THE EFFECTS OF SINGLE BOUTS OF AEROBIC EXERCISE, VIDEOGAME PLAY, AND EXERGAMING ON COGNITIVE CONTROL

BY

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THESIS

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ABSTRACT

The effects of single bouts of aerobic exercise, action videogame playing, and exergaming on event-related brain potentials and task performance indices of cognitive control were studied. Thirty-six young adults performed a modified flanker task during four separate, counterbalanced sessions, using a within-subjects design. Participants were trained on the flanker and gaming tasks prior to completing the experimental conditions, and then completed a cardiorespiratory fitness assessment. Each session consisted of 20 minutes of activity followed by cognitive testing once heart rate (HR) returned to within 10% of pre-exercise levels. The experimental activities consisted of seated rest, seated videogame play, treadmill-based aerobic exercise, and exergame-based aerobic exercise; the latter two conditions occurring at an intensity of 60% of maximum HR. Task performance indicated decreased reaction time interference following treadmill exercise relative to seated rest and videogame play. Further, P3 amplitude replicated previous research as it was larger following treadmill exercise compared to rest, suggesting an increased allocation of attentional resources during the cognitive control task. The seated videogame and exergame did not differ from any other condition. These findings indicate that single bouts of treadmill exercise may improve cognitive control through an increase in the allocation of attentional resources and greater interference control during cognitively demanding tasks. However, similar benefits may not occur following single sessions of aerobic exergaming or seated videogame participation.

To My Mom and My Dad

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CHAPTER 1: INTRODUCTION

Individuals in today's industrial and technological societies are becoming increasingly sedentary and unfit, leading to an increased incidence of multiple chronic diseases, including cardiovascular disease, hypertension, stroke, osteoporosis, type II diabetes, obesity, certain types of cancer, anxiety, and depression (American College of Sports Medicine [ACSM], 2010). Recent estimates indicate that for the first time in the history of the United States, the rise of life expectancy may cease and the youth of today may live less healthy and shorter lives than the preceding generation (Olshansky, Passaro, Hershow, Layden, Carnes, Brody et al., 2005). Even with this knowledge, physical inactivity remains a major concern with less than 50% of adults in the United States partaking in at least 30 minutes of moderate-intensity activity, five days per week, or 20 minutes of vigorous-intensity activity, three days per week (Centers for Disease Control and Prevention [CDC], 2008). Additionally, it has been reported that approximately 25% of individuals engage in no-leisure time physical activity whatsoever (CDC, 2005).

Recent technological advances have allowed for increases in sedentary behavior. Videogame play has become one of the potential contributing factors to the lack of physical activity and exercise in the United States. Approximately 68% of all households in the United States play some form of computer or videogames, making for an $11.7 billion industry (Entertainment Software Association [ESA], 2009). Sedentary activities, including videogame and television use, have been causally linked to obesity and physical inactivity in adolescents (McMurray, Harrell, Deng, Bradley, Cox, & Bangdiwala, 2000; Vandewater, Shim, & Capolovitz, 2004). Although videogame usage is high in the U.S. population, many believe that videogame play is typically reserved for youth. As indicated in a non-peer reviewed source, such a belief is inaccurate, as the average game player was 35 years old in 2008 (ESA, 2009). Therefore, this lack of physical activity that may be associated with videogame play may not only be present in children, as it is also apparent in older populations.

In addition to the physical concerns manifested through the lack of physical activity, concerns for brain health and cognition also exist. Increases in physical activity and aerobic fitness have been linked to improved cognition, with disproportionately greater increases in cognitive control (Colcombe & Kramer, 2003; Hillman, Erickson, & Kramer, 2008). Cognitive control describes a subset of processes which is responsible for adjustments in perceptual selection, response biasing, and the online maintenance of contextual information (Botvinick, Braver, Barch, Carter, & Cohen, 2001). These processes describe goal-directed behaviors concerned with the selection, scheduling, and coordination of processes underlying perception, memory, and action. The core processes of cognitive control comprise inhibition (i.e., the ability to ignore distracters and maintain focus), working memory (i.e., the ability to hold information in one's mind and manipulate it), and cognitive flexibility (i.e., the ability to switch perspectives, attention, or response mappings; Diamond, 2006). Recently, both videogame play and physical activity researchers have begun to assess the influence of these activities on cognitive control.

Since the advent of videogames, there has been speculation regarding the damaging repercussions that may occur due to extended game play. Estimates suggest that individuals play videogames between 7 and 13 hours a week (Buchman & Funk, 1996; Gentile & Anderson, 2003). It has been suggested that violence displayed in videogames may be linked to aggressive thoughts, feelings, and behaviors (Anderson & Bushman, 2001; Anderson, 2004). However, recent advances have indicated that videogame play may benefit education and cognitive function. Videogame players (VGPs) have been found to perform better on visual attention and mental rotation tasks, and are faster on numerous other tasks with no reduction in accuracy (De Lisi & Wolford, 2002; Dye, Green, & Bavelier, 2009; Green & Bavelier, 2003; Green & Bavelier, 2006a; Green & Bavelier, 2006b). Additionally, recent research has indicated that expert players may have an enhanced ability to switch between two tasks while maintaining both rule sets in working memory (Boot, Kramer, Simons, Fabiani, & Gratton, 2008), indicating better cognitive flexibility.

Specifically, training individuals for as little as 10 hours on videogames, including action, first person shooter (FPS), and strategy games, may enhance cognition, including task switching processes, which reflect one of the core components of cognitive control (Green & Bavelier, 2006b; Green & Bavelier, 2003; Basak, Boot, Voss, & Kramer, 2008; Goldstein, Cajko, Oosterbroek, Michielsen, van Houten, & Salverda, 1997). However, some opposition to this view exists, as Kronenberger and colleagues (2005) have evidenced an association between videogame play and interference, indicating that videogame play may decrease the ability to inhibit irrelevant information. Additionally, functional magnetic resonance images (fMRI) of individuals exposed to large amounts of media violence, including VGPs, indicated that activation in the anterior cingulate cortex (ACC) and the inferior frontal gyrus was reduced during a task which incorporates interference, compared to non-VGPs. This pattern of brain activation displayed by VGPs was similar to individuals who have a disruptive behavior disorder (DBD) with aggressive features (i.e., individuals diagnosed with oppositional-defiant disorder or conduct disorder and displayed at least one symptom of aggressive behavior toward people, animals, or property within the last 6 months; Mathews, Kronenberger, Wang, Lurito, Lowe & Dunn, 2005). This study suggests that individuals who are exposed to large amounts of media violence due to videogame play and television (i.e., individuals who participate in activities where a great deal of violence is present) and do not display trait aggression, have differential brain activation relative to normal individuals (Mathews et al., 2005). This difference in brain activation may affect cognition, as activation in the ACC has been negatively correlated with reaction time on motor tasks (Naito, Kinomura, Geyer, Mawashima, Roland & Zilles, 2000). The literature surrounding videogame play and cognition reveals no corroborating evidence that indicates that game play is associated with facilitations or decrements in cognitive function. Therefore, more research is necessary to make greater generalizations about the underlying changes that videogame play has on cognitive function.

In addition to the influence of videogame playing on brain health and cognition, it is becoming widely known that exercise and cardiovascular fitness may have a facilitative effect on cognitive control. For example, aerobic exercise interventions may aid in recovering lost brain function caused by aging and also may attenuate brain degeneration (Colcombe & Kramer 2003; Hall, Smith, & Keele, 2001). Numerous studies have led to the conclusion that increasing cardiovascular fitness through training may enhance the strength of cognition in older adults (Colcombe, & Kramer, 2003). These claims have also been assessed in younger adults as well, indicating that an increase in fitness is associated with an increase in attentional processing and cognitive control (Kamijo, O'Leary, Pontifex, Themanson, & Hillman, 2010; Pontifex, Hillman, & Polich, 2009; Themanson & Hillman, 2006; Themanson, Pontifex, & Hillman, 2008).

Recently, research has begun to assess the effects of cognitive function following a single bout of aerobic exercise, indicating that an acute bout of exercise may lead to transient improvements in cognitive function, including reductions in response time (RT) and increases in accuracy on a variety of tasks ranging from visual discrimination to cognitive control (Hillman, Snook, & Jerome, 2003; Kamijo, Nishihira, Hatta, Kaneda, Wasaka, Kida, & Kuroiwa, 2004;

Sibley, Etnier, & LeMasurier, 2006; Tomporowski, 2003). However, other research has suggested that acute bouts of physical activity may have little to no effect on cognition (Yagi, Coburn, Estes, & Arruda 1999; Grego, Vallier, Collardeau, Bermon, Ferrari, Candito et al., 2004). Potential reasons for the disparate findings may be due to differences in exercise intensity, type, and duration (Tomporowski & Ellis, 1986) or differences in the properties of the cognitive tasks employed (Lambourne & Tomporowski, 2010).

In addition to task performance measures (i.e., RT, response accuracy), which are routinely used in cognition research, event-related potentials (ERPs), electroencephalographic (EEG) activity evoked by events in the stimulus-response environment, are useful in deciphering aspects of cognition that are influenced by chronic and acute physical activity participation. One prominent component of an ERP in the stimulus-locked waveform is the P3 (or P300), which is a positive-going component that occurs approximately 300-800ms following the presentation of a stimulus. The amplitude of this component has been related to the amount of attentional resources allocated toward the stimulus environment, while the latency is thought to be a metric of stimulus classification (i.e., stimulus processing) speed (Polich & Kok, 1995). In recent years, the P3 has been assessed following single bouts of aerobic exercise, revealing an increase in amplitude and a reduction in latency (Hillman et al., 2003; Kamijo, Nishihira, Higashiura, & Kuroiwa, 2007; Kamijo, Hayashi, Sakai, Yahiro, Tanaka, & Nishihira, 2009). Specifically, individuals have exhibited a reduction in the time necessary to classify a given stimulus (i.e., shorter P3 latency), and greater attentional allocation toward a stimulus (i.e., larger P3 amplitude) following a single bout of aerobic exercise relative to seated rest (Hillman et al., 2003; Kamijo et al., 2004; Kamijo et al., 2009). To date, no research has used ERPs to examine the effects of a single bout of videogame play.

Recent advances in technology has allowed for individuals' movements to be assessed by videogame consoles. These games allow for the participants' movements to be tracked using sensor pads, force plates, or wireless sensors, such that when a movement is initiated, the game is able to capture such movements and depict them via a virtual character in the game. Dance Dance Revolution® (DDR®), Nintendo Wii™, and Wii Fit™, are common active videogames, or exergames, that many individuals across the U.S. play in their leisure time, or rely upon for their physical activity. These types of games may help to increase individuals' energy expenditure during game play while limiting sedentary activities (Miyachi, Yamamoto, Ohkawara, & Tanaka, 2010). However, since these games are relatively new, limited research has been conducted to determine the efficacy of exergames on cognition.

1.1. PURPOSE

The purpose of the proposed study was to assess the effects of single bouts of videogame play, exergaming, and aerobic exercise on task performance and neuroelectric indices of cognition.

1.2. HYPOTHESIS

It was hypothesized that a single bout of moderate aerobic exercise would enhance cognition as measured via task performance and the P3 component, replicating previous research (Davranche, Hall, & McMorris, 2009; Hillman et al., 2003; Hillman, Pontifex, Raine, Castelli, Hall, & Kramer, 2009; Kamijo, Hayashi, Sakai, Yahiro, Tanaka, & Nishihira, 2009; Pontifex, Hillman, Fernhall, Thompson, & Valentini, 2009). Following treadmill-based aerobic exercise, it was expected that participants would respond more accurately and exhibit shorter RT, suggesting transient improvements in task performance following the cessation of exercise. Additionally, participants were expected to exhibit shorter P3 latency and larger P3 amplitude, indicating faster cognitive processing speed and greater allocation of attentional resources, respectively. Exergaming was expected to exhibit a similar trend as the treadmill-based aerobic exercise given that the exercise elicited by the games is similar in intensity and duration. Lastly, seated videogame play was predicted to show no significant improvements in cognition, as measured via task performance and the P3 component.

CHAPTER 2: LITERATURE REVIEW

2.1. OVERVIEW

A growing body of literature has emerged suggesting that cardiovascular health is one major factor which may help to maintain a normal lifestyle and ward off degenerative diseases (U.S. Department of Health and Human Services, 2000). Despite mounting evidence leading researchers to believe that physical activity is important in daily life, only 23 percent of adults engage in regular, vigorous physical activity for 20 minutes or more on three or more occasions per week in the United States (U.S. Department of Health and Human Services, 2000). Further, recent evidence has indicated that children are becoming increasingly unfit and sedentary, which may have a substantial impact on lifestyle factors and several chronic diseases, including type II diabetes and obesity, typically believed to be adult onset diseases (Secretary of Health and Human Services and the Secretary of Education, 2007).

2.2. COGNITIVE CONTROL

When researchers explore how exercise and physical activity are related to cognition, many different types of paradigms, tapping multiple aspects of cognition, have been investigated. Colcolmbe and Kramer (2003) observed that the greatest benefits associated with physical activity and fitness are found for cognitive control (also referred to as ‘executive control’). Cognitive control refers to an overarching set of cognitive processes involved in the regulation of goal-directed behavior (Botvinick et al., 2001; Meyer & Keiras, 1997; Norman & Shallice, 1986). These processes include selection, scheduling, and maintenance of computational processes responsible for perception, memory, and action (Meyer & Keiras, 1997; Norman & Shallice, 1986). The core cognitive components, collectively deemed cognitive control, are inhibition, working memory, and cognitive flexibility (Diamond, 2006). Inhibition refers to the ability to ignore distracters and focus on relevant aspects of the stimulus environment. Working memory is the ability to hold and manipulate information in short durations. Lastly, cognitive flexibility refers to the process of efficiently switching between behaviors (Diamond, 2006).

One theory of cognitive control assumes a top-down approach to cognitive processing and execution of action (Norman & Shallice, 1986). This model indicates that there are two subsystems working in conjunction for the selection and control of actions, that is, contention scheduling and the Supervisory Attentional System (SAS). Contention scheduling operates during tasks that are well-learned or automated, where conscious processing is not necessary. However, during times when attention to a specific event is needed or in situations of novel events, there is competition among action schemas. During this time, there is a manipulation by the SAS to select the appropriate schema and inhibit the incorrect one, providing more efficient means of processing and action execution (Norman & Shallice, 1986).

Of the core processes of cognitive control, inhibitory control, has been the most studied by acute exercise researchers (e.g., Davranche et al., 2009; Hillman et al., 2003; 2009; Kamijo et al., 2007; 2009). Davidson and colleagues (2006) argue that through inhibitory control, individuals base their response on choice, rather than on impulse. That is, one must deliberately suppress task irrelevant information in the stimulus environment, and deliberately override the prepotent response to correctly execute a response.

2.2.1. Flanker Task

One task often used to elicit cognitive control is the Eriksen flanker task (Eriksen & Eriksen, 1974). The task requires participants to utilize varying amounts of cognitive control through the different conditions employed (i.e., congruent and incongruent), where perceptuallyinduced response interference is evoked. The flanker task requires an individual to view a group of letters (or arrows in modified versions of the task), attend to the middle stimulus, and distinguish between two stimuli which are presented. Congruent stimuli (e.g., HHHHH) result in faster and more accurate responses; incongruent stimuli (e.g., HHSHH) result in slower and less accurate responses, due to the centralized target and flanking stimuli necessitating activation of multiple (opposing) action-schemas (Eriksen & Eriksen, 1974; Eriksen & Shultz, 1979). That is, during incongruent arrays, both correct and incorrect response-mappings are activated due to the centralized stimulus and the flanking stimuli, respectively. Thus, these trials require greater amounts of interference control as individuals must inhibit the flanking stimuli to execute the correct response (Spencer & Coles, 1999).

2.3. EVENT-RELATED BRAIN POTENTIALS

Behavioral measures have helped researchers describe individual performance on a variety of cognitive tasks. Beyond these assessments of individuals' overt actions, event-related brain potentials (ERPs) provide a covert means to gain insight into the relationship between acute bouts of exercise or videogames and cognitive control. This allows for assessment of a subset of brain processes that occur between the stimulus onset and response production. ERPs are a class of EEG activity that occurs in response to, or in preparation for, a stimulus or response (Coles, Gratton & Fabiani, 1990). EEG is a method for recording differences in electrical potentials between various regions of the scalp, where the neuroelectric activity reflects synchronous firing of large groups of neurons (Hugdahl, 1995). This neuronal activity can reflect both exogenous (i.e., independent of the cognitive processing of the stimuli) or endogenous processes, which are higher-order cognitive processes requiring active participation (Hugdahl, 1995).

2.3.1. P3 Component

The P3 (also known as the P300 or the P3b) component of ERPs is an endogenous component of the stimulus-locked waveform that has garnered considerable attention in the acute exercise literature. The P3 is a positive going deflection, with topographic maximum over the central-parietal cortex, which occurs between 300 and 800 milliseconds following the presentation of a stimulus (Polich & Kok, 1995). The P3 reflects the neuronal activation associated with the allocation of attentional resources involved in updating working memory or stimulus engagement (Polich, 1997; Polich, 2007). The amplitude is believed to reflect the amount of attentional resources that have been allocated to a given stimulus, and is measured as the change in voltage from the pre-stimulus baseline to the largest positive peak within a time window. The latency is believed to reflect stimulus classification or cognitive processing speed, and is measured from the stimulus onset to the maximum peak in the given latency window (Polich, 2004; Polich & Kok, 1995). The literature on cognition and exercise has primarily dealt with task performance measures (i.e., accuracy, RT). However, there is a growing body of literature, which has employed neuroelectric measures in order to gain insight into the underlying effects of exercise on behavior.

2.4. PHYSICAL ACTIVITY AND COGNITIVE CONTROL

2.4.1. Fitness and Cognitive Control

Sedentary behavior has both a physical and economic impact on individuals in the U.S. due to the high rates of medical costs associated with the debilitative diseases that it potentially causes. Additionally, there is a large body of literature that links physical activity with improvements in brain function and cognition. Animal research has indicated that environments enriched with exercise equipment (e.g., running wheels, climbing boxes, etc.) have had a positive effect on neurogenesis and on the neural systems that are involved in learning and memory (van Praag, 2006), indicating that physically active behaviors may influence the neural underpinnings of cognitive function.

Additionally, it has become widely known that exercise and cardiovascular fitness may aid aspects of cognition and may attenuate brain degeneration; however, cognitive control seems to be enhanced to a greater extent than other forms of cognition (Colcombe, Kramer, Erickson, Scalf, McAuley, Cohen et al., 2003; Hall, Smith, & Keele, 2001). Numerous studies have led to the conclusion that increasing cardiovascular fitness, through increases in physical activity, may have the ability of enhancing the strength of cognition in older adults (Colcombe, & Kramer, 2003). Through this research, it seems that there is a positive effect of exercise on cognitive ability across the lifespan. However, more research is needed to uncover the nature of this relationship to determine what forms of cardiovascular exercise may facilitate cognition.

Though much of the research on physical activity and cognition has primarily indicated that cardiovascular fitness has a facilitative effect on cognitive control across the lifespan (Buck, Hillman, & Castelli, 2008; Castelli, Hillman, Buck, & Erwin, 2007; Hillman, Belopolsky, Snook, Kramer, & McAuley, 2004; Polich & Lardon, 1997), the literature on the transient relation of single bouts of exercise to cognition is in its infancy. Of the small literature-base that does exist, findings have been conflicting due to the lack of consistency in exercise type, duration, and type of cognitive task. Numerous studies have indicated that an acute bout of exercise may improve cognitive function (Hillman et al. 2003; Kamijo et al., 2004; Sibley, Etnier, & LeMasurier 2006; Tomporowski, 2003). However, other researchers have held the belief that single sessions of physical activity may have little to no effect on the ability to process information (Grego et al., 2004; Yagi et al., 1999).

2.4.2. Cognitive Control During Exercise

Researchers also wish to understand what occurs in the brain during a single bout of physical activity. A recent theory proposed by Dietrich (2006) attempts to address this relatively unexplored phenomenon. Specifically, the transient hypofrontality theory (THT) was proposed to explain what may occur in the brain while an individual is forced to process information associated with the bout of exercise and the cognitive task, essentially leading to a dual task environment. The THT states that moving the body requires a significant amount of brain activity and the increased demand for motor functions requires certain non-essential processes to be diminished. These processes include cognitive abilities, such as cognitive control tasks, which utilize the prefrontal cortex. However, recent research surrounding this theory suggests that Dietrich (2006) may be incorrect in his assumptions about the dual task of exercise and cognitive tasks. Though research has indicated that there may be reductions in cognitive function during aerobic exercise, recent research has indicated increases in the allocation of attentional resources during dual-task protocols, which may refute Detrich's hypofrontality theory (Grego et al., 2004; Pontifex & Hillman, 2007).

The literature surrounding this topic is limited in that there are only a handful of researchers who have examined cognition during exercise. They either measured the underlying physiology or the behavioral changes associated with the dual tasks of mental performance and physical activity. Dietrich and Sparling (2004) assessed the THT, asking participants to cycle, run, or rest while completing two different cognitive tasks. Results of their experiment indicate that aerobic exercise hinders completion of a task that taps pre-frontal cognition, with no changes in a task that is prefrontal-independent. However, the results are limited because the paradigm did not allow for assessment of baseline measures that are crucial to understanding exercise-induced changes in performance. Further, given that a between-subjects design was used, there may have been some differences in groups completing exercise or rest.

Dietrich and Sparling's (2004) study also has another limitation, as the sole use of behavioral measures is not a sufficient indicator of the neural allocation to assess hypofrontality. To date, only three studies have assessed the underlying physiological responses elicited during single bouts of aerobic exercise. One study observed the electrophysiology of 12 elite cyclists during a 3-hour cycling test. Results indicated that the P3 component increased in amplitude between the first and second hour, but these changes dissipated during the third hour of exercise (Grego et al., 2004). The authors' argued that the increase in amplitude reflected an increase in cognitive functioning through the second hour of exercise, but after the 108th minute, this effect disappeared, suggesting that cognition was limited at that time due to fatigue. The latency of the component increased after the second hour indicating delays in processing information, also due to fatigue. The results of the study suggest that during the first hour of cycling, greater allocation of attentional resources was evidenced, indicative of increases in cognitive function. However, the increase in the P3 latency following the second hour of aerobic exercise indicates delayed processing speed. The authors' argue that long term bouts of exercise may cause a combination of arousal and later, central fatigue, causing the changes elicited in the neuroelectric indices of cognition (Grego et al., 2004).

Taking a more general approach to the effects of cognition during exercise, one study assessed non-elite performers during a shorter bout of aerobic exercise. Pontifex and Hillman (2007) studied changes in cognition during a bout of cycling. Forty-one younger adults (20.2 years ± 1.6 years) cycled at 60% of their maximal heart rate and performed a modified flanker task while ERPs were measured. The task was also completed at rest and the two were compared. Accuracy during incongruent trials decreased during exercise, an effect not observed for the congruent trials. Additionally, during exercise, there was an increase in P3 amplitude at the frontal and lateral scalp sites. P3 latency also increased during exercise relative to rest, indicating that processing speed was reduced during active participation in exercise. These results suggest that aerobic exercise was detrimental to the performance of a task, which required variable amounts of cognitive control. Additionally, it was argued that there was competition for the allocation of available resources in the brain, leading to the recruitment of additional resources, causing a reduction in the performance of cognitive control tasks.

Relative to Dietrich (2006), Pontifex and Hillman (2007) also indicate that there is a negative effect on cognition during exercise, however due to the increases in the allocation of attentional resources in the frontal regions; they argued that there is an increase in prefrontal recruitment, not a decrease as suggested by the THT. Yagi, Coburn, Estes, and Arruda (1999), using an auditory and a visual oddball task, found a decrease in P3 amplitude and a shorter P3 latency during exercise where the bout of aerobic exercise elicited a heart rate between 130 and 150 beats per minute. The differing evidence surrounding cognition during exercise shows that additional research is needed to better understand the in-task exercise-cognition relationship.

2.4.3. Cognitive Control Following a Single Bout of Exercise

Many researchers have narrowed their focus regarding the changes in cognitive functioning elicited following submaximal exercise. As Tomporowski (2003) explains in his review of literature, there is a general trend of improved cognition after submaximal exercise when compared to pre-exercise measures. Similar results have been reported by Lichtman and Poser (1983), wherein 64 participants took part in either submaximal exercise or a hobby class. They found that only the exercise group had significant improvements in cognitive function after activity. Sibley, Etnier, and LeMasurier (2006) studied changes in performance on the Stroop Color-Word Interference test after exercise. Seventy-nine college students first took a baseline measurement of Stroop performance then cycled at a self-paced intensity. It was found that interference, or the ability to refrain from making a preponent response, improved following exercise.

Results from a recent study (Hillman et al., 2003) indicated that an acute bout of exercise may affect neuroelectric function and alter cognitive control due to an increase in the allocation of neural resources in a group of young adults. Following a single, 30-min bout of exercise and after participants' heart rate returned to within 10% of pre-exercise levels, increases in P3 amplitude were observed, suggesting benefits to cognitive functioning. The P3 latency was unchanged following exercise for the neutral condition (i.e., congruent trials) of the flanker task. However, P3 latency decreased for incongruent trials, requiring greater cognitive control. These results indicate selective improvements in cognitive functioning following an acute bout of exercise (Hillman et al., 2003).

Other researchers have also used the P3 component to examine post-exercise effects on brain and cognition. Nakamura and colleagues (1999) assessed a group of younger adults and had them run at a comfortable jogging pace for 30 minutes. Results indicated that following exercise, there was an increase in the P3 amplitude at the central and parietal sites. This suggests that individuals were allocating more resources to the stimuli following the bout of exercise. Nakamura et al.'s (1999) findings are consonant with the findings provided by Hillman and colleagues (2003). However, Yagi et al. (1999) found no changes in the P3 amplitude or latency following a 10-min bout of exercise at a heart rate between 130 and 150 beats per minute.

Therefore, open questions remain regarding how neuroelectric aspects of cognition are altered by exercise.

Hillman and colleagues (2009) extended their acute exercise findings by examining preadolescent children and found that following a single bout of cardiovascular exercise, there was an increase in the P3 amplitude and an increase in the response accuracy during the more difficult portion of the task (i.e., the incongruent trials of a flanker task). Their findings indicate that a single acute bout of moderate exercise (e.g., walking) may have a facilitative effect on cognition and attention. Additionally, it was found that these children increased their performance on an academic achievement test, which may help demonstrate that even children should continue to exercise to effectively function throughout their lifespan.

Recent research has assessed the underlying changes in working memory following both aerobic and anaerobic exercise. Behavioral results following a 30 minute bout of aerobic exercise at 60%-70% of VO_{2Max} indicated shorter RT immediately following the cessation of exercise and 30 minutes following the exercise session as compared with baseline measures. Further, there was a greater reduction in the RT on more difficult tasks that required greater amounts of working memory, another aspect of cognitive control. However, no changes were found following seated rest or an anaerobic exercise regimen, which included seven different exercises designed to incorporate all major muscle groups (Pontifex et al., 2009). The results of this study suggest that different modes of exercise have differential effects on cognitive control.

However, other researchers have attacked this research question by utilizing numerous exercise intensities to determine changes in cognitive function. Duzova et al. (2005) used an anaerobic maximal exercise test and evoked brain potentials using an oddball task. The results indicated that there was no effect of this intense bout of exercise on cognitive function. Magnié and colleagues (2000) had participants complete a graded exercise test (GXT) using a cycle ergometer and then evoked ERPs following volitional exhaustion using an auditory oddball task. Results indicated that there was an increase in the P3 amplitude following exercise and an overall reduction in the P3 latency following the bout of exhaustive exercise in all participants. Across the two studies, the results suggest that maximal aerobic exercise may elicit facilitations in cognitive function through an increase in attentional resource allocation and the reduction of stimulus classification speed, after HR and body temperature return to baseline levels, whereas maximal anaerobic exercise does not elicit any behavioral or neuroelectrical changes. The underlying changes that have been evidenced following a single session of maximal aerobic exercise are interesting; however, recent reports have assessed differences in the alterations of cognition between submaximal and maximal aerobic exercise.

To better understand these discrepant findings, Kamijo and colleagues (2004) asked participants to exercise at three different intensities. During the low intensity exercise, the participants exercised between 7 and 9 on the Borg rating of perceived exertion (RPE) scale (Borg, 1970). The moderate intensity level had participants exercise between a 12 and 14 on the RPE scale. The high intensity level occurred when the participants cycled to volitional exhaustion. The results revealed that following moderate intensity exercise, during the Go portion of the task, where the subject was to respond to stimuli, an increase in P3 amplitude at the frontal and central regions was observed. During the No-Go portion of the task, where the participant was asked to inhibit their response (i.e., increased cognitive control requirements), a global increase in amplitude was observed. However, following the high intensity exercise, there was a global decrease in amplitude of the P3 component of the ERP. This pattern of results suggests that there is a facilitative effect on cognition immediately following moderately intense exercise. However, decrements in cognitive control follow exhaustive exercise. The difference between this study and that of Magnié et al. (2000) is the time between the cessation of the exercise bout and the assessment of ERPs. In Kamijo et al. (2004), the task began approximately 3-minutes following the exercise bout, whereas Magnié et al. (2000) began the task after the individuals' HR and body temperature returned to baseline levels. Therefore, facilitations following acute maximal aerobic exercise may only be elicited following rest.

Using a similar task paradigm to that of Hillman and colleagues (2003), Kamijo et al. (2007) indicated that cognitive control is altered following single bouts of aerobic exercise. In this study, it was found that RT was reduced for both congruent and incongruent trials of a flanker task following three different bouts of exercise at differing intensities (light, moderate, and hard). Additionally, it was found that following light and moderate bouts of exercise, P3 amplitude increased, indicating an increase in the allocation of attentional resources. Lastly, results indicated that there was only a difference between P3 latency of the congruent and incongruent trials during the baseline session, a result not seen following exercise. As P3 latency was reduced in the incongruent trials following exercise, this indicates faster stimulus classification speed. Kamijo and colleagues (2009) followed this study by examining the P3 component using a flanker paradigm attempting to assess if there was a difference between age groups and exercise intensity. The results indicated that RT was shorter for both young adults and older adults following a moderate intensity exercise bout (e.g., 74% of HR_{max}) as compared with both light intensity (55% of HR_{max}) and rest, with a marginal decrease at the light intensity as compared with rest. In the younger group, it was found that the moderately intense exercise elicited larger P3 amplitude, but not in the older group. Additionally, in both groups there was a decrease in the P3 latency following both exercise bouts. This suggests that both light and moderate exercise bouts facilitate cognitive control across the lifespan. However, there may be differing mechanisms underlying the observed changes for different age groups (Kamijo et al., 2009).

Davranche, Hall, and McMorris (2009) followed similar trends of research, assessing single bouts of exercise on cognition. A flanker task was used consisting of three different trials that varied according to their level of congruency. Individuals who exercised at 50% maximal aerobic power showed a reduction in RT, with no effect on accuracy. This study indicated that participants were better able to classify the stimuli and then complete a response mapping following a single bout of aerobic exercise with no changes in accuracy, as compared to rest.

Recent research has indicated that benefits accrue following aerobic exercise at 40% of maximal aerobic power. Results indicate improved performance on a stop signal task for response inhibition and response execution up to 52 minutes following the cessation of exercise (Joyce, Graydon, McMorris, & Davranche, 2009). These findings are consonant with that of Hillman and colleagues (2003), who state that the heightened state of cognition lasted up to 48 minutes following the cessation of exercise. In sum, there seems to be an overall consensus indicating that cognitive function is enhanced up to approximately one hour following a single session of submaximal aerobic exercise. However, little knowledge exists concerning the causes of these underlying changes in cognition, which still need to be further explored.

2.5. VIDEOGAMES AND COGNITION

Evidence supports the notion that physical activity may be inversely related to chronic disease, including cardiovascular disease, hypertension, stroke, osteoporosis, type II diabetes, obesity, types of cancer, anxiety, and depression (ACSM, 2010). However, even with this knowledge, sedentary behavior is still a major concern. Specifically, 48.8% of adults in the

United States reported engaging in at least 30 minutes of moderate-intensity activity, five days per week, or 20 minutes of vigorous-intensity activity, three days per week (Centers for Disease Control and Prevention, 2008); whereas, 23.7% of individuals reported no leisure-time physical activity (CDC, 2005). One contributing factor to this limited amount of physical activity and exercise in U.S. adults is the use of sedentary materials, such as videogames. Approximately 68% of all American households play computer or videogames, with the average game player being 35 years of age (ESA, 2009).

2.5.1. Videogames Players and Cognition

Over the past few decades, videogames have become increasingly popular. With new technological advances, more realistic videogames are being designed, which have allowed for these games to reach a broader array of individuals. With more individuals playing videogames, researchers have begun to form opinions about the consequences of game play on the individual and society at large.

Violent videogame usage has been associated with aggressive feelings, thoughts, and behavior (Anderson, 2004; Anderson & Bushman, 2001). Videogame play of greater than one hour a day has been linked to lower grade point averages as compared to individuals who played less than one hour a day (Chan & Rabinowitz, 2006). Additionally, Anderson and Dill (2000) indicate that there is a negative correlation between grade point averages and time playing videogames. Though the use of videogames increases sedentary behavior and aggressive behaviors, researchers have begun to assess the potential positive outcomes to using this technology. Rosser and colleagues (2007) suggest that individuals who play more than three hours of videogames per week had 37% fewer errors and 27% faster completion in laparoscopic surgical skills. Some work suggests that videogame usage may be related to improvements in certain types of cognition. VGPs tend to be faster on numerous different tasks, with no speed-accuracy trade off (Dye, Green, & Bavelier, 2009). Additionally, numerous studies, using a wide variety of tasks, have indicated that VGPs have superior performance on visual attention tasks and the ability to mentally rotate objects (De Lisi & Wolford, 2002; Green & Bavelier, 2003; Green & Bavelier, 2006a; Green & Bavelier, 2006b).

However, in opposition, recent research has indicated that videogame playing may be negatively related to cognitive control (i.e., the ability to inhibit extraneous variables in an environment, in order to maintain goal-directed information processing). A moderate positive relationship has been identified between videogame experience and Stroop interference (i.e., the difference in RT between the more difficult task, and an easy task; Kronenberger et al., 2005). Additionally, using fMRI, it was found that active gamers, high in media violence, failed to activate structures in the ACC and lateral frontal cortex during incongruent trials of a counting Stroop task, whereas the low VGPs showed this activation, suggesting that cognitive control in VGPs may be diminished (Mathews et al., 2005). Bailey, West, and Anderson (2009) have made claims regarding the effects of videogame play on proactive and reactive cognitive control. Proactive control is said to be the future-oriented form of regulation which occurs before the onset of a stimulus, whereas reactive control is the just-in-time form of regulation. These were assessed using three different ERP components; the medial frontal negativity (MFN) and frontal slow wave were considered indices of proactive control, and the conflict slow potential (SP) was used to index reactive control. Results of this study indicated that the MFN and frontal slow wave were attenuated in VGPs, while no effects were observed for the SP. Such a pattern of findings indicates that videogame play may have a negative influence on proactive cognitive control, but no effect on reactive control.

However, some evidence exists to suggest that videogame use may enhance cognitive control. Expert videogame players showed a smaller switch cost as compared to non-experts, suggesting enhanced cognitive control through the ability to switch between two task sets (Boot et al., 2008). Recent work by Karle and colleagues (2010) has indicated that VGP experts were generally faster than non-game players, with the additive benefit of reduced switching costs. However, after a secondary experiment, it was observed that VGPs did not selectively benefit for task switching. Their interpretations of this studies indicated that VGPs had superior ability to control selective attention (Karle et al., 2010). These claims are similar to those of Castel, Pratt, and Drummond, (2005), who believe that VGPs and non-VGPs have similar mechanisms to guide visual attention, but those who play videogames have quicker stimulus-response mappings, which lead to faster execution of responses. Additionally, it was found that FPS games may help to decrease the switch cost in a task switching paradigm, indicating individuals who play these types of games have greater cognitive flexibility as compared to non-gamers (Colzato, van Leeuwen, van den Wildenberg, & Hommel, 2010). Chisholm and colleagues (2010) indicated that VGPs were quicker than non-VGPs even during a task where irrelevant stimuli were present. Additionally, VGPs showed smaller capture effect, suggesting that they were able to utilize an internal strategy to reduce the effect of the irrelevant information.

Interestingly, it was found that training non-VGPs on an action videogame increased their visual attention (Green & Bavelier, 2003). Additionally, training for 25 hours on Super Tetris, a game which asks subjects to mentally rotate objects into the correct positions, improved more than non-gamers on a working memory task (e.g., faster RT on the Sternberg task), but the same effect was not seen using the Stroop Color Word Test (Goldstein et al., 1997). Typically, it has been found that games similar to Tetris (i.e., Pac-Man and Donkey Kong), which are thought to be first generation-type games, tend not to show improvements in cognitive control processes, but show improvements in RT (Clark, Lanphear, & Riddick, 1987; Dustman, Emmerson, Steinhaus, Shearer, & Dustman, 1992). However, newer games have begun to be researched in training paradigms. In one study (Boot et al., 2008), it was found that with the exception of Tetris, action or strategy game practice of 21 hours, as comparatively to a control group, did not improve performance on a group of cognitive tasks tapping into attention, memory, and cognitive control. Training on FPS videogames has shown improvements in enumeration, useful field of view, and attentional blink tasks (Green & Bavelier, 2003; Green & Bavelier, 2006b). Additionally, a real-time strategy game, when trained for 23.5 hours, allowed older adults to have significant improvements in cognitive control function tasks (such as, task switching, working memory, visual short-term memory, and reasoning), as compared to control subjects (Basak et al., 2008).

Even with the numerous studies that have assessed cognitive function and videogame play, the evidence does not give an overall picture of how game play alters cognitive function. Many studies have indicated that videogames increase visual spatial abilities and cognitive control, while others state that VGPs are negatively associated with cognition. This could be due to the extreme differences in the literature and the different tasks that were employed. Therefore, more work in this area is necessary to see if a larger picture emerges as how videogames alter cognitive function.

2.5.2. Single Sessions of Videogame Play on Cognition

The overall trend of videogame research has assessed how VGPs are different from non-players with respect to cognition. Some researchers have begun to understand the consequences of single bouts of videogame play on cognition. This literature base is extremely limited with only a few studies assessing acute bouts of videogame play. Many individuals believe that playing videogames can help increase mood and may decrease stress. Russoniello and colleagues (2009) attempted to assess this belief with the use of EEG and psychological assessments. Results indicated that a casual videogame (e.g., Bejeweled II) played for 20-min reduced left frontal alpha brain waves, which is indicative of improved mood. Additionally, there were reductions in anger, vigor, emotional fatigue, and confusion as compared to a control group. These findings suggest that a single bout of videogame play may help to improve overall mood.

Additional research has assessed single bouts of videogame play on cognition similar to the previously mentioned studies about VGPs and non-VGPs. Results of a study conducted by Orosy-Fildes and Allan (1989) indicated that a single bout of videogame play decreased participants' RT by as much as 50 ms on a simple task. Recent research has determined how different videogames may alter cognition follow a single session of videogame play for 14-18 minutes. Individuals were separated into three groups, a non-violent videogame, a violent videogame, and a control condition (e.g., internet search), and were assessed before and after their conditions on the SynWin task. This task consists of four components that need to be completed continuously with all rule-sets maintained for approximately five minutes. The tasks that needed to be completed were the Sternberg working memory, mathematical adding, auditory discrimination, and selective attention tasks. The researchers allowed four trials of the SynWin task prior to the experimental condition, so that individuals were proficient and in an effort to reduce learning effects. Results indicated that there were significant increases in the SynWin scores for both violent and non-violent VGPs following the experimental condition as comparatively to the control group. These results suggest that videogame play, no matter what content is employed, may increase cognitive performance (Bartlett, Vowels, Shanteau, Crow, & Miller, 2009).

Though the relatively unexplored field of single bouts of videogame play on cognition does seem to have a promising outlook, the studies that have been conducted have certain limitations. The studies have not employed a within-subjects design, but rather have utilized a cross-sectional approach. As such, the groups that were assessed following videogame play may have initially been different. Therefore, more research on single bouts of videogame play should be pursued to gain an overall understanding of the effects on cognition.

2.6. VIDEOGAMES AND PHYSICAL ACTIVITY

In recent years, technology has advanced so that an individual's movement can be assessed by a gaming console so that the character on the videogame completes movements that mirror that of the gamer. The use of DDR®, Nintendo Wii™, and Wii Fit™ are three of the physically active games, or exergames, that have grown in popularity since their introduction. These types of games may help to attenuate inactivity and allow players to increase their energy expenditure during game play (Miyachi et al., 2010). Several studies indicate that these types of games force the gamer to increase their overall energy expenditure, but not as much as the actual activity (Graves, Ridgers, & Stratton, 2008; Graves, Stratton, Ridgers, & Cable, 2008; Lanningham-Foster, Foster, McCrady, Jensen, Mitre, & Levine, 2009; Lanningham-Foster, Jensen, Foster, Redmond, Walker, Heinz et al., 2006). However, these studies have shown that playing these games may not contribute toward the recommended daily amount of exercise because of the relatively low intensity. Miyachi and colleagues (2010) argue that these measurements may have been underestimated due to the use of the Intelligent Device for Energy Expenditure and Activity (IDEEA) system. Using a metabolic chamber, these researchers have indicated that playing Wii Fit™ and Wii™ Sports may actually count toward the daily amount of exercise required following ACSM and AHA guidelines. Specifically, it was found that the aerobic tasks offered by Wii Fit™ elicited a MET value of 3.4 ± .09, which classifies the activities as moderate intensity (Miyachi et al., 2010).

Wii Fit™ is an active video system in which movements are picked up by both a force-plate and a wireless receiver (Wii Fit™; Nintendo Inc., Kyoto, Japan). Many different tasks can be completed including, yoga, balance, resistance, and aerobic exercise. Moreover, the aerobic exercise tasks include numerous activities, which may help to increase the heart rate and get participants moving. These tasks include an aerobic step task, similar to an aerobic fitness class, rhythm boxing, stepping and punching to a beat, and finally, Hula Hoop®, forcing the participant to continuously change their center of gravity in a circular motion. To date, since the advent of games similar to these, little research has gained an understanding of whether there are any changes in cognitive function, including aspects of cognitive control, which may occur following a single bout of active videogame play. Additionally, no research has attempted to explore how exergames influence cognition.

CHAPTER 3: METHODOLOGY

3.1. PARTICIPANTS

Thirty-six participants (18 males, 18 females) between the ages of 18 and 25 years were recruited from the undergraduate population at the University of Illinois at Urbana-Champaign. All participants provided written informed consent, which was approved by the Institutional Review Board of the University of Illinois at Urbana-Champaign. Participants completed the Physical Activity Readiness Questionnaire (PAR-Q), the Edinburgh handedness inventory (Thomas, Reading, & Shephard, 1992; Oldfield, 1971), and had normal or corrected-to-normal vision based on the 20/20 standard. Participants were instructed to abstain from physical activity on the days they visited the laboratory. Table 1 lists participants' inclusion-exclusion criteria.

Table 1 Inclusion-Exclusion Criteria for Participants

Inclusion	Exclusion
1. 18-25 years of age	Below 17 or above 25 years of age
2. K-BIT composite score at or above 85	K-BIT composite score below 85
3. Pass PAR-Q	Any physical disability that prohibits physical activity
4. Perform cognitive tasks with at least 50% accuracy in all task conditions	Performance below 50% accuracy in any cognitive task or task condition
5. Successful completion of graded exercise test	Evidence of abnormal observed/reported responses or conditions during graded exercise testing
6. Corrected (near and far) acuity 20/20 or better	Corrected (near and far) acuity of greater than 20/20

3.2. PROCEDURES

Participants visited the laboratory on five separate occasions at the same time of day. The first session was a practice session and the final four sessions were counterbalanced to reduce the possibility of learning or habituation effects. On the first visit, participants completed the informed consent, and were then fitted with a Polar Heart Rate monitor (Model A1, Polar Electro, Finland). Participants then completed the PAR-Q to screen for previous health issues that may be exacerbated by acute exercise, the Edinburgh Handedness Inventory, health history and demographic information, and completed the Video Game Usage Questionnaire (Gentile, 2009). A trained experimenter administered the Kaufman Brief Intelligence Test (K-BIT; Kaufman & Kaufman, 1990). Participants received approximately 10 minutes of practice on the three aerobic Wii Fit™ games, with task instructions preceding each of the games. Following the Wii Fit™ training, an experimenter read task instructions and allowed the participant to choose their MarioKart® character and vehicle. Participants practiced MarioKart® for 10 minutes. An experimenter then led the participant to a sound attenuated room and read aloud the flanker task instructions. Participants were given 20 practice trials with the experimenter in the room, and then received a block of 200 trials as a learning session. Following the flanker task, the participant's height and weight were measured using a stadiometer and a Tanita BWB-600 digital scale, respectively, and completed a graded exercise test (GXT) to assess their VO_{2Max}, which is considered to be the criterion measure of cardiorespiratory fitness (ACSM, 2010).

The final four sessions included 20 minutes of either MarioKart®, Wii Fit™, treadmill walking, or quiet reading. Prior to each session, a Polar Heart Rate Monitor was applied and the participants sat quietly to allow measurement of their baseline HR. During the MarioKart® session, the participants used the same character and vehicle that they chose on their first visit to the lab. Following game play, the participants were prepared for neuroelectric measurement and participants' responses (ERPs, RT, and response accuracy) were collected during the flanker task. During the Wii Fit™ session participants completed six-minute versions of the three aerobic games, including Hula-Hoop®, Aerobic Step, and Rhythm Boxing. The entire Wii Fit™ session lasted approximately 20 minutes. Next, participants were prepared for neuroelectric measurement. During the treadmill session, participants walked on the treadmill at 60% HR_{max}. An experimenter carefully matched the speed of the treadmill to ensure that participants worked at the same intensity for both the Wii Fit™ and treadmill sessions. They were then prepared for neuroelectric measurements. During the quiet reading session, participants sat on a chair and were instructed to read a campus newspaper prior to being prepared for neuroelectric measurement. During each experimental session, an experimenter assessed HR, RPE (Borg, 1970), and the feeling scale (FS; Hardy & Rejeski, 1989). The flanker task was completed after participants' HR returned to within ±10% of pre-exercise levels (approximately 22 minutes).

3.3. MEASURES

3.3.1. Cardiorespiratory Testing

The GXT was conducted on a Life Fitness motor-driven treadmill (Brunswick Corporation, Schiller Park, IL, USA) using a modified Balke protocol. Participants were given a 2-minute warm-up to determine a running pace, then the grade was increased by 3% every 2-minutes, until volitional exhaustion. Respiratory exchange ratio (RER) and 20-second averages of oxygen uptake (VO_2) were collected using a computerized indirect calorimetry system (ParvoMedics True Max 2400). Oxygen consumption was expressed in $mL \cdot kg^{-1} \cdot min^{-1}$ and was based on a maximal effort when the participants achieved at least two of the four following criteria:

1. Plateau in oxygen consumption resulting in an increase of less than 2 $mL \cdot kg^{-1} \cdot min^{-1}$, despite an increase in workload
2. Achievement of maximum heart rate equating to 95% of age-predicted HR maximum (220 – age)
3. Self-reported RPE greater than 17
4. RER of 1.10 or greater

3.3.2. Electroencephalogram (EEG) Recording

EEG activity was recorded at 64 electrode sites based on the International 10-20 system (Jasper, 1958) using a Neuroscan Quik-cap (Neuro, Inc., Charlotte, NC, USA). The data were referenced to the average of the mastoid leads (M1, M2) with AFz serving as the ground electrode and impedances <10 kΩ. Electrodes were placed above and below the left orbit and on the outer canthus of each eye to monitor bipolar electro-oculographic (EOG) activity. Continuous data were sampled at 500 Hz and amplified 500× with a Neuroscan Synamps amplifier (Neuro, Inc., Charlotte, NC, USA).

Data were corrected for EOG activity using a spatial filter (Compumedics Neuroscan, 2003). Epochs were created from -100 to 1000 ms around the stimuli, and baseline corrected using the 100 ms pre-stimulus period. Data were filtered using a zero phase shift 30Hz (24 dB/octave) low pass filter. A linear detrend was applied across the entire epoch to control for DC drift. Trials with artifacts exceeding ±75 µV and response errors were rejected. The P3 was defined as the largest positive-going peak within a 300-520 ms latency window from stimulus onset. The peak data were output in ACSII format and analyzed using SPSS 14.0.

3.3.3. Flanker Task

A modified flanker task (Pontifex & Hillman, 2007; Pontifex, Scudder, Brown, O'Leary, Wu, Themanson et al., 2010) was used, which displays an array of arrows. The congruent trials consisted of the target arrow being flanked by arrows facing the same direction (e.g., <<<<< or >>>>>). The incongruent trials consisted of the target arrow being flanked by arrows facing the opposite direction (e.g., <<><< or >><>>). Participants were instructed to attend to the middle arrow and press a button using their left thumb when the target arrow faced to the left (e.g., '<') and their right thumb when the target arrow faced to the right (e.g., '>'). The participants were instructed to respond as quickly and as accurately as possible. One block of 200 trials, which were randomized across task conditions, was given during each session. Each block consisted of 100 congruent trials and 100 incongruent trials, with an equal probability of right and left facing target arrows. The stimuli were 3.0 cm tall and presented in the middle of a computer screen on a black background for 100 ms, with a counterbalanced inter-trail interval of 1000, 1200, and 1400 ms. The participants sat one meter from the screen during the task.

3.3.4. Wii Fit™ Aerobic Games

The Wii Fit™ game console is a recent technology where the use of hand controllers and a balance board are used to complete different tasks. Three different aerobic games were chosen as they all included cardiorespiratory exercise, increasing participants' heart rate. The Aerobic Step game (4.0 ± 0.6 METs; Miyachi et al., 2010) is similar to a step class where the individual has to step on and off the balance board at a particular time in different combinations. A scrolling bar along the middle of the screen indicates which type of step the individual must make. There are four different steps that the game offers: normal step on and off the board, a side step on and off the board from behind the board, a side step to the left and right of the board, and a knee raise.

The game provides feedback for perfect timing, good timing, or a missed step. Rhythm boxing (3.9 ± 0.7 METs; Miyachi et al., 2010) is similar to the Aerobic Step game, but has the addition of using a remote control for each hand. The remote controllers in the hands monitor participants' punching. The individual steps off the board one or more times and throws punches with both hands. The individual watches a teacher complete the action and then completes the action three times, twice with voice-over guidance and once with no assistance. The Hula Hoop® task (4.2 ± 1.2 METs; Miyachi et al., 2010) places the participant in a virtual world and asks the individual to shift their center of gravity in a circle in one direction for three minutes and then the other direction for another three minutes. The individual starts with one Hula Hoop® and throughout the session they are instructed to shift their weight to one side of the board in order to catch other Hula Hoops®. Participants were instructed to try to achieve the best score on each task. The tasks were counterbalanced. Heart rate, RPE, and FS were assessed every two minutes during the session.

3.3.5. MarioKart®

The object of MarioKart® Wii™ is to race around a track in a kart or on a motorcycle and beat computerized drivers in a three lap race. The task uses the Wiimote™ placed in a small steering wheel. The wheel assesses the drivers' motion. To turn to the right, the driver must turn the wheel to the right and to turn to the left, the driver must turn to the left. During the race, drivers have the ability to gather numerous tools to beat the other drivers. These tools include shells, which, when an individual is hit by one, stop the drivers' motion, speed boosts, and bombs. However these items can be picked up by the computerized characters, which can be used against the player. The participants were instructed to try to achieve the best finishing spot for each race. HR was assessed every two minutes during the session. RPE and FS were assessed after the completion of each race.

3.4. STATISTICAL ANALYSIS

Preliminary analyses were conducted to examine the order in which the sessions occurred to ensure that the observed effects were not due to the order in which participants completed their sessions. These analyses employed an additional between-subjects variable that accounted for the individualized order of the four experimental sessions for each participant. In total, there were 24 different session orders that were completed. The between-subjects variable was used with each of the analyses described below for each of the dependent variables.

HR and RPE data were analyzed using a 4 (Condition: Rest, Treadmill, MarioKart®, Wii Fit™) × 3 (Time: Pre-, During-, Post-session) repeated measures ANOVA. Additional one factor repeated measure ANOVAs and follow up paired samples t-tests with Tukey's HSD procedure were used to determine significant differences between conditions at each time point.

Analyses were conducted separately for task performance measures (RT and response accuracy) using a 4 (Condition: Rest, Treadmill, MarioKart®, Wii Fit™) × 2 (Congruency: Congruent, Incongruent) repeated measures ANOVA. Additional analyses examining interference scores (i.e., the difference between congruent and incongruent trails for both accuracy and RT) were conducted using a one factor (Condition: Rest, Treadmill, MarioKart®, Wii Fit™) repeated measures ANOVA and paired-samples t-tests with Tukey's HSD procedure to determine specific differences between conditions.

P3 analyses were conducted using 25 electrode sites (five coronal sites within each of five regions). P3 values (amplitude, latency) were submitted to a 4 (Condition: Rest, Treadmill, MarioKart®, Wii Fit™) × 2 (Congruency: Congruent, Incongruent) × 5 (Region: Frontal-, Fronto-Central, Central, Centro-Parietal, Parietal) × 5 (Site: 3, 1, z, 2, 4) repeated measures ANOVA.

The reported significances for the *F* values were those obtained using the Greenhouse-Geisser correction. When appropriate, follow up analyses were conducted using additional repeated measures ANOVAs and paired-samples t-tests with Tukey's HSD correction. The family-wise alpha level was set at 0.05.

CHAPTER 4: RESULTS

4.1. PARTICIPANT DEMOGRAPHICS

All of the collected participant characteristics decomposed by gender are presented in Table 2.

Table 2 Mean (Standard Deviation) Demographic Information for All Participants and for All Participants Categorized by Sex

Variable	All Participants *M (SD)*	Females *M (SD)*	Males *M (SD)*
Sample size (*n*)	36	18	18
Age (years)	21.2 (1.5)	20.6 (1.3)	21.8 (1.6)
BMI	23.3 (3.0)	22.7 (2.6)	24.3 (3.2)
IQ (K-BIT composite)	106.8 (7.3)	106.6 (7.7)	107.1 (7.1)
VO_{2max} (mL/kg/min)	45.2 (5.9)	41.5 (4.2)	48.9 (5.0)
Max HR (bpm) during GXT	195.1 (7.9)	193.8 (8.1)	196.3 (7.8)
TV during week (hr)	2.26 (1.7)	1.81 (1.4)	2.72 (1.8)
TV during weekend (hr)	3.42 (2.2)	2.89 (2.0)	3.94 (2.2)
Computer during week (hr)	4.17 (2.9)	4.56 (3.0)	3.78 (2.9)
Computer during weekend (hr)	4.18 (3.0)	4.00 (1.5)	4.36 (4.0)
Videogame during week (hr)	0.53 (0.8)	0.03 (0.1)	1.03 (1.0)
Videogame during weekend (hr)	1.01 (1.2)	0.31 (0.8)	1.72 (1.2)
PA during week (hr)	1.43 (0.7)	1.31 (0.6)	1.56 (0.9)
PA during weekend (hr)	1.46 (1.0)	1.44 (0.9)	1.47 (1.1)

4.2. SESSION ORDER

Preliminary analyses were conducted to test whether the order of the treatment sessions, which was counterbalanced across all participants, had a relationship with any of the dependent variables. Findings revealed no significant main effects or interaction involving Session Order for response accuracy, [F (69, 36) = .763, p = .840, η^2 = .585], or RT, [F (69, 36) = 1.519, p = .166, η^2 = .744]. Additionally, findings revealed no significant main effect involving Session Order for P3 Amplitude, [F (69, 36) = 1.344, p = .191, η^2 = .720]. However, a Condition × Site × Session Order interaction was found, [F (276, 144) = 6.412, p = .002, η^2 = .348]. Decomposition of this interaction by examining each of the five Sites within the four Conditions revealed no significant differences. Thus, all further analyses were collapsed across Session Order.

4.3. SESSION INTENSITY

Figure 1 provides session intensity as indexed by HR and RPE.

4.3.1. Heart Rate

The omnibus analysis revealed main effects of Condition, [F (3, 105) = 151.162, p < .001, η^2 = .812], and Time, [F (2, 70) = 737.102, p < .001, η^2 = .955], which were superseded by a Condition × Time interaction, [F (6, 210) = 257.132, p < .001, η^2 = .880]. Decomposition of this interaction by examining Condition within Time revealed increased mean HR for Treadmill Walking, Wii Fit™, and MarioKart® relative to Seated Rest during the experimental manipulations, [t*'s* (35) ≥ 5.780, p ≤ .001]. Additionally, an increase in mean HR was revealed during the experimental manipulation for Treadmill Walking and Wii Fit™ relative to the MarioKart® session, [t*'s* (35) ≥ 19.297, p ≤ .001], whereas no significant differences were observed between the Treadmill (M = 117.08, *S.E.* = 1.471) and Wii Fit™ (M = 115.28, *S.E.* = 2.198) sessions, confirming the successful titration of the two exercise interventions so that they were equal in intensity. No differences in HR were observed at Pre-Session, [*t's* (35) ≤ 1.829, *p* ≥ .05]. A significant increase in HR was found prior to the flanker in the Wii Fit™ session (M = 75.56, *S.E.* = 1.440) as compared to Rest (M = 71.167, *S.E.* = 1.386) and MarioKart® (M = 72.64, *S.E.* = 1.436), [*t's* (35) ≥ 2.366, $p \leq .05$]. However, this increase was within 10% of baseline HR.

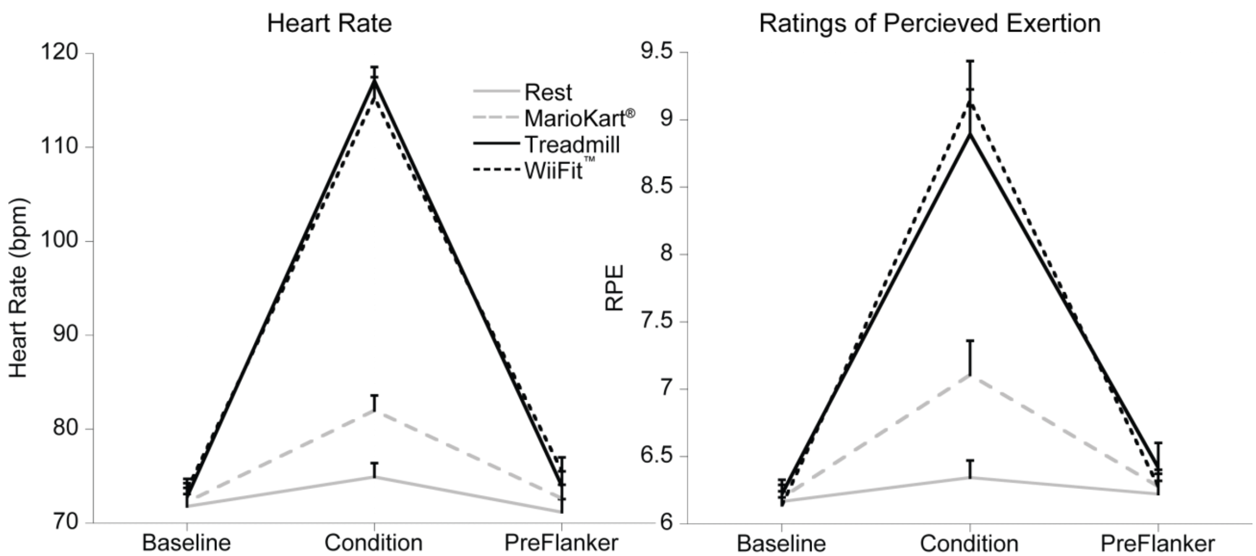

Figure 1 – Mean HR (b·min-1; ± *S.E.*) and RPE values at Baseline, across the entire experimental protocol, and immediately prior to the flanker task.

4.3.2. Ratings of Perceived Exertion

The omnibus analysis revealed main effects of Condition, [F (3, 105) = 36.839, $p < .001$, $\eta^2 = .513$], and Time, [F (2, 70) = 84.440, $p < .001$, $\eta^2 = .707$], which were superseded by a Condition × Time interaction, [F (6, 210) = 41.525, $p < .001$, $\eta^2 = .543$]. Decomposition of this interaction by examining Condition within Time revealed increased RPE for Treadmill Walking and Wii Fit™ relative to seated rest and MarioKart® during the experimental manipulations, [*t's*

(35) ≥ 6.418, $p \leq .001$]. Additionally, a significant difference between MarioKart® and Rest was observed, [t (35) = 4.538, $p \leq .05$], with higher RPE ratings for MarioKart®. No significant differences for RPE were observed between Treadmill Walking and Wii Fit™, [t (35) = .796, p = .432].

4.4. BEHAVIOR

Figure 2 depicts all task performance data as a function of intervention mode.

4.4.1. Accuracy

Accuracy analyses replicated the robust Congruency effect in the literature, [F (1, 35) = 34.115, $p < .001$, $\eta^2 = .513$], with more accurate responses for congruent trials (M = 97.05, $S.E.$ = .39) relative to the incongruent (M = 89.12, $S.E.$ = 1.15) trials. No main effect or interaction was observed involving Condition, [F*'s* (3,105) ≤ 1.612, $p \geq .202$, $\eta^2 \geq .032$]. Analyses of the interference effect (congruent ACC – incongruent ACC) revealed no observed effects, [F (3, 105) = 1.612, $p = .202$, $\eta^2 = .044$].

4.4.2. Response Time

RT analyses revealed a main effect for Congruency, [F (1, 35) = 329.36, $p < .001$, η^2 = .904], with incongruent trials (M = 395.28, $S.E.$ = 6.438) yielding longer RT compared to congruent trials (M = 346.19, $S.E.$ = 4.947). No main effect of Condition was observed, [F (3, 105) = 1.024, $p = .385$, $\eta^2 = .028$]. However, a Condition × Congruency interaction was observed, [F (3, 105) = 3.425, $p < .05$, $\eta^2 = .089$], but decomposition of this interaction revealed no significant differences. Analyses of the interference effect (incongruent RT – congruent RT) revealed a significant effect for Condition, [F (3, 105) = 3.313, $p < .05$, $\eta^2 = .086$]. Paired samples t-tests revealed a decrease in RT interference for Treadmill Walking (M = 43.94, $S.E.$ =

2.637) as compared to both Seated Rest (*M* = 49.003, *S.E.* = 2.264) and MarioKart® (*M* = 49.440, *S.E.* = 2.278), [*t's* (35) ≥ 2.506, *p* ≤ .05].

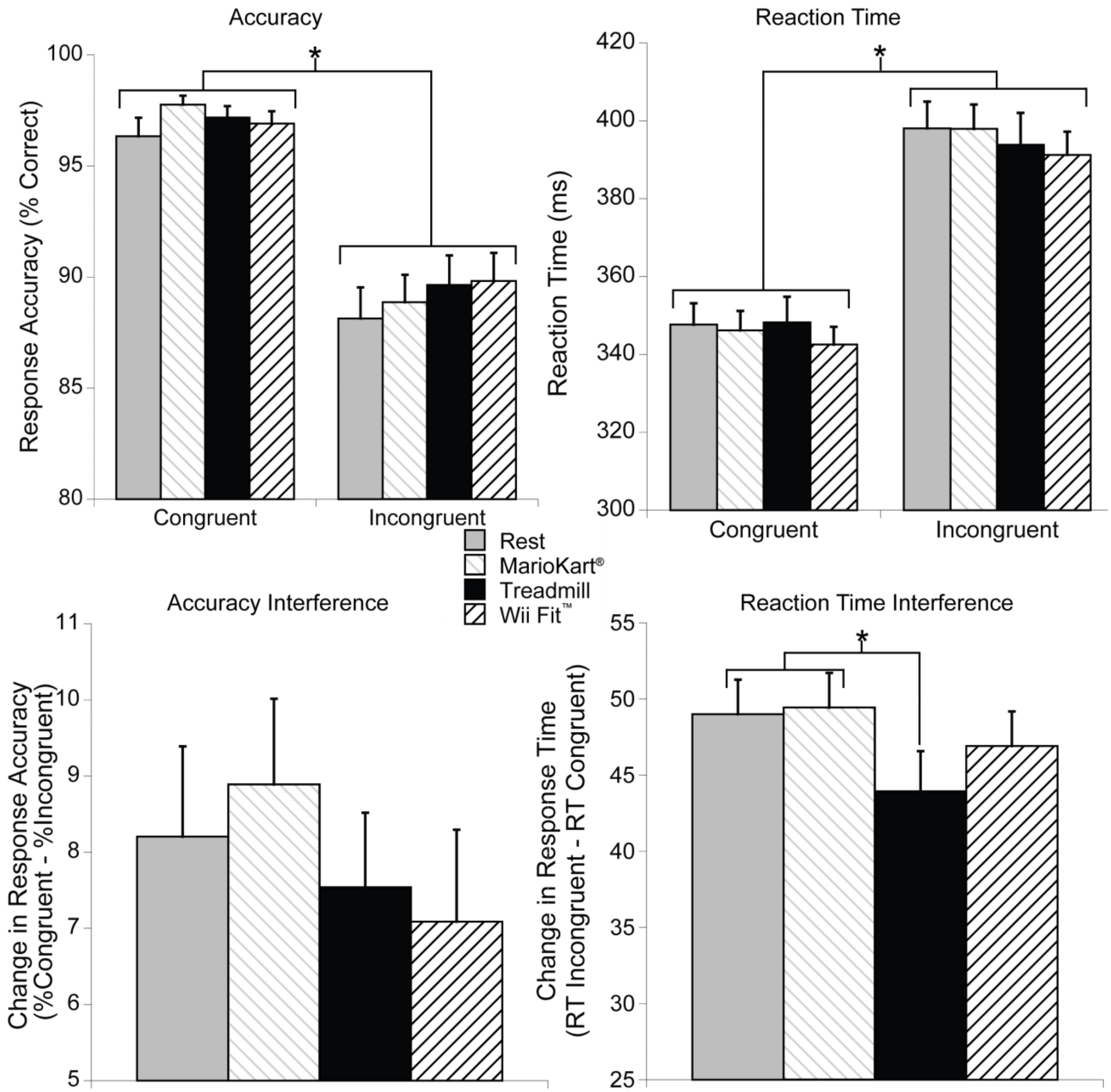

Figure 2. RT and response accuracy data as a function of the intervention modes. Error bars indicate standard error of the mean.

Note. * indicates significance at p < .05.

4.5. P3-ERP COMPONENT

Figure 3 depicts stimulus-locked grand averaged waveforms combined across flanker congruency for all midline sites.

4.5.1. P3 Amplitude

The omnibus analysis revealed a main effect for Condition, [F (3, 105) = 2.845, $p < .05$, $\eta^2 = .075$]. Paired samples t-test revealed that there was an increase in P3 amplitude following Treadmill Walking (M = 7.610, $S.E.$ = .609) compared to Rest (M = 5.973, $S.E.$ = .565), [t (35) $\geq$ 2.534, $p \leq .05$]. P3 amplitude following Wii Fit™ (M = 6.885, $S.E.$ = .564) and MarioKart® (M = 6.990, $S.E.$ = .504) did not differ from any other Condition, (Tukey's $HSD_{critical}$ = 1.578), [t's (35) $\leq$ 2.040, $p \geq .05$]. Additional main effects were found for Congruency, [F (1, 355) = 10.457, $p < .01$, $\eta^2 = .230$], Region, [F (4, 140) = 34.697, $p < .001$, $\eta^2 = .498$], and Site, [F (4, 140) = 16.895, $p < .001$, $\eta^2 = .326$]. However, these were superseded by a Congruency × Region, [F (4, 140) = 5.996, $p < .01$, $\eta^2 = .146$], Congruency × Site, [F (4, 140) = 8.184, $p < .001$, $\eta^2 = .190$], and Region × Site, [F (16, 560) = 2.858, $p = .01$, $\eta^2 = .075$]. Decomposition of the Congruency × Region interaction by examining Congruency within each Region revealed that incongruent trials exhibited larger P3 amplitude compared to congruent trials at the Fronto-Central, [t (35) = 4.316, $p \leq .001$], Central, [t (35) $\geq$ 4.134, $p \leq .001$], and Centro-Parietal, [t (35) $\geq$ 2.783, $p \leq .01$], regions. Decomposition of the Congruency × Site interaction by examining Congruency within each Site revealed that incongruent trials exhibited larger P3 amplitude compared to congruent trials at Site 1, [t (35) = 3.190, $p \leq .01$], Site z, [t (35) = 4.357, $p \leq .001$], Site 2, [t (35) = 3.302, $p \leq .01$], and Site 4, [t (35) = 2.327, $p \leq .05$]. No effect was observed at the 3 Site, [t (35) = 1.800, $p = .081$].

Decomposition of the Region × Site interaction by examining the five Sites within each Region revealed significant main effects at each of the regions, [F's(4, 140) $\geq$ 5.174, $p \leq .003$, η^2

≥ .129]. Paired samples t-tests in the Frontal region revealed larger P3 amplitude at Fz, compared to the F4 site, [t (35) = 4.299, $p \leq .001$]. At the Fronto-Central region, FC1, FCz, and FC2, had larger P3 amplitude than FC4, [t's (35) ≥ 6.032, $p \leq .001$], and FCz was greater than the FC3 site, [t (35) = 2.706, $p \leq .01$]. In the Central region, C3, C1, Cz, and C2 sites were greater than C4, [t's (35) ≥ 3.147, $p \leq .001$]. At the Centro-Parietal region, CP1, CPz, and CP2 had larger P3 amplitude compared to CP4, [t's (35) ≥ 4.483, $p \leq .001$], and CP1 and CPz were larger than CP3, [t's (35) ≥ 4.916, $p \leq .001$]. At the Parietal region, Pz was larger than P3 and P4, [t's (35) ≥ 3.154, $p \leq .01$].

4.5.2. P3 Latency

The omnibus analysis revealed main effects for Congruency, [F (1, 35) = 80.312, $p < .001$, $\eta^2 = .695$], and Region, [F (4, 140) = 16.366, $p < .001$, $\eta^2 = .319$], which were superseded by a Congruency × Region interaction, [F (5, 175) = 3.406, $p < .05$, $\eta^2 = .089$]. Decomposition of this interaction revealed that across all Regions, incongruent trials (M = 407.203, $S.E.$ = 3.891) yielded longer latency compared to congruent trials (M = 374.859, $S.E.$ = 4.528). In addition, a Region × Site interaction was observed, [F (16, 560) = 4.728, $p < .001$, $\eta^2 = .119$]. Follow-up analyses indicated significant Region effects for each of the five different sites, [Fs (4, 140) ≥ 4.218, $p \leq .021$, $\eta^2 \geq .108$]. Paired samples t-tests indicated that at the 3 site, the latency at P3 was shorter than at F3, FC3, C3, [t's (35) ≥ 4.184, $p \leq .01$]. At the 1 site, the latency of P1 was shorter than F1, [t's (35) = 3.622, $p = .001$]. At the 2 site, the latency at P2 was shorter than F2, FC2, C2, and CP2, [t's (35) ≥ 4.363, $p \leq .001$]. At the 4 site, the latency at P4 was shorter than F4, FC4, C4, and CP4, [t's (35) ≥ 5.452, $p \leq .001$]. No effects of Condition were observed for P3 latency.

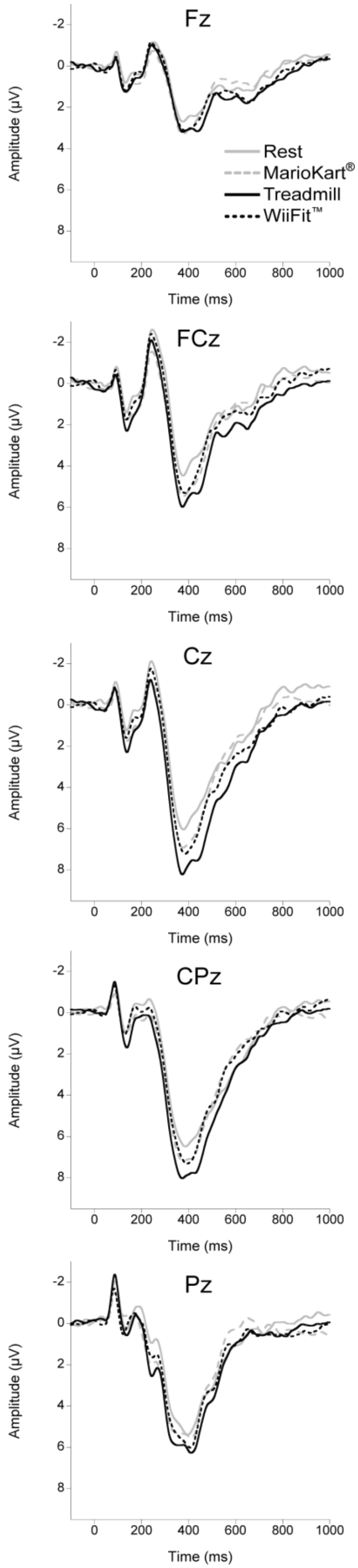

Figure 3. Stimulus-locked grand-averaged waveforms for each condition at midline sites, collapsed across congruency.

CHAPTER 5: DISCUSSION

In the present study, the effects of single bouts of treadmill-based exercise, videogame play, and exergaming on cognition were investigated using neuroelectic and task performance measures. Overall, the current findings revealed that a single, acute bout of light-to-moderate, treadmill-based aerobic exercise facilitated cognitive performance and altered the P3 component during a task requiring cognitive control, while no such changes were observed following a single session of videogame or exergame play. Specifically, individuals exhibited reduced RT interference and larger P3 amplitude following treadmill-based aerobic exercise, whereas no facilitative or debilitative effects of single bouts of videogame or exergame play were revealed. The current findings indicate that single bouts of treadmill-based aerobic exercise may facilitate cognitive control through an increase in the allocation of attentional resources and through a reduction in interference, with no significant changes observed following active or seated videogame play as compared to baseline.

5.1. EXERCISE INTENSITY

The study was designed to hold exercise duration and intensity constant between the two active interventions (i.e., treadmill walking, exergaming). The study protocol was successful in this respect, as HR and RPE did not differ across the two conditions, indicating that the overall intensity of the exercise conditions were approximately 60% of maximal HR. The HR values were similar to those observed in the light intensity condition indicated in previous research on acute exercise and cognition in young adults (Kamijo et al., 2007). Additionally, increased HR and RPE were observed during the seated videogame play (MarioKart®) relative to seated rest, indicating that there was a general increase in arousal during videogame play as compared to resting quietly. Such an effect was expected given the engaging nature of videogaming.

5.2. TASK PERFORMANCE MEASURES

Results of the present study revealed longer RT and reduced response accuracy for incongruent trials compared to congruent trials, replicating the robust flanker effect reported in the literature (Eriksen & Eriksen, 1974; Hillman, Motl, Pontifex, Posthuma, Stubbe, Boomsma et al., 2006; Kramer, Hahn, Coen, Banich, McAuley, Harrison et al., 1999). Similar to previous research on acute aerobic exercise (Davranche et al., 2009; Hillman et al., 2003; Kamijo et al., 2007), no changes in response accuracy were elicited in any experimental condition. However, unlike previous research (Bartlett et al., 2009), no changes in accuracy following videogame play were revealed. Differences may be due to the fact that Bartlett et al. (2009) used a task that was more similar to videogame play compared to the flanker task. That is, the SynWin task was comprised of four separate tasks, which had participants switch between in order to earn a higher score. Therefore, changes in cognition due to single bouts of videogame play may only be elicited in tasks that require task switching. Future research should aim to incorporate this aspect of cognitive control to test this hypothesis, and may wish to include a number of cognitive control tasks to understand the general vs. selective nature of videogame play on cognitive control more broadly.

RT analyses revealed no condition effect, indicating that following videogame play, exergaming, and treadmill-exercise, there were no significant differences in response speed. Unlike previous research (Hillman et al., 2003; Kamijo et al., 2007), which used a flanker task comprised of letters, this study found no changes in RT. However, the present study corroborates previous research that incorporated lower intensity aerobic exercise and similar task settings

(Hillman et al., 2009; Kamijo et al., 2009), indicating that RT may not be altered following treadmill exercise at 60% of maximal heart rate. Orosy-Fildes and Allan (1989) indicated that a single session of videogame play elicited a 50 ms reduction in simple RT. The task completed in the aforementioned study had participants press a button to four different colored lights, similar to a visual discrimination task. The flanker task used in the present study had individuals selectively attend to one stimulus while inhibiting others. Given the modified flanker task used herein, the lack of differences in RT following videogame play may be due to the cognitive task selected, as both tasks tap different aspects of cognitive function. Therefore, it may be that RT in tasks requiring inhibitory control is not sensitive to single bouts of videogame play.

Novel to this report, a single session of treadmill-based aerobic exercise resulted in a reduction in RT interference compared to both rest and seated videogame play, indicating greater control of inhibitory aspect of cognition following participation in aerobic exercise. Specifically, the interference effect examines the cost of conflict produced by the presence of non-relevant stimuli in the perceptual field. As such, the results of this study indicate that a single bout of treadmill-based aerobic exercise may attenuate interference by approximately 10%, suggesting that acute exercise may enhance cognitive control through the management of conflict in the visual environment. Behaviorally, this study indicates that both videogame play and exergaming do not exert a similar influence on cognitive control.

It is interesting to note that there were no significant differences in cognition following a single bout of active videogame play, even though heart rate was similar between the two different exercise manipulations. Hockey (1997) proposed a compensatory control model, accounting for the effects on performance observed during stressful conditions or under high workload. This model proposed two adjoining negative feedback loops, where the lower loop is an automatic control loop, and the upper loop is reserved for effortful control. The lower loop is considered the automatic control, where well learned skills are maintained with little effort. The upper loop manages the regulation of effort during stressful conditions. As applied to the present study, one might consider treadmill walking as an automatic skill, where little effort is needed to perform the task. However, completing the tasks set forth by the Wii Fit™ games may be more difficult due to their changing nature and forcing participants to pay attention to the correct actions. Further, all participants expressed familiarity with a treadmill, while only a minority of the participants had prior experience with the Wii Fit™ games. Although practice was given to the participants (i.e. during the shortened versions on their first session), the second time the games were played, new techniques were required. Additionally, a 10-minute practice session would not allow for performance of the games to become automatic, indicating that there may still be a learning curve. Hockey (1997) suggested that during the effortful control loop, it may be necessary to manage cognitive resources through mobilizing increases in effort to complete the task. Therefore, the potential changes that may have been elicited due to aerobic nature of the Wii Fit™ games may have been negated due to neural taxing caused by the dual-task requirements of exercise and videogame play, leading to no changes in performance on the flanker task.

5.3. P3 AMPLITUDE

The present study indicates that following the cessation of a single bout of treadmill exercise, P3 amplitude is increased relative to seated rest. This result corroborates numerous studies, which have used flanker tasks (Hillman et al., 2003; 2009; Kamijo et al., 2007; 2009) to suggest that acute exercise may serve to increase allocation of attentional resources. One interesting note is the general increase in P3 amplitude that is elicited by a single session of treadmill exercise. As evidenced in recent reports (Hillman et al., 2003; Kamijo et al., 2007; 2009), the general increase in P3 amplitude corroborates previous research in young adults, indicating that a single session of aerobic exercise increased P3 amplitude in both the congruent (or neutral) and the incongruent (or incompatible) conditions (Hillman et al., 2003; Kamijo et al., 2007; 2009). The present study additionally increased the number of sites that were used in the statistical analysis, giving broader knowledge of the overall increase in the topographic pattern of activation of the P3. Recent reports in preadolescent children have indicated that there is a general increase in P3 amplitude at the frontal, fronto-central, central, and parietal sites, and a selective increase at the centro-parietal sties; that is, a larger increase in P3 amplitude following the incongruent trials as compared to the congruent trials was indicated (Hillman et al., 2009). As such, the present study indicates that treadmill-based aerobic exercise at 60% of maximal heart rate increases the P3 amplitude in both the congruent and incongruent stimuli.

Novel to this study is the additions of video gaming and exergaming. To date, there are only a handful of studies which have examined neuroelectric indices of cognition along with videogaming. This is the first study to assess P3 amplitude following a single bout of videogaming and exergaming. The present study indicates that 20 minutes of videogame or exergame play elicit no changes from baseline following a single session of seated or active videogame play with respect to cognitive control. Kronenberger and colleagues (2005) indicated a positive correlation between videogame playing and Stroop interference, while Mathews and colleagues (2005) found that VGPs did not show activation in the anterior cingulate and lateral frontal cortices during incongruent trials in a Stroop task. Additionally, videogame play has been liked to negative influences on proactive cognitive control, evidenced through different ERP components (Bailey et al., 2009). However, training on videogames has been associated with facilitation in cognition, including cognitive control (Basak et al., 2008; Boot et al., 2008; Clark et al., 1987; Dustman et al., 1992; Goldstein et al., 1997). The lack of observed effects following a single bout of videogame play indicate that seated videogame play does not elicit changes in the allocation of attentional resources during a task which comprises of cognitive control. In sum, the present study indicates that P3 amplitude is selectively increased following a single session of treadmill-based aerobic exercise, suggesting an increase in the allocation of attentional resources.

5.4. P3 LATENCY

The present study indicates longer P3 latency following the incongruent trials as compared to the congruent trials. This corroborates previous research (Hillman et al., 2003, Kamijo et al., 2007; 2009), suggesting that participants required more time to classify the incongruent stimuli, relative to congruent stimuli.

The present study did not observe changes in P3 latency following any of the experimental conditions. Previous reports have indicated that P3 latency is reduced following a single session of aerobic exercise (Hillman et al., 2003; Kamijo et al., 2007; 2009). Hillman and colleagues (2003) observed a reduction in latency that was selective to the incongruent trials, suggesting that exercise may only have a facilitative effect on stimulus classification during tasks which are attentionally demanding. Additionally, Kamijo and colleagues (2007) observed similar findings, indicating a selective reduction in P3 latency following incongruent trials. Magnié et al. (2000) indicated that immediately following a session of maximal aerobic exercise, there was a reduction in P3 latency, using an auditory oddball task, and suggested that exercise increased the arousal of the central nervous system eliciting quicker classification. Hillman et al. (2003) and Kamijo et al. (2007) have argued against a general arousal effect, due to the fact that only the incongruent trials exhibited a shorter latency following a single session of exercise, indicating faster classification speed to the more difficult portion of the task. Kamijo and colleagues (2009) indicated that there was a general reduction in both the congruent and incongruent P3 latencies following single bouts of aerobic exercise at two different intensities (i.e., 55% and 75% HR_{Max}). These results were only evidenced in young adults, similar in age to the present study. Additionally, Hillman and colleagues (2009) observed no change in preadolescents' P3 latency following exercise at 65% maximal HR, using a similar flanker task (i.e., arrows). However, the present study incorporated a task design where the stimulus duration was shorter than that used in previous research (Hillman et al., 2003; Kamijo et al., 2007; 2009). This change in task design may account for the lack of findings with respect to P3 latency as the difficulty of the task may not have allowed for modulation of the time course of this component. As such, future work needs to systematically manipulate flanker stimuli and timing to better understand the inconsistent nature of the P3 latency effect. Additionally, the present research employed treadmill-based aerobic exercise, whereas previous research examining changes in P3 latency have utilized cycle ergometry (Kamijo et al., 2007; 2009). Lambourne and Tomporowski (2010) have indicated through meta-regression analysis, that larger effect sizes were evidence following cycling as compared to treadmill-based activities, indicating a greater increase in cognition following cycle ergometry. Therefore, the present findings may provide some support for this notion, suggesting that changes in temporal aspects of information processing may be neutralized by the more effortful process of treadmill-based exercise.

Lastly, P3 latency did not differ as a function of videogame or exergame play. To date, this is the first study which has assessed neuroelectric indices of cognitive control following a single bout of videogame play; as such, little is known about the underlying changes that may occur due to videogame play. As a beginning point, the present study indicates that there are no changes in stimulus classification speed (as indexed via P3 latency) following 20 minutes of videogame play, treadmill-based aerobic exercise or exergaming at 60% maximal heart rate.

5.5. LIMITATIONS

The present study has several limitations. First, a modified flanker task was used to measure cognitive control. Therefore, only one aspect of cognitive control (i.e., interference control) was investigated. Future research should examine other aspects of cognitive control to determine the breadth and variability of the observed effects. A second limitation is that the videogames may not be similar to games used in the videogame literature. Previous research on videogames has examined FPS, strategy, and other action videogames (Boot et al., 2008; Clark et al., 1987; Dustman et al., 1992; Goldstein et al., 1997; Green & Bavelier, 2003). Therefore, it is difficult to generalize the results of this study to other categories of videogames. Lastly, with the numerous conditions and experimental manipulations, the sample size may have been underpowered to detect significant differences for certain dependent measures. Future researchers may wish to employ a larger sample to further elucidate this issue.

5.6. CONCLUSIONS

In conclusion, the effect of seated videogame play, aerobic exergaming, and treadmill-based aerobic exercise on cognitive control was examined. The present findings extend previous research indicating alterations in cognitive control following single bouts of aerobic exercise (Davranche et al., 2009; Hillman et al., 2003; 2009; Kamijo et al., 2007; 2009). The present study observed that a single bout of treadmill-based aerobic activity at 60% of maximal heart rate facilitates cognition by increasing the ability to successfully manage interference and increasing the allocation of attentional resources toward a given stimuli. However, as

Tomprowski and Ellis (1986) indicate, little is known regarding the effects of exercise on cognitive function, with a considerable dearth of knowledge on the duration, type, and intensity of exercise leading to cognitive facilitation. In the present study, results indicated that exergaming, as a form of aerobic exercise, did not successfully influence cognitive control. The lack of significant results may be due to the competition of resources during exergaming, which may have caused cognitive fatigue. Thus, this type of exercise may differ considerably compared to more traditional means of exercise, such as treadmill-based activities, due to its non-repetitive manner. Additionally, even though previous research has made considerable claims that long term use of videogames may cause social and cognitive impairments (Anderson & Bushman, 2001; Kronenberger et al., 2005; Mathewes et al., 2005; Bailey et al., 2009), the present study indicates that a single session of seated videogame play does not enhance or impair cognitive control as compared to baseline.

In sum, single bouts of treadmill-based aerobic exercise may facilitate cognitive control through enhanced interference control and increases in the neural underpinnings supporting the allocation of attentional resources. Such benefits were not derived following a single sessions of exergaming or action videogame play. The present findings provide a strong foundation for further examination of the effects of acute videogames play, exergaming, and aerobic activity on cognitive control.

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APPENDIX A: INFORMED CONSENT

UNIVERSITY OF ILLINOIS
AT URBANA-CHAMPAIGN

Department of Kinesiology & Community Health

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Informed Consent Form

"Acute Exercise, Video Gaming, and Cognitive Control"

Investigator Directing Research: Charles Hillman, Ph.D., University of Illinois at Urbana-Champaign, (217) 244-2663, chhillma@illinois.edu.

You are being invited to participate in a research study about the relationship between acute exercise and cognitive function. This form is designed to provide you with information about the study. If you agree to participate, you will visit the laboratory on four occasions and complete one exercise test, two short exercise bouts, three cognitive tasks while connected to an electroencephalogram (EEG), and several paper and pencil tests that measure demographics and health information. Before you agree, you must provide informed consent indicating that you:

1. Are informed about the procedure.
2. Give your consent voluntarily (i.e., participate because you want to).
3. Know that you can withdraw your consent at any time.
4. Are at least 18 years of age

To make an informed decision, we need to tell you about the nature of the procedure and the potential risks and/or benefits.

<u>Nature of the procedure</u>
As a participant, you will be asked to participate in four laboratory visits. These visits will occur in a random order. You will need to come prepared to exercise on each day; though you will only exercise during three of the four visits. During your first visit, you will complete a questionnaire that measures your intelligence. This questionnaire is administered by an experimenter and will require you to look at pictures or read words and indicate their meaning. In addition, you will be asked to complete a health history and demographics questionnaire, a questionnaire that determines which is your dominant hand, and a questionnaire that determines your readiness to exercise.

During your four visits to the laboratory you will perform different types of exercise followed by a standard cognitive task. During the cognitive task you will be seated in a comfortable chair and your brain's reactions will be recorded through the use of sensors placed on the scalp. The

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experimenter will explain to you where these sensors will be placed before s/he attaches them. The sensors are both painless and harmless. They merely record the electrical signals naturally produced by your brain. The task involves watching a series of symbols that will appear on a computer screen in front of you. You will be asked to press one of two buttons during each trial. If at any time you find any of these procedures uncomfortable, you are free to discontinue your participation without penalty.

Two of the visits will include 20 minutes of exercise at a moderately difficult pace. One exercise session will occur on a treadmill where you will be asked to walk or run. The other exercise visit will ask you to use the Wii Fit Aerobics package. The other two visits will include a 20 minute rest period where you will be seated comfortably in a chair and participation in a non-exercise driving video game. Each of these four visits (i.e., treadmill, Wii Fit Aerobics, seated rest, driving game) will include the cognitive task. On the day of seated rest you will be asked to perform an exercise test at the end of the visit.

For this exercise test, you will be given an orientation to the equipment necessary for aerobic fitness testing (i.e., treadmill, mouthpiece, noseclip). You will participate in a maximal exercise test, which measures your fitness level by having you walk/run on a treadmill at a vigorous pace. You will have a chance to practice on the treadmill prior to testing. This test should not last longer than 10 minutes, and will be supervised by a minimum of two people who are certified in Cardiopulmonary Resuscitation (CPR) and First Aid. If at any time you find any of these procedures uncomfortable, you are free to discontinue your participation without penalty.

Each session will take approximately 90 minutes. You will be paid $10.00/hour (i.e., $15/1.5 hours) for your participation. Should you decide to withdraw participation prior to the completion of the experiment, you will still be compensated for each of the sessions that you completed and for the session that you withdrew rounded up to the nearest half hour.

Potential Risks and Benefits

The benefits of this line of research are to gain further insight into the influence of exercise on the brain. As such, this research will provide a basic understanding of whether exercise has a role in cognitive performance related to attention, memory, and the speed of mental processing.

All procedures, techniques, equipment, and measures to be used in the study are routinely used in educational and research settings involving human subjects. No individual methodological element is new, untested, or of questionable safety for the health and general well being of human subjects. You must understand that as a result of your participation in this study, you may experience some minor skin irritation from the application of the sensors at the scalp recording sites. Although occurring only in rare instances, you may experience a headache from wearing the electrode cap. You will need to wash your hair with warm water to completely remove the electrode gel that is used during EEG testing.

It is necessary to inform you that when individuals who have been sedentary engage in exercise, there is a chance of incurring minor injury and likely some discomfort due to the intensified use of major muscle groups that have not received a great deal of use. However, we do not anticipate that any major injuries will occur. There is also a very slim chance that sudden death or cardiac irregularities can occur while exercising. As noted, this is very rare and the benefits of exercise are known to outweigh the risks. However, at all times you will have two or more staff members trained in CPR and First Aid in attendance.

We have taken all possible steps to ensure that the data collected during this project are kept private. The experimenter will assign you an arbitrary code number, which will be used throughout the experiment. Only this code will be used when analyzing or reporting the experiment. Any identifying information will be kept in a locked location in the Neurocognitive Kinesiology Laboratory and the locked record files of the Principal Investigator.

When you sign this document, you are stating that the experiment has been fully explained to you, and that you understand that the data obtained from this study are to be used for research purposes only, not for the evaluation or diagnosis of any disorder, and that such data will remain confidential, except as required by law. You are also stating that you have had the opportunity to ask questions concerning any and all aspects of the procedures involved, that you are aware that participation is voluntary, and that you may withdraw your consent at any time. Your decision to participate, decline, or withdraw from participation will have no effect on your grades at, status at, or future relations with the University of Illinois. No individual will be identified during the dissemination of any findings stemming from this study.

In the event of physical injury resulting from this research study, immediate medical treatment is available from a number of health care providers in the area. However, the University of Illinois does not provide medical or hospitalization insurance coverage for participants in this research study, nor will the University of Illinois provide compensation for any injury sustained as a result of participation in this research study, except as required by law. If at any time, day or night, you experience adverse physical symptoms, you should immediately contact your personal physician or emergency personnel (i.e., dial 911).

You will be given a copy of this consent form for your records. If at any time, either now or later, you have a question, you are free to ask it, and you may contact the researcher, Dr. Charles Hillman (217-244-2663, chhillma@illinois.edu), who is responsible for this study. If you wish to speak with someone specifically about complaints or concerns regarding *rights as a participant* in this study, you may contact the University of Illinois Institutional Review Board (217) 333-2670 (E-mail: irb@illinois.edu). If you wish, you may contact them by making a collect call.

I, the undersigned, hereby consent to be a participant in the project described above conducted in the Department of Kinesiology and Community Health at the University of Illinois, and certify that I am 18 years of age or older.

Signature of Participant: ______________________ Date: ______________

Signature of experimenter: ____________________ Date: ________________

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APPENDIX B: PAR-Q

Physical Activity Readiness Questionnaire (PAR-Q)

Common sense is your best guide in answering these questions. Please read the questions carefully and answer each one honestly. Check ☐ YES or ☐ NO opposite the question if it applies to you.

YES NO

☐ ☐ 1. Has your doctor ever said you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?

☐ ☐ 2. Do you feel pain in your chest when you do physical activity?

☐ ☐ 3. In the past month, have you had chest pain when you were not doing physical activity?

☐ ☐ 4. Do you lose your balance because of dizziness or do you ever lose consciousness?

☐ ☐ 5. Do you have a bone or joint problem (for example, back, knee, or hip) that could be made worse by a change in your physical activity?

☐ ☐ 6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?

☐ ☐ 7. Do you know of <u>any other reason</u> why you should not do physical activity?

APPENDIX C: HEALTH HISTORY AND DEMOGRAPHICS QUESTIONNAIRE

Health History and Demographics Questionnaire

Please check those items that apply and give date(s) of onset of condition or illness, if known.
Indicate the symptoms that you have experienced by circling **Yes** or **No**.

General Information

Date of Birth: ______________________

Age: ______________________

Dominant hand: Right Left Equal Preference

Are you Color Blind: Yes No

Sex: Male Female

Years of Education (High School = 12; College = 16): ______________________

How much sleep do you regularly get? ______________________

How much sleep did you get last night? ______________________

How many siblings do you have? ______________________

How old are they? ______________________

What is their gender? ______________________

Do you play a musical instrument? YES NO

If so, what instrument? ______________________

How much time do you spend watching television on an average day:

During the week? ______________________Hours

During the weekend? ______________________Hours

How much time do you spend on a computer on an average day:

During the week? ______________________Hours

During the weekend? ______________________Hours

How much time do you spend playing video games on an average day:

During the week? ______________________Hours

During the weekend? ______________________Hours

Sub #: _________

How much time do you spend being physically active on an average day:

During the week? ____________________Hours

During the weekend? ____________________Hours

In what activities/sports do you participate? ____________________

What is the highest level of education obtained by your mother?
a) Did not complete high school
b) High School Graduate
c) Some College
d) Bachelor Degree
e) Advanced Degree

What is the highest level of education obtained by your father?
a) Did not complete high school
b) High School Graduate
c) Some College
d) Bachelor Degree
e) Advanced Degree

What is your approximate household income?
a) <10,000
b) 10,000-20,000
c) 21,000-30,000
d) 31,000-40,000
e) 41,000-50,000
f) 51,000-60,000
g) 61,000-70,000
h) 71,000-80,000
i) 81,000-90,000
j) >90,000

Does your Mother work: Yes No

Does your Father work: Yes No

Do you consider yourself to be Hispanic or Latino: Yes No
A person of Mexican, Puerto Rican, Cuban, South or Central American, or other Spanish culture or origin, regardless of race.

What race do your consider yourself?
a) American Indian or Alaska Native
b) Asian
c) Black or African American
d) Native Hawaiian or other Pacific Islander
e) White or Caucasian
f) Other

Sub #: __________

Cardiovascular Health History		
Do you have any of the following:		
Pain or discomfort in the chest, neck, jaw, arms, or other areas that may be related to poor circulation.	YES	NO
Heartbeats or palpitations that feel more frequent or forceful than usual or feeling that your heart is beating very rapidly.	YES	NO
Unusual dizziness or fainting.	YES	NO
Shortness of breath while lying flat or a sudden difficulty in breathing that wakes you up while you are sleeping.	YES	NO
Shortness of breath at rest or with mild exertion (like walking two blocks).	YES	NO
Ankle swelling unrelated to injury.	YES	NO
Feeling lame or pain in your legs brought on by walking.	YES	NO
A known heart murmur.	YES	NO
Unusual fatigue with usual activities.	YES	NO
Have you ever had a Heart Attack?	YES	NO
General Health History		
Have you been diagnosed with a past or present cardiovascular disease?	YES	NO
Do you have any significant heart rhythm disorders?	YES	NO
Is it a chronic disorder?	YES	NO
Have you been diagnosed with hypertension?	YES	NO
Have you been diagnosed with peripheral vascular disease?	YES	NO
Have you ever been diagnosed with a pulmonary disease such as asthma or emphysema?	YES	NO
Are you epileptic?	YES	NO
Do you have arthritis? If so please explain:	YES	NO
Are you diabetic? If so please explain:	YES	NO

Sub #: __________

Question	YES	NO
Have you been diagnosed with any kind of cancer? If so please explain:	YES	NO
Do you have osteoporosis?	YES	NO
Do you have a hearing loss or wear a hearing aid?	YES	NO
Have you recently been hospitalized? If so please explain:	YES	NO
Have you ever lost consciousness as a result of hitting your head? When did this occur? Where did you hit your head? How long were you unconscious?	YES	NO
Have you ever lost consciousness as a result of any other type of injury or seizure? When did this occur? How long were you unconscious?	YES	NO
Have you ever been diagnosed with Dyslexia?	YES	NO
Have you ever been diagnosed with an attentional disorder?	YES	NO
Do you take Ginkgo Biloba supplements?	YES	NO
When was the last time you took Ginkgo Biloba?		

Medications: Are you presently taking or have taken any of the following medications within the past two months? Please circle your answer.

Asprin, Bufferin, Anacin	Tranquilizers
Blood Pressure pills	Weight reducing pills
Cortisone	Blood thinning pills
Cough Medicine	Dilantin
Digitalis	Allergy Shots
Hormones	Water pills
Insulin or Diabetic pills	Antibiotics
Iron or poor blood medications	Barbiturates
Laxatives	Phenobarbital
Sleeping pills	Thyroid medicine

Other(s):____

Other Habits

How many cups of regular coffee do you have daily?	
How many caffeinated soft drinks do you have daily?	

Sub #: _________

How many cups of tea do you have daily?	
How many cans of beer do you have weekly?	
How many glasses of wine do you have weekly?	
How many ounces of liquor do you have weekly? (1 shot = 2 oz)	
How many cigarettes do you smoke daily?	
How many cigars or pipes do you smoke daily?	
If you are an ex-smoker, how many years since you quit?	
How many years have you been a smoker?	
How often would you rate your stress level as HIGH?	Occasionally Frequently Constantly
What is your current relationship status:	Married Divorced Widowed Engaged Dating Single
How stressful would you rate your relationship?	High Stress Moderate Stress Low Stress
When was the last time you: Had a caffeinated substance?	
Had a tobacco product?	
Had an alcoholic beverage?	
Ate last?	
What did you have to eat?	
Exercised?	
What type of exercise?	
How long did you exercise for?	
How hard did you work out?	Light Moderate Heavy
Taken any stimulants or sedatives? If so please explain:	YES NO
Do you wear glasses?	YES NO
Have you had an eye exam in the last year?	YES NO
What was your visual acuity?	

Sub #: _________

Is there anything else you feel we should know about you or your current/past health?	YES NO

Females only:		
Are you taking any contraceptives?	YES	NO
Do you have a Norplant implant?	YES	NO
Do you receive Depo Provera injections?	YES	NO
Are you pregnant at this time?	YES	NO
Have you given birth recently?	YES	NO
Is your menstrual cycle regular?	YES	NO
What is your normal cycle length in number of days? *(i.e. 24, 27, 30)*		
What was the date of the beginning of your last period?		

APPENDIX D: EDINBURGH HANDEDNESS INVENTORY

Participant ID: ____________

EDINBURGH HANDEDNESS INVENTORY

Please indicate your preferences in the use of hands in the following activities by:

Put "+ +" **in the appropriate column**	If your hand preference is so strong that you would never try to use the other hand unless absolutely forced to.
Put **"+" in the appropriate column**	If you prefer to use one hand over the other.
Put a "+" **in both columns**	If you have no preference.

Some of the activities require both hands. In these cases the part of the task, or object, for which hand preference is wanted is indicated in brackets. Please try to answer all of the questions, and only leave a blank if you have no experience at all of the object or task.

		LEFT	RIGHT
1.	Writing		
2.	Drawing		
3.	Throwing		
4.	Scissors		
5.	Toothbrush		
6.	Knife (without fork)		
7.	Spoon		
8.	Broom (upper hand)		
9.	Striking Match (match)		
10.	Opening Box (lid)		
i.	Which foot do you prefer to kick with?		
ii.	Which eye do you use when using only one?		

APPENDIX E: VIDEOGAME USAGE QUESTIONNAIRE

<u>Video Game Usage Questionnaire</u>

Please circle the response that best answers each question.

1. Over time, have you been spending much more time thinking about playing video games, learning about video-game playing, or planning the next opportunity to play?	*Yes*	*Sometimes*	*No*
2. Do you need to spend more and more time and/or money on video games in order to feel the same amount of excitement?	*Yes*	*Sometimes*	*No*
3. Have you tried to play video games less often or for shorter periods of time, but are unsuccessful?	*Yes*	*Sometimes*	*No*
4. Do you become restless or irritable when attempting to cut down or stop playing video games?	*Yes*	*Sometimes*	*No*
5. Have you played video games as a way of escaping from problems or bad feelings?	*Yes*	*Sometimes*	*No*
6. Have you ever lied to family or friends about how much you play video games?	*Yes*	*Sometimes*	*No*
7. Have you ever stolen a video game from a store or a friend, or have you ever stolen money in order to buy a video game?	*Yes*	*Sometimes*	*No*
8. Do you sometimes skip household chores in order to spend more time playing video games?	*Yes*	*Sometimes*	*No*
9. Do you sometimes skip doing homework in order to spend more time playing video games?	*Yes*	*Sometimes*	*No*
10. Have you ever done poorly on a school assignment or test because you spent too much time playing video games?	*Yes*	*Sometimes*	*No*
11. Have you ever needed friends or family to give you extra money because you spent too much money on video-game equipment, software, or game/Internet fees?	*Yes*	*Sometimes*	*No*

Gentile, D. A. (2009) *Psychological Science, 20*, 594-602.

CURRICULUM VITAE

Kevin C. O'Leary, B. S.

Curriculum Vitae

Updated July 20, 2010

Work Address

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University of Illinois at Urbana-Champaign
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906 South Goodwin Avenue
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Education

2008 – Present	Master's Student in Kinesiology, Emphasis in Exercise Psychology University of Illinois, Urbana-Champaign, IL Anticipated graduation date: August, 2010 Advisor: Charles H. Hillman, Ph.D.
2004 – 2008	Bachelor of Science in Exercise Sport Science, Department of Health and Human Performance Elon University, Elon, NC Graduated Magna Cum Laude

Professional Interests

Research Interests:

My primary research interests lie in the field of neurocognitive kinesiology using neuroelectric measures to assess the relationship between physical activity, physical fitness, brain, and cognition. My current research focus is on both acute and chronic physical activity and its relation to cognitive ability in both adaptation and development across the lifespan of humans spanning from childhood to adulthood.

Teaching Interests:

My main teaching interests lie in the realm of kinesiological psychology and exercise science. Additionally, I am interested in the study of physical activity/sport and how the society portrays such activities.

Professional Experience

Teaching Experience:

2009 – 2010

Social Science of Human Movement (KIN 140)
Head Teaching Assistant
Department of Kinesiology & Community Health
University of Illinois Urbana-Champaign, Urbana, IL

Responsible for coordinating course content for seven laboratory section of an introductory level kinesiology course (150-200 students). Responsible for overseeing all instructional materials and course examination content as well as duties associated with the instruction of laboratory sections. Instructed students on psychological and sociological concepts which related to sport and exercise, evaluation of assignments, and assigning grades for the laboratory sections of the class.

2008 – Present

Social Science of Human Movement (KIN 140)
Teaching Assistant
Department of Kinesiology & Community Health
University of Illinois UrbanaChampaign, Urbana, IL

Responsible for preparing and presenting lecture material, the evaluation of assessments and engaging the class in three discussion sections.

2006 – 2008

Biomechanics
Teaching Assistant
Department of Health and Human Performance
Elon University, Elon, NC

Responsible for improving the work on the Hu-M-aN program, a biomechanical analysis tool, and teaching undergraduate students how to analyze movement of the body in a laboratory setting. Additional *responsibilities include working with students out of class on any lecture material and teaching certain full lectures when needed. This included tutoring sessions with students.*

2006 – 2008

Anatomy

Teaching Assistant – The Elon Anatomy Teaching Assistants Program
Department of Biology
Elon University, Elon, NC

Responsible for implementing proper study techniques in a lecture setting for students requiring extra help. Acted as a tutor and a mentor for students in both the laboratory and lecture setting.

Research Experience:

2008 – Present

Graduate Research Assistant

Neurocognitive Kinesiology Laboratory
Department of Kinesiology & Community Health
University of Illinois, Urbana-Champaign, IL

Responsible for participant recruitment, data collection, reduction, and analysis including the creation of experimental protocols, task design, and equipment preparation for numerous studies that examine the relationship between physical activity/fitness and cognition. Additional responsibilities include implementation of training procedures for neuropsychological, cardiorespiratory, and electroenceplographic testing (Laboratory Director: Charles H. Hillman, Ph.D.)

2006 – 2008

Research Assistant

Exercise Sports Science Laboratory
Elon University, Elon, NC

Responsible for participant recruitment, data collection, reduction, and analysis, including the creation of experimental protocols, database management, equipment preparation on multiple studies that examine the relationship between physical activity/fitness, cognition and affect. (Major Professors: Walter R. Bixby Ph.D. and Eric E. Hall Ph.D.)

Scholarship

Peer-Reviewed Journal Articles (in print or accepted)

1. Pontifex, M. B., Scudder, M. R., Brown, M. L., **O'Leary, K. C.**, Wu, C., Themanson, J. R., & Hillman, C. H. (2010). On the number of trials necessary for stabilization of error-related brain activity across the lifespan. *Psychophysiology, 47*, 767-773.

2. Del Giorno, J. M., Hall, E. E. **O’Leary, K. C.**, Bixby, W. R., & Miller, P. C. (2010). Cognitive function during acute exercise: A test of the transient hypofrontality theory. *Journal of Sport and Exercise Psychology, 32*, 312-323.

3. Kamijo, K., **O’Leary, K. C.**, Pontifex, M. B., Themanson, J. R., & Hillman, C. H. (in press). Aerobic fitness effects on neuroelectric indices of cognitive and motor task preparation. *Psychophysiology.*

Abstracts (in print or accepted)

1. O’Leary, K. C., Scudder, M. R., Brown, M. L., Gilbert, T. R., Flynn, Z. A., Pontifex, M. B., Hillman, C. H. (in press). The effects of single bouts of aerobic exercise, videogame play, and exergaming on attentional control. *Psychophysiology.*

2. Wu, C., Pontifex, M. B., **O’Leary, K. C.**, Scudder, M. R., Raine, L. B., Johnson, C. J., Hillman, C. H. (in press). Aerobic fitness and intra-individual variability in preadolescent children. *Psychophysiology.*

3. Pontifex, M. B., O’Leary, K. C., Johnson, C. J., Scudder, M. S., Raine, L. B., Motl, R. W., Castelli, D. M., Hillman, C. H. (in pres). From ERPs to academics. *Psychophysiology.*

4. Pontifex, M. B., Scudder, M. R., Brown, M., **O’Leary, K. C.**, Wu, C., Themanson, J. R., & Hillman, C. H. (2009). Stabilization of error-related brain activity across the lifespan. *Psychophysiology, 46*, S37.

5. Kamijo, K., **O'Leary, K. C.,** Pontifex, M. B., Themanson, J. R., & Hillman, C. H. (2009). Aerobic fitness improves cognitive task preparation. *Psychophysiology, 46*, S37.

6. **O'Leary, K. C.**, Del Giorno, J. M., Bixby, W. R., Hall, E. E., & Miller, P. C. (2008). The effects of maximal exercise on cognitive performance. 2008 Southeast American College of Sports Science Conference, Birmingham, AL.

7. Del Giorno, J. M., **O'Leary, K. C.**, Hall, E. E., Bixby, W. R., & Miller, P. C. (2008). The influence of exercise intensity on cognitive function during and following submaximal exercise. 2008 Southeast American College of Sports Science Conference, Birmingham, AL.

8. Bixby, W. R., **O'Leary, K. C.**, Del Giorno, J. M., Hall, E. E., & Miller, P. C. (2008). Is cognitive performance altered by maximal exercise? *Medicine & Science in Sports & Exercise. 40*(5), S363-S364.

9. Del Giorno, J. M., Hall, E. E., Bixby, W. R., **O'Leary, K. C.**, & Miller, P. C. (2008). Cognitive function during and following submaximal exercise: Does exercise intensity matter? *Medicine & Science in Sports & Exercise. 40*(5), S363.

10. **O'Leary, K. C.**, Bixby, W.R. (2008). The effects of maximal exercise on cognitive performance. 2008 National Conference of Undergraduate Research, Salisbury, MD.

Posters (not included in Abstracts)

1. Del Giorno, J. M., **O'Leary, K. C.**, Hall, E. E., Bixby, W. R., & Miller, P. C. (2007). Exercise and cognition. Presented at the 2007 Summer Undergraduate Research Experience, Elon, NC.

2. **O'Leary, K. C.**, Bixby, W.R. (2008). The effects of maximal exercise on cognitive performance. Presented at the 2008 Student Undergraduate Research Forum Elon, NC.

Professional Development

Fall 2008 – Present Weekly Seminar for Topics on Brain and Cognition

Honors and Awards

2008 – Present Named to the University of Illinois at Urbana-Champaign "List of Teachers Ranked as Excellent by Their Students

Spring 2007	Phi Kappa Phi Honor Society
Spring 2007	Gamma Sigma Alpha Greek Honor Society
Fall 2005	Phi Eta Sigma Honor Society

Professional Affiliations:

2007 – 2009	American College of Sports Medicine
2006 – 2008	National Athletic Trainers Association
2009 – Present	Society for Psychophysiological Research

Certifications/Licensures:

2008 – Present	American Red Cross First Aid
2008 – 2009	American Red Cross CPR
2009 – Present	American Heart Association for the BLS for Heathcare Providers Program – CPR & AED