mouse to move three circular discs from one tower (left peg) to the right (destination peg) (see Appendix B). The subject was allowed to move only one disc at a time and a large disc could never be placed on top of a smaller one. The discs should be moved from one tower to another in the least number of moves. The number of moves taken by each subject to move the pegs was recorded.

2.6 DESIGN AND DATA ANALYSIS

The independent variable was group (fit, unfit) while dependent variables were Simple/Choice Reaction Time (SRT, CRT), Simple/Choice Movement Time (SMT, CMT), Discrete 6-Choice RT (D6CRT), dual task-tracking RT (DT-TSRT), Probed Memory (PM), Numeric Vigilance for three series (NV) and Tower of Hanoi.

For memory capacity, a Group x memory capacity (8, 10) with repeated measures on memory length was computed. For memory duration, a Group x duration (80,100) with repeated measures on time was computed.

The design of the study was level of physical fitness (higher fit vs. lower unfit) with the following dependent variables: discrete simple reaction time, discrete 6 choice reaction time, a dual task, numeric vigilance, and probed memory (3 series).

Separate group ANOVAs were calculated for the dependent variables for measures of the separate components of information processing with a probability value of .05. Follow-up ANOVAs were calculated where necessary.

3.0 RESULTS

The primary purpose of this investigation was to examine the various components of information processing to determine whether aerobic fitness level was related to attention, memory, and decision making in children. In other words, were fit children better able to attend to the task appropriate cues, keep more in memory for a longer duration, make better decisions, or plan and solve problems effectively? The results of this study are arranged into five sections: fitness level comparison, attention, memory, decision making and executive function. All ANOVA tables are in Appendix E and F.

3.1 FITNESS COMPARISON

Since the main purpose of the paper was to examine the relationship of fitness level to memory, the subjects needed were divided into a higher and lower fit group. This was done by ranking forty-six subjects based on their VO2, and eliminating the middle six. To determine that the groups differed on fitness level an ANOVA was calculated on the dependent variable VO2max The analysis revealed that the fitness level of the two groups were significantly different, $\underline{F}(1, 38) = 55.22$, $\underline{p} = .00$, (see Table 2).

Table 2: Means (SD) for aerobic power capacity across fitness level

Group	Peak Aerobic Power*
Lower-Fit group	29.26ml/kg/m (8.40)
Higher-Fit group	49.18ml/kg/m (8.54)

* $p < .05$

3.2 ATTENTION

General attention was measured using visual simple reaction time (VSRT), visual simple movement time (VSMT), auditory simple reaction time (ASRT) and auditory simple movement time (ASMT). Selective attention was measured using secondary task reaction time (STRT), secondary task reaction time minus visual simple reaction time (STRT-VSRT) and time-on-task (TOT) for tracking task.

3.2.1 General Attention

Attention in this study examined alertness and preparation of the motor response system using VSRT and VSMT, ASRT and ASMT. A group (lower-fit, higher-fit) ANOVA indicated that there were no significant difference between the two groups on the following dependent variables; VSRT, $F(1, 38) = 1.126$, VSMT, $F(1, 38) = .124$, ASRT, $F(1, 36) = 1.428$, ASMT, $F(1, 36) = .316$, (see Table 3 for means and SD).

Table 3: Means (SD) for attention across groups and tests

	VSRT	VSMT	ASRT	ASMT
Lower-Fit group	528.80	326.45	503.20	356.80
	(131.04)	(96.40)	(139.95)	(138.91)
Higher-Fit group	490.15	316.35	453.44	324.72
	(96.71)	(84.43)	(113.88)	(209.18)

3.2.2 Selective Attention

The test of selective attention was secondary task reaction time (STRT) which involved selectively attending to the primary task and when appropriate, responding to a secondary task. A univariate ANOVA with fitness level as the independent variable was computed on the dependent variable secondary task reaction time (STRT), simple dual reaction time (DUALRT) was attained by subtracting visual simple reaction time (VSRT) from STRT. Results indicated that the high-fit group was not significantly different from the low-fit group across tests: STRT, $F(1, 38) = .715$, DUALRT, $F(1, 38 =.141$, and TOT, $F(1, 38) = .797$ (see Table 4).

Table 4: Means (SD) for selective attention across groups and tests

	STRT	DUALRT	TOT
Lower-Fit group	522.90	101.50	47.35
	(69.80)	(82.72)	(12.25)
Higher-Fit group	548.10	111.65	43.95
	(93.90)	(84.43)	(113.88)

3.3 MEMORY

Memory capacity was measured using probed memory capacity of eight (P8) and ten (P10) letters to establish if there were differences in memory length for the two groups. Memory duration was measured using vigilance hits at 80- (V80H) and 100- (V100H) three-digit numbers per minute to establish if there were differences in memory duration for the two groups. Thus duration at 80-three-digit numbers per minute provides more time between presentations, thus the 100-digit presentation should be superior to the 80-three-digit-numbers per minute.

3.3.1 Memory Capacity

A Group (lower-fit, higher-fit) x capacity (Capacity 8, Capacity10) ANOVA with repeated measures on capacity did not reveal significant differences between the two groups, $\underline{F}(, 33) = .004$, or the group x capacity interaction for the dependent variable capacity, $\underline{F}(1, 33) = .009$. The capacity main effect was however significant, $\underline{F}(1, 33) = 10.71$, $\underline{p} = .003$, (see ANOVA Table 10 in Appendix E). Both groups performed better on capacity at 8-letters than capacity at 10-letters. The group x capacity means % correct hits and standard deviations are in Table 5.

Table 5: Means % correct hits (SD) for memory capacity at P8 and P10

	Capacity 8	Capacity 10
Lower- Fit group	77.22 (12.62) N = 18	69.44 (13.27) N = 18
Higher- Fit group	77.65 (10.01) N = 17	69.41 (10.44) N = 17

3.3.2 Memory duration

A group (lower-fit, higher-fit) x duration (80 % Hits, 100 % Hits) ANOVA with repeated measures on duration and the dependent variable number of hits did not reveal significant differences between the two groups, $F(1, 37) = 1.951$, or the group x capacity interaction, $F(1, 37) = .069$. The duration main effect was however significant, $F(1, 37) = .415$ $p = .523$, (see ANOVA Table 11 in Appendix E). Both groups had more hits at duration of 80 % than at 100 %. Group x duration means and standard deviations are in Table 6.

Table 6: Means (SD) for memory duration at 80 % Hits and 100 % Hits

	Duration 80 % Hits	Duration 100 % Hits
Lower- Fit group	9.00 (2.59)	9.20 (2.70)
	N = 20	N = 19
Higher- Fit group	9.78 (1.58)	10.26 (3.34)
	N = 20	N = 19

3.4 DECISION MAKING

Decision time was measured by subtracting visual simple reaction time from visual choice reaction time, (VCSRT minus VSRT) and visual movement time (VSMT) determined whether the subjects continued to think as the moved.

3.4.1 Decision Time

A univariate ANOVA with fitness level as the independent variable was computed on the dependent variable decision reaction time (DRT) and VSMT. Results indicated that the high-fit group was not significantly different from the low-fit group across tests: VSRT, $F(1, 37) = .074$ and VSMT, $F(1, 37) = .004$.

Table 7: Means (SD) for Decision Time across groups and tests

Group	Decision Reaction Time	Decision Movement Time
Lower- Fit group	102.52 (83.21) N=19	360.26 (104.66) N = 19
Higher- Fit group	109.50 (76.72) N=20	358.30 (80.39) N = 20

Movement time (VSMT) was also evaluated to determine if the subjects were continuing to make their decision as they moved. If the choice movement time is larger than the simple movement time, the subjects are continuing to process information as they move. The results indicated that the choice movement time was larger than simple movement time for both groups. Mean VSMT M = 326.45, VCMT M=360.26 (lower-fit group) and mean VSMT M =316.40, VCMT M= 358.30 (higher-fit) see Table 8.

Table 8: Means (SD) for visual choice RT and visual choice MT

Group	VSMT	VCMT
Lower- Fit group	362.45	360.26
	(96.40)	(104.66)
	N=19	N = 19
Higher- Fit group	316.40	358.30
	(84.43)	(80.39)
	N=20	N = 20

3.5 EXECUTIVE FUNCTION

The Tower of Hanoi measured the executive planning and problem-solving ability of subjects using time-to-complete (TOHTIME), number of errors (TOHERR) and number of moves (TOHMOVE) as dependent variables.

3.5.1 Planning and Problem-Solving Time

A univariate ANOVA with fitness level as the independent variable was computed on the dependent variables TOHTIME, TOHERR and TOHMOVE. The results indicated that the higher-fit groups were not significantly different from the lower-fit group across tests, $F(1, 38) = .929$, $F(1, 38) = .104$ and $F(1, 38) = .324$. Means and standard deviations are shown in Table 9.

Table 9: Means (SD) for Planning and Problem solving Time across groups and tests

Group	Tower of Hanoi Time	Tower of Hanoi Error	Tower of Move
Lower- Fit group	43.00 (34.78)	.150 (.366)	12.60 (5.20)
Higher- Fit group	52.95 (30.37)	.950 (2.11)	13.40 (3.51)

4.0 DISCUSSION

Research studies have convincingly demonstrated a relationship between a physically fit and active lifestyle and cognitive functioning in the elderly population (Bjorkland, 1991; Clarkson-Smith & Hartley, 1989; Chodzko-Zacjko, 1991; Spurdoso 1975). Since this phenomenon has not been extensively studied in children, this study focused on the relationship of fitness and the components of cognition in children. The few studies examining the relationship of fitness and cognitive functioning in children relied heavily on academic performance as a key measure of cognition and used a wide variety of academic performance measures. The previous studies on the topic also concentrated on adult-child relationships and ignored the most essential elements (attention, memory, decision making) of information processing. The few studies that have looked into the relationship of physical fitness and information processing have failed to address what aspects of information processing are responsible for the differences found in how children process information. To date, no studies have investigated the effect of physical fitness on attention, memory and decision making in children. Thus, the unique aspect of this study was that, it examined this relationship amongst children.

In this study, methodological shortcomings of focusing mainly on academic performance as a key measure of cognition have been avoided by examining attention, memory and decision making as key elements of cognition. It was anticipated that methodological improvements in the present study would help establish if physical fitness has a relationship with attention, memory and decision making in children as shown in the elderly population. Thus the purpose of the current study was to investigate the various components of information processing to determine whether fitness level was related to attention, memory, and decision making in children. In other words, are fit children better able to attend to the task appropriate cues, or are they able to keep more in memory for a longer duration, or do they make better decisions.

Based on existing evidence of SRT and MT studies on adults, it was predicted that higher-fit subjects would perform better in attention as measured by dual task-tracking and discrete reaction tasks (SRT, SMT) than their lower-fit counterparts. For memory, higher-fit subjects were expected to perform better by obtaining a high percentage of correct responses on probed memory test for both 8- letters and 10- letters. Higher-fit subjects were also expected to keep information in memory longer by getting a higher score on percentage of correct response 'hits' at both 80% and 100% of correct responses although there would be fewer differences at 100% correct response. For decision making higher-fit subjects were expected to out perform their lower fit counterparts on discrete-6 CRT tasks (RT) while decision MT would remain the same. Finally, higher-fit subjects were expected to score higher and make fewer errors than their lower-fit counterparts on the Tower of Hanoi test of executive function.

The results of aerobic fitness level between higher-fit and lower-fit supported the selection hypothesis since the two groups were significantly different from each other on level of aerobic fitness. This was important for the interpretation of the hypotheses.

The hypothesis that higher-fit children would perform better in attention tasks, than their lower-fit counterparts was not supported in the study but the data demonstrated a trend. Alertness and preparation of the motor response system tests revealed that although not significant, higher-fit groups were faster than lower-fit groups for the visual simple reaction time (VSRT) task (mean difference 38.7 ms), visual simple movement time (VSMT) (10.1 ms difference), auditory simple reaction time (ASRT) (49.8 ms) and auditory simple movement time (ASMT) (32.08 ms difference). This trend suggests that the higher fit children attended better to task appropriate cues. This trend is related to other studies on elderly population (Bjorkland, 1991; Clarkson-Smith & Hartley, 1989; Chodzko-Zacjko, 1991; Spirduso, 1975) where authors found older subjects who were physically active, or underwent fitness intervention demonstrated faster reaction and movement times on cognitive measures than their low fit or nonexercising counterparts. Even though there were differences between higher-fit and lower-fit groups in attention and memory tests, the differences were not significant. It was however essential to test the relationship between the level of aerobic fitness and the dependable variables by correlation tests.

A correlation was computed to test the relationship between the level of fitness of the two groups and the dependable variables in the study. The correlations were not significant. Since the means and standard deviations were large for some tests resulting in large variability, a comparison of means and standard deviations was done with previous studies (Hillman, et al 2005; Mokgothu, 2000). For RT, Hillman's study reported the following means and standard deviation; high-fit children M = 430.7 (53.4) and low-fit children M =509.1 (83.2) and for Mokgothu, RT means and standard deviations were as follows; high-fit M = 333.77 (75.24) and low-fit M = 363.78 (60.66). The means for this study were higher than that of the other two studies; for the higher-fit children even though the children in this study were older (12-14 years), the RTs of the older children should have been lower than the younger. The children in the Hillman study (8-9 years) responded 122 ms faster than those in this study while the higher fit children in the Mokgothu study (7-9 years) responded 219.63 ms faster. The lower-fit children in the Hillman study responded similarly to those in this study while the children in the Mokgothu study responded 139.42 ms faster. The fit children in the Mokgothu study were habitually active, they lived in rural Botswana, which might account for the differences. In addition the variability in this study was greater (between 113.9 and 139.9 for the higher- and lower-fit children respectively as compared to between 53.4 and 83.2 for the previous studies). The other factors responsible for variability in this study could be resulting from factors such as genetics, weather and the time of test as opposed to the test itself.

One of the basic rationales that can be constructed to explain this trend may be the physiological mechanisms of increased cerebral blood flow or cerebral circulation hypothesis, structural changes in the nervous system and modified arousal levels (Sibley & Etnier, 2003) that cause alteration in brain neurotransmitters brought about as a result of exercise. The cerebral circulation hypothesis contends that physical activity increase brain blood flow, which in turn benefits the cognitive functioning of the organism, due to increased supply of nutrients to the brain. Travis (1998) has also associated speed of processing and executive function with changes in brain structure and function as a result of ongoing myelination and synaptic pruning as a result of exercise.

The fact that the two groups did not reveal significance results in reaction and movement time tests of attention could be attributed to slower processing speed associated with their age. Attention is known to be limited, and an individual can attend to only one thing at a time or think only one thought at a time. The suggestion here is that too great a demand on attentional capacity overwhelms the individual especially young children whose capacity to handle environmental information is still developing. There has also been reported difficulty in searching for and retrieving information into memory by children (Chi, 1977a, 1977b).

For the selective attention task, secondary task reaction time (STRT), STRT minus visual simple reaction time (VSRT) and time on task (TOT) revealed no significant difference between the higher-fit and lower-fit groups. The test of selective attention was secondary task reaction time (STRT) which involved selectively attending to the primary task and when appropriate responding to a secondary task. The implication of the results indicating that STRT, and STRT minus visual simple reaction time (VSRT) and time-on-task (TOT) did not reveal any significant difference suggests that children are less efficient in selecting appropriate information and produce larger interference from irrelevant distracters. The fact that the hypothesis was not supported despite a trend can also be based on reported studies on attention (Colombo, 2001; Enns & Cameron, 1987; Gallagher & Thomas, 1986) that younger children's ability to process relevant information and to selectively inhibit irrelevant information is affected by their inefficient strategy use.

The results on the attention tasks appear to be in agreement with the definition of attention that it is limited, an individual can attend to only a restricted amount of information at a time and that children differ from adults in how they attend to environmental cues. Adults appear to overcome distractions and produce accurate responses to the target in a wide variety of tasks. The results are also reflective of the concept that if a specific movement activity requires attention, then some or all of the individuals' limited attentional capacity must be allocated to the performance. Therefore, since attention is limited, interference will occur if another activity requires attention and as a consequence, speed or quality of performance is negatively affected. This test established that both groups, regardless of fitness level, recognized relevant information at the same speed and efficiency.

Memory is commonly believed to be responsible for the ability to store information as well as manipulating it for brief periods of time. For memory, higher-fit subjects were expected to perform better by obtaining high percentages of correct responses on the probed memory test at 10- letters with fewer differences at 8 letters. The higher-fit subjects were also expected to keep information in memory longer by getting higher scores or 'hits' at both 80 % and 100 %. These hypotheses were not supported by the numeric vigilance and probed memory tests. The two groups did not differ in performance at both 8-letters and 10-letters as well as at 80- and 100-three-digit numbers per minute. These results are reflective of a developmental trend in memory capacity that memory span is age related and was not at this point related to level of fitness. As age increase, so does the memory span. For capacity, there was a difference of .43 % correct response between the two groups at 8-letters while at 10-letters (.03 % correct responses) both groups were overloaded and performed poorly. The two groups were able to keep more information in memory by scoring higher for 8-letters compared to 10-letters (see Figure 3).

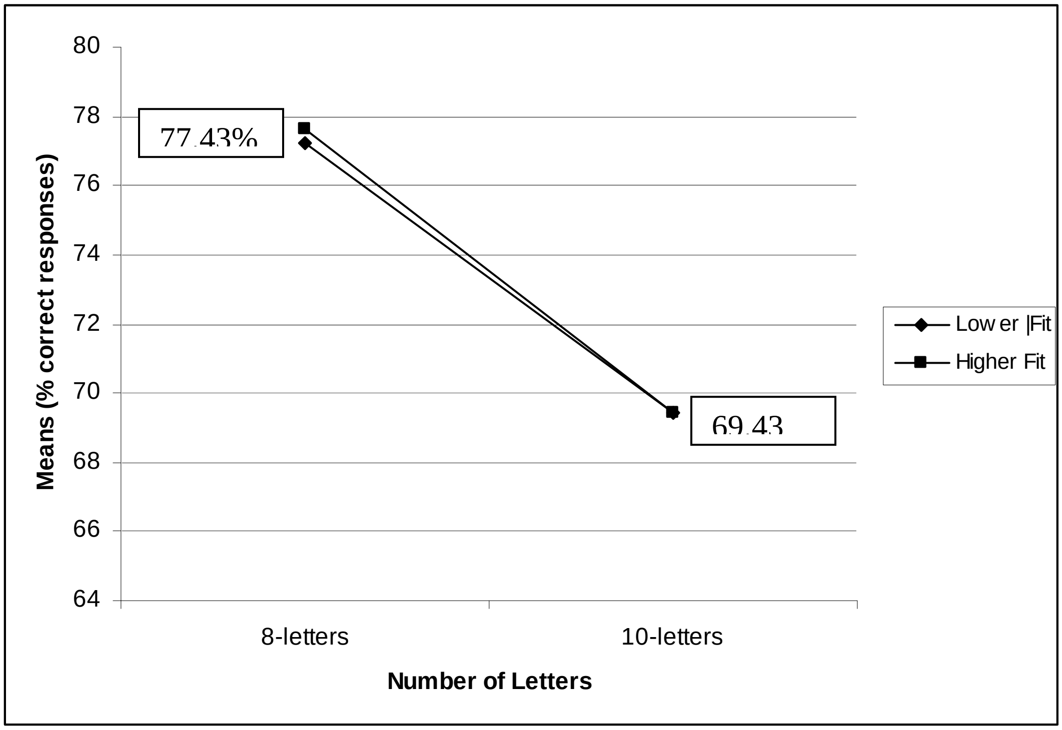

Figure 3 The mean percentage correct response with 8- and 10- letters

This result, that both groups do better at 8-letters than at 10-letters supports the view that the working memory has limited capacity; the memory storage was able to more efficiently store and retrieve information that was short, 8-letters, than one that required more memory storage 10-letters.

The groups did not differ significantly in memory duration tests, however, both were able to keep information longer in memory to enable them to perform better at 100-three digit numbers per minute than at 80-three-digit numbers per minute. For duration, there was a difference of .78 hits between the two groups at 80-three-digit numbers per minute while at 10-three-digit numbers per minute there was a greater difference of 1.06 hits between the two groups (see Figure4). The higher-fit group performed better than the lower-fit group in both tests. This task was meant to test Bjorkland and Coyle's (1995) suggestion that with practice and experience children become more efficient at using their working memory space based on universal agreement that practice and experience improves performance of different motor skills. The higher-fit subjects better performance could be related this suggestion.

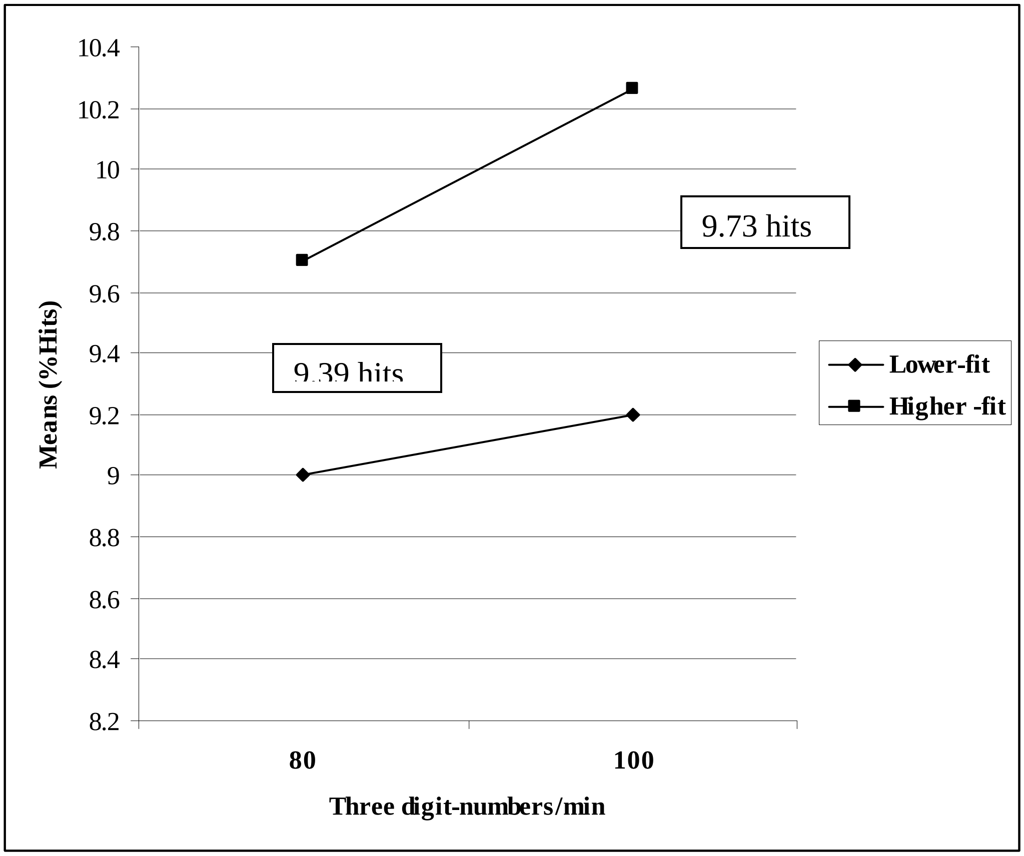

Figure 4: The Mean percentage hits with 80- and 100 three digit numbers/min

The memory hypothesis was designed to examine the effect of aerobic fitness on memory capacity and duration of higher-fit and lower-fit subjects. Memory is an important feature of information processing that has strong implications for performance. The fact that the hypothesis was not supported, could be related to memory studies that suggest children's ability to handle information from the environment is limited and age mediated (Miller & Vernon, 1996). Young children are known to experience difficulty in the amount of information they can handle at any time. Memory duration was measured by numeric vigilance. Information in working memory is known to last no more than 30 s, whereby if not rehearsed, or processed, it is lost or replaced by another stream of information. The results of this test suggest that children do not simultaneously process incoming information from the environment, instead they switched between two demanding tasks, especially when two tasks compete for the same attentional capacity. The individual will then make a decision based on information available on memory.

The decision making hypothesis was not supported; the decision time between the two groups was not significantly different. Miller, et al. (1986) further suggest that children have difficulty distinguishing between relevant and irrelevant information and as a result they spent more time trying to distinguish between relevant and irrelevant information and consequently the time to make a decision on which move to take suffers.

To validate choice movement time, simple movement time must be compared to choice movement time. The choice movement time was larger than the simple movement time, for both groups. The Lower-fit mean group's difference was 257.74 and the higher-fit group's mean difference was 248.8. The difference in means between simple movement time and choice movement time implies that the subjects were continuing to process information as they moved (lower-fit 33.81ms; higher-fit 41.9 ms; (see Table 9).

The test of executive function was used to evaluate children's ability to plan and solve problems. Thus, if children do well in this test, it would suggest that, they have efficient executive functioning. The executive functioning is regarded as a key component underlying development, since young children struggle in focusing attention of relevant stimuli and are prone to interference from irrelevant stimuli (Bjorklund & Harnishfeger, 1990; Dempster, 1992).

The results revealed that there were no significant differences between the two groups across the dependent variables. Interestingly, and in opposition to the prediction of this study, the lower-fit group completed the Tower of Hanoi task quicker (43 s) than the higher-fit group

(52.95 s. The mean error for the lower-fit (.150 s) was also better than that of the higher-fit group (.950 s), see Table 9. The results imply that the lower-fit group took a shorter time to complete the tasks than the higher-fit group and they also had fewer errors. The explanation for this discrepancy may be due to the fact that some students indicated being familiar with the Tower of Hanoi, and having played it before which enabled them to complete the task quickly and with fewer errors than others. Eleven subjects (3-higher-fit and 8-lower-fit) indicated having played the Tower of Hanoi previously; however, two of the eleven in the high-fit did not do well in the test. Twenty-one of the subjects indicated completing the task based on mistakes, thus they used a trial-by-error strategy. Two subjects when asked 'what strategy they used to complete the task?' indicated that they completed the task by 'just guessing' a notion that could be responsible for the large standard deviation in the data (SD=34.8 for lower-fit and SD=30.4 for higher-fit). One subject in lower-fit group, who indicated that he was guessing, completed the Tower of Hanoi test in 158 seconds instead of less than 10- seconds prescribed in the instrument, made 18 instead of 7 moves prescribed and had 1 error. The same subject who belonged to the lower-fit group was also identified as responsible for the outlier, (see Appendix F). The other subject who guessed was in the lower-fit group and took 46 s to complete the task, 46 instead of 7 moves and had 1error but statistically was not outlier. The large standard deviations also suggest that some subjects in both groups were just not paying attention. Two outliers were identified for Tower of Hanoi move and time**.** (see Appendix F)

While the trend suggests that small improvements in speed of response may be associated with aerobic fitness, it is also important to discuss the variability evident within groups. The source of variability in this study could be addressed from a measurement or an individual standpoint. The children's attention span is limited, especially if they are performing a task that is not necessarily exciting for them. This was evident during testing when children kept asking the researcher how long the test will take and ‘when will they be done’. The cognitive tests were long and unappealing to children as they might be to adults. At the end of the test subjects were asked the following questions ‘what task was the most difficult?’ What strategy they used to complete the different tasks?’ It was interesting, though evident in the data that thirty-two of the subjects said ‘Numeric Vigilance’ was the most difficult. This is consistent with what has been discussed so far that children’s memory capacity is limited in the amount of information it can handle.

Overall, the study has shown that though not significant, there is a potential relationship between physical fitness and information processing elements of attention, memory, decision making and executive function which needs to be explored further.

The results of this study, just like in adult studies, potentially points to the importance of maintaining a physically active lifestyle since it has both health and cognitive benefits. The schools systems have drastically cut physical education programs in schools as they are viewed as extra curricular. Physical education programs in public schools are the first to experience cuts over other academic subjects as public demands to improve test scores in schools mounts. There is compelling evidence that participation in physical activity and fitness is also declining and there is evidence that children nowadays spent more time in sedentary pursuits such as television watching and video games and less time on any form of physical activity. Therefore, if physical activity and fitness can benefit cognition, through information processing, schools need to increase physical activity to increase fitness and not decrease time spent in physical fitness programs such as physical education. Thus, a proven relationship between physical fitness and cognition could be used as an argument to support, retain, and perhaps even improve physical education programs in schools. Physical fitness experiences among children should be seen as a potential starting point for children to develop health habits and has been shown to enhance rather than inhibit cognitive performance.

It is also well acknowledged amongst education circles that children learn best by moving and through active experience. The most important relevance to this study is the fact that if you stay physically active throughout childhood chances are that you will continue the practice into adulthood.

4.1 LIMITATIONS OF STUDY

At the outset, the current study had limitations despite improvements in methodology from previous studies. The cognitive tests performed on the computer were long and tiring for some for children (35 min) which could have affected their performance, however, other studies (Clark, 2007) used the same tests with the same aged girls. The subjects in this study were boys, since a similar study with girls revealed significant differences amongst fitness groups across tests points to gender as having played part in variability (Clark, 2007). Some subjects complained of being tired during the test, and it is possible that they guessed at the answers. The fact that some subjects might have had more experience in use of the computer, especially Tower of Hanoi, might have bearing on the results.

Given the age group of subjects (12- to 14-years) the insignificant difference in performance of cognitive tests might be that the age did not afford great variability or possibly afforded greater variability. While the cognitive test (PsychE) might be a valid instrument of psychomotor evaluation, the instrument has not been tested extensively with children. It is important to mention that this study should be viewed as preliminary since no studies have looked at the effects of physical fitness on cognition using the elements of information processing. An additional issue is the period of data collection was the last three weeks of the year, and formal teaching for PE had stopped and subjects had to choose between free time and participating in the study. Some subjects gave preference to free time than the tests in the study, which could have affected their performance. The hot weather could also have affected the subjects' performance.

4.2 FUTURE RESEARCH

It is important for future studies to examine if the effect of physical fitness to cognition is general or specific to certain aspects of information processing. The sample size of twenty students per group may have been insufficient to enable the tests to reveal significance. Future studies might involve creating a cognitive instrument that is age appropriate and appealing to children, the instrument used has proved to be tiring and less interesting for children. The test could also be administered on different days to maintain subjects' motivation and attention on tasks. Finally, future studies could examine the effect of physical fitness as measured by muscular strength or endurance or habitual physical activity instead of aerobic fitness.

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APPENDIX A

EXTENDED LITERATURE REVIEW

5.0 EXTENDED LITERATURE REVIEW

The importance of a physically active lifestyle is receiving increased attention more than ever. In addition to health related benefits, research studies have associated physical activity and physical fitness with general and selective benefits in cognitive function for both older adults and children (Dwyer, et al 2001; Grissom, 2005; Kramer & Colcombe, 2003: Hillman, Weiss, Hagberg & Hatfield 2002).

While studies demonstrate a relationship between an active lifestyle and cognitive functioning in the elderly population (Chodzko-Zacjko, 1991; Clarkson-Smith & Hartley, 1989; Spurdoso 1975), this phenomenon has not been extensively studied in the pediatric population. The relationship is of significant importance in the school system because a large portion of school time is spent in the cognitive and academic domain, thus examining the potential relationship between physical activity and cognition is important.

Although benefits of physical exercise and fitness are acknowledged, physical activity and fitness programs in schools are viewed as extra curricular. Physical education programs in public schools are the first to experience cuts over other academic subjects as public demands to improve test scores in schools mounts. Participation in physical activity and fitness levels are also declining and there is evidence that children nowadays spent more time in sedentary pursuits such as television watching and video games and less time on any form of physical activity (Green, 2004; Malina, 1996; Sibley & Etnier, 2003). Therefore, if physical activity and fitness can benefit academic performance, schools need to increase physical activity to increase fitness and not decrease time spent in physical fitness programs such as physical education. Thus, a proven relationship between physical fitness and academic achievement could be used as an argument to support, retain, and perhaps even improve physical education programs in schools.

The object of this study was to examine the relationship of physical fitness to the information processing components of attention, memory and decision-making. Therefore, the review of literature for this paper started by discussing the overall model of information processing and examined short term sensory store, attention, working memory capacity and duration, and decision making. Following the review of literature, studies that associated physical fitness with cognition was discussed to establish if a connection exists. Finally methodology, procedures including instruments, measurements, subjects and data analysis that was carried out in the study was described.

It is well known that older children and adults process information faster than younger children. Gallagher and Thomas (1986) demonstrated that given the same information older children are able to integrate that information into prior experiences and demonstrate a speeded decision. The question becomes, what are the older children and adults doing differently that speeds their use of processing information. In order to answer this question, the various components of the information processing model are reviewed and specific components that might be sources of adult-child differences addressed.

5.1 INFORMATION PROCESSING APPROACH

The information processing approach provides an understanding of how individuals handle internal and environmental information. When we process information, in addition to the cognitive and neural processing of the physical characteristics of the stimuli, allocation of attention, stimulus relevance and memories of past experience are important (Baddeley, 2000; Schmidt, R., A., 1988; Schmidt & Wrisberg, 2004).

An important assumption of this model is that, serial and non-overlapping processing exists between a stimulus and a response. Therefore, the information processing approach to cognitive functioning attempts to understand the stimulus-response relationship. The stimulus is information entering through the short term sensory store while the response is the resulting behavior.

Utilizing the information-processing model in Figure 4, a framework for examining the characteristics of attention, memory and decision-making is provided. Initially, all sensory information is maintained in sensory store and via attention and perception, information is moved into working memory or conscious thought. When the information is in working memory, prior experiences that are in long term memory can provide direction to the selection of the skill. For all actions, many alternatives exist from which the individual must select. Finally, the motor response is programmed and the muscular system is organized for the desired movement. Throughout the information processing cycle the individual must attend first to environmental information to select the important cues, selectively attend to the important information in memory, and then base the decision on the task criteria.

In order to understand the processes involved in information processing among children, the key components of the model, namely attention, memory and decision making are discussed next. Given that the Short Term Sensory Store (STSS) is the most peripheral and takes place where senses store what has been received before any cognitive processing occurs, it is necessary to begin this discussion with STSS.

5.1.1 Short Term Sensory Store

STSS refers to the fact that, after experiencing a stimulus, information about that stimulus is briefly held in memory in the exact form it was received, until it can be further processed. It is the most peripheral component of memory where environmental information first enters the system and each stream of information is held for only a few hundred milliseconds before the next stream replaces it. An example is, if a line of print is flashed at an individual very rapidly, for example, for one-tenth of a second, all the letters one can visualize for a brief moment after that presentation constitute the STSS. It is at STSS where the character and features of the stimuli are first registered and held according to their sensory modality (auditory, visual or tactile). These features are however not perceived at this stage, because they occur prior to conscious involvement by the individual, hence very little processing occurs. Some of the features registered at the STSS might include the shape of the object, the feel of a surface or sound coming from a nearby place (Rose, 1997).

It is at the STSS where the individual must direct his/her attention to the different aspects of the registered stimuli for selection for further processing in memory. In the case of selective attention, the remaining stimuli which one chooses not to attend to will disappear instantly or will be replaced by the next stream of information. By nature, the STSS involves no processing as it occurs before conscious involvement by the individual. Once information has entered STSS, depending on its relevance, or pertinence to the task at hand, it is then transferred to the working memory via selective attention which is discussed next.

5.1.2 Attention

One component of cognitive functioning that is usually considered the core of information processing and has not been measured throughout the studies comparing fit and unfit individuals is attention. A central concept in the information processing approach, attention, is a difficult and elusive phenomenon to define, therefore scientists and psychologists have preferred to operationalize attention. Horn (1992) has conceptualized attention as the amount of information that can be attended to at any one time as well as the ability to switch from one source of information to another. Schmidt and Lee (1999) have described attention as focalization and limitation of information processing resources.

What appears to be consistent in the various definitions of attention is that; it is limited (an individual can attend to only a restricted amount of information at a time) and it is selective (an individual needs to select and attend to meaningful information or ignore irrelevant information). The component of attention that is of importance to this study is selective attention. Children differ in how they attend to the environmental cues which is covered next.

5.1.3 Selective Attention

Related to the limited-capacity view is the concept that human beings can selectively allocate attention to different inputs or tasks. Selective attention is conceived as a process by which certain information is preferentially selected for detailed processing while other information is ignored. A common example of selective attention is the cocktail party phenomenon (Cherry,

1953) where an individual in a party crowd can attend selectively to a conversation with one person even though noise and a number of other conversations are taking place around them. Furthermore if during that conversation someone in the crowd mentions the individual's name, his or her attention is immediately diverted to that person in the crowd.

It is during the stimulus-identification stage of information processing that several segments or 'streams' of information are processed simultaneously and in parallel. Each stream of information is then held for a few hundred milliseconds in different short-term sensory stores (STSS) before being replaced by the next segment. While a considerable amount of information passes through a person's STSS, not all of the information reaches a conscious level, rather, a selective attention mechanism selects some of the information in STSS for further processing while the remainder is lost or replaced by the next stream. It is at this point where it is believed the final decision regarding what information is selected for further processing is made depending on its relevance to the task at hand.

Selective attention abilities of adults are more efficient when compared to those of children. Adults appear to overcome distractions and produce accurate responses to the target in a wide variety of tasks. On the other hand children are less efficient selectors than adults; they produce larger interference effects from irrelevant distracters than adults, (Davies & Thomson, 1988; Ridderrinkhof et al 1997; Ridderrinkhof, & van der Molen, 1995).

Ross (1976) proposed three phases in which development of selective attention occurs: overexclusive; 2- to 5-years of age, children most often pay attention to one stimulus and are easily distracted, overinclusive; 6- to 11-years of age, children attend to several environmental stimuli and selective attention; from 11-years, children develop the ability to selectively attend to task-appropriate cues and ignore irrelevant information. These phases show that older children are much more likely to ignore information that is irrelevant or that distracts from the central activity than are younger children. An example of Ross's study was demonstrated by Miller, et al (1986). Children aged 6-, 8-, and 10-year-olds were asked to remember the location of items they had already seen behind closed doors by opening those doors. Eight- and 10- year olds were more likely than the 6-year olds to open doors that contained relevant stimuli such as 'items to remember'.

In a study to predict cognitive development in late childhood and adolescence, Travis (1998) used a selective attention task to investigate age-related changes in speed of processing and executive function of twenty-five 4th, 8th and 12th grade students. The selective attention consisted of 200 common geometric shapes randomly ordered (40 each of squares, triangles, circles, hexagons and diamonds). Each shape was presented for 175 ms, with an inter-stimulus interval of 1.3 s. The subjects were instructed to respond to one of the shapes with a right button press (target 20 %), and a left button press to all other shapes (standard 80 %). Each subject received three blocks of 200 trials with different targets in successive blocks: triangles, squares and diamonds, respectively. Subjects were told to emphasize both speed and accuracy, thus, speed was regarded as a component shaping development. RTs were averaged for correct target and standard responses for each block (right button for presses to the target stimuli and left to standards). Accuracies were calculated as the percentage of correct responses. A one-way ANOVA with three levels of grade revealed a significant main effect for grade, with performance reflecting improvement in selective attention with age. The accuracy rates steadily declined for 4th and 8th grader students over blocks when compared to that of 12th graders. RTs were also faster for the 8th and 12th grade subjects than the 4th graders. These studies indicate that older children perform more efficiently than younger children in tasks that require irrelevant information to be ignored as relevant information is being processed.

Investigating selective attention of children with attention deficit hyperactivity disorder (ADHD), a recent study (Brodeur & Pond, 2001) examined the influence of age on a selective attention task in a sample of children with and without ADHD. Although the study included children with ADHD which is not specifically relevant to this study, older children without ADHD were more efficient in selective attention tasks than younger children without ADHD. Thirty-two children (6- to 8-years olds, 9- to 12-year olds) completed a visual attention task. The subjects were told that they would see pictures of clothing (tie, shirt etc) on the computer screen, and that they should indicate what they saw by depressing a corresponding button on the keyboard. They were also informed they would hear words in the headphones but they should ignore the words in the headphones and respond as quickly as possible in response to the pictures without making errors. Children were presented with a visual stimuli on the screen for 3000 ms or until a response was made. While all children experienced distraction, younger children were affected more by the headphones than were older children. Mean RTs and accuracy scores for older children were significantly different from that of younger children (mean RT=137.01, mean ACC 0.59 for younger group and Mean RT =83.12 ACC 1.04 for older group).

Similar to other reported studies on attention (Enns & Cameron, 1987; Colombo, 2001; Gallagher & Thomas, 1986; Guttentag & Ornstein, 1990) younger children have deficits in skills that are needed to develop and use strategies for selective attention and they produce larger effects from irrelevant distracters when compared with older children (Ridderrinkhof, et al 1997). Thus, the younger children’s ability to process relevant information and to selectively inhibit irrelevant information is affected by their inefficient strategy use. Furthermore, Wickens and Benel (1982) indicate that the ability to efficiently allocate attentional capacity improves with age and that developmental differences in attending to dual tasks may be due to lack of automation and how the individual deploys their attentional skills. Thus, as children grow older they become more adept at controlling the allocation of their attention and require less of the capacity resources.

Becoming more efficient at selective attention which requires less capacity has been demonstrated to be sensitive to the fitness level of older adults. Physically fit older adults have demonstrated a less rapid decline in attentional capacity than their less-fit peers, and consequently perform better on tasks in which attentional resources are a limiting factor (Enns & Girgus, 1985; Chodzko-Zacjko, 1991). These studies suggest that cognitive tasks, which require effortful processing, should be more sensitive to the effects of fitness than tasks, which can be performed with minimal attention.

Since attentional capacity is limited, the question becomes; are young children more limited in their capacity than older children or adults. One way to determine limits of attention is through the use of a dual task paradigm. A dual-task, which is used to measure the limit of the individual's processing capacity or attention, was used in this study to determine the attentional demands of the primary task while simultaneously performing the secondary task.

The type of secondary task called probe technique usually uses a probe whereby an auditory or visual stimulus is presented at different times during the performance of the primary task. Consequently, if the primary task is demanding, there will be little attentional capacity to spare for the secondary task, resulting in a slower probed RT, however, if little capacity is required for the primary task, then there will be attention capacity for the secondary task resulting in fast and accurate RTs. Thus, poor secondary task performance will be expected to accompany a difficult primary task.

In the dual-task approach, the task of interest is usually the primary task. However a key question is the selection of the secondary task that accompanies the primary task. In selecting a secondary task it is critical to establish if the secondary task elicits structural or capacity interference. Structural interference is caused by simultaneous use of common processes needed for both tasks (eg simultaneous tapping and aiming) while capacity interference arises when cumulative attentional (visual tracking and auditory response) demand of the two tasks exceeds the available central processing capacity (Kahneman, 1973). One purpose of this study was to compare the attentional demands of active and inactive children after attentional demands of the primary task have been met, therefore, the secondary task selected in the dual-task test of this study used different sensory and response modes (capacity interference) than that needed for the primary task. The test had a primary task, tracking and a secondary task, reaction to an auditory and visual stimulus.

In examining selective attention using the dual task paradigm, the subject is required to attend to the main task and then randomly is required to respond to a second task. The individual is to maintain performance on the main task and respond as quickly as possible to the second task. While directing attention toward the primary task may show deficits in the performance speed or quality of the secondary task, shifting attention to the secondary task may cause the primary task to suffer while the secondary task improves. These measures of deficits and impairments in the primary task while shifting attention to the secondary task are used as measures of selective attention. In this study, selective attention, as a component of information processing was tested on fit and unfit children to establish if fit children are able to focus their attention better than unfit children. If the children's performance on the primary task is stable and there are decrements in the secondary task, they are not distracted by the secondary task and appropriately attending selectively. If however there is a decrement in the primary task, the individual has not selectively attended to the appropriate cues.

The focus so far has been on the limitations of selective attention and that children's attentional ability is less efficient when compared with that of older children and adults. Once the individual has processed information from STSS by selectively attending to some information and ignoring some, the information is moved into working memory which is discussed next.

5.1.4 Memory

Memory, which is usually viewed as the storage of material emanating from the activities of the various information-processing stages, is an important process associated with production of effective movements. As observed in the preceding sections, memory is continually used throughout waking hours. Like attention, memory is a critical factor to the understanding of information processing and motor performance. Everywhere in our lives, be it playing sport or conversing with friends we are often faced with situations that require memory to produce action. Two types of memory are discussed next, working memory and long term memory.

5.1.4.1 Working Memory

Working memory, also referred to as short term, involves holding information for brief periods of time, and then forgetting it or deciding to process it further. When information is moved into working memory via selective attention, controlled information processing activities are applied to information in the working memory. For example, a person is using working memory when he or she is trying to recall a telephone number that was heard a few seconds earlier or the name of a person who has just been introduced. Thus, information in working memory can be held only as long as the individual can direct his or her attention to it, if they direct their attention elsewhere, individuals forget the contents, with complete loss accruing in perhaps 30 s (Schmidt & Wrisberg, 2004). Because of the active role played by working memory, it is widely believed to be responsible for the ability to store and manipulate information for brief periods of time (Conlin, Gathercole, & Adams, 2005) and considered to have a limited capacity with storage duration of about 20 to 30 s (Gabbard, 2004). Thus, the working memory is characterized by capacity - amount of information that will reside in working memory and duration - length of time information will remain in working memory. The working memory is then, used as a workspace to briefly store information presented in the immediate past before further processing and like attention it has limited capacity and duration for storing information. Memory capacity and duration are discussed next.

5.1.4.2 Capacity of working memory

One feature in processing of information that has strong implications for performance is the concept that memory is limited in its capacity to handle information from the environment. Gabbard (2004) notes that if a specific movement activity requires attention, then some (or all) of an individual's limited capacity must be allocated to the performance. In this case, since capacity is believed to be limited, interference will occur if another activity requires these resources resulting in either loss of speed or quality of performance.

In a classical study, to quantify the capacity limit associated with working memory, Miller (1956) proposed that, for a remarkable number of different kinds of information, working memory capacity for young adults is at most around 7 $\pm$ 2 items, or chunks of information. The fact that we can easily recall seven digits justifies Miller's proposition.

There is however, evidence in memory capacity research suggesting that children's working memory improves markedly up to early adolescence with substantial changes from two digits in 2- and 3- year-olds to about five digits occurring at age 7-years (Dempster, 1981) after which the process steadily increase to adulthood. Thomas, Thomas, Lee, Testerman, and Ashy (1983) have found that children's ability to recall distance improves with age as does the apparent use of processing strategies such as rehearsal.

As children age, they are quick to recognize relevant information and become more skilled at performing cognitive operations that are linked to motor operations. This notion is also supported by current research approaches which regards to working memory as emphasizing active processing as opposed to merely a memory store (Baddeley, 2000; Gallagher, French, Thomas, & Thomas, 1996). In order to process information in working memory, a memory strategy is adopted. Development of children's memory strategies as a process is viewed as analogous to the development of skill.

A study to determine relationship of speed of processing and working memory in adults was also demonstrated in children (Miller & Vernon, 1996). The authors administered a battery of computer based reaction time and memory tests to 4- to 6- year old boys and girls. The working memory was assessed using color, shape and tone spans where participants had to recall the sequence of presentations by pressing one of the three keys on the computer screen that correspond with the presented stimuli. Capacity was measured by requiring the subject to remember a series of red and yellow color squares or green squares and triangles (presented individually or together) sequences or series (red and yellow squares, ranging from 2-7 squares in length). The study revealed distinct developmental trends in processing speed and memory capacity; memory span was highly correlated with age, whereby, as age increased so did the memory span.

It has so far been established that not only is memory limited in its capacity to handle information from the environment but the length of time information will remain in working memory is also limited, therefore duration is discussed next.

5.1.4.3 Duration of working memory

The most important characteristic of working memory is that, it retains information for a limited amount of time only. A nice illustration of this limitation was a study by Adams and Dijkstra (1966), who were among the first to show that, not only is information lost from working memory after about 20-30 s but most importantly that movement information has short duration in working memory. In a classic study that became the standard pattern for what was termed motor short-term memory research, Adams and Dijkstra wanted to establish if motor or kinesthetic information is also lost as rapidly as verbal information in the working memory. The authors had their subjects blindfolded, seated and asked to move to a stop on a linear positioning task, a free moving handle that slides along a metal rod. The task was to move the handle to a stop and then return the handle to a starting point. Following a specified time interval, with the stop removed, the subject repeated the task by moving the handle to a point where she or he estimated the location. The experimenter scored accuracy by recording how far the subject's estimate was from the criterion location. The authors' idea was that if verbal information in the working memory has short duration, so does the motor information. The results of their study indicated that the motor or kinesthetic information suffers the same fate of short duration as verbal information in the working memory. Studies (Dempster, 1981; Kail, 1991; Miller & Vernon, 1996) that have been conducted after Adams and Dijkstra's investigations have generally supported the notion that duration of kinesthetic information in working memory is about 20-30 s.

There are two reasons why the current study used working memory to examine the aspects of information processing that may be responsible for the differences found in how children process information. First, Bjorkland and Coyle (1995) have suggested that with practice or experience children become more efficient at using their working memory space. There is a universal agreement that practice and experience improves performance of different motor skills, this study wanted to establish if participating in activities that lead to fitness provided the children with experience at using their working memory and therefore fit children would be better able to use their working memory when compared to unfit children.

Secondly, the studies reviewed on limitation of memory capacity and duration has always been that as children mature, so does their search strategy and memory capacity. The few studies that have looked into the relationship of physical fitness and information processing have however failed to address what aspects of information processing may be responsible for the differences found in how children process information. Therefore, this study examined the memory capacity and duration aspects of working memory, which is an important component of information processing. In this study, numeric vigilance and probed memory test were used to assess the children's working memory. For numeric vigilance, three-digit numbers, randomly differing from the previous one, were presented on a computer screen at a rate of 100/min and 80/min and subjects were required to identify the duplicates by pressing a spacebar as they occurred. For probed memory, the subjects were shown a series of eight and ten consonants; a new consonant was added every second. The subjects were instructed to remember and recall one second after the whole eight and ten characters had been displayed on the screen.

Since working memory has limited capacity and duration, it briefly stores information that has been presented in the immediate past as well as information that has been retrieved from long term memory. Long term memory is discussed next.

5.1.5 Long Term Memory

Unlike working memory, long term memory (LTM), or knowledge base, can store much larger quantities of information and it is considered limitless in both capacity and duration. This component of memory contains information about specific past events as well as general knowledge about the world. The fact that LTM appears to have unlimited capacity and duration characteristics, makes it different from working memory. Information that is stored in the LTM results from controlled and generally effortful processing which involves rehearsal and connection of old information with the new. This study was not directly investigating LTM but through working memory children access LTM. Thus working memory briefly stores information presented in the immediate past as well as information that has been retrieved from LTM.

A noteworthy phenomenon in LTM is that while memory capacity and duration are equally limited, motor skills in LTM seem to be recalled after a long time of non-use than verbal skills. A famous example is that of remembering how to ride a bicycle after several years while remembering a poem learned from school around the same time might provide some difficulty (Magill 1989).

5.1.6 Decision Making

Working memory, including capacity and duration, have been reviewed. Within working memory, individuals need to make decisions and execute a response. While studies on decision-making have examined how adults make decisions, few have explored this important aspect of children's decision making. As mentioned in the preceding paragraphs, it is during response selection in working memory that the individual must decide what movement or action to make given the goal and the environmental stimuli. The idea of information processing theory is that information from each component is integrated and synthesized in working memory in order to make a decision.

Studies show that strategies employed by older children and adults are different from those used by younger children. Davidson (1991) examined the decision making strategies of second-, fifth-, and eighth-grade students using a decision board, a method used previously with adults. A decision board procedure involves a presentation of information about alternatives or choices, which allows subjects to open doors to examine information about different alternatives before making decisions. This procedure permits the experimenter to record what information is examined as well as the order in which the information is uncovered.

The results showed that, compared with younger children, the older group searched significantly fewer alternatives as well as fewer dimensions of those alternatives. Older children searched information more efficiently and systematically resulting in better decisions than younger children. Younger children have difficulties distinguishing between relevant and irrelevant information. Similarly, other researchers found that younger children attend to irrelevant information more than older children in speeded classification tasks (Hagen & Hale,

1973) and display differences in attention to relevant information in memory tasks (Miller, et al 1986).

In summary, research studies on decision-making have focused on developmental differences across childhood. In particular studies have mostly focused either on when different age groups of children make decisions or how young children differ from adults in decision making. Having said this, it is possible that the young child's effective search strategy might simply be following a different, less adequate, strategy than that of older children. Unlike adults, few studies have looked at the effect of physical activity on decision making of young children of the same age group. One purpose of this study was to examine the effect of physical activity on decision making of younger children, whereby, participants were expected to perform tasks on the computer that required them to make quick decisions by responding as quickly as possible to auditory and visual stimuli based on a number of alternatives.

5.2 RELATIONSHIP OF PHYSICAL FITNESS TO COGNITION

While the object of this study was not to address cognition in children, it was important to discuss how cognition develops and relates to information processing and decision making. The remainder of this section will review measures of cognition, studies that have investigated information processing differences between adults and children and tie the tests used in this research to the components of information processing. Studies that looked into the relationship of physical activity and the various components of information processing were discussed last.

5.2.1 Cognition

In general terms, cognition is the act of knowing and knowledge is gained via mental process. Gabbard (2004) refers to cognition as "an integral part of perceiving, recognizing, conceiving, decision making, reasoning and varying any of the perceptual-conceptual processes" (pp 225). Cognition is also regarded as a major psychological determinant in the ability to program information (Gabbard, 2005). Programming helps individuals formulate thought which results in either verbal or physical expression. According to Gabbard, attention, perceptual awareness and information stored in working memory all influence programming. Therefore, in order for the individual to produce a thought or motor response, information is collected from the environment through any of the six senses, and through selective attention, that information is passed on to the working memory, where a decision as to effect a motor response is made, this process is known as information processing.

5.2.2 Cognition and Fitness

Various studies have investigated information processing differences between adults and children including speed of processing, attention, memory and decision making and all concluding that children process information differently from adults. This study investigated if children who were more physically fit were more attentive, remembered more and made better decisions than those children who were less fit.

For older adults cross-sectional studies have found a positive relationship between fitness and cognition by examining information processing speed using simple and choice reaction time measures (Bjorkland, 1991; Rowland, 1980). Active older adults have faster simple (SRT) and choice reaction times (CRT) when compared with their older sedentary counterparts.

A great majority of research studies demonstrate a relationship between an active lifestyle and cognitive functioning in the elderly population (Chodzko-Zacjko, 1991; Etnier, Salazar, Landers, Petruzzello, Han, Nowell, 1997; Clarkson-Smith & Hartley, 1989; Sherphard, 1996; Spurdoso, 1975a 1980b), however, this phenomenon has not been extensively studied in children. The relationship becomes significant in the school system because not only is a large portion of school time spent in the cognitive and academic domain, over years, Physical Education programs have become unpopular in the schools system. Therefore, examining the potential relationship between physical activity and cognition is important. Physical activity and fitness are also declining as evidenced by how nowadays, children spent more time in sedentary pursuits such as TV watching and video games and less time on any form of physical activity and fitness.

Studies that have proposed to explain the relationship of physical activity, fitness and cognition have relied either on physiological mechanisms or learning/development mechanisms. The physiological mechanism, resulting from purposeful movement causes some integrated activity of the central nervous system (CNS) with the body periphery, such that the CNS must be able to identify and perceive sensory input, determine useful actions and execute those actions with correct movement sequencing, timing and coordination (Light & Spirduso 1990). The increased cerebral blood flow hypothesis is based on physical changes in the body that occur as a result of exercise where moderate-to-high intensities of exercise have shown large increases in cerebral blood flow as a function of exercise. Research studies further indicate that cerebral blood flow then benefits cognitive functioning of the organism due to the increased supply of essential nutrients (glucose and oxygen) to the brain (Chodzko-Zacjko, 1991; Madden, Blumenthal, Ekelund, & Emery, 1989). The learning/developmental mechanism explains the relationship via learning experiences that aid, and may even be necessary for, proper cognitive development (Sibley & Etnier, 2003).

Previous studies that have looked into the relationship of cognition and fitness in children have been hampered by difficulties with focusing their studies mainly on academic performance as the key measure of cognition and use a wide variety of academic performance measures. Most of the studies have also suffered methodological shortcomings, including use of wide variety of cognitive and fitness measurements and validity issues.

The academic performance tests that have been used in studies of fitness and cognition used a wide variety of “cognitive” measures such as perceptual skills, IQ, academic achievements, arithmetic, reading, verbal tests and memory (Sibley & Etnier 2003), scholastic ratings (Dwyer, et al 2001), reading and math (Tremblay, Inman & Willms 2000), pre-SAT scores (Grissom, 2005), mathematics (Gabbard & Barton 1979; McNaughten & Gabbard 1989),and student perception of academic performance (Lindner, 1999).

Consequently, the validity and reliability of the various cognitive measures is questionable since many of the measures were created for the specific study and validity and reliability measures were not reported. The problems with the measures of physical fitness were the variety of measures used. The measures included self-reported (Lindner, 1999), cycle ergometer, anaerobic measures and walking (Dwyer, et al.). Given the few studies on each of the measures, conclusions are difficult to make. Despite all these varied measures of cognition, a meta-analysis (Sibley & Etnier, 2003) concluded that there was a positive relationship between fitness and cognition. The group that was exposed to physical activity scored better on the variety of cognitive measures.

The current study investigated the various components of information processing to determine whether fitness level improved attention, memory, and decision making. In other words, were fit children better able to attend to the task appropriate cues, were they able to keep more in memory for a longer duration, and did they make better decisions.

The difficulties with previous research on cognition have been addressed and what follows is how measures used in this study would address these problems. The measure of physical fitness used in this study was aerobic performance as measured by a cycle ergometer test. Aerobic capacity is a measure that is felt to be the most important in relation to cognition and information processing.

The tests used in this study are part of the Psychomotor Evaluation test (PsychE). These psychomotor performance tests, especially reaction time and movement time, have been used by researchers to explore the various components of information processing. The PsychE is an integrated program that is used to assess psychomotor and cognitive tests using tasks and methodologies, derived from research in experimental psychology and ergonomics that assess memory, perception and attention (Hope, et al 1998). The tests in this battery were used to measure selective attention, memory capacity and duration and decision making.

Probably one of the most comprehensive studies investigated the relationship between fitness test scores (FITNESSGRAM) and standardized reading and mathematics scores of 884,715, 5th, 7th and 9th grade students enrolled in California public schools. Grissom (2005), found a consistent positive relationship between overall fitness and standard mathematics and reading scores. Thus, as overall fitness scores improved, mean achievement scores also improved in a statistically significant way.

While findings of these studies suggest that fitness is related to general improvements in cognitive function, they however, do not provide any understanding of the underlying mechanisms by which physical fitness impacts the key components of cognition such as attention, memory and decision making. Thus, reviewed studies so far indicate that the effects of physical activity and fitness are not global; physical fitness appears to affect certain aspects of cognitive processes. Therefore, this study utilized components of information processing model to provide a framework for assessing the impact of physical fitness and cognition.

What the reviewed studies have not addressed was what component of the information processing continuum was affected by physical fitness. In an initial attempt to separate the various components of information processing Mokgothu (2000a) investigated memory capacity and decision making of 7- and 9- year-old habitually active and sedentary children drawn from rural and urban areas of Botswana, Africa. The rural children were considered naturally fit (which was confirmed by a sub-maximal exercise test) by virtue of their habitually active lifestyle. All children completed anthropometric measures and sub-maximal cycle ergometer tests. Cognitive tests included simple and choice reaction time (SRT, CRT) and measured response time to stimulus and decision making time respectively. Simple and Choice movement time (SMT, CMT) measured interval between start of movement and its completion and Simon game measured memory sequence. Results indicated that the rural fit group exhibited faster SRT (287.00 msec, SD=52.73 msec) and CRT (381.00 msec SD=64.68) than their urban unfit group (322.20 msec, SD=34.35 msec) and (414.36 msec, SD=30.98 msec) respectively. The SMT showed a trend for the rural fit children faster on choice reaction time but all groups similar on

CMT. The results implied that fitness was a factor in cognitive functioning, thus physical fitness may play a role in determining how children process information.

Follow-up pilot data (Mokgothu, 2001b) using more sophisticated testing (PsychE test Battery), and expanding on the previous study, added the following cognitive measures: a) Discrete 6-choice reaction time b) Dual task-tracking - The test had a primary task of tracking and a secondary RT task. The test measured impairments in the secondary task while maintaining the focus on primary task. Subject followed a smooth but randomly moving target on the computer (using a mouse) while responding to a secondary task by pressing the spacebar whenever a small sun symbol appeared randomly on the computer screen. The task measured the subject's selective attention through RT and SMT. The fit performed better than unfit groups for SRT and SMT. Results show that fitness level has an effect on different points in the information processing cycle. This study expanded the previous studies to investigate attention, memory and decision making.

Accordingly, Hillman, Castelli and Buck (2005) further explored this fitness-cognition relationship by examining underlying brain functions associated with cognition in high- and low-fit children and adults. Fitness was assessed by the FITNESGRAM, and cognitive function was measured by neuroelectric and behavioral responses to a stimulus discrimination task. Results showed that high-fit children had faster RT than low-fit children. High-fit children also indicated faster neurocognitive processing as measured by the P-3 response. The P-3 (component of event-related brain potetials) is theorized to index processes involved in the allocation of attention and working memory resources. The results of this study suggests that fitness was associated with increasing neuroelectric indices of attention and working memory resources, and response speed, which as a consequence may influence the speed of performance in children.

5.2.3 Information Processing Components Justification

Taken together, successful motor performance is based on a combination of three important components of information processing. First, attention (perceptual recognition) by selectively attending to task demands relevant to the task at hand; second, speed of memory functions; being able to effectively search, retrieve and recall information quickly and accurately; and third, decision-making; being able to distinguish between relevant and irrelevant information and determine the appropriate response. The components and how they were measured by different tests is discussed next.

5.2.3.1 Selective Attention

Attention is an important factor in achievement of motor tasks since it involves alertness and preparation of the motor system to affect a response. To successfully perform a motor task, the individual needs the ability to select and attend to meaningful information. The test of selective attention in this study was the Dual Task-Tracking and Simple Reaction Time. The task involved attention to a primary task while performing a secondary task as appropriate. The individual was instructed to perform the main task and when prompted, respond to the second task as needed. The individual should not reduce the performance on the main task. An auditory distracter cue intermittently and randomly sounds and the individual was asked to respond as quickly as possible but without reduction in the performance of the primary task.

If there was no deficit in the primary task, the individual was selectively attending to the primary task. If there was a decrement in the secondary task, the individual was ignoring the irrelevant cues. If there was no decay in either the primary task or the secondary task, the individual had sufficient memory to complete both tasks. If the subject had a decrement in either the primary or the secondary task, the individual was distracted. This task required the subject to use a computer mouse to follow a smooth but randomly moving target (primary task) on the computer screen as close as possible. At random intervals a stimulus in the form of an auditory beep (secondary task) was presented. The subject was asked to press the space bar of a computer keyboard as soon as the auditory stimulus was heard. The test was also able to measure the subject's reaction time and time-on-task.

5.2.3.2 Memory Capacity and Duration

According to Bjorkland & Coyle (1995), with practice or experience, children become more efficient at using their working memory space. If higher fit children were more physically active and thus were more experienced due to regular practice, their motor skills should be enhanced by practice and experience, therefore, this test should establish if higher fit children assumed to be experienced at using their working memory, would perform better than their lower fit counterparts in memory tests. Memory tests included measures of capacity and duration.

The memory capacity component of information processing is limited in its capacity to handle information. Young children are known to experience difficulty in the amount of information they can handle at any time. The probed memory task was used to measure capacity of working memory. The capacity of working memory was determined by presenting the subject with a sequence of eight and ten consonants with a new consonant being added every second. The consonants remained visible until the last consonant was displayed upon which all consonants were be blanked. The subject was then presented with a consonant and asked whether or not it had been part of the prior list, the answer was given by clicking 'yes' or 'no' with the mouse on the computer screen. The list length of consonants was eight and ten where 50% of the probe consonants belonged to the original list. This test measured capacity since remembering whether the consonant was part of the original list involved the ability to store information in memory with the ability to retrieve it later. The capacity was determine by the performance of each of the lists where the list with the best performance determined as the capacity length.

Memory duration, which is the length of time the information can reside in working memory, is limited. The numeric vigilance test was used to assess the subject's memory duration. Information in working memory is known to last no more than 30 s, whereby if not rehearsed, or processed, it is lost or replaced by another stream on information. This test established if subjects were quicker and more efficient in recognizing relevant information (duplicates). The subject was asked to identify duplicates of three-digit numbers shown on a computer screen by pressing the spacebar as soon as a duplicate appeared. The three-digit numbers were shown on a computer screen. To measure the duration of memory, rate of presentation was included 100 and 80-three digit numbers per minute. Each number differed randomly from the prior number in one digit. A sample might be 122, 172, 721, 721, 227, 274, 285, 874 containing a single duplicate 721. Correct responses, missed duplicates and incorrect duplication responses were recorded. Test duration was nine minutes.

5.2.3.3 Decision Making

One way this study measured decision making was by subtracting simple reaction time from choice reaction time. Movement time, which is the time required to complete the motor response, was used to determine whether they were continuing to think as they moved. Decision making was measured by a combination of the Discrete Simple RT and Discrete 6-choice RT. The Discrete Simple RT initially measured alertness and preparedness using an auditory stimulus. The test assessed the subject's alertness by measuring the interval of time between stimulus onset (auditory beep) and the initiation of motor response (lifting finger from home key). The task required the subject to respond as quickly as possible to the auditory beep, a task which involved reacting as quickly as possible to the stimuli.

The Discrete 6- choice RT and movement time were also used to measure decision making. The discrete simple reaction and movement time were subtracted from the choice reaction and movement time to measure decision time. It was expected that the decision reaction time would vary and decision movement time remain the same. If the decision movement time differed, that indicated that the subject was continuing to decide what response to make.

In summary the purpose of this study was to examine the relationship of physical fitness to the information processing components of attention, memory and decision-making.

APPENDIX B

APPENDIX B SHOWS IRB, RECRUITMENT PROCEDURES, M-ABC PROTOCOL, INSTRUCTIONS AND TESTING PROCEDURES.

IRB COVER SHEET (revised 4/27/06)

Date of Submission: 3/18/2007		IND #: IDE #: HDE#: If there is an IND or IDE number provided, please include 4 copies of the investigational drug or device brochure.	IRB #: 0205109 **IRB USE ONLY:** DATE STAMP:
Reason for Submission			
New Project			
Response to Comments			
Reconsideration			
Disapproval Resubmission			
Modification			
Renewal			
Renewal with Modification	X		
Adverse Event Report			
Response to Audit			

PART A – DEMOGRAPHIC INFORMATION		
Title of Study: The Influence of Physical Activity and Physical Fitness on the Cognitive Processes of Children		
Principal Investigator Information:		
Name: Allen R. Wagner	Title: Doctoral Student	
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E-mail address: alwagnerpaci@comcast.net		
Name of Department Chair:		
Co-Investigators: **Comfort J. Mokgothu**, Gary E. Clark, Jere D. Gallagher Ph.D.		
Coordinator Information (Please list the person that the IRB can contact with questions):		
Name: Allen R. Wagner		
Address: 100 Textor Drive North Versailles, PA 15137		
Phone number: 412-824-8651	Fax number: 412-829-1145	
E-mail address alwagner@comcast.net		
PART B – LEVEL OF RISK/TYPE OF REVIEW REQUESTED		
Indicate the level of risk:	[**X**] Minimal	[ ] Greater than Minimal
Indicate the type of review requested:	[ ] Full Board	[**X**] Expedite
PART C – RECRUITMENT INFORMATION		

Number of participants to be enrolled at this site (Note that the University of Pittsburgh IRB considers a participant to be enrolled if s/he signs an informed consent document. If a higher number of participants must be enrolled for screening in order to hit a targeted accrual number, please indicate the higher number.)	100
Number of participants to be enrolled at multicenter sites. Please provide 4 copies of the multicenter protocol. If this is not a multicenter study, please indicate "N/A."	0
Indicate whether this site is the coordinating center for this study.	[X] Yes [ ] No
Indicate whether this site is the data coordinating center for this study.	[X] Yes [ ] No
Indicate the gender of all participants in this research study.	[X] Male [X] Female
Indicate the age range of all participants in this research study.	6-13
Indicate the duration of study participation per participant.	3-HOURS
Indicate the duration of the entire study.	12 MONTHS

Indicate all sites where research procedures will be performed.

[ ] University of Pittsburgh	[ ] UPMC Horizon	[ ] UPMC Passavant	[ ] UPMC St. Margaret
[ ] UPMC Bedford	[ ] UPMC McKeesport	[ ] UPMC Presbyterian	[ ] Children's
[ ] UPMC Braddock	[ ] UPMC Montefiore	[ ] UPMC Shadyside	[ ] Magee
[ ] UPMC Cancer Centers	[ ] UPMC Northwest	[ ] UPMC Southside	[X] Other (specify)E.Allegheny S.D.

PART D – SOURCE OF SUPPORT	
Indicate all applicable sources of support and provide additional information as noted:	
[ ] Federal	Name of Sponsor:
	Awardee Institution:
	Grant Number:
	Grant Title:
For a federally funded study, please provide a copy of the entire grant application with salary information redacted.	
[ ] Commercial	Name of Sponsor:
For a commercially funded study, please provide either a check, a payment form from the IRB website or a request for waiver of the fee.	
[ ] Foundation	Name of Sponsor:
[ ] Other	Name of Sponsor:
[X] No support	

PART E: CONFLICT OF INTEREST

If the response to any of these questions is "yes," please attach detailed information including who has the conflict to permit the IRB to determine if such involvement should be disclosed to potential research subjects.

Does the principal investigator or any co-investigator or research coordinator involved in this study (or in aggregate with his/her spouse, dependents or members of his/her household):		
a. possess an equity interest in the entity that either sponsors this research or owns the technology being evaluated that exceeds 5% ownership interest or a current value of $10,000?	[ ] Yes	[X] No
b. receive salary, royalty, or other payments from the entity that either sponsors this research or owns the technology being evaluated that is expected to exceed $10,000 per year?	[ ] Yes	[X] No
c. have an agreement with the University or an external entity that would entitle sharing current or future commercial proceeds related to the technology being evaluated (e.g., royalties through a license agreement)?	[ ] Yes	[X] No
d. have a financial relationship with a start-up company (which is being monitored by the Entrepreneurial Oversight Committee) that has an option or license to utilize the technology being evaluated?	[ ] Yes	[X] No

PART F: RESEARCH PROCEDURE BILLING

If the response to both questions below is "yes," research fiscal and compliance review is required. If the participant does not visit any of the facilities listed or if the study involves only interviews or questionnaires, research fiscal review is not required. The IRB and/or institutions listed also have the authority to request a research fiscal review based on their review of the research submission.

Will testing, services, or procedures be performed, samples obtained, or hands-on care be provided regardless of whether it is being paid for by the study or billed as conventional care?	[ ] Yes	[X] No
Will these be done at a UPMC facility (including Children's Hospital of Pittsburgh or Magee-Womens Hospital)?	[ ] Yes	[X] No

PART G: ADDITIONAL APPROVALS REQUIRED		
Has this protocol been reviewed by a local scientific review committee? (Note: studies that are federally or commercially sponsored do not require a local scientific review to be conducted. However, there are specific departments that do require local review. Please check with your department if you are unsure.)	[X] Yes Please attach approval letter	[ ] No Indicate the reason:
Does this research involve the administration, for research purposes, of a drug (investigational or FDA approved)?	[ ] Yes Attach IDS notification	[X] No
Does this protocol involve the exposure of human subjects to ionizing radiation (excluding the standard diagnosis or treatment procedures, performed in a routine clinical manner and frequency)? (Note: If you are unsure of whether the study requires submission to the RDRC, please consult Appendix D of the IRB Reference Manual.)	[ ] Yes Attach RDRC/HUSC approval letter	[X] No
Does this research study involve the deliberate transfer of recombinant DNA (rDNA) or DNA or RNA derived from rDNA into human subjects?	[ ] Yes Attach IBC-rDNA approval letter	[X] No

CERTIFICATION OF INVESTIGATOR RESPONSIBILITIES

By signing below I agree/certify that:

1. I have reviewed this protocol submission in its entirety and that I am fully cognizant of, and in agreement with, all submitted statements.

2. I have adequate resources and facilities to carry out the proposed research.

3. I will conduct this research study in strict accordance with all submitted statements except where a change may be necessary to eliminate an apparent immediate hazard to a given research subject.
   - I will notify the IRB promptly of any change in the research procedures necessitated in the interest of the safety of a given research subject.
   - I will request and obtain IRB approval of any proposed modification to the research protocol or informed consent document(s) prior to implementing such modifications.

4. I will ensure that all co-investigators, and other personnel assisting in the conduct of this research study have been provided a copy of the entire current version of the research protocol and are fully informed of the current (a) study procedures (including procedure modifications); (b) informed consent requirements and process; (c) potential risks associated with the study participation and the steps to be taken to prevent or minimize these potential risks; (d) adverse event reporting requirements; (e) data and record-keeping requirements; and (f) the current IRB approval status of the research study.

5. I will not enroll any individual into this research study: (a) until such time that the conduct of the study has been approved in writing by the IRB; (b) during any period wherein IRB renewal approval of this research study has lapsed; (c) during any period wherein IRB approval of the research study or research study enrollment has been suspended, or wherein the sponsor has suspended research study enrollment; or (d) following termination of IRB approval of the research study or following sponsor/principal investigator termination of research study enrollment.

6. I will respond promptly to all requests for information or materials solicited by the IRB or IRB Office.

7. I will submit the research study in a timely manner for IRB renewal approval.

8. I will not enroll any individual into this research study until such time that I obtain his/her written informed consent, or, if applicable, the written informed consent of his/her authorized representative (i.e., unless the IRB has granted a waiver of the requirement to obtain written informed consent).

   - I will employ and oversee an informed consent process that ensures that potential research subjects understand fully the purpose of the research study, the nature of the research procedures they are being asked to undergo, the potential risks of these research procedures, and their rights as a research study volunteer.

9. I will ensure that research subjects are kept fully informed of any new information that may affect their willingness to continue to participate in the research study.

10. I will maintain adequate, current, and accurate records of research data, outcomes, and adverse events to permit an ongoing assessment of the risks/benefit ratio of research study participation.

11. I am cognizant of, and will comply with, current federal regulations and IRB requirements governing human subject research including adverse event reporting requirements.

12. I will make a reasonable effort to ensure that subjects who have suffered an adverse event associated with research participation receive adequate care to correct or alleviate the consequences of the adverse event to the extent possible.

13. I will ensure that the conduct of this research study adheres to Good Clinical Practice guidelines.

14. I will ensure that all listed investigators have the appropriate credentials to conduct the portion of the study in which they are involved.

Allen R. Wagner	Allen R. Wagner	3/18/2007
Principal Investigator Name (typed)	Principal Investigator signature	Date

Research Protocols

1.0 Objectives and Specific Aims

The aim of this series of studies is to evaluate the relation of cognitive processing to physical fitness level and physical activity level. Study 1 (Table 1) will examine how cognitive processing differs in physically fit and unfit children. Study 2 (Table 2) will examine how physical activity, sedentary behavior, and fitness level affects cognitive processing.

2.0 Background and Significance

2.1 Background

Research continues to address the issues of physical activity and physical fitness across the life span. One benefit of physical activity for an older population is improved cognitive performance (Chodzko-Zacjko 1991, Emery 1995, Hassm'en, Koivula, 1997, Spirduso, 1975) as measured using simple and choice reaction time paradigms. Adult research investigating the relationship between fitness level and cognitive function has shown a difference for choice but not simple reaction time tasks (Chodzko-Zacjko 1991, Emery, Huppert, and Schein 1995, Spirduso, 1975). Differences have also been shown for response selection or the speed of decision-making. Other studies support the theory that physical fitness can affect the decision making process in an older population (Etnier, Salazar, Landers, Novell, Petruzzello & Han, 1997). Similar research designs completed on children have also shown potential, however these studies are not as numerous as those on adults. Generalizations from adult studies must not be haphazardly applied to children for as the literature demonstrates children are not miniature adults. Younger children are regarded as less capable of controlling their attentional resources (Guttentag & Ornstein, 1990). Children also differ from adults in their ability to process and recall information (Thomas, Thomas, & Gallagher 1994; French, Thomas, & Thomas, 1996, Ladewig, Gallagher, Campos, 1996, Thomas et. al, 1994). With these differences in mind it is interesting that pediatric cognitive processing has not been more thoroughly addressed. Mokgothu (2000) examined the relation of fitness and cognitive function in Botswanan children and found limited correlations. His recommendations for future research included examining the benefits of fitness as related to cognitive functioning. His study looked at fitness level of the subjects but did not control for the physical activity level of the subjects The current study will introduce a more sensitive tool to measure cognitive function. It is hypothesized that physically fit children will have a higher cognitive processing level and that the cognitive processing levels of children will be higher following physical activity as opposed to physical inactivity.

2.2 Significance

Research data in adults indicate a connection between habitual physical fitness and cognitive function/performance but comparable information for children is limited. Research comparing activity levels to cognitive function/performance is almost nonexistent. A relationship between either physical fitness or physical activity and cognitive processing in children would provide grounds for improving education programs and increasing time allocated for physical education and exercise activities in a pediatric population. If the hypotheses of these studies are supported the need for a physically active lifestyle in children will be given more validity.

3.0 Research Methods

3.1 Apparatus and Procedures

Physical Activity Level

The physical activity level of the subject will be part of the design. Subjects will participate in a physically active or physically inactive session while having their heart rate monitored. A Polar Protrainer NV heart rate monitor will be used to collect heart rate information. Subjects will wear a small monitor attached to the chest, which through telemetry sends a signal to a watch-sized receiver on the wrist. The heart rate monitor gives instantaneous readings and stores information on the time spent within, above, and below the training heart rate zone. For the purposes of this study physical inactivity will consist of the subject sitting at a desk doing paper and pencil activities (reading, coloring, etc.) in which the heart rate remains below the training heart rate level for 30 minutes. The physical activity session will consist of the normal games and activities in which the subjects are participating where the heart rate is within a bandwidth training heart rate level (220-the age of the subject *.50-.80) for 30 minutes

Health Related Physical Fitness Assessment

Fitness for this study is defined as falling within the age appropriate health related fitness zones for muscular flexibility, muscular strength/endurance, body composition (Cooper Institute for Aerobics Research, 1999) (Cooper Institute for Aerobics Research, 1999) and physical work capacity. A child who falls within or above the health related fitness standards on all measurements will be considered physically fit.

Flexibility (Hamstring) will be assessed using the Back Saver Sit-and-Reach test (Cooper Institute for Aerobics Research, 1999). This test uses a standard sit and reach box (12 inch high box with a yardstick attached with the 9-inch mark at the edge of the box.). Subjects remove shoes and sit with hips parallel to the box and one leg straight with the foot against the box and the other leg bent with the foot flat on the floor. The subject places one hand on top of the other with the palms down and reaches as far as possible. The subject attempts this four times with the best score recorded. The same procedure is repeated for the other leg.

Muscular Strength/Endurance (Abdominal and Upper Body) Curl-ups will be used to measure abdominal strength and endurance (Cooper Institute for Aerobics Research, 1999). Equipment consists of a cardboard strip 30 inches long and 4 ½ inches wide for 10-to-17 year-olds and 3 inches wide for 5-to-9 year-olds. The subject lies on a mat with knees bent and feet flat with the arms and hands flat (palms down) at their side. The subject begins with their fingers touching the near side of the measuring strip and curls up until their fingers touch the far side of the strip and then lower until their head lightly touches the mat. Repetitions are performed to an announced cadence of one curl-up every 3 seconds.

Upper body strength and endurance will be assessed using a modified pull up test (Cooper Institute for Aerobics Research, 1999). This assessment uses a modified pull up bar where the student lies on their back to grab the bar using an overhand grip (reverse push up). The bar is adjusted so that it is 1 to 2 inches above the subject's reach when they are lying on the floor and an elastic band is placed 7 to 8 inches below the bar. The starting position has the subject hanging from the bar, arms and body straight with the heels touching the floor. The subject's body should not be touching the mat. To perform the test the subject pulls up until the elastic band touches just below the chin. The subject then lowers until the arms are straight. The test is continued until the subject performs two incorrect pull-ups.

Body Composition: The Bodyfat Analyzer (Tanita TBF-305) will be used to measure body composition. It is the size of a bathroom scale and calculates the child' body fat percentage. The

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instrument is attached to a small unit that displays the reading for each subject. The subject removes his/her shoes and socks and stands on a Detecto-Medic Balance scale to measure height to the nearest cm. After recording the height of the subject on paper, the body fat analyzer will be switched on. The instrument will be calibrated for 'child' and the appropriate 'gender' will be selected. The height of the subject will be entered into the unit. The subject will step on the scale and remain motionless for 15 seconds. The unit will produce a printout of the subject's height in feet and inches, weight in pounds, body mass index, fat percentage, and fat mass.

Aerobic Capacity will be assessed using a physical work capacity test. A Monark Cycle Ergometer (model 818) will be used to assess Cardiorespiratory fitness. The seat will be adjusted to 95% of the subjects leg length with the ball of the foot on the pedal at maximal leg extension. The subject will assume an upright-seated posture with hands properly positioned on the handlebars and will be given a 2-min. warm up period to familiarize him or herself with the equipment. Since the subjects are children the initial load setting will be .25 kg with a pedal rate of 60 rev/min. Using a Polar heart rate monitor the subjects heart rate will be monitored every minute. Cycling will be terminated when the subject attains a heart rate of 150 b/min. or requests termination of the test due to fatigue. Exercise intensity will be increased gradually through the stages of the test using work increments of .5, 1, 1.5, 2, 2.5, 3, 3.5kg. An estimate of PO150, PO195, VO2 at 150, and VO2 at 195 will be calculated using a linear regression equation. Using the ACSM's metabolic equation [Resistance x 2 (constant) x 60 (rev/min) x 2.33 (pedal distance) + (2 x PO) + 300 (body weight + 3.5 resting HR] absolute VO2 max will be calculated. To find the relative VO2 max, the absolute VO2 max will be divided by the subjects body weight. Upon completion of the test subjects will cool down for 2 minutes at .30 rpm.

Cognitive Assessment

Cognitive Assessment will be completed using the Psych E self-contained computer program for conducting psychomotor assessment. The program runs on an IBM-compatible personal computer and records all scores and times. The programs six tests require a total administration time of approximately 20 minutes. Program designers selected these tests from the literature, to assess psychomotor function (Hope, Woolman, Gray, Asbury, & Millar, 1998).

1.) Discrete simple reaction time: The subject holds down the spacebar. After a random interval (1 to 10 seconds) a small sun symbol (signal) appears in a random position on the screen. The test consists of 20 trials. On the appearance of the signal, the subject is required to lift his/her finger from the spacebar and press any of the target keys; these are the keys 4-9 on the top row of the keyboard. For correct responses, the total reaction time and its components are recorded separately to within 1 millisecond.

2.) Discrete 6-choice reaction time: The subject depresses the spacebar and a representation of the 6 target keys (keys 4-9 on the top row of the keyboard) is shown on the computer screen. After a random interval (1 to 10 seconds) one of these keys is highlighted and the subject is required to press the corresponding key on the keyboard. For each correct response, reaction time and movement time are recorded.

3.) Duel task – tracking and simple reaction time: This test has a primary task of tracking, and a secondary reaction task. The test is designed to measure impairments in the secondary task while keeping the subject focused on the primary task. The primary task requires the subject to use a mouse to follow a smooth but randomly moving target on the computer screen (percentage

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of time-on-target is recorded). At random intervals the secondary task stimulus (a small sun symbol) is presented. The time taken for the subject to press the spacebar is measured, with total response time, reaction time and movement time being recorded separately

4.) Numeric vigilance: Three-digit numbers are presented on the computer screen at a rate of 100 per minute. Each number differs randomly from the previous number in one of the digits. Of the numbers presented during the test, 8% are duplicates of the previous number. The subject is required to identify these duplicates and press the spacebar as they occur. Correct responses ("hits"), missed duplicates ("misses"), and incorrect duplications responses ("false alarms") are recorded. Test duration is four minutes.

5.) Probed memory: This test assesses short-term memory. Subjects will be instructed that they will be shown a series of consonants, and to try to remember the letters. A sequence of eight consonants is presented with a new consonant being added every second. All the consonants in the sequence remain visible until the last consonant in the list is displayed. After an additional one second the complete sequence of 8 characters is blanked out. The subject is presented with a consonant and asked whether or not it had been part of the list; 50% of the probe consonants belong to the original list. The percentage of correct responses is recorded.

6.) Semantic long-term memory: This test displays category-word pairs selected at random from a database of 20 categories and 760 words. The words used are of two kinds: high-dominance (frequently used in everyday communication) or low-dominance (infrequently used in everyday communication). Equal numbers from each dominance category are used in the course of a single test. A category-word pair is presented to the subject who has to decide, and indicate with a key press whether or not the word represents a member of the displayed category. Separate reaction times are recorded for high dominance, low dominance and negative presentations.

3.2 Research Methods

Subjects for the two studies will be children 6 to 12 years-of-age enrolled in or attending programs in the North Versailles School District, University of Pittsburgh or Indiana University of Pennsylvania. An informed consent will be obtained for all subjects. Data will be collected over a two or three-day period depending on the study. Study 1 (Table 1) will measure subjects health related fitness level, achievement assessment and cognitive assessment. Analysis will determine if fitness level has an affect on cognitive processing. Study 2 (Table 2) will further expand study 1 by introducing physical activity or inactivity. The design for Study 2 will divide subjects into two procedural subgroups to control for a learning curve with the subjects being either physically active or inactive prior to taking the cognitive assessment. This will allow the researcher to examine the affect of physical activity on cognitive processing.

Table 1
Study 1 – Fitness Level as Related to Cognitive Function

Session #	Task	Required Testing Time
Session 1	Assess Health Related Fitness	30 minutes
Session 2	Cognitive Assessment	30 minutes

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Table 2
Study 2 – Cognitive Function as Related to Physical Fitness and Physical Activity
The subjects will be randomly divided into different protocols.

Session #	Subgroup 1	Subgroup 2	Required Testing Time
Session 1	Assess Health Related Fitness	Assess Health Related Fitness	30 minutes
Session 2	Physical Inactivity Session Cognitive Assessment	Physical Activity Session Cognitive Assessment	30 minutes
Session 3	Physical Activity Session Cognitive Assessment	Physical Inactivity Session Cognitive Assessment	30 minutes

3.3 Design and Data Analysis

Subjects will be classified as fit or unfit based on their health related fitness scores. In Study 1 the fit and unfit groups will be compared on cognitive assessment measures. Thus the design of the study is fitness level (fit and unfit). The dependent variables are simple reaction time, choice reaction time, dual task-tracking and simple reaction time, vigilance, probed memory and semantic long-term memory. The hypothesis for study 1 is that the physically fit subjects will perform significantly better on the dependent variables that the unfit subjects. A multivariate ANOVA will be calculated with follow-up ANOVA's when appropriate.

In study 2 the independent variables are fitness level (fit and unfit) and physical activity level (active, inactive). The design is therefore fitness level by physical activity level with repeated measures on the last factor. The dependent variables are simple reaction time, choice reaction time, dual task-tracking and simple reaction time, vigilance, probed memory and semantic long-term memory. It is hypothesized that the fit subjects will perform better than the unfit subjects on the dependent variables and that physically active fit subjects will score better on the dependent variables than all other treatment groups.

4.0 Human Subjects

4.1 General Characteristics – Minority Inclusion and Non-Discriminatory Statement

The study will be conducted using subjects enrolled in programs at Indiana University of Pennsylvania campus, University of Pittsburgh Campus, and elementary and secondary schools in the North Versailles School District, Allegheny County Pennsylvania. No exclusion criteria shall be based on race, ethnicity, gender, or HIV status.

4.2 Inclusion of Children in Research

1. The age ranges included are elementary school aged children (ages 6-12). The rationale for using this age range is the educational significance that this line of research could have. Supporting rationale is that it is the emphasis area (motor development) for the investigators and that research in this age group is deficient as compared to adolescents and adults.

2. The facilities required for data collection are more than adequate at each site, including gymnasiums and classrooms. The camps and classes that operate at each location have developmentally appropriate equipment and facilities, as the preexisting programs already cater to this age group.

3. Required sample sizes for the statistical analysis that will be used have been examined to ensure a statistically powerful test. Participation of 20 subjects would suffice.

4. It is anticipated that a total of **100** subjects will be enrolled (approximately 20 subjects from each site).

5. Not applicable

Criterion 1: The research presents no greater than minimal risk to the involved children.

(45 CFR 46.404)

4.4 Recruitment Procedures

Potential subjects will be children enrolled in camps and educational programs at the University of Pittsburgh, Indiana University of Pennsylvania, and East Allegheny School District These programs normally incorporate the same or similar activities as the data being collected as part of their normal itinerary. All parents/guardians of children participating in these programs will receive a letter inviting them to participate in the study.

4.5 Risk/Benefit Ratio

The risks involved in the study are minimal; children may experience fatigue or soreness. Children will be individually tested and their scores will be explained to them in private. Recommendations will be given to each child on how to improve their test results with special consideration given to children with poor fitness or body composition test results.

The principle and co investigators will oversee the data safety and monitoring with at least one of the investigators being on site for all data collection. To ensure confidentiality all data collected will remain on the person of the investigators or in a locked office.

The investigators will monitor all parts of the research study including participant recruitment (all children enrolled in the programs will be invited to participate), data quality, and constant analysis of risk benefit ratio to determine the need for study modifications or termination and will review pertinent scientific literature for information that may affect safety of study participants or the ethics of the research study.

The researchers have a commitment to comply with the IRB's policies for reporting serious and unexpected adverse events as discussed in the IRB Reference Manual (Chapter 3.0, sections 3.4 and 3.5). The principle and co investigators will annually review all data and safety monitoring procedure and report to the IRB the frequency of monitoring, a summary of adverse event data, a summary of current literature that could affect safety or ethics of the study, the outcome of procedural reviews to ensure subject privacy and research confidentiality, and any changes in the benefit-to-risk ratio of study participation with final recommendations for continuing, changing, or terminating the study.

5.0 Cost and Payment

5.1 Research Study Cost

There is no cost to the subject for participating in the study.

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5.2 Research Study Payments

No one will be reimbursed for participation in this study.

6.0 Appendices

Qualifications of investigators

Principle Investigator

Allen R. Wagner has a Bachelors degree in Health and Physical Education, a Masters degree in Physical Education, and is a Certificated School Guidance Counselor. He currently is completing a Ph.D. in motor development. He has been an educator working with children for 37 years, has taught physical education for 27 years and been a school guidance counselor for 10 years.

Co-investigators

Gary Clark has a Bachelors degree in recreation, a Masters degree in Physical Education and is a Pennsylvania certified Health and Physical Education teacher. He currently is completing a Ph.D. in motor development. Over the last 12 years he has been involved in a variety of programs for children from preschool to the college level. He has coached a variety of sports, directed and worked at a sport and physical activity camps, worked in the fitness industry, taught health and physical education (K-12) in the Pennsylvania public school system, and has taught a variety of undergraduate and graduate courses at the collegiate level.

Comfort J. Mokgothu is a doctoral candidate in the department of Health and Physical Activity. He completed Bachelor of Education (Physical Education) from the University of Plymouth (UK), and a Master of Science (Developmental Movement) from the University of Pittsburgh (USA). He maintains a faculty position at the University of Botswana (Department of Physical Education). He previously has collected data sanctioned by the University of Pittsburgh IRB.

Jere Gallagher has a PhD in Motor development. She has conducted research-using children as subjects for more than twenty years.

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From: Allen R. Wagner Principal Investigator IRB #: 0202109

Study: "The Influence of Physical Activity and Physical fitness on the Cognitive Processes of Children"

To: University of Pittsburgh Institutional Review Board

Cc: Michelle Lemenager

Subject: Data & Safety Monitoring Plan

Date: 4/27/2007

Pursuant to the requirements of the University of Pittsburgh Institutional Review Board the Principal Investigator and the Co-Investigators have held the annual meeting and reviewed the status of the Data & Safety Monitoring of the current research of The Influence of Physical Activity and Physical fitness on the Cognitive Processes of Children. We respectfully submit the following findings:

Monitoring participant recruitment: The principle and co-investigators continually monitor all parts of the research study including participant recruitment (all children enrolled in the programs will be invited to participate) and continue to comply with the requirements of the University of Pittsburgh Institutional Review Board procedures and practices for the recruitment of subjects.

Data quality: The principle and co-investigators continue to individually test the children and explained their scores to them in private. Recommendations are given to each child on how to improve their test results with special consideration given to children with poor fitness or body composition test results.

The principle and co investigators continue to oversee the data safety and monitoring with at least one of the investigators being on site for all data collection. To ensure confidentiality all data collected the data has and will continue to remain on the person of the investigators or in a locked office.

Changes in risk-benefit ratio: The principle and co-investigators have reviewed all data and current literature that could affect safety or ethics of the study, to ensure subject privacy and research confidentiality, and based on this review and the continued monitoring of all aspect of the research study have not found any changes in the benefit-risk ratio of the study.

Found occurrences of adverse events: The investigators have not found occurrences of adverse events during the study to date of this report.

Breaches of confidentiality: The investigators have found no breaches of confidentiality of confidentiality to the date of this report.

The researchers have a commitment to comply with the IRB's policies for reporting serious and unexpected adverse events as discussed in the IRB Reference Manual (Chapter 3.0).

Date: 7/21/06

MODIFICATION REQUEST FORM*

*NOTE - Please see Guidelines, section 3.1.1 for information regarding whether a modification can be expedited or if it requires full board review.

Principal Investigator: Allen R. Wagner

IRB Number: 0205109

Protocol Title: The Influence of Physical Activity and Physical Fitness on the Cognitive Processes of Children

I request the following modifications to the currently approved research Cover Sheet/Protocol/Consent form(s). Corresponding modifications are highlighted in the attached revised copies.

Principal Investigator

4//25//2007
Date

PLEASE FILL OUT THE FOLLOWING INFORMATION:

1. How many subjects have been enrolled into this study to date? 61

2. How many subjects are you anticipating enrolling into this study? 100

3. Current status of the protocol:

- ☐ remains ongoing (open to additional enrollment).
- ☐ remains ongoing (permanently closed to additional enrollment but subjects continue to undergo research-elated interactions).
- ☐ remains ongoing (permanently closed to additional enrollment and all subjects have completed protocol-related treatments/interactions but the research remains active for long-term follow-up of subjects). **Note**: that the IRB considers long-term follow-up to be limited to review of medical records (i.e., information collected for clinical purposes) and checking for survival status either through contact with the subject or by a review of the National Death Index).
- ☐ remains ongoing (the **ONLY** research activity is data analysis).

1. Cover Sheet/ Protocol/Consent Form (circle): Page 1 , Paragraph CO-INVESTIGATOR:
Changed from: CO-INVESTIGATOR:
Gary E. Clark, Jere Gallagher PhD.
Change to: CO-INVESTIGATOR
Comfort J. Mokgothu, Gary E. Clark Jere Gallagher PhD.

Rationale/Justification for Change: Additional Researcher added.

2. Cover Sheet/Protocol/ Consent Form (circle): Page 1 PART C—RECRUITMENT INFORMATION

Change from: Number participants to be enrolled at this site 30-60

Change to: Number participants to be enrolled at this site 100

Rationale/Justification for Change: Additional subjects added to continue the study.

3. Cover Sheet/Protocol/ Consent Form (circle): Page 1 , Paragraph 1ST

Changed from:

CO-INVESTIGATOR:
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Changed to:

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Phone: 412-648-1774

Rationale/Justification for Change: Additional Researcher added.

4. Cover Sheet/ Protocol /Consent Form (circle): Page 6, 4.2 no. 4

Changed from: 3—60

Change to: 100

Rationale/Justification for Change: Additional subjects added to continue the study.

5. Cover Sheet/ Protocol /Consent Form (circle): Page 8 , Paragraph 3

Changed from:

Co-investigators

Gary Clark has a Bachelors degree in recreation, a Masters degree in Physical Education and is a Pennsylvania certified Health and Physical Education teacher. He currently is completing a Ph.D. in motor development. Over the last 12 years he has been involved in a variety of programs for children from preschool to the college level. He has coached a variety of sports, directed and worked at a sport and physical activity camps, worked in the fitness industry, taught health and physical education (K-12) in the Pennsylvania public school system, and has taught a variety of undergraduate and graduate courses at the collegiate level.

Jere Gallagher has a PhD in Motor development. She has conducted research-using children as subjects for more than twenty years.

Change to:

Co-investigators

Gary Clark has a Bachelors degree in recreation, a Masters degree in Physical Education and is a Pennsylvania certified Health and Physical Education teacher. He currently is completing a Ph.D. in motor development. Over the last 12 years he has been involved in a variety of programs for children from preschool to the college level. He has coached a variety of sports, directed and worked at a sport and physical activity camps, worked in the fitness industry, taught health and physical education (K-12) in the Pennsylvania public school system, and has taught a variety of undergraduate and graduate courses at the collegiate level.

Comfort J. Mokgothu is a doctoral candidate in the department of Health and Physical Activity. He completed Bachelor of Education (Physical Education) from the University of Plymouth (UK), and a Master of Science (Developmental Movement) from the University of Pittsburgh (USA). He maintains a faculty position at the University of Botswana (Department of Physical Education). He previously has collected data sanctioned by the University of Pittsburgh IRB.

Jere Gallagher has a PhD in Motor development. She has conducted research-using children as subjects for more than twenty years.

Rationale/Justification for Change: Additional Researcher added.

INSTITUTIONAL REVIEW BOARD
UNIVERSITY OF PITTSBURGH
RESEARCH STUDY RENEWAL REPORT

Current IRB #: 0205109

Protocol Title: The Influence of Physical Activity and Physical Fitness on the Cognitive Processes of Children

Principal Investigator: Allen R. Wagner
****

Provide below a brief (1-2 paragraph) updated abstract of the research study to address the current status of the study including its specific aims, rationale and significance, experimental design and methods. Also, please respond to each of the following requests for information.

Over the past thirty years research has concentrated on investigating the effects of physical activity on the physiological components of the human body. The research however has not thoroughly examined the effects of fitness and physical activity on cognitive functioning, especially in children. The purpose of this study is to examine two aspects of the mind body connection: Specifically how the physical fitness level and the physical activity level of children affect cognitive processing. In older populations physical activity has already been shown to relate to cognitive function (Emery 1995, Hassm'n, Koivula, 1975). When fit adults are compared to sedentary, low fit groups, the fit adults demonstrate faster simple and choice reaction times meaning that they are faster at making decisions (Rowland 1990, Chodko-Zojko 1991). The research design in this study expands these adult findings to children using a paradigm including, simple and choice reaction time, a vigilance task, a dual task, and probed and semantic memory tasks.

Subjects for the study will be children ranging in age from 6-to-12 years-of-age. Subjects will be assessed using several methods. Heart rate will be monitored using a Polar Protrainer NV heart rate monitor. A psychomotor cognitive processing assessment (including simple reaction time, choice reaction time, dual task-tracking and simple reaction time, vigilance, probed memory and semantic long-term memory) will be made using the self contained Psych E computer program. Body composition will be calculated using the Tanita TBF-305 Bodyfat Analyzer. Finally health related fitness will be assessed using back saver sit-and-reach (hamstring flexibility), curl-ups (abdominal strength), modified pull-ups (upper body strength) and physical work capacity (cardiorespiratory fitness) will be measured using a stationary Monark Cycle Ergometer.The fitness levels of the subjects will be determined using heart rate, body composition, and health related fitness. Fitness levels of the subjects will then be compared to their cognitive processing as measured by the Psych E computer program. Cognitive processing will be assessed twice, once following a 30 minute sedentary period in which the subject is completing paper and pencil work and a second time following 30 minutes of physical activity with the subject maintaining a training heart rate. Fitness level and physical activity level will be compared to cognitive processing.

****

Research Subject Enrollment:

1. A total of 0 subjects have been entered into this research protocol at this site during this renewal

interval.

a. Breakdown of subjects by gender: Female: 0; Male: 0
b. Breakdown of subjects by race/ethnicity:
White: 0; Hispanic: 0; Black: 0; Asian: 0; Other 0

For studies that involve children, please provide the following:

c. Breakdown of subjects by age:
0-2: 0; 3-7: 0; 8-11: 0; 12-15: 0; 16-18: 0
d. Were any children in foster care at the time of enrollment? ☒ No ☐ Yes (If yes, from whom was consent for participation in research obtained?)

2. A total of 61 subjects have been entered into this research protocol at this site since its initial approval.

Note: If enrollment into this research study, to date, is less than 20% of the projected enrollment based on the proposed annual accrual rate [i.e., proposed total number of subjects at this site/proposed total study duration] provide a rationale for this slow enrollment and a justification as to why this research should be continued: _____

3. Has subject accrual to date reflected the ethnic, gender and racial demographics of Pittsburgh and the surrounding area and/or the patient population of the UPMC; or the demographics of the alternate site(s) where this research is being conducted?

☐ No – Provide a justification for the failure, to date, to accrue subjects in accordance with these ethnic and gender demographics and address the steps that will be taken to correct this deficiency. _____
☒ Yes
☐ No subjects enrolled during renewal period

4. Have there been any subject withdrawals from the study? Please note that this includes any subject who signs a consent form and then decides not to participate or subjects that are withdrawn from the study by the investigator.
☐ No ☒ Yes; Reasons for withdrawal include the following: Not interested in continuing.

Unanticipated Problems.

- **If any of the following unanticipated problems or adverse events have been reported previously to the IRB, summarize problem/event below, and describe outcome.**
- **For those problem/events that have not been reported previously, complete an Unanticipated Problem or Adverse Event Form and attach a copy to this submission**

1. Describe any failure to follow the informed consent process as outlined in your currently approved research protocol.

☒ None; ☐ New (Form attached); ☐ Previously Reported: Description:_____

2. Describe any **UNEXPECTED** adverse events of moderate or greater severity associated with the conduct of this research protocol <u>at this site</u>.

☒ None; ☐ New (Form attached); ☐ Previously Reported: Description:_____

3. Describe any **SERIOUS** unexpected adverse events associated with the conduct of this research protocol <u>at other sites</u> (if applicable)

☒ None; ☐ New (Form attached); ☐ Previously Reported: Description:_____

4. Describe any changes in the profile of adverse events (in terms of frequency, severity, or specificity) since the last IRB review.

☒ None; ☐ New (Form attached); ☐ Previously Reported: Description:_____

5. Describe any deviations from the IRB-approved protocol.

☒ None; ☐ New (Form attached); ☐ Previously Reported: Description:_____

6. List any subject complaints and your response to them.

☒ None; ☐ New (Form attached); ☐ Previously Reported: Description:_____

7. Describe any breaches of subject confidentiality?

☒ None; ☐ New (Form attached); ☐ Previously Reported: Description:_____

8. Describe any modifications to the currently approved research protocol or informed consent document that were <u>not approved</u> by the IRB prior to implementation?

☒ None; ☐ New (Form attached); ☐ Previously Reported: Description:_____

9. Describe any unanticipated problems (besides those noted above) involving risks to participants or others?

☒ None; ☐ New (Form attached); ☐ Previously Reported: Description:_____

Risk/Benefit Considerations:

1. Describe any changes in research procedures that may have a fiscal impact on either the subject or UPMC?

   ☒ None; ☐ Changes submitted for UPMC Fiscal Review; Copy of revised UPMC Fiscal Review Letter is attached

2. Describe any change in the benefit and risk considerations of study participation as defined in the currently approved research protocol

   ☒ None; ☐ IRB Modification Request Form is attached, with modified consent form and/or addendum consent form attached, if appropriate

3. Are you aware of any recent scientific publications or other reports that may potentially impact the continued conduct of this research study or the benefit and risk assessment of study participation?

   ☒ No; ☐ Yes, a copy of the article is attached

4. Is there any new information on risks and/or benefits associated with study participation that may influence the willingness of current or future research subjects to participate in this research project?

   ☒ No; ☐ Yes, a copy of the relevant information is attached, and a description of how this information will be disseminated to current and future research subjects (if appropriate): _____

Required Attachments (All paperwork is required regardless of the status of the protocol):

☒ 1. Cover Sheet (marked 'renewal' or 'renewal with modifications')
☒ 2. Renewal Report Form
☒ 3. Data and Safety Monitoring Report:
   a. Single site: Attach a report from the local Data and Safety Monitoring Plan as described in your research protocol.
   b. Multicenter study: Attach a report from both the local and central Data and Safety Monitoring Plan as described in your research protocol.
☒ 4. Modification Form (if modifications are being requested)
☒ 5. Protocol (with any modifications highlighted)
☒ 6. Consent Document(s) (with any modifications highlighted)
☐ 7. Sponsor Information (Industry Sponsored Studies Only)
   a. Four (two for expedited submissions) copies of the current version of the sponsor's clinical protocol;
   b. Four (two for expedited submissions) copies of the current investigational drug or device brochure.

Status of the Protocol:

Note: Studies designated as **minimal risk** either through an expedited review process or by a full board committee can be expedited at the time of renewal unless substantial modifications which change the risk/benefit ratio are requested.

This research protocol:

☒ remains ongoing (open to additional enrollment).

☐ remains ongoing (permanently closed to additional enrollment but subjects continue to undergo research-related interactions).

☐ remains ongoing (permanently closed to additional enrollment and <u>all</u> subjects have completed protocol-related treatments/interactions but the research remains active for long-term follow-up of subjects). **Note**: that the IRB considers long-term follow-up to be limited to review of medical records (i.e., information collected for clinical purposes) and checking for survival status either through contact with the subject or by a review of the National Death Index). **Renewal may be expedited.**

☐ remains ongoing (the **ONLY** research activity is data analysis). **Renewal may be expedited.**

☐ is terminated (Date of termination: _____).
Please attach a final report. See IRB Reference Manual, Chapter 3, Section 3.5.3 for instructions.

****

I certify that the above information is correct:

Principal Investigator Signature

3/18/2007
Date

University of Pittsburgh
Institutional Review Board
Approval Date: May 01, 2007
Renewal Date: May 29, 2008
IRB Number: 0205109

University of Pittsburgh

School of Education
Health, Physical and Recreation Education

140 Trees Hall
Pittsburgh, Pennsylvania 15261
412-648-8320
Fax: 412-648-7092

CONSENT TO ACT AS A SUBJECT IN A RESEARCH STUDY

TITLE: The Influence of Physical Activity and Physical Fitness on Cognitive Processing in Children

PRINCIPAL INVESTIGATOR:

Allen R. Wagner
Guidance Counselor (Retired)
East Allegheny School District
1150 Jack Run Road
North Versailles, PA 15137
Telephone: 412-855-1934

CO-INVESTIGATOR:
Comfort J. Mokgothu
Doctoral Candidate
107 Trees Hall
University of Pittsburgh
Pittsburgh, Pa 15261
412-648-9183

Gary E. Clark
Department of Kinesiology
The Pennsylvania State University
268J Recreation Hall
University Park, PA 16802
Office: 814-865-5780

Jere Gallagher PhD.
Associate Dean, School of Education
5610 WWPH
University of Pittsburgh
230 South Bouquet Street
Pittsburgh PA 15260
Phone: 412-648-1774

Parent/Guardians Initials ________

University of Pittsburgh
Institutional Review Board
Approval Date: May 01, 2007
Renewal Date: May 29, 2008
IRB Number: 0205109

SOURCE OF SUPPORT: None

Why is this research being done?

The purpose of these studies is to establish the relationship between cognitive processing, physical fitness levels, and physical activity levels in children. This research design expands previous adult findings to children using a paradigm including, simple reaction time, choice reaction time, vigilance, a dual task, probed memory and semantic long term memory tasks as measures of cognitive processing. The question addressed is how does the physical fitness level and the physical activity level of children affect cognitive processing?

Who is being asked to take part in this research study?

Your child is being invited to take part in this study. Participation in this study is limited to children who are 6-12 years of age enrolled in or attending programs in the North Versailles School District as well as children involved in programs at the University of Pittsburgh or Indiana University of Pennsylvania. This group of school age children will be assessed using various measures of physical performance and cognitive performance. Your child's physical fitness and activity levels will be identified to determine if this impacts various aspects of cognitive performance.

What procedures will be performed for research purposes?

Your child will be asked to be physically active for a ½ hour period of time. This time will be spent performing a physical work capacity assessment using a stationary bicycle ergometer. Your child will be required to ride a stationary bicycle for approximately 15 minutes. Part of this time may also be spent participating in the games and activities they are normally involved in (i.e. games, football, Frisbee, swimming). Your child will also be required to complete a sit and reach, curl up, and modified pull up test. While your child is physically active they will wear an elastic band around their chest and a watch on their wrist to monitor their heart rate. Body composition and weight will be measured as well using a Body fat Analyzer that looks and works like a bathroom scale.

Your child will also be asked to use a computer (Psych E) program to assess simple reaction time, choice reaction time, movement time, short-term memory, long-term memory and attention using a vigilance task. These tasks are completed by following directions on a computer screen and pressing buttons on a computer type keyboard.

RISKS AND BENEFITS

What are the possible risks, side effects, and discomforts of this research study?

Your child's risk for participation in the study is minimal. Many of the activities are a normal part of the program that your child is participating in. The child might experience fatigue or soreness from the fitness test.

What are the possible benefits from taking part in this study?

The **possible** benefit is knowing how your child performed on each of the assessments. The investigator will be glad to inform you of your child's scores and explain them. Every attempt will be made during the study to make this a pleasant experience for your child.

What is the effect if I decide not to take part in this research study?

If your child decides not to take part in this research study, your child will participate in the program as it is regularly scheduled.

Parent/Guardians Initials ________

NEW INFORMATION

If I agree to take part in this research study, will I be told of any new risks that may be found during the course of the study?

You will be promptly notified if any new information develops during the conduct of this research study, which may cause you to change your mind about continuing to participate.

COSTS and PAYMENTS

Will I be charged for the costs of any procedures performed as part of this research study?

You will not be charged for any of the procedures performed for the purpose of this research study.

Will I be paid if I take part in this research study?

There will be no compensation for participation in this research study.

COMPENSATION FOR INJURY

Who will pay if I am injured as a result of taking part in this study?

University of Pittsburgh researchers and their associates who provide services at the UPMC Health System (UPMC HC) recognize the importance of your child's voluntary participation in their research studies. These individuals and their staffs will make reasonable efforts to minimize, control, and treat any injuries that may arise as a result of this research. If you believe that your child is injured as a result of the research procedures being performed, please contact immediately the Principal Investigator or one of the co-investigators listed on the first page of this form.

Emergency medical treatment for injuries solely and directly related to your child's participation in this research study will be provided to your child by the hospitals of the UPMC HC. It is possible that the UPMC HS may bill your insurance provider for the costs of this emergency treatment, but none of these costs will be charged directly to you. If your child's research-related injury requires medical care beyond this emergency treatment, you will be responsible for the costs of this follow-up care unless otherwise specifically stated below. You will not receive any monetary payment for, or associated with, any injury that your child suffers in relation to this research.

CONFIDENTIALITY

Who will know about my participation in this research study?

Your child will not be specifically identified in any publication of research results. If any individual's data is reported, name or initials will not identify the individual. The information will only be accessible to the investigators listed in the first page of this document. According to University policy, all research records must be kept for a period of at least five years. In unusual cases, your child's research records may be inspected by appropriate government agencies or be released in response to an order from a court of law. Any information obtained about your child from this research will be kept as confidential (private) as possible. An exception to confidentiality is information on child abuse and neglect that is obtained during research, if that is identified during research, it will immediately be reported to appropriate authorities.

RIGHT TO PARTICIPATE or WITHDRAW FROM PARTICIPATION

Is my participation in this research study voluntary?

Your child's participation in these research studies is completely voluntary. Your child does not have to take part in these research studies and, should you or your child change your mind, your child can withdraw from these studies at any time. Your child's current and future status with the University and any other benefits for which your child qualifies will be the same whether your child participates in this study or not.

Parent/Guardians Initials ________

University of Pittsburgh
Institutional Review Board
Approval Date: May 01, 2007
Renewal Date: May 29, 2008
IRB Number: 0205109

If I agree to take part in this research study, can I be removed from the study without my consent?

If the investigator observes that your child does not want to continue or cannot complete a task, your child may be withdrawn from the study. You understand that signing this consent form does not necessarily mean that you child will participate in all of the listed tasks. Signing the consent form will permit screening of your child for the age appropriate tasks in the study. For example the vigilance and memory tasks require a level of vocabulary that young children may not possess.

VOLUNTARY CONSENT

All of the above has been explained to me and all of my current questions have been answered. I understand that I am encouraged to ask questions about any aspect of this research study during the course of this study, and that such future questions will be answered by the researchers listed on the first page of this form.

Any questions I have about my rights as a research participant will be answered by the Human Subject Protection Advocate of the IRB Office, University of Pittsburgh (1-866-212-2668).

____
Participant's (Child's) Name (Print)

I understand that, as a minor (age less than 18 years), the above-named child is not permitted to participate in this research study without my consent. Therefore, by signing this form, I give my consent for his/her participation in this research study.

______________________________ ______________________________
Parent's or Guardian's Name (Print) Relationship to Participant (Child)

______________________________ ____________________
Parent/Guardian's Signature Date

Parent/Guardians Initials ________

University of Pittsburgh
Institutional Review Board
Approval Date: May 01, 2007
Renewal Date: May 29, 2008
IRB Number: 0205109

VERIFICATION OF EXPLANATION

I certify that I have carefully explained the purpose and nature of this research to the above named child in age appropriate language. He/she has had an opportunity to discuss it with me in detail. I have answered all his/her questions and he/she provided affirmative agreement (i.e. assent) to participate in this research study.

______________________________ __________________
Investigator's Signature Date

____
Investigator's Printed Name

This research has been explained to me, and I agree to participate.

______________________________ __________________
Signature of Child-Subject Date

____
Printed Name of Child-Subject

I certify that I have explained the nature and purpose of this research study to the above-named individual(s), and I have discussed the potential benefits and possible risks of study participation. Any questions the individual(s) have about this study have been answered, and we will always be available to address future questions as they arise.

Allen R. Wagner M.Ed. PRINCIPAL INVESTIGATOR
Printed Name of Person Obtaining Consent Role in Research Study

______________________________ ______________
Signature of Person Obtaining Consent Date

Parent/Guardians Initials _________

COPY OF LETTER SENT TO PARENTS

Dear Parent-Guardian

I am pleased to announce that the East Allegheny School District in co-operation with the University of Pittsburgh School of Education will continue an educational research project in physical education that began last year. Mr. Allen R. Wagner former EA 9th & 10th grade guidance counselor will supervise the program for the University of Pittsburgh. I encourage you to permit your child to participate in this educational project.

The informed consent form that you find included with this letter is part of the process required by the University of Pittsburgh for any research project and explains in detail the activities that will be used.

The data collection does not take long (Data is collected during 1 or 2 class periods) during the school day. Most of the data collection will be done during regularly scheduled physical education classes and involve activities that the students normally participated in.

The attachments to this letter and the consent form explain all of the activities in great detail. If you would like your child to have the opportunity to participate in this program please initial or sign at the designated areas and have your child return the permissions to the guidance secretary, Mrs. Gorski in the first floor Guidance office.

Gary Pieffer
Principal
East Allegheny Middle/ High School

MOVEMENT ABC

CHILD MOVING ENVIRONMENT CHANGING

We are trying to identify children who have movement coordination problems. Rate each child on a scale of 0 to 3 on each of the following items:

0	1	2	3
very well	**just okay**	**almost**	**not close**

1. **Move around classroom/school while avoiding collision with other moving person.**
2. **Use non stationary playground/gymnasium apparatus such as swings unassisted.**
3. **Ride moving vehicles such as pedal cars, tricycles, and bikes (as appropriate for age).**
4. **Pull/push wheeled vehicles such as wheelbarrow, library and mat trolleys.**
5. **Participate in chasing games (tag, mouse and rat).**
6. **Run to catch an approaching ball.**
7. **Run to kick an approaching ball.**
8. **Run to hit/strike an approaching ball using racket, stick or bat.**
9. **Use skills of catching, kicking, striking and/or throwing to participate in a team game.**
10. **Move around keeping control of a bouncing ball.**
11. **Move to enter a turning jump rope**
12. **Move in a variety of directions styles and speeds while keeping time to a musical beat.**
13. **Keep time to a musical beat by clapping or tapping foot**
14. **How would you rate the child's level of fitness on a scale of 1 to 10 with 1 being least fit and 10 being most fit?**

Movement ABC

<u>Instruction to the Teacher</u>

I am asking you to evaluate this child on their coordination. Please read each item carefully and indicate on a scale from 0 to 3 with 0 indicating very well and 3 indicating not close.

0	1	2	3
very well	just okay	almost	not close

Anthropometric Measures

<u>Instruction to the Subject</u>

I want you to take of your shoes and socks and step on this scale and stand tall so that I can take measures of your height and weight. When I ask you to step on the scale, you will stand with your heels on circles, and the balls of your feet on the ovals. Stand still until I ask you to step off the scale. Do you have any questions? I now want you to step on this scale as soon as it reads '00' and sit upright for few seconds.

Cycle Ergometer Test

<u>Instruction to the Subject</u>

Today I am going to give you a cycle ergometer test which measures your level of fitness. First, I want you to attach this belt around your chest, the belt has a transmitter that senses your HR and two electrodes that must be in contact with your skin in order to send signal to the watch. It is recommended that you wet the electrodes with water. The transmitter should be at a point just below the chest where your ribs meet (sternal notch). Do you have any questions?

Now step onto the cycle so I can adjust saddle height. I want you to pedal at 50rpm and maintain that rhythm for 2-minute warm-up to get used to the bike and prepare for first stage. At the end of each stage and before the next stage, I will increase resistance by adding half a kilogram of weight. I want you to maintain a consistent paddling rate throughout the test. While cycling I will ask you how you feel and I want you to show me your level of fatigue on this chart, by pointing to a number that corresponds with your level of fatigue in a scale of 0 to 10. "0 being very easy and 10 being too hard." The test will continue until your heart rate reaches 160 b/min. or you request the test to be stopped due to fatigue. At the end of the exercise, I want you to cool down by continuing to peddle for an additional 2 min at .30 rpm after which the test will be stopped. Do you have a question before we START?

Cognitive Tests

The response board will be positioned at a child-sized desk with the computer screen 5 inches behind the response board.

Instruction to the Subject

You are going to do some tests on the computer that assess you ability to pay attention, make some quick decisions and remember some information. I want you to sit on this chair and face the computer on the table in front of the chair.

The Discrete simple reaction time

Instruction to the Subject

I want you to press down this home key with the index finger of the hand you write with and as soon as you hear a beep, I want you to lift your finger and press the number 6 response key on this board as quickly as possible. You will have to return to the home key to start the next trial. Do you have any questions? I will now give you three practice trials. Do you have any questions? Now, you will have 20 test trials.

Discrete 6-Choice Reaction Time

Instruction to the Subject

I want you to press down this home key with the index finger of the hand you write with and when one of the keys in the computer screen (4-9) is highlighted, I want you to lift the same index finger from the home key to press the corresponding highlighted response key on the response board as quick as possible. Do you have any questions? I will now give you three practice trials. Do you have any questions? Now, you will take the test which consists of 20 presentations.

Dual Task-Tracking and Simple Reaction Time

Instruction to the Subject

For this test I want you to use a computer mouse to follow this moving ball on the computer screen as close as possible. As soon as you hear a beep I want you to press the space bar of the computer with the other hand while still following the ball closely. Do you have any questions? You will have three practice trials before the test starts. Do you have any questions? Now you will do the test for 4 minutes.

Numeric Vigilance

Instruction to the Subject

I want you to closely watch the 3-digit number as they appear on the screen and every time a 3-digit number is repeated; I want you to press the space bar of the keyboard immediately. The three-digit numbers will be presented on a computer screen first at a rate of 80-three digit numbers per minute and then at a rate of 100-three digit numbers per minute and the digits will differ from the previous pattern in one of the digits. Do you have any questions? I will allow you

30 seconds practice time. Do you have any questions? Now I want you to do the test for four minutes.

Probed Memory

Instruction to the Subject

You will see a sequence of consonants on the screen. The consonants will remain visible for a while. After a second all eight consonants will disappear and you will be shown a consonant and asked whether the consonant was part of those shown previously. You will answer by clicking ‘yes’ or ‘no’ with the mouse on the computer screen. Do you have any questions? Now I want you to practice three times. Do you have any questions? I now want you to do the test where 4, then 6, then 8 length consonants will appear in 20 presentations.

Tower of Hanoi

Instruction to the Subject

I want you to use a computer mouse to move 3 circular discs from a source Picket Left to a Destination Picket Right. You are allowed to move only one disc at a time and a large disc can never be placed on top of a smaller one. The discs should be moved from one tower to another in the least number of moves. Now, I want you to show me the understanding of the rules by illustrating the incorrect moves. Do you have any questions? Now I want you to start the test, and try to complete the task with a least number of moves and time. The number of moves taken will be recorded.

APPENDIX C

TOWER OF HANOI

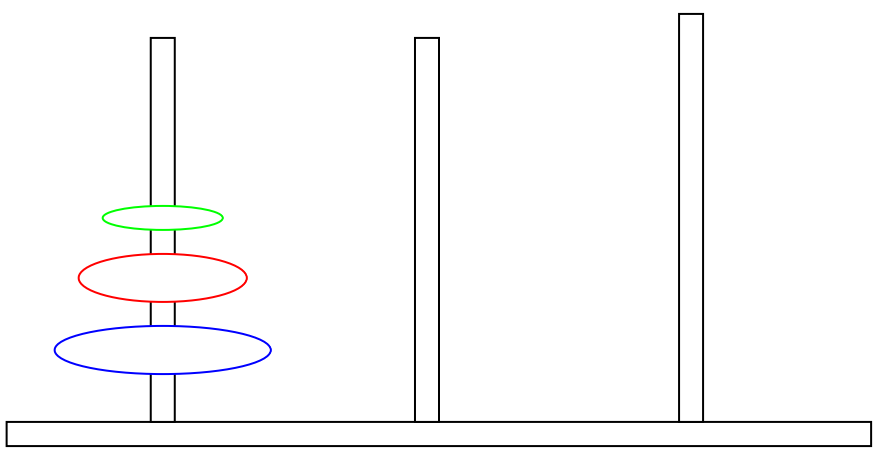

Figure 5: Tower of Hanoi

APPENDIX D

VO2 DATA SHEET

Subject Number:______________________________

Gender: Male/Female (Circle One)

Height: Feet______________ Inches__________

Weight: Pounds___________ Race ___________

Cycle Ergometer/VO2		Heart rate and Omni Scale			
Warm Up		_____	_____	_____	_____
25 watts	Stage 1	_____	_____	_____	_____
50 watts	Stage 2	_____	_____	_____	_____
75 watts	Stage 3	_____	_____	_____	_____
100 watts	Stage 4	_____	_____	_____	_____
Warm Down		_____	_____	_____	_____
		HR	HR	HR	HR

APPENDIX E

ANOVA TABLES

Table 10 ANOVA summary table for Memory Capacity

Tests of Within-Subjects Effects

Source	df	MS	F
Group		.67	.00
Error	3	169.74	
Capacity		1120.92	10.71
Group x Capacity		.92	.01
Error	3	104.67	

Table 11 ANOVA summary table for Memory Duration

Tests of Within-Subjects Effects

Source	df	MS	F
Group		16.72	1,95
Error	7	8.57	
Duration		2.21	.42
Group x Duration		.37	.07
Error	7	5.32	

APPENDIX F

TOWER OF HANOI OUTLIERS

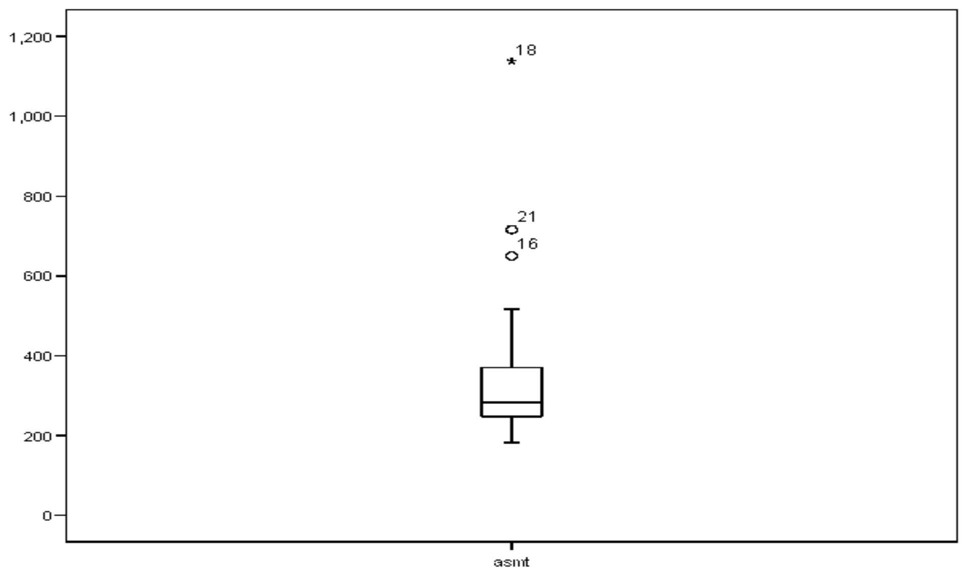

Figure 6: Tower of Hanoi Outliers for Move

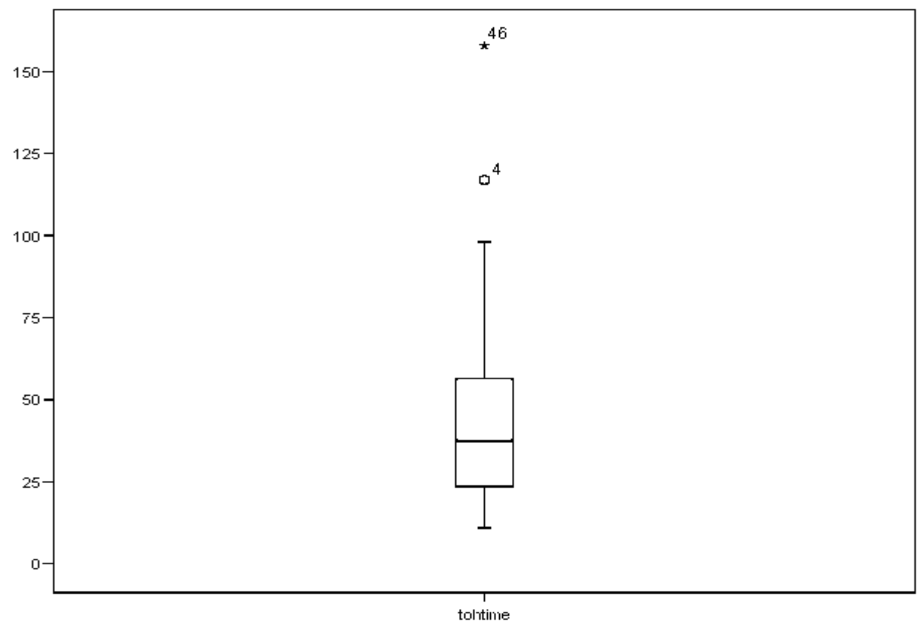

Figure 7: Tower of Hanoi for Error

APPENDIX G

ANOVA SUMMARY TABLES

Table 12 ANOVA summary table for Aerobic fitness (Vo2)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3967.267(b)	1	3967.267	55.228	.000
Intercept	61540.887	1	61540.887	856.712	.000
group	3967.267	1	3967.267	55.228	.000
Error	2729.686	38	71.834		
Total	68237.840	40			
Corrected Total	6696.953	39			

Table 13 ANOVA summary table for Attention (VSRT)

Source	Type III Sum of Squares	df	Mean Square	F	SSig.
Corrected Model	14938.225(b)	1	14938.225	1.126	295
Intercept	10382591.025	1	10382591.025	782.849	000
group	14938.225	1	14938.225	1.126	295
Error	503977.750	38	13262.572		
Total	10901507.000	40			
Corrected Total	518915.975	39			

Table 14 ANOVA summary table for selective Attention (VSMT)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1020.100(b)	1	1020.100	.124	.726
Intercept	4131918.400	1	4131918.400	503.202	.000
group	1020.100	1	1020.100	.124	.726
Error	312027.500	38	8211.250		
Total	4444966.000	40			
Corrected Total	313047.600	39			

Table 15: ANOVA summary table for attention (ASRT)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	23453.198(b)	1	23453.198	1.428	.240
Intercept	8670018.250	1	8670018.250	527.986	.000
group	23453.198	1	23453.198	1.428	.240
Error	591153.644	36	16420.935		
Total	9356372.000	38			
Corrected Total	614606.842	37			

Table 16: ANOVA summary table for selective attention (ASMT)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	9748.268(b)	1	9748.268	.316	.577
Intercept	4400266.163	1	4400266.163	142.645	.000
group	9748.268	1	9748.268	.316	.577
Error	1110518.811	36	30847.745		
Total	5554645.000	38			
Corrected Total	1120267.079	37			

Table 17: ANOVA summary table for selective attention (sec. task RT)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6350.400(b)	1	6350.400	.715	.403
Intercept	11470410.000	1	11470410.000	1291.410	.000
group	6350.400	1	6350.400	.715	.403
Error	337589.600	38	8883.937		
Total	11814350.000	40			
Corrected Total	343940.000	39			

Table 18: ANOVA summary table for selective attention (DUALRT)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1030.225(b)	1	1030.225	.141	.709
Intercept	454329.225	1	454329.225	62.366	.000
group	1030.225	1	1030.225	.141	.709
Error	276823.550	38	7284.830		
Total	732183.000	40			
Corrected Total	277853.775	39			

Table 19: ANOVA summary table for Decision making (TOT)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	115.600(b)	1	115.600	.797	.378
Intercept	83356.900	1	83356.900	574.719	.000
group	115.600	1	115.600	.797	.378
Error	5511.500	38	145.039		
Total	88984.000	40			
Corrected Total	5627.100	39			

Table 20: ANOVA summary table for Decision making (DecisionT)

Source	Type III Sum of Squares	df	Mean Square	F	SSig.
Corrected Model	473.853(b)	1	473.853	.074	.787
Intercept	438024.622	1	438024.622	68.532	.000
group	473.853	1	473.853	.074	.787
Error	236487.737	37	6391.560		
Total	676014.000	39			
Corrected Total	236961.590	38			

Table 21: ANOVA summary table for Decision making (CMT)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	37.552(b)	1	37.552	.004	.948
Intercept	5030937.039	1	5030937.039	581.702	.000
group	37.552	1	37.552	.004	.948
Error	319999.884	37	8648.646		
Total	5353579.000	39			
Corrected Total	320037.436	38			

Table 22: ANOVA summary table for executive function (Tohmove)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6.400(b)	1	6.400	.324	.572
Intercept	6760.000	1	6760.000	342.689	.000
group	6.400	1	6.400	.324	.572
Error	749.600	38	19.726		
Total	7516.000	40			
Corrected Total	756.000	39			

Table 23: ANOVA summary table for executive function (Toherr)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6.400(b)	1	6.400	2.779	.104
Intercept	12.100	1	12.100	5.255	.028
group	6.400	1	6.400	2.779	.104
Error	87.500	38	2.303		
Total	106.000	40			
Corrected Total	93.900	39			

Table 24 ANOVA summary table for executive function (Tohtime)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	990.025(b)	1	990.025	.929	.341
Intercept	92064.025	1	92064.025	86.358	.000
group	990.025	1	990.025	.929	.341
Error	40510.950	38	1066.078		
Total	133565.000	40			
Corrected Total	41500.975	39			