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The Effect of Aerobic Fitness on Visuospatial Attention in Young Adults

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by

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ABSTRACT
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The recently popular commercial brain- and visual-training programs have become a multimillion dollar industry with claims to enhance various cognitive functions. Although no empirical evidence directly supports the efficacy of these programs, sport expertise has been shown to influence cognition, lending indirect support for training efficacy. However, researchers investigating attention and sport expertise have not previously controlled for level of physical activity, which may also contribute to enhanced cognitive processes. Prior studies have shown strong correlations exist between physical fitness and cognition in both children and older adults. Yet, few studies have examined this relation in young adults, and no studies have examined the effect of aerobic fitness on cognition while controlling for sport participation and action video game playing habits. The purpose of this study was to determine the extent to which aerobic fitness relates to visuospatial attention performance in young adults while controlling other factors. A secondary purpose was to identify a potential physiological mechanism underlying the relation between exercise and cognition. Heart rate variability has been linked to both aerobic fitness and cognitive performance and was used in this study. Thirty-five healthy adults (ages 18-29) participated. Data collection included submaximal VO_{2max}, BMI, motivation, sport involvement, performance on two visual attention tasks, and heart rate variability. BMI, motivation, and sport involvement did not significantly correlate with aerobic fitness and were excluded from further statistical analyses. Contrary to our hypothesis, performance on the attention tasks did not significantly correlate with aerobic fitness while controlling for sport participation (MOT: r = .120, *p* = .250; CVAT: r = .166, *p* = .174). Heart rate variability also did not significantly correlate with visual attention (SD: r = .064, *p* = .375; LF/HF: r = - .312, *p* = .057). The findings of this study did not support a relation between aerobic fitness and visual attention in young adults. The effect of chronic exercise on cognition may be more apparent in children and older adults who are still cognitively developing or experiencing age-related cognitive declines. To improve visual attention in young adults, more study is required to determine the efficacy of 'brain' training.

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Chapter 1: Introduction

Millions of dollars are invested into commercially available visual training programs which claim to enhance visual and cognitive functions. By doing simple games or exercises, these programs claim to enhance memory, attention, depth perception, concentration, and reaction time. These programs are targeted at athletes looking to gain a competitive edge (www.SportsEyeSite.com accessed on 2/9/12), older adults trying to prevent or reverse cognitive decline (www.PositScience.com accessed on 2/9/12), business men or women (www.Eyegym.com accessed on 2/9/12), school children (www.Eyegym.com accessed on 2/9/12), individuals with attention deficit disorder or other learning disabilities (www.Cogmed.com accessed on 2/9/12), and everyday people who want to improve their basic cognitive skills (www.Luminosity.com accessed on 2/9/12). While substantial anecdotal evidence supports the efficacy of these programs, virtually no empirical evidence confirms the claims purported by these training programs, and yet this market is forecasted to reach $1.5 billion by the year 2015 (Roubein, 2011). However, the literature points to a simpler, less expensive route toward cognitive benefits which athletes, older adults, children, and the general public must consider.

The secret to improved cognitive function may be as simple as getting away from the computer and exercising. Current research shows positive effects of physical activity on cognition in both humans and primates (Rhyu et al., 2010). One potential physiological explanation for this enhancement is increased blood flow to the brain.

Heart rate variability, the variation in time between successive beats, is associated with arterial pressure, respiration, and vasomotion (Malliani, Pagani, Lombardi, & Cerutti, 1991) which facilitate blood flow. Research shows that long-term aerobic training alters autonomic control of the heart. Additionally, lower heart rate variability is associated with greater effort allocation and better performance on several tasks requiring attention (Borger et al., 1999; Egelund, 1982). This relation between attentional performance and long-term aerobic exercise has been examined in several populations.

With a growing elderly population, many researchers are examining the prevention and possible reversal of age-related cognitive declines. Several cross-sectional studies have found that physically active older adults outperform sedentary older adults on tasks of visual attention (Roth, Goode, Clay, & Ball, 2003), working memory (Shay & Roth, 1992), processing speed (Hillman, Kramer, Belopolsky, & Smith, 2004; P. J. Smith et al., 2010), executive control (Colcombe & Kramer, 2003), and memory (Albert et al., 1995). Prospective longitudinal studies have explored the effects of introducing sedentary older adults to exercise interventions. Kramer et al. (1999) randomly assigned 124 previously sedentary older adults to an aerobic group (walking) or anaerobic group (stretching and toning). After six months of exercising, performance on tasks that require executive control improved for the aerobic group but not for the anaerobic group. These findings are consistent with results from a meta-analysis (Colcombe & Kramer, 2003) conducted on 18 intervention studies that showed executive control processes reaping the most benefit from physical activity compared to other processes (e.g., visuospatial and controlled processes).

Another population in which the association between physical exercise and cognition has been studied is children and pre-adolescents. A meta-analysis (Sibley & Etnier, 2003) reviewed 44 studies of physical activity and cognitive performance in eight categories: perceptual skills, IQ, achievement, verbal and math tests, memory, developmental level/academic readiness, and other. The other category consisted of areas such as creativity and concentration. Performance in all cognitive categories, except memory, significantly correlated with physical activity with an overall effect size of 0.32. The analysis also revealed that physical activity is equally beneficial to physically and mentally disabled children as it is to non-disabled children. Sibley and Etnier (2003) also found that the type of physical activity was not a significant moderator variable suggesting any type of physical activity will benefit cognitive performance.

Surprisingly few studies exist on aerobic fitness related to cognition in younger adults, and the findings are equivocal. For example, in an early intervention study by Blomquist and Danner (1987), participants (n=66) between the ages of 18-48 improved on the Posner name access test, which assess selective attention, when their aerobic fitness improved by 15%. However, other studies (Shay & Roth, 1992) found no significant fitness-related differences in performance of high-fit young adults and low-fit young adults on visuospatial, verbal memory, and sensorimotor tasks.

While the literature on older adults and children has provided insight into the effect of chronic exercise on cognition in those respective populations, gaps do exist and potential confounds need to be addressed for younger adults. More studies need to examine the relation between exercise and cognition in the young adult population in order to elucidate whether the enhancing effects of long-term exercise are limited to performance associated with developing cognitive functions (i.e., children and pre-adolescents) and to age-related declines in cognitive abilities (i.e., the older adult population). The discrepancies between existing studies on young adults may be due to several factors including overly simplistic cognitive tasks, or the need for a greater difference in aerobic fitness between high-fit and low-fit groups. In addition, an issue with most studies relating exercise and cognition is a failure to control for factors known to influence cognition such as training on spatially demanding tasks. For example, children and adolescents (ages 7 to 17) who played action video games are more efficient at using spatial cues to enhance processing of a target than their non-action video game playing counterparts (Dye, Green, & Bavelier, 2009), yet numerous studies examining cognitive and academic performance in children and adolescents do not control for video game playing habits.

In addition to not controlling for video game playing, the type of physical activity (i.e., open skill or closed skill. See definitions below for descriptions of open skill and closed skill sports) and level of expertise in that activity are also generally not controlled. Based on results from a study by Giglia et al. (2011), open skill sport athletes (i.e., national and regional level volleyball players) demonstrated more symmetrical allocation of visuospatial attention compared to closed skill athletes (i.e., national level rowers) and sedentary controls when performing a line bisection judgment task.

Therefore, the differences observed between active and inactive older adults may be explained by differences in type of physical activity and/or level of expertise in that particular activity.

Conversely, research regarding the relation between sport expertise and perceptual and cognitive functions in expert and novice athletes oftentimes do not control for aerobic fitness level. Studies on sport expertise have shown that compared to novices and non-athletes, expert athletes are faster and more accurate at recognizing and recalling patterns of play (Abernethy, 1986), more effective with visual search strategies (Williams & Davids, 1998), selectively attend to different information in the environment (Adolphe, Vickers, & Laplante, 1997), have shorter reaction times (Zwierko, 2007), are faster to shift attention (Castiello & Umilta, 1992), and are more accurate at anticipating events given a particular set of circumstances (Hagemann, Strauss, & Cañal-Bruland, 2006). This expert advantage has been demonstrated in several open skill sports including volleyball (Adolphe et al., 1997; Anzeneder & Bosel, 1998; Castiello & Umilta, 1992), squash (Abernethy, 1990), tennis (Farrow & Abernethy, 2002; Scott, Scott, & Howe, 1998; Williams, Ward, Knowles, & Smeeton, 2002), badminton (Abernethy & Russell, 1987), and handball (Zwierko, 2007). The question that remains, however, is the extent to which these advantages are due to sport expertise or simply the higher level of aerobic fitness.

Existing research examining visual and cognitive enhancement through sport expertise has not controlled for aerobic fitness level. There are glaring gaps in the sport expertise research largely in part due to the assumptions made that either aerobic fitness does not influence cognitive functions or that expert athletes and novices have the equivalent aerobic fitness levels. Conversely, the work investigating the relation between exercise and cognition has been primarily performed with participants at risk for age-related declines in cognitive functions (i.e., the older adult population) or with participants who are currently in a stage of developing cognitive functions (i.e., children and pre-adolescents). Additionally, these studies have not controlled for factors such as video game playing or sport expertise, which have been found to influence cognitive and perceptual functions.

Statement of Purpose

The purpose of this study was to fill an important gap in the literature by determining the extent to which aerobic fitness level in young adults relates to visuospatial attention. The body of research addressing physical activity and cognition has primarily focused on older adults and on school-age children. More research needs to be done regarding this relationship in younger adults to elucidate whether this enhancement persists in this age group. Additionally, the results will inform researchers in the area of sport expertise. To address this objective, performance accuracy on two visuospatial attention tasks was compared to VO_{2max} percentile while controlling for action video game playing and open-skill sport participation.

Hypotheses

Primary research hypothesis. Accuracy on the two tests of visuospatial attention will be positively correlated with aerobic fitness such that participants in higher VO_{2max} percentiles will outperform participants in the lower percentiles on the two visuospatial attention tasks.

Secondary research hypothesis. Participants with low heart rate variability during the Covert Visuospatial Attention Task will outperform (i.e., have a greater percentage of correct responses) the participants with high heart rate variability.

Delimitations

Results from this study may only be generalized to individuals or populations similar to the sample used in the study. Specifically, the results may be applicable to healthy adults between the ages of 18-29 years. The results may not be directly applied to individuals who play action video games for more than four hours a week or who have a neurological or psychological disorder.

Limitations

The limitations of this study include:

- The present research design cannot determine a causal linkage between aerobic fitness and visuospatial attention.
- Self-selection cannot be excluded as a possible confound. Individuals with innately superior visuospatial attention skills may prefer closed-skill sport

participation. Individuals with lesser visuospatial skills may avoid physical exercise.

- A sub-maximal physical fitness test was used to predict VO_{2max} instead of a maximal fitness test.
- Participants may have engaged in open skill activities in their youth.
- Visuospatial 'training effect' may occur with cell phone or portable device usage.

Assumptions

The assumptions made in conducting this study are:

- Participants responded truthfully on all questionnaires.
- The Covert Visuospatial Attention Task and Multiple Object Tracking Task assessed identified components of visuospatial attention.
- Participants performed as accurately as possible on the visual attention tasks.
- The YMCA bike test is an accurate assessment of aerobic fitness.

Significance

To date, no studies regarding aerobic fitness and cognition have controlled for potential enhancement due to action video game playing or open-skill sport participation. The results of this study partially support an alternative explanation for the cognitive and attentional differences between experts and novices. Future studies should begin to examine a causal linkage and possible transfer to daily tasks that require visuospatial attention (e.g., driving).

Definition of terms

Action video games. Action video games are characterized by a fast-paced environment, quick decision-making, spatial and temporal unpredictability, peripheral processing, and the tracking of multiple objects and action plans that need to be accurately executed (Green, Li, & Bavelier, 2009).

Aerobic fitness. Aerobic fitness, sometimes referred to as cardiorespiratory fitness, can be defined as the ability to absorb, transport, and use oxygen (ACSM, 1998). Aerobic fitness is measured using oxygen consumption (VO_2), blood pressure, and heart rate.

Closed skill sport. The environment is static with little or no uncertainty. The skill is the movement. Attention is internal, monitoring how closely the movement matches the ideal movement. Examples include cycling, track and field, and swimming.

Covert visual attention. Covert attention is defined as the selection of visual information at a cued location independent of eye position (Carrasco & McElree, 2001).

Open skill sport. Athletes are required to respond to sensory stimuli in a dynamically changing environment (Cox, 2002). Open skill activities are characterized by temporal and spatial uncertainty. The movement and goal of the activity are not synonymous; the movement is a means to an end. Attention is external, monitoring the position of the opponent and strategizing (Allard & Burnett, 1985). Examples include team sports, racquet sports, martial sports, and billiards.

Visuospatial attention. Visuospatial attention can be defined as focusing one's resources on a specified spatial location within the visual field (Allard & Burnett, 1985).

Chapter 2: Review of Literature

Introduction

Many commercially available brain- and visual-training programs claim to enhance visual attention among other cognitive functions. Despite their overwhelming anecdotal support, there is virtually no scientific evidence validating the efficacy of these programs. The literature regarding the effects of physical exercise on cognition and the relation between sport expertise and visuospatial skills suggests a different avenue, through aerobic exercise, that may contribute to enhanced visual attention. A positive relationship between aerobic fitness and cognition has been observed in the older adult population and in school-age children. Conversely, sport expertise in open skill sports and action video game playing are associated with enhanced cognitive and perceptual functions. Further exploration into the effects of aerobic fitness on visual attention in the young adult population, along with consideration of potential confounds (i.e., open skill activities and video game playing), may provide insight into the influence of aerobic fitness on cognition. The following review of the literature will address visual attention, visual attention and sport expertise, exercise and cognition in older adults, children, and young adults, possible physiological mechanisms underlying these cognitive benefits, exercise related to heart rate variability, and the effect of video game playing on visual attention.

Visual Attention

Why is attention important? Attention shapes and creates our experience of reality. We attend to our highest priority at that moment. If our priority changes, attention shifts accordingly. Every action, whether it be conversing, working, driving, or studying, requires attention for successful performance. Attention can be simply defined as focusing or concentrating on a relevant aspect of the environment while simultaneously ignoring irrelevant stimuli. Visual attention consists of two neural systems. One system is controlled by cognitive (top-down) factors such as previous experiences, knowledge, goals or expectations. The other system is involuntary and controlled by sensory stimulation (bottom-up) without input from higher cognitive areas.

In top-down processing, information flows from higher cognitive centers, such as prefrontal cortex and follows a dorsal pathway through the posterior parietal cortex to primary visual cortex. Top-down processing involves voluntarily directing attention towards currently relevant stimuli amongst distracters, and biasing the individual toward probable locations in which stimuli may appear (Kastner & Ungerleider, 2000). An example of top-down attention is searching for Waldo in a chaotic and distracting scene. Top-down attentional control may or may not be accompanied by eye movements. Any task during which attention is directed or shifted based on instructions or goals of the paradigm uses top-down, voluntary control.

In stimulus-driven or bottom-up processing, information flows from sensory input through perceptual analysis and to motor output (Corbetta & Shulman, 2002) and involves attentional functions driven by stimulus characteristics or sensory context (Treisman & Gelade, 1980). The cortical pathway for stimulus-driven attention is through temporoparietal and ventral frontal cortex primarily in the right hemisphere (Corbetta & Shulman, 2002). An example of bottom-up attention is hearing a telephone ring or alarm clock. Attention is immediately directed to the source of the sound and the previously engaged task is abandoned or temporarily suspended. A famous paradigm that utilizes stimulus-driven attentional control is the inattentional blindness task. The inattentional blindness phenomenon states that sometimes observers fail to notice an unexpected object (e.g., a man dressed as a gorilla) when attending to a different process or target (e.g., counting passes during a basketball game) even if that object is directly in front of them (Memmert, 2009).

A common metaphor that attempts to explain how both top-down and bottom-up attention functions is that of attentional resources. Attentional resources are a limited supply of attention reserves that can be divided among multiple processing tasks as long as that limit is not exceeded (Kahneman, 1973). Allocation of attention is controlled by the individual to process relevant information (McDowd, 2007). Information not attended to is not processed. If processing of multiple streams of information requires more attentional resources than are available, one of two outcomes will occur: Either performance will decline or information will be prioritized and processed sequentially (McDowd, 2007). The amount of attentional resources available to an individual varies per person and is influenced by several factors including age, health, stress (Hellawell & Brewin, 2002), anxiety and fatigue (Zohar, Tzischinsky, Epstein, & Lavie, 2005).

Visual attention can be divided into four sub-processes: selective attention, divided attention, shifting/switching attention, and sustained attention. Depending on the task context, one or more sub-processes may be required for successful task performance. While there are other sub-processes of visual attention, the present study focused on these four facets because they are used in everyday tasks such as driving, conversing, and multi-tasking.

Selective attention involves directing attention to one particular target or task and ignoring or not processing other sources of information in the environment (Coull, 1998). For example, doing homework in a noisy coffee shop requires one to selectively attend to the homework and ignore the surrounding conversations and din. Failure to selectively attend causes distraction and could potentially be extremely dangerous (e.g., while driving) (McDowd, 2007). In sport studies, selective attention is often assessed by examining visual search strategies. The number and duration of saccades and fixations of a visual display are analyzed. Spatial or event occlusion is another technique used in sport (sometimes used in combination with temporal occlusion). A video of a movement (e.g., a tennis serve) is shown with various regions of the display occluded (e.g., occluded serving wrist or occluded hips of server). However, these techniques rely on eye movements, which do not necessarily correspond to attention. Successful performance of the attention tasks proposed in the present study depends on the participant's ability to selectively attend to peripheral objects and locations in the absence of eye movements.

Divided attention, another facet of attention, entails processing more than one source of information or performing multiple tasks at a given time. For instance, one might cook a meal while singing or knit while watching television. If an analogy of selective attention is to shine a spotlight on a target of interest, divided attention would be to split the spotlight to shine it on multiple locations. This is an important component of attention because many settings in life require effective divided attention between multiple tasks. Generally, humans can easily perform two tasks simultaneously without negatively affecting performance relative to each task performed separately (McDowd, 2007). The complexity, difficulty, and modality of the tasks may cause performance to suffer on one or both tasks. Traditionally, the multiple object tracking (MOT) task (Pylyshyn & Storm, 1988) is used to assess attentional capacity; however, in order to successfully perform the task, attention must be divided amongst multiple target objects. Abundant evidence suggests that participants are able to simultaneously track 4 to 5 objects (Pylyshyn et al., 1994; Pylyshyn, 2001). Studies have demonstrated that attention is divided, much like a split spotlight, amongst these 4 to 5 target objects (Sears & Pylyshyn, 2000). The MOT task will be used in this experiment to specifically assess participants' ability to divide attention.

Shifting or switching attention, another attribute of attentional processes, is the process of redirecting the focus of attention to other objects or aspects of the environment (Posner, 1980), because attentional resources are limited. Shifting attention may be advantageous when attending to multiple tasks becomes impossible, either due to insufficient resources or overlapping resources. However, shifting attention between tasks or sources of information has memory demands. When one switches from one task to another, the individual must remember the status and task requirements of the first task in order to efficiently resume after attention is switched back to the first task (McDowd, 2007). For example, when a phone call interrupts an individual writing a paper, the individual must shift attention back to the paper and recall the ideas and train of thought once the call has ended. These additional memory demands often result in a greater error tendency and slower performance following the additional shift (McDowd, 2007). The Covert Visuospatial Attention Task (CVAT) proposed in this study requires the shifting of attention from a central cue to a peripheral location, yet memory demands are minimized because the target peripheral letter streams remain in the same location for the duration of the task. This paradigm allows changes in performance to be attributed to differences in attention without the possible confound of memory deficits.

The ability to sustain one's attentional focus for a prolonged period of time is an additional component of attention. Standardized tests are an example of a type of task that requires sustained attention. A great deal of effort and control are necessary to avoid distracting thoughts or environmental events and to focus on the present task. As time progresses on a given task, the difficulty of sustaining attention increases and efficiency decreases (McDowd, 2007). This effect is called the vigilance decrement (Oken, Salinsky, & Elsas, 2006). Efficiency of sustained attention is also affected by stress, fatigue, frequency of target presentation, and predictability of target location (McDowd, 2007). Both of the attention tasks used in this study require a degree of sustained attention. The CVAT requires sustained attention to continuously changing letter streams for three minute periods. The MOT requires sustained attention divided amongst four objects for periods of seven seconds.

Visual Attention and Sport Expertise

Research on expert and novice athletes has shown that sports expertise is associated with enhanced visual attention. Uncovering the essential attributes which distinguish expert athletes from novices is valuable because it provides a strong basis for determining the practices that most likely promote the development of expertise (Williams & Davids, 1998). Research in this area is rather extensive yet focuses entirely on athletes involved in open skill sports.

Sport expertise and visuospatial attention. The ability to selectively attend to specific visual information in a display to anticipate or predict a future event is often considered one of the most important perceptual skills in motor performance (Williams, et al., 2002). For example, in sport, the ability to use postural cues to predict an opponent's intended movement is an invaluable performance advantage (Singer et al., 1994). For this reason, a great deal of the expertise literature is dedicated to examining differences in selective attention and anticipation skills between experts and novices.

Sport expertise studies have shown that expert athletes outperform novices and non-athletes on visuospatial attention tasks. Differences in visual search strategy between expert and novice soccer players have been investigated by Williams et al. (1998; 1994). Participants viewed two test films with 13 soccer action sequences. During each trial, participants followed the play buildup and verbally anticipated which player would receive the final pass. Novice soccer players tended to fixate on the ball and the player passing the ball. Expert soccer players predominantly fixated on more peripheral aspects of the play such as positions and movements of other players. An awareness of peripheral players and movements most likely contributed to the superior anticipatory performance exhibited by expert players. In this same study, differences in search rate were also observed. Expert players had more fixations of shorter duration compared to their novice counterparts. Other studies have found that expert soccer players exhibit fewer fixations of longer duration (Helson & Pauwels, 1993). Expert athletes also have different strategies for selectively attending to visual cues seemingly advantageous for anticipation. Compared to novices, experts attend to information earlier in the stages of an opponent's movement (Farrow & Abernethy, 2002), thus granting more time to process the information and plan a response. Additionally, expert athletes have demonstrated the ability to use advance visual cues in volleyball (Adolphe, 1997), squash (Abernethy, 1990), tennis (Farrow & Abernethy, 2002; Scott, et al., 1998;

Williams, et al., 2002), badminton (Abernethy & Russell, 1987), and soccer (Williams, et al., 1994).

Two approaches are commonly used to study visuospatial attention among expert and novice athletes. The information processing paradigm states that how people move their eyes (saccades) and how long they look (fixation activity, duration and location) can be used to model visual information acquisition (Hagemann, et al., 2006). The basic assumption of this approach is that eye movement patterns reflect the underlying perceptual strategies (Abernethy, 1988). An issue with this eye tracking approach is that knowledge of all perceived stimuli cannot be guaranteed. Attention has been dissociated from gaze such that fixation may be centrally located, but attention is oriented peripherally (Posner, 1980). This separation of focus of attention and gaze fixation location is referred to as covert attention. Therefore, attentional differences in anticipation related to sport expertise cannot be inferred from eye tracking data alone. The other common approach used to study selective attention is the spatial or event occlusion technique, which is often used in conjunction with the temporal occlusion paradigm (Hagemann, et al., 2006). Specific information sources (e.g., the kicking leg of a soccer player) are occluded during a video sequence in order to identify the most informative visual cues. The occlusion of an important information source will lead to degradation in performance compared to control conditions (Hagemann, et al., 2006).

The issue with the techniques currently used to assess visuospatial attention in sport is that not all components of visual attention are measured. While the spatial occlusion approach assesses selective attention, it does not provide insight into the divided, shifted, or sustained processes of attention. Additionally, the analysis of saccades and fixations may provide information about where and how often a participant is shifting his or her gaze, but this does not necessarily correspond to shifts in attention. For example, a basketball player may be gazing at his offensive opponent but covertly attending to the point guard whose pass he is trying to intercept.

The combination of the Covert Visuospatial Attention Task (CVAT) and the Multiple Object Tracking (MOT) task has advantages over the commonly used techniques for assessing the components of visuospatial attention. The CVAT requires participants to *selectively attend* to a central letter stream while ignoring peripheral letter streams. Once a cue letter is perceived, attention *shifts* to a peripheral location. Attention must be *sustained* for 18 trials, approximately 3 minutes. During the MOT task, participants must attentionally *select* the targets amongst the four identical and randomly moving objects and *divide* attention amongst 4 objects. Attention must be *sustained* during the 55 trials (7 seconds each) of the MOT task. An advantage that both the CVAT and MOT have over traditional techniques is that participants must covertly attend to peripheral targets while maintaining central fixation. This ensures that results were due to attentional performance rather than eye movements.

Sport expertise and other critical components of visuospatial attention. Expert athletes practicing different sports exhibit greater flexibility in attentional shifting and orienting attention to cued areas (Castiello & Umilta, 1992; Enns & Richards, 1997;

Nougier, Ripoll, & Stein, 1989; Nougier & Rossi, 1999; Nougier, Stein, & Bonnel, 1991). The majority of these studies use Posner's paradigm (1980) or a modified version. In the basic paradigm, a central cue is presented at fixation that serves to orient the participants' attention towards the probable stimulus location. In 80% of the trials, the stimulus appears in the cued location (valid condition). In 20% of the trials, the stimulus appears in the uncued location (invalid conditions). Reaction time and accuracy are recorded as participants respond to the stimulus. Posner's paradigm is used in many studies to assess voluntary, covert attentional shifts. There is an issue with the invalid condition of this paradigm; it cannot be determined whether attention shifts because the features of the stimulus are consistent with the participant's goals (voluntary) or because a salient stimulus captures attention (involuntary, stimulus-driven). Stimulus-driven or bottom-up attentional control and voluntary attention are modulated by separate mechanisms. The current design of Posner's paradigm does not dissociate voluntary and involuntary attentional shifts and therefore is not the most appropriate measure of voluntary covert attentional shifts. An alternative paradigm for testing attentional shifting is the CVAT. During this task, the participant voluntarily shifts his or her attention to a peripheral location based on the cue letter shown in the central letter stream. No salient stimuli capture attention during this task, and the participant must actively attend to the letter streams to perceive a cue letter.

In addition to expert athletes' abilities to shift attention, they are also frequently required to divide their attention to successfully perform in dual-task situations. To examine the relation of sport expertise and divided attention, Smith and Chamberlin

(1992) conducted a study in which soccer players dribbled through cones while performing a secondary visual-monitoring task. The addition of the secondary task disrupted the dribbling of novice players (compared to dribbling in isolation) but did not affect the expert players' dribbling. A potential confounding factor of this study is the modality of the secondary task. Beginning soccer players require more visual feedback regarding their movements to manipulate the ball while dribbling, thus a secondary task in the visual modality would use overlapping attentional resources. The experienced players have more automated control over their dribbling, relying less on visual feedback, and therefore their performance would suffer less. Beilock, Carr, MacMahon, and Starkes (2002) controlled for this by using an auditory-based secondary task. Compared to novices, expert soccer players dribbled significantly faster through cones during the dual-task condition. Another paradigm for testing divided attention is the MOT task. Unlike the dual-task situations, participants only perform one task. Yet, during this task, attention is divided amongst several target objects while identical distracter objects are ignored.

Sustained attention is the process of maintaining focus on a target or spatial location for an extended period of time (Coull, 1998). Many sports require a certain extent of sustained attention for successful performance. Wrestlers in particular must be exceptional at sustaining attention. For several consecutive minutes, they must effectively attend to the opponent's position and movements to anticipate upcoming attacks and to guide counterattacks. While this temporal process of attention is vital to sport performance, little research exists regarding sport expertise and sustained attention (Memmert, 2009). Sustained attention could be tested by assessing performance on a task, such as the CVAT, which requires the participant to maintain attention while continuously searching for cue letters in a letter stream.

In sum, expert athletes have advanced visuospatial attention skills. Compared to novices, experts appear to selectively attend to more meaningful information sources that facilitate quick and accurate anticipation and decision-making (Farrow & Abernethy, 2002; Williams & Davids, 1998; Williams, et al., 1994), demonstrate more efficient visual search strategies (Williams & Davids, 1998; Williams, et al., 1994), effectively orient and shift attention (Castiello & Umilta, 1992; Enns & Richards, 1997; Nougier, et al., 1989; Nougier & Rossi, 1999; Nougier, et al., 1991), and effectively divide attention in dual-task situations (Beilock et al., 2002). Additionally, elite athletes successfully attend to and draw information from earlier cues than novices (Singer et al., 1994). This superiority seen in experts is assumed to be the product of a greater task-based knowledge developed over years of sport-specific practice and instruction coupled with more effective visual search behaviors (Williams et al., 2002).

However, the vast majority of sport expertise studies have not measured the athletes' level of fitness. Physical condition cannot be excluded as a possible confounding factor for the observed differences in performance on visual attention tasks. Additionally, these studies have examined athletes in open skill sports (e.g., volleyball, soccer, basketball) who capitalize on exceptional spatial skills. A study must be conducted to determine if physical fitness alone is related to performance on visuospatial attention task while controlling for open skill sport experience.

Health Benefits of Physical Activity

The known benefits of physical exercise are extensive. In addition to boosting energy and improving mood, regular exercise reduces the risk of several conditions and diseases such as diabetes, cancer, hypertension, cardiovascular disease, obesity, depression, neurodegenerative diseases, and osteoporosis (Warburton, Nicol, & Bredin, 2006). Recent research strongly suggests a relation between physical activity and cognitive improvements, at least in certain populations, as well.

Cognitive benefits in older adults. Numerous studies have investigated the effect of physical activity on age-related cognitive declines associated with older adults. These studies show that regular participation in physical activity is related to faster reaction time (Clarksonsmith & Hartley, 1990; Hillman, Kramer et al., 2004), working memory and reasoning (Clarksonsmith & Hartley, 1990; Kramer et al., 1999; Shay & Roth, 1992; Weuve et al., 2004), attention and concentration (Roth et al., 2003; Shay & Roth, 1992), decision-making processes (Hillman, Weiss, Hagberg, & Hatfield, 2002), and visuospatial functioning (Shay & Roth, 1992). Deficits in these areas, which negatively affect quality of life, do not seem to be evenly distributed (Hillman, Belopolsky, Snook, Kramer, & McAuley, 2004). Visuospatial skills (Shay & Roth, 1992) and executive control functions (e.g., inhibition, planning, working memory, complex discrimination) (Hillman, Belopolsky et al., 2004; Kramer et al., 1999) are more susceptible to age-related declines than more automatic cognitive processes (e.g., verbal skills).

Specific exercise or physical activity characteristics were examined to determine what types of activity and what intensity are required to see fitness-related changes or differences in cognition. A meta-analysis of 18 articles (197 effect sizes) showed that older adults who participated in aerobic training in combination with strength training displayed greater performance improvement on cognitive tasks than older adults who only trained aerobically (Colcombe & Kramer, 2003). Conversely, another study found that older adults who participated in aerobic training programs had greater improvement on executive control tasks as compared to those who participated in anaerobic training (Kramer et al., 1999). Brief exercise training programs (1-3 months) were as effective as moderate duration programs (4-6 months), but not as effective as long-term training programs (6+ months) (Colcombe & Kramer, 2003). Additionally, short bouts of exercise (<30 min) did not significantly influence cognitive function (Colcombe & Kramer, 2003). In a longitudinal study of older women, participants who walked a minimum of 4.3 hours a week had significantly better cognitive performance (Weuve et al., 2004). These findings suggest that an exercise-related cognitive enhancement will be more apparent in individuals who have been physically active for more than six months than in individuals who do not exercise on a regular basis or at all.

A major issue with many cross-sectional studies on fitness of older adults, and fitness studies in general, is that self-reported physical activity surveys or questionnaires are used as a sole determinant of fitness level. While these questionnaires can be used to initially screen for potential participants, actual physiological or performance measures of aerobic fitness must be incorporated in order to verify differences between active and inactive participants and to accurately assess whether fitness changes have occurred in intervention studies (Shay & Roth, 1992). In a study by Shay and Roth (1992), both an initial physical activity telephone screening and an actual fitness assessment (submaximal bicycle ergometer test) helped classify participants in either a high-fit or low-fit group. Although several studies relied on self-reports of activity level as the fitness measure (Clarksonsmith & Hartley, 1990; Hillman, Belopolsky et al., 2004; Roth et al., 2003; Weuve et al., 2004), Shay and Roth (1992) found discrepancies between self-reports and fitness tests for 28.6% of participants. The proposed study will therefore use a physical fitness test, rather than self-reported physical activity, to divide participants into high-fit and low-fit groups.

Cognitive benefits in children and pre-adolescents. Due to the evident rise in obesity in children and cuts to physical education classes in schools, several recent studies have examined the impact of physical activity on children's academic achievement. Hillman, Castelli, and Buck (2005) studied the neuroelectric response of high-fit and low-fit preadolescent children while doing a visual discrimination task. Specifically, the P3 which is an endogenous component of event-related brain potentials was measured to determine its sensitivity to fitness-related differences in cognition. The P3 occurs when the participant attends to or discriminates between stimuli usually 300-800ms after stimulus onset (Polich, Ladish, & Burns, 1990). Findings revealed high-fit children had greater P3 amplitudes when compared to low-fit children, indicating a greater allocation of attention and working memory resources devoted to the stimulus. High-fit children also had faster P3 latency, which suggests faster cognitive processing. These findings were consistent with similar studies conducted with older and younger adults (Hillman, Belopolsky et al., 2004). Some may argue that time devoted to physical activity is time taken from academics. A study by Dwyer, Coonan, Leitch, Hetzel, and Baghurst (1983) found that this was not the case. Academic performance did not suffer despite reduced time spent in academic subject areas (e.g., math, science, reading) in exchange for time at recess or physical education class. In school-age children, increased physical activity was related to performance on perceptual skills, verbal tests, intelligent quotient, math tests, academic achievement, memory, and developmental level (Sibley & Etnier, 2003).

Cortical changes associated with improved cognitive function due to fitness have been demonstrated. A recent fMRI study provides evidence for an association between aerobic fitness and brain structure and function in preadolescent children (Chaddock et al., 2010). The study was conducted in an effort to elucidate the neurocognitive benefits of regular physical exercise. Magnetic resonance imaging revealed that high-fit children had greater bilateral hippocampal volume and greater performance accuracy on a relational memory task than low-fit children. Relational memory involves forming associations, such as remembering not only which uniform to wear, but where it was last seen. The results of this study are consistent with previous research showing that aerobically fit older adults have larger hippocampal volumes than less aerobically fit older adults (Erickson et al., 2009). Although MR imaging is not a focus of the present study, this research is important because it suggests that structural changes in the brain may accompany the functional changes observed in aerobically fit individuals.

Cognitive benefits in young adults. Few studies have examined the relationship between aerobic fitness level and cognition in young adults, and those that have report mixed results. For example, a study by Stroth, Hille, Spitzer, and Reinhardt (2009) found that participants who aerobically trained for six weeks improved on tasks of visuospatial memory compared to controls. However, Shay & Roth (1992) designed a study using three age groups: young (n=32, 18-28 years old), middle (n=35, 35-45 years old), and older (n=38, 60-73 years old). Each group was further divided into high-fit and low-fit based on self-reported physical activity level and submaximal fitness testing. Participants performed a battery of cognitive tests. No fitness related differences were observed for the middle and young age groups. Additionally, a meta-analysis (Etnier, Nowell, Landers, & Sibley, 2006) examining the relationship between aerobic fitness and cognitive performance found that young adults generally failed to show exercise-related enhancement on tasks which older adults were specifically susceptible to exercise-related improvements. This discrepancy may be due to a lack of age-related decline in young adults or to the usage of overly simplistic cognitive tasks (Salthouse & Hasker, 2006).

Few studies on young adults have found exercise-related improvements on certain cognitive functions, but not others. For example, in a study conducted by Stroth et al. (2009), twenty-eight students between the age 17 and 29 years old were either placed in a control group or the intervention (running) group. The intervention group engaged in endurance running at an intensity based on lactate threshold for 30 minutes three times a week. After six weeks of training, the running group demonstrated an enhanced positive affect as well as improved visuospatial memory. However, the intervention did not facilitate selective attention as measured by the d2 Test of Attention (Brickenkamp, 2002). The d2 Test is a timed cancellation task that assesses processing speed, rule compliance, and accuracy. The participant is given a sheet of paper with fourteen lines containing the letters “d” and “p” (47 characters per line). Each letter has one, two, three, or four dashes located above or below the letter. In fifteen seconds, the participant must scan each line and mark each “d” that has two accompanying dashes. The absence of an effect may be explained by the controlled-processing hypothesis (Chodzko-Zajko, Schuler, Heinl, & Ellis, 1992) which states that tasks which require controlled, effortful processing are likely to be more sensitive to aerobic fitness differences than tasks that use more automated processing. Therefore, the visuospatial attention tasks utilized in the proposed study will be complicated and demand conscious effort from the participants.

Possible physiological mechanisms underlying cognitive benefits. Although the mechanisms underlying the relationship between aerobic exercise and cognitive function are not clearly understood, currently four hypotheses based on animal and human data explain how aerobic exercise may affect cognition. The enhanced cognitive function associated with physical exercise may be mediated by cerebral blood flow, brain neurotransmitters, neurogenesis, and/or regulation of neurotrophins.

The first hypothesis states that increased cerebral blood flow and angiogenesis (Kleim, Cooper, & VandenBerg, 2002) are the primary mechanism. Studies have shown that moderate to high intensity exercise results in large increases in cerebral blood flow (Jorgensen, Perko, & Secher, 1992). The increased blood flow allows for an increased supply of nutrients such as glucose and oxygen, which are crucial for cognitive functions (Chodzko-Zajko, 1991). For example, walking increased the rate of oxygen consumption in healthy older adults, which was associated with faster reaction time and enhanced performance on executive control processes (Kramer et al., 1999). Additionally, Rogers, Meyer and Mortel (1990) found that retirees with an active lifestyle displayed enhanced brain vascularization relative to their sedentary counterparts. In a study by Isaacs, Anderson, Alcantara, Black, and Greenough (1992), the density of the vasculature in the cerebral cortex increased in rats that repeatedly exercised on a treadmill for one month. These rats also had shorter vascular diffusion distances compared to non-exercising rats (Isaacs et al., 1992).

The second hypothesized mechanism involves changes in brain neurotransmitters. Exercise has been shown to increase levels of serotonin (Winter et al., 2007), norepinephrine (Mitchell, Flynn, Goldfarb, Ben-Ezra, & Copmann, 1990), and dopamine (Spirduso & Farrar, 1981). Studies examining the long-term effect of exercise on neurotransmitters have found prolonged elevated levels of norepinephrine in humans (Poehlman, Gardner, & Goran, 1992) and animals (Radosevich et al., 1989). These findings are significant because an association between elevated levels of norepinephrine and improved memory in mice had been shown (Zornetzer, 1985). Additionally, treadmill running decreased the rate of dopamine depletion in hemi-parkinsonian rats (Poulton & Muir, 2005).

The third hypothesis states that exercise up-regulates neurotrophins such as brain-derived neurotrophic factor (BDNF) which support neuronal survival and differentiation (Schinder & Poo, 2000). Long-term effects of exercise on the brain are likely mediated by brain-derived neurotrophic factor (BDNF) (Cotman & Berchtold, 2002). BDNF supports the survival of neurons and promotes the growth of new neurons and synapses. When rats voluntarily wheel-run, BDNF levels in the hippocampus increase after several days and remain elevated for several weeks with continued exercise (Neeper, Gomez-Pinilla, Choi, & Cotman, 1995). Physical exercise induces BDNF gene expression and the release and synthesis of several other neurotrophic factors which then facilitates higher-order cognitive functions (e.g., learning, memory, and thinking), neurogenesis, angiogenesis, and plasticity (Cotman & Berchtold, 2002; Deslandes et al., 2009). It is now well known that adult mammalian brains can produce new neurons in the hippocampus and in the layer of cells surrounding the lateral cerebral ventricles (Ploughman, 2008; van Praag, Christie, Sejnowski, & Gage, 1999; van Praag, Kempermann, & Gage, 1999), brain areas involved in learning and memory. Neurogenesis has also been observed in the olfactory bulb and dentate gyrus (van Praag, Kempermann et al., 1999; van Praag et al., 2002). Adult neurogenesis can be regulated by several factors including physical exercise (van Praag, Christie et al., 1999; van Praag, Kempermann et al., 1999), aging (Kuhn, Dickinson-Anson, & Gage, 1996), environmental enrichment (Kempermann, Kuhn, & Gage, 1997), and stress (Gould, Woolley, & McEwen, 1990).The effect of physical exercise on post-injury neuronal recovery and survival has been shown (Carro, Trejo, Busiguina, & Torres-Aleman, 2001). Rats that ran (1 km per day) prior to an induced brain injury had spared neurons and improved 90% of function when running persisted for five weeks following the lesion. Additionally, chances of survival following cerebral stroke and spared neurons increase if rats voluntarily run (0.8km per day) for the two weeks preceding the stroke (Stummer, Weber, Tranmer, Baethmann, & Kempski, 1994).

Aerobic exercise and heart rate variability. In addition to brain changes associated with fitness, long-term endurance exercise also affects how the autonomic nervous system regulates heart rate (Carter, Banister, & Blaber, 2003). Endurance exercise can be defined as engaging in an activity during which heart rate is elevated to 60-80% of maximum for a minimum of 20 minutes (Carter et al., 2003). Studies have shown that long-term aerobic training increases parasympathetic activity and decreases sympathetic activity involved in heart functions at rest (Goldsmith, Bloomfield, & Rosenwinkel, 2000; Gregoire, Tuck, Yamamoto, & Hughson, 1996). Parasympathetic activity regulates the heart rate at rest, whereas sympathetic activity regulates heart rate during exercise (Brenner, Thomas, & Shephard, 1997; Goldsmith et al., 2000). These exercise-induced changes result in lower resting heart rate and increased heart rate variability (HRV) at rest (Goldsmith et al., 2000; Shi, Stevens, Foresman, Stern, & Raven, 1995). Endurance athletes have a lower resting heart rate as well as a faster heart rate recovery after exercise (Brenner et al., 1997), and demonstrate lower sympathetic activity during submaximal exercises when compared to sedentary individuals (Goldsmith et al., 2000; Gregoire et al., 1996). Heart rate variability is defined as the rhythmic periodicity of the sinoatrial neural discharge (Demeersman, 1993) or the variation in time between successive heart beats (Borger et al., 1999). A high HRV indicates good adaptability and is associated with a healthy, well-functioning autonomic nervous system (Evrengül et al., 2005). Low HRV is associated with poor or abnormal adaptability of the autonomic system (Evrengül et al., 2005).

Several studies have examined how HRV affects performance. Heart rate variability is considered to be an index of effort allocation or motivation (Borger et al., 1999). Factors such as respiration, body movement, and speaking also affect HRV but occur only at higher frequencies of the HRV (> 0.14 Hz) (Jorna, 1992). The 0.10 Hz component, or midfrequency range (0.07 to 0.14 Hz), is therefore considered the most accurate index of effort allocation (Jorna, 1992). Increasing the complexity of arithmetic, sentence comprehension, and memory tasks reduces HRV (Jorna, 1992). Studies have found a performance decrement to be associated with an increase in HRV in car drivers (Egelund, 1982), children with ADHD (Borger et al., 1999), and healthy adults performing a sustained attention task (Mulder, Veldman, Van der Veen, Van Roon, Rüddel, Schächinger, Mulder, 1992). In sum, a lower HRV is associated with greater effort allocation and better task performance. As an indicator of autonomic cardiac control, HRV will be evaluated in the present study during performance of the attention tasks because long-term aerobic exercise alters parasympathetic and sympathetic activity of the heart. Additionally, lower HRV is associated with better performance on attentional tasks.

Cognition and exercise conclusions. The literature supports an association between aerobic fitness level and cognition in animals, older adults, and children. However, research examining these facilitative effects of physical exercise on young adults remains equivocal. None of these studies control for the type of exercise or other activities that may influence the dependent measures. For example, the high-fit adults may play competitive racquet sports. Research shows that expert tennis players are more efficient and effective at selectively attending to visual cues (Williams et al., 2002). Also, the high-fit children in the study by Hillman et al. (2005) may be avid action video game players. Studies have shown that individuals who regularly play action video games have superior selective attention as compared to non-video game players. These potential confounding factors are not being controlled for in this body of literature. To determine the relationship between visuospatial attention and aerobic exercise, confounding factors such as video game playing must be controlled.

Visual Attention and Video Game Playing

With the recent surge of interest in video games, several researchers have explored whether or not playing video games affects perceptual or motor skills. Green and Bavelier (2003) conducted four cross-sectional experiments to determine if differences in visual attention existed between habitual video game players and non-video game players. Video game players had played action video games at least four days a week for a minimum of one hour per day for six months. In the Green and Bavelier (2003) study, participants performed the flanker compatibility task and enumeration task to assess attentional capacity. Results from both confirmed that action video game players exhibit enhanced attentional capacity compared to non-video game players. Video game players also outperformed non-video game players at all eccentricities and distractor levels, indicating that video game playing enhances the attentional capacity and its spatial distribution (Green & Bavelier, 2003). Next, participants performed an attentional blink paradigm during which they had to detect a target presented a few milliseconds after another target. At early lags, video game players performed better than non-video game players. This suggests that video game players have an enhanced ability to shift attention and to process information over time.

While differences between video game players and non-video game players have been well established, a causal relationship between video game playing and attention enhancement is still heavily debated. The effect seen in the first few experiments in the study by Green and Bavelier (2003) may have been due to population differences. The authors keenly admit that by choosing video game players, individuals with innately better visual attention skills may have been selected. The video game players may have become avid players because of their inherent attentional skills whereas the non-video game players may have avoided video games because their attentional skills were innately weaker (Green & Bavelier, 2003). To address this potential confound, a training experiment was also conducted. Non-video game players were instructed to play the action video game *Medal of Honor* for one hour a day for ten consecutive days. A control group was instructed to play *Tetris*, a non-action game that requires attending to one object at a time. The action video game training group improved on all tasks (enumeration, attentional blink, useful field of view) after only ten hours of training thus increasing their attentional capacity, its spatial distribution and temporal resolution (Green & Bavelier, 2003).

Not all types of video games have been shown to benefit visual function. Participants trained to play action video games show greater improvements in visual function compared to participants trained to play non-action video games, demonstrating that action video games alone contribute to visual changes (Achtman, Green, & Bavelier, 2008). Cohen, Green, and Bavelier (2007) examined which specific video game characteristics contribute to visual enhancement. They found the greatest enhancement with action video games which require precise, rapid visual function to guide aiming movements accurately. Action video games are characterized by high speed of events and moving objects, spatial and temporal unpredictability, tracking moving objects while ignoring distractors, and a high degree of peripheral processing (Green, Li, & Bavelier, 2010). Therefore, in the present proposal, only participation in action video games will be controlled.

In sum, compared to non-video game players, action video game players are superior on tasks measuring spatial distribution and temporal resolution of visual attention, the number of objects that can be attended, and the efficiency of visual attention (Green & Bavelier, 2003). A causal relationship has been demonstrated between action video game playing and visual enhancement with action video game training resulting in improved visual attention. Given the strong evidence for visual enhancement associated with action video game playing, the present study, which seeks to examine the relationship between visual attention and aerobic fitness, will control for action video game playing habits.

Conclusion

Brain- and visual- training programs are being developed and marketed as an easy way to improve cognitive and perceptual functions despite a lack of supporting empirical evidence. The literature does provide strong evidence that physical exercise is an alternative means to improving cognitive and visual functions. Physical activity or exercise has beneficial effects in older adults and school-age children. This evidence, along with the hypothesized mechanisms for this exercise-related enhancement, suggests that the positive relationship between exercise and cognition may exist in the young adult population as well. Two important confounding variables in the experiments reviewed above must be accounted for to clearly establish a relationship between aerobic fitness and attention function in young adults. Expert athletes of open skill sports and habitual action video game players, have extensive practice with visuospatial attention and demonstrate superior visuospatial and cognitive functions compared to novices athletes and non-video game players. Participation in open skill sports or activities and action video game playing will be controlled for in the present study in an effort to eliminate these possible confounds.

Chapter 3: Methods

The purpose of this study was to determine the extent to which aerobic fitness level is related to visuospatial attention in young adults. Several confounding factors, such as action video game playing and open skill sport participation, may make interpretation of the findings difficult and thus must be controlled. Aerobic fitness level was compared to accuracy performance on the visual attention tasks to assess the influence of aerobic fitness on visual attention in the young adult population.

Participants

Participants (n=35) were volunteers with an age range of 18-29 years. Participants were recruited by informal advertisements sent to local speed skating, cycling, and running clubs as well as to various social clubs and organizations at the University of Wisconsin-Milwaukee. Pre-screen questionnaires (Appendix A) were sent out electronically to ensure that inclusion and exclusion criteria were met prior to scheduling an appointment. Upon scheduling a testing time, participants were asked to refrain from any physical exertion, caffeine intake or smoking at least two hours prior to coming to the lab. Participants had normal or corrected-to-normal vision and were free from lower extremity or spine injury in the previous six months. Participants who played action video games for more than four hours a week were excluded from this study (Green & Bavelier, 2003). All participants provided informed consent (Appendix B) as approved by the Institutional Review Board of the University of Wisconsin – Milwaukee.

Sample size was based on power analysis (G*Power; Erdfelder, Faul, & Buchner, 1996) for a correlation coefficient of 0.4 and 0.8 power to show a moderate effect.

Procedure

After being fully informed of the study and signing an informed consent form (Appendix B), participants were asked to complete a modified PAR-Q form (Appendix C) and a modified version of the Task and Ego Orientation in Sport Questionnaire (TEOSQ) (Appendix D). The TEOSQ was used as a descriptor to ensure that any variations in visual attention performance were related to aerobic fitness differences and not differences in motivation. The original TEOSQ (Duda, 1989), a 13-item questionnaire designed for competitive athletes was modified for this study to evaluate both elite athlete and non-active participants ego (6 items) and task (7 items) orientations toward an activity of their choosing. Task orientation focuses on gaining or improving skill or knowledge and performing to the best of one's ability (Nicholls, 1989). Ego orientation focuses on the comparative performance or demonstration of one's skills relative to others and emphasis is placed on ability (Nicholls, 1989). For the proposed study, the instructions were changed to prompt the participant to consider feelings of success during an activity rather than during a sport. This adaptation was necessary to apply the questionnaire to the non-active group participants who most likely do not engage in sports. Only one of the 13 items was changed from "I score the most points/goals/hits, etc." to "I get the most compliments." The Wilcoxon signed rank test found no evidence of a difference in median scores for the modified item compared to the median scores on the other 5 ego items on the questionnaire ($z = -1.05$, $p > .05$), thus confirming the internal consistency reliability. Each item on the TEOSQ is scored on a 5-point Likert-type scale from 1 = *strongly disagree* to 5 = *strongly agree*. The median ego-oriented score and median task-oriented score were calculated for each participant and were used as a covariate to account for the potential influence of motivation orientation on task performance.

To address the issue of open skill activity involvement and its known relation with visual attention, participants were screened on their involvement in such activities. Participants were asked by the researcher to verbally report any sports or activities they have participated in that require a rapid response to a changing environment. Participants were asked to report current and previous participation as well as the frequency, duration, and level of competition of each activity. Reported open skill activity participation was scored in the following manner: 2 = current participation in open skill sports or activities, 1 = previous participation in open skill sports or activities, and 0 = no present or previous participation in open skill sports or activities. By quantifying open skill experience, we were able to statistically account for this known influence when examining the relation between aerobic fitness and visual attention.

Next, height and weight were measured prior to testing to calculate BMI and for use in the VO_{2max} prediction equation. Body mass index was used as a descriptor in this study. Overweight and obese adults (BMI > 25) have demonstrated poorer performance on tasks of executive function compared to normal weight adults (BMI 18.5-24.9)

(Gunstad et al., 2007). Therefore, we wanted to assess BMI as a possible covariate in this study.

Additionally, each participant wore a Zephyr Bioharness™ (Zephyr Technology, Annapolis, MD) during the two attention tasks. The Zephyr Bioharness™ is a chest strap with sensors that collect heart rate, respiration rate, acceleration, and skin temperature (www.zephyr-technology.com accessed on 2/24/12). Data were logged in the portal device and later uploaded to a PC where data were displayed using OmniSense software.

The participant performed two visuospatial attention tasks in the Visuomotor Laboratory and a sub-maximal fitness test in the Human Performance and Sport Physiology Laboratory, both at the University of Wisconsin-Milwaukee. The attention tasks were counterbalanced among participants. All participants performed the attention tasks before the physical fitness assessment to ensure that any physical fatigue from the fitness test did not affect performance on the visual attention tasks.

Visuospatial attention tasks. Two visual attention tasks were required to test the multiple facets of attention. The Covert Visuospatial Attention task (CVAT) assessed selective attention, sustained attention, and attentional shifting. The Multiple Object Tracking task (MOT) provided a robust assessment of multiple attentional processes because attention must be divided amongst multiple targets (Sears & Pylyshyn, 2000), the targets must be selectively attended while non-targets are ignored, and attention must be sustained across spatial and temporal changes.

Covert visuospatial attention task. The Covert Visuospatial attention task required participants to detect a peripheral target at a cued location while maintaining central visual fixation. The stimulus consisted of a centrally-located Rapid Serial Presentation (RSVP) letter stream and four peripherally located letter streams labeled 'A', 'B', 'C', and 'D' (Figure 1). The central letter stream consisted of one letter shown for 125 ms (8Hz) prior to another letter being shown. The letters changed continuously throughout the run of 16 trials. Cue letters consisted of 'A', 'B', 'C' and 'D' and indicated the location to which the participant was to shift his or her attention for a particular trial. Based on which of the four cue letters ('A', 'B', 'C', or 'D') was shown and perceived in the central letter stream, the participant immediately shifted attention to the designated peripheral letter stream and peripherally attended for the presence of an 'X' in the specified letter stream. When the 'X' was shown, the participant left clicked on the computer mouse with the preferred hand and shifted attention back to the central letter stream in preparation for the next trial. An auditory tone indicated the end of the trial to ensure the participant shifted attention back to the central RSVP in preparation for the next trial. Instructions provided to the participant alerted them to catch trials (no 'X' in the peripheral letter stream). There were two catch trials per run (12% of collected trials). The peripheral letter streams were equidistant from the central RSVP (12° of visual angle). The central letter stream and the four peripheral target letter streams were always present and their locations did not change. Letters in each stream were displayed for 125 ms (8Hz). Pilot data on three individuals (two of them naïve to the task) determined the speed that would minimize ceiling effects (Appendix E).

Participants were allowed to practice and become familiar with the letter speed until 75% of the cue letters ('A', 'B', 'C', or 'D') in the central letter are reported. Five runs of 16 trials (four trials to each of the four peripheral letter streams) were collected for each participant. Only the last three runs collected were included in the analysis. Pilot data revealed that performance plateaus after the first two runs of this task. Participants were instructed to maintain central fixation throughout the run. Eye tracking ensured that participants maintained central fixation. Trials in which saccades were made were excluded from further analysis (5.74 ± 5.07 trials). The stimulus for the Covert Visuospatial Attention Task (CVAT) was developed and was presented using Presentation software (Neurobehavioral Systems; Albany, CA).

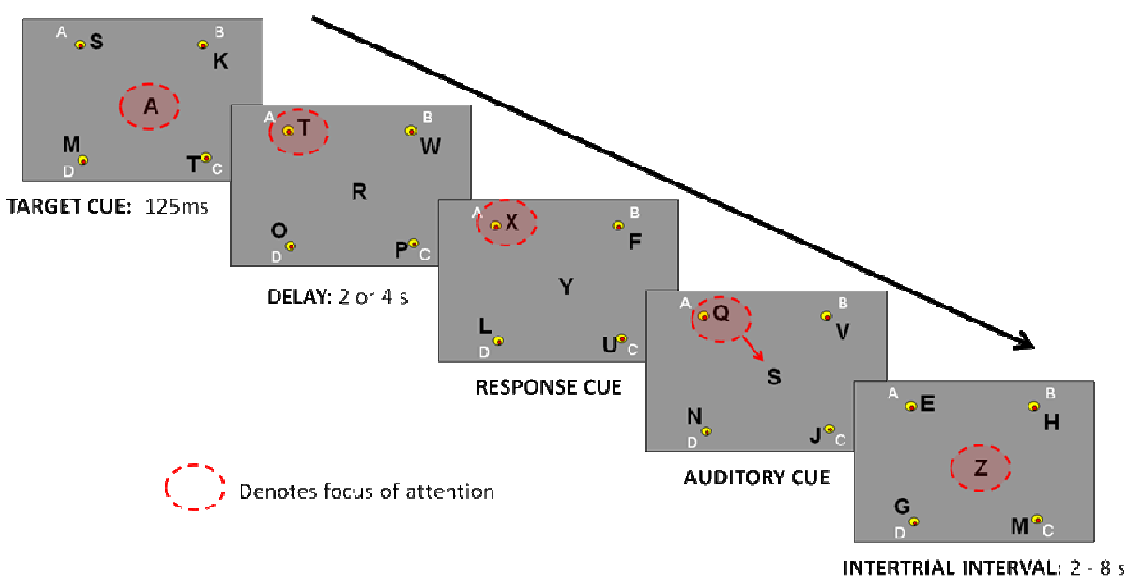

Figure 1. Covert Visuospatial Attention Task. This is a representative trial of the CVAT. The display consists of one central and four peripheral Rapid Serial Visual Presentations (RSVP), which is a continuously changing letter stream. When a cue letter (in this example 'A') is perceived, attention is shifted to the designated peripheral RSVP. When the response cue, 'X', is perceived in the peripheral letter stream, the participant clicks the computer mouse. An auditory signal indicates the trial is complete and attention should be shifted back to the central letter stream in preparation for the next trial.

Multiple object tracking task. The Multiple Object Tracking (MOT) task developed by Pylyshyn and Storm (1988) is often used to study divided attention and sustained attention. The task required participants to track a subset of randomly moving identical objects while maintaining central visual fixation. The stimulus was developed and was presented using MATLAB (MathWorks; Natick, MA). The script was provided by Professor Zenon Pylyshyn at Rutgers University. Each participant viewed the display with his or her head positioned in a chin rest. Participants were instructed to maintain central fixation at a center cross during each trial. Participants pressed a key to begin each trial. A set of ten identical black dots (radius 0.5°) were displayed on a computer screen, each with a randomly assigned initial position (Figure 2). Four of the objects were made visually distinct by temporarily flashing and turning white to indicate their status as targets. Prior research using the MOT task indicates that subjects can successfully track four to five objects (Pylyshyn & Storm, 1988). The optimal ratio of targets to distracters was determined with pilot testing for the present study. All objects then randomly moved at a rate of 5°/s about the screen for seven seconds. If an object reached the edge of the display, it was reflected by reversing the perpendicular component of its velocity. The objects overlapped when crossing paths. At the end of the trial, the objects automatically stopped. Participants then clicked on the four targets that they believed to be the original targets. Participants were allowed to perform five practice trials. Fifty-five trials were collected. Participants were allowed to rest their eyes as needed between trials. Eye tracking ensured that participants maintained central fixation throughout the run. Trials in which saccades were made or the objects were visually tracked were excluded from further analysis (2.77 ± 4.22 trials).

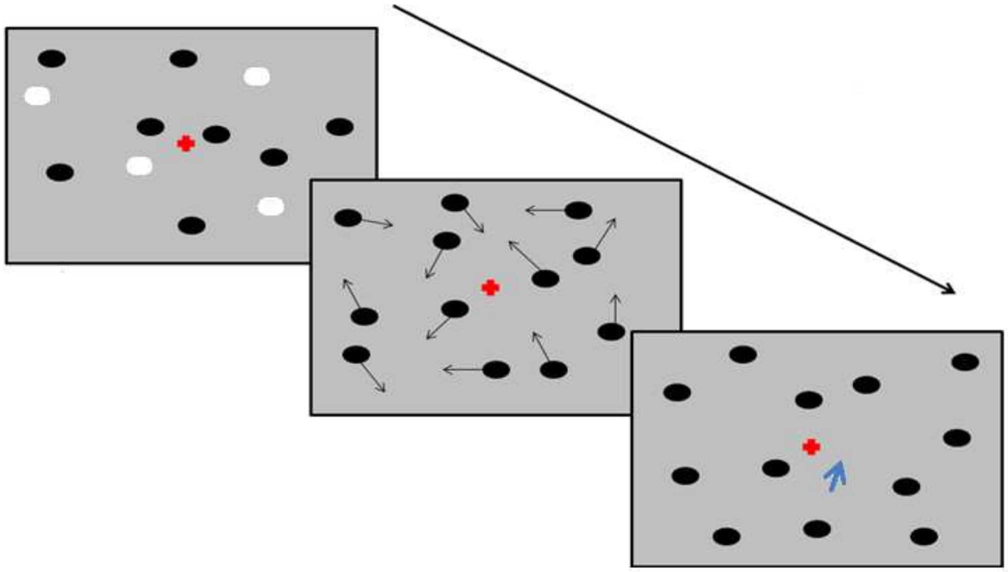

Figure 2. Multiple Object Tracking Task. This is a representative trial of the MOT task. Four of the objects are made visually distinct, indicating that they are target objects. When the participant pressed the space bar, all objects became identical and randomly moved about the screen. After 7 seconds, the objects automatically stopped moving. The participant then clicked on the four targets.

Physical fitness assessment. Participants completed the testing session by performing a biycle ergometer test. The objective of the YMCA cycle ergometer submaximal test (Appendix F) is to estimate VO_{2max} for men and women as a measure of cardiovascular fitness. Before beginning the test, participants were given an opportunity to stretch, warm-up, and review the instructions. A calibrated Monark 828E cycle ergometer (Varberg, Sweden) was used, and seat height was adjusted such that the participant's leg was straight and fully extended when the heel was in contact with the pedal at its lowest point. The protocol consisted of three or more consecutive workloads designed to raise the heart rate between 110 bpm and 150 bpm or 85% of the age-predicted max heart rate (i.e., 220 – age = HRmax). YMCA guide to fitness testing and instruction was followed (Golding et al., 1989). Participants were monitored throughout the test for signs of fatigue or exercise intolerance such as a very red face, profuse sweating, or the inability to speak in response to a question. Predicted maximal oxygen consumption was calculated using the stable exercise heart rate, two of the workloads, and the age and weight of the participant in a regression equation (Golding, 2000). Due to sex differences in VO_{2max}, VO_{2max} scores were converted into gender-specific percentiles to allow for comparison between aerobic fitness of both males and females together to performance on the attention tasks. The raw VO_{2max} to percentile conversion was performed using the equation of the fitted trend line to the norms and corresponding percentiles for males and females in the age range of 20-29 years presented in the *ACSM's Guidelines for Exericse Testing and Prescription* (2010) (Appendix G).

Analysis.

The dependent measures were accuracy on the CVAT and accuracy on the MOT. One-tailed Pearson's correlations were run separately between VO_{2max} and BMI, VO_{2max} and task score, and VO_{2max} and ego score to determine whether these variables were covariates. Partial correlations were performed between VO_{2max} and MOT and VO_{2max} and CVAT performance while controlling for open skill sport involvement. Eye tracking data from four participants were not further analyzed because over 75% of the trials were lost due to loss of pupillary or corneal reflection. Data from one participant were removed from the analysis due to an incomplete submaximal fitness test.

To assess the physiological connection between aerobic fitness and visual attention, two measures of HRV were calculated and compared to aerobic fitness level and visuospatial attention performance. Two analyses were performed to evaluate heart rate variability: 1.) time domain analysis and 2.) frequency domain analysis. The standard deviation (SD) of the R-R interval is one of the most commonly used measures of HRV. While the SD of R-R interval can provide information regarding the overall variation in HR, it does not evaluate the oscillatory components within the signal (Malliani, Lombardi, & Pagani, 1994). The ratio, LF/HF, is another measure of HRV that has been used to describe the balance or interaction between parasympathetic and sympathetic influences (Tripathi, Mukundan, & Mathew, 2003). The low frequency (LF) and high frequency (HF) components of the R-R interval are interpreted as indicators of sympathetic (Inoue, Miyake, Kumashiro, Ogata, & Yoshimura, 1980) and parasympathetic influences on the heart respectively (Malik, 1996). In the present study, SD of the R-R interval and the LF/HF were both used as measures of HRV.

For both analyses, the baseline measure was taken immediately after the bioharness was applied while the subject received instructions on the attention tasks. This typically occurred at 1 minute or as soon as the data were within 2 standard deviations of the mean which corresponded to the participant having securely put on the bioharness. Due to timing difficulties between the eye tracking software and the bioharness software, data were visually inspected to determine when the CVAT trials occurred. Participants for whom all 5 trials could not be visually identified were not included in the heart rate analysis. Eight participants were excluded from this analysis based on this criterion. The average CVAT performance (percent correct) of the eight excluded participants was 53.67 ± 25.95 compared to 64.34 ± 13.97 for the participants included in the HRV analysis. The average VO_{2max} percentile for the excluded participants (34.39 ± 32.28) was similar to the average VO_{2max} percentile of the included participants (34.07 ± 26.17). Inter-beat interval (R-R) data, collected with the Zephyr Bioharness, were analyzed using Kubios software (Kuopio, Finland). The R-R standard deviation of each CVAT run (lasting 3:09) was taken from a 2 minute and 30 second sample and averaged across the three runs used for analysis for a given participant. The average trial R-R SD was then divided by the SD at baseline. To determine the ratio of low frequency (LF) to high frequency (HF) HRV during the CVAT trials, a power spectral density analysis using a Fast Fourier transform was used. The LF/HF of each CVAT set of trials (runs) was taken from the same 2 minute and 30 second sample as the R-R SD and averaged across the three runs for a given participant. The baseline LF/HF was then subtracted from the average LF/HF to provide a difference score. Pearson correlations were performed to determine the relation among both measures of HRV (i.e., SD of the R-R interval and LF/HF) and aerobic fitness and visual attention performance during the CVAT. Heart rate data were not analyzed during the MOT task because the duration of the trials was not sufficient to get an adequate sample for power analysis.

Chapter 4: Results

We examined the relation between aerobic fitness level and performance on visuospatial attention tasks in young adults while controlling for action video game playing and accounting for the influence of open skill sport participation. It was hypothesized that aerobic fitness would positively correlate with accuracy on the Multiple Object Tracking task (MOT) and Covert Visual Attention Task (CVAT) while controlling for the following possible confounds: BMI, motivation orientation, and open skill activity participation. Table 1 shows the participant demographics, ranges, and modes for relevant measures.

Subject	**Age** (years)	**BMI**	**VO_{2max}** (mL/kg/min)	**VO_{2max} percentile**	**Open skill score**	**Ego score**	**Task score**
1	28	25.9	33.3	6.22	0	3	4
2	29	19.7	29.4	11.31	0	2	4
3	23	22.9	37.6	17.71	0	3	5
4	22	21.7	28.3	8.11	0	4	5
5	24	20.8	29.3	10.99	0	1.5	4
6	21	21.4	33.3	28.01	0	3	4
7	24	25.4	36.2	12.59	2	4	5
8	21	21.9	37.3	49.42	2	4	3
9	23	26.3	42.3	73.25	1	3	5
10	23	25.1	27.3	5.85	1	4	5
11	28	23.9	46.36	61.96	1	5	5
12	25	27.2	35.78	11.3	2	4	5
13	27	19.5	29.79	4.97	0	4	4
14	29	21.8	42.89	75.55	1	2	5
15	24	29.4	40.82	33.06	2	1	4
16	28	25.2	31.04	4.96	1	2	5
17	24	21.9	28.5	8.63	1	3.5	4
18	22	20.5	37.71	51.6	2	2.5	5
19	20	23	46.2	61.2	1	3.5	4

20	18	24.3	31.57	5.04	2	3	5
21	24	22.1	39.14	24.57	1	3	4
22	20	21.4	40.28	64.48	1	2	5
23	28	22.8	36.73	46.35	2	2.5	4
24	24	22	46.18	86.3	2	4	5
25	25	25.8	35.18	9.67	1	3	4
26	28	19.6	51.14	96.89	1	4	5
27	18	25.9	25.61	3.37	2	3	4
28	20	24.6	34.16	32.47	2	4	5
29	24	28	42.5	42.05	2	3.5	5
30	23	24	39.25	25.1	1	3	4
31	21	22.5	36.12	12.34	1	4	4
32	28	20.7	49.3	74.6	2	3.5	4
33	19	20.7	37.24	49.1	1	4	4
34	21	23.5	35.97	42.23	0	5	5
35	18	22.5	36.24	43.69	0	2	4
MCT	**23.54**	**23.25**	**36.86**	**34.14**	**1**	**4**	**4**

Table 1. Participant demographics. Female participants are shaded in grey. Averages are presented at the bottom of the table for age, BMI, VO_{2max}, and VO_{2max} percentile. The mode is presented for open skill score, task score, and ego score (MCT = measures of central tendency).

Potential confounds

To make the comparison between performance on the visual attention tasks and aerobic fitness level, we had to initially remove any influence due to potential confounds. BMI has been shown to be related to a lower VO_{2max} in obese individuals (So & Choi, 2010). However, none of the participants in this study qualified as obese (>30). Additionally, the task and ego orientation questionnaire was administered prior to testing to ensure that differences in visual attention performance were not related to differences in motivation to complete the tasks. Studies on sport expertise suggest that athletes of open skill sports have superior visual attention compared to novices and non-athletes (Nougier & Rossi, 1999; Castiello & Umiltá, 1992), which may reflect the athlete's motivation to succeed. We sought to control for this known influence while examining the relation between aerobic fitness and visual attention. Separate one-tailed Pearson correlations showed that BMI (r = -.266, p = .062), task orientation (r = .187, p = .141), ego orientation (r = .096, p = .292), and open skill activity participation (r = .239, p = .083) did not significantly correlate with VO_{2max} percentile. These findings suggest that aerobic fitness is not related to any of these factors.

Aerobic fitness and visual attention

Performance on the MOT task (72.78 ± 8.75 percent correct) did not significantly correlate with VO_{2max} percentile while controlling for open skill activity participation (r=.120, p=.250). Figure 3 shows the distribution of MOT scores. All participants performed better than chance (40%) on this task. Interestingly, performance on the MOT task was significantly related to task orientation score (p < .05).

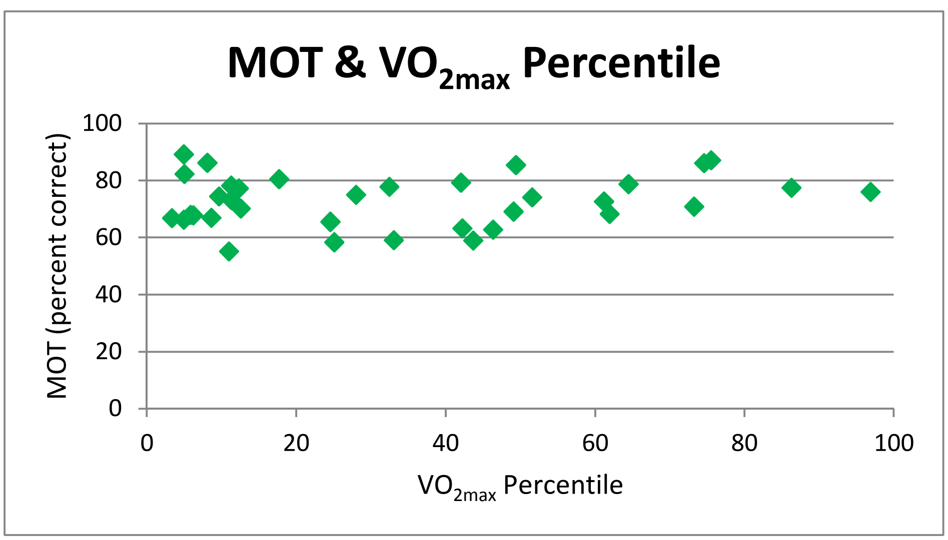

Figure 3. Multiple Object Tracking task and VO_{2max} Percentile. The distribution of scores on the MOT task across VO_{2max} percentiles.

Performance on the CVAT task (61.90 ± 17.56 percent correct) also did not significantly correlate with VO_{2max} percentile while controlling for open skill activity participation (r = .166, p = .174). Figure 4 shows the distribution of CVAT scores. Performance on the CVAT was significantly correlated with open skill activity participation (r = .307, $p < .05$). Performances on the CVAT and MOT task were significantly related (r = .540, $p < .01$; Figure 5).

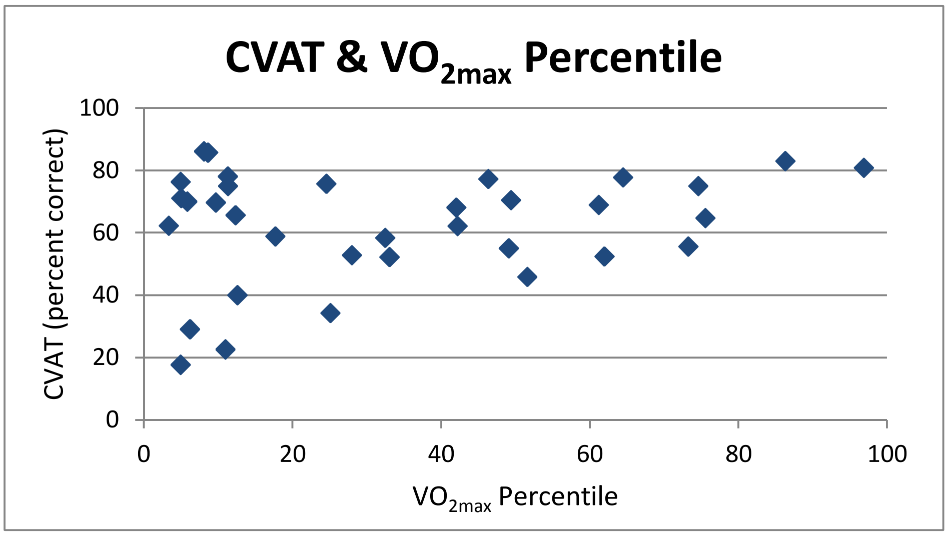

Figure 4. Covert Visual Attention Task and VO_{2max} Percentile. The distribution of scores on the CVAT and corresponding VO_{2max} percentiles.

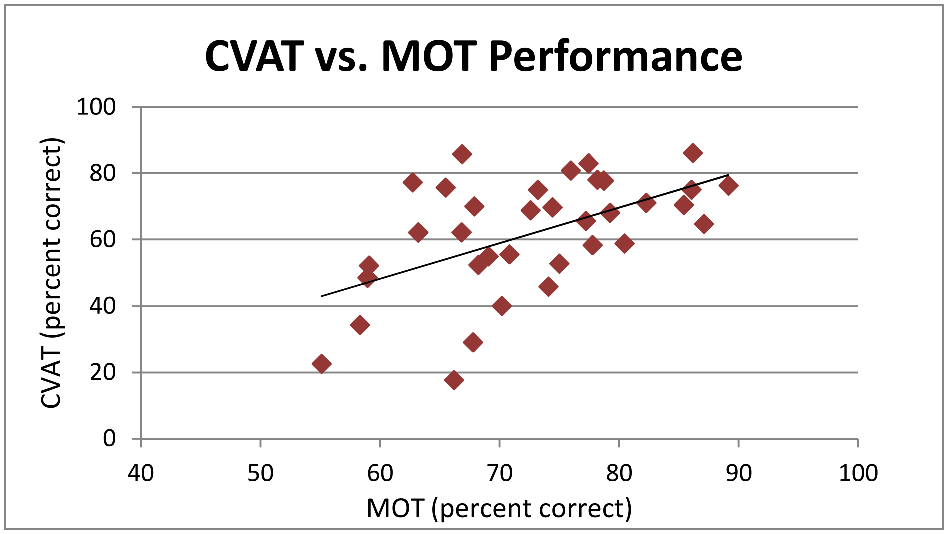

Figure 5. CVAT vs. MOT performance. Percentage correct on both attention tasks across participants is presented above. Performances on the tasks were positively correlated.

Heart rate variability

Based on previous literature, we expected the physiological linkage between aerobic fitness and enhanced visual attention performance to be explained by heart rate variability during the visual attention task. Our secondary hypothesis stated that heart rate variability (HRV) during the CVAT task would correlate with performance on that task; specifically, a lower HRV would be associated with greater percentage correct. The findings in this study did not support a correlation between CVAT performance and HRV as measured by the standard deviation of the R-R intervals (r = .064, *p* = .375). Additionally, the standard deviation was not related to VO_{2max} percentile (r = -.061, *p* = .381). The frequency domain analysis of HRV performed in the present study did reveal a significant relation between the LF/HF and VO_{2max} percentile (r = .360, $p < .05$; Figure 6). The LF/HF was not significantly related to performance on the CVAT (r = -.312, *p* = .057); however, a trend did exist (Figure 7).

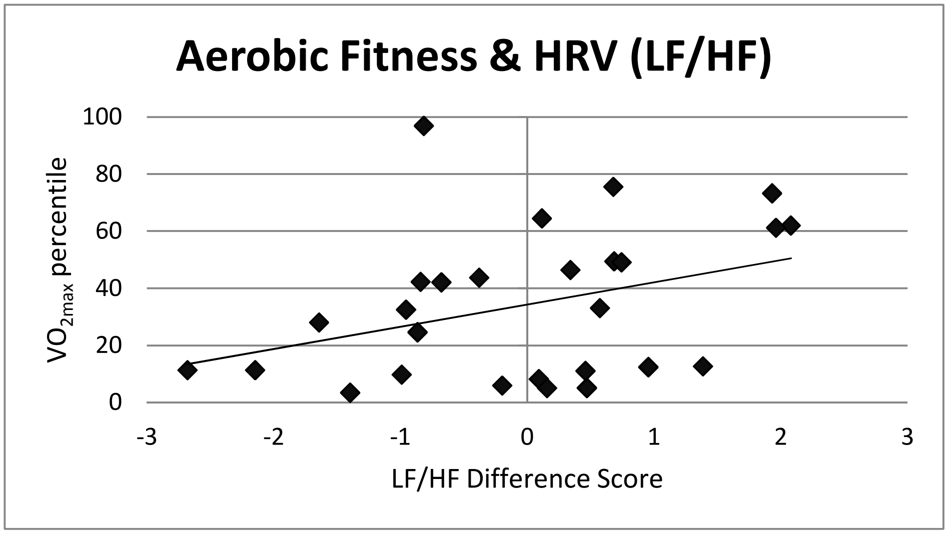

Figure 6. Aerobic fitness and heart rate variability as measured by LF/HF. Aerobic fitness level (VO_{2max} percentile) positively correlated with LF/HF difference score. Participants who had a high level of aerobic fitness tended to have a higher LF/HF during the CVAT task relative to baseline.

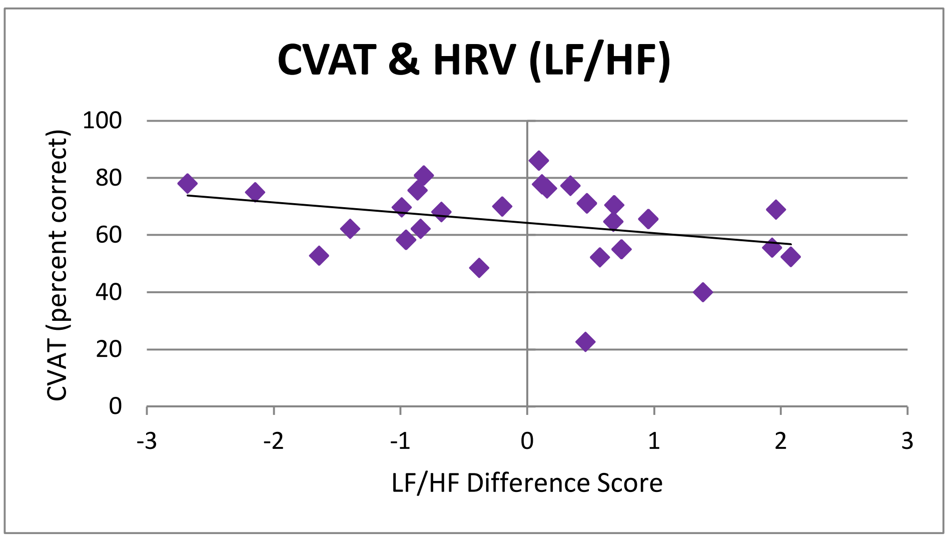

Figure 7. Performance on the CVAT and heart rate variability as measured by LF/HF. A greater percentage correct on the CVAT task was generally associated with a lower ratio between low frequency and high frequency components. The difference score reflects the difference between the averaged LF/HF during the CVAT trials and baseline. A negative LF/HF difference score means LF/HF was lower during the task than at baseline.

Summary

In this study, potential confounds such as BMI, task and ego orientation, and open skill activity participation were not significantly related to aerobic fitness level. Performance on the visual attention tasks did not significantly correlate with aerobic fitness level while controlling for the influence of open skill activity participation. Performance on the MOT task was significantly related to task orientation score. This finding may be explained by the tendency of task-oriented individuals to measure their success in terms of their personal improvement from trial to trial. Performance on the CVAT was significantly related to open skill activity involvement. The time domain analysis of the heart rate data provided insignificant findings in terms of HRV related to performance on the CVAT task. However, the frequency domain analysis showed a significant relation between the LF/HF and VO_{2max} percentile, but not with performance on the CVAT task.

Chapter 5: Discussion

The present study was conducted to further the body of research that has examined the relation between aerobic fitness and cognitive performance. In order to accomplish this objective, participants performed two visuospatial attention tasks and performed a submaximal fitness test to predict aerobic fitness level. Data were collected on potential confounds including BMI, motivation, and involvement in open skill activities. It was hypothesized that aerobic fitness level (VO_{2max}) would correlate with performance on the visuospatial attention tests (MOT and CVAT) while controlling for the influence of open skill activity involvement. This hypothesis was not confirmed. Aerobic fitness did not significantly correlate with performance on the visual attention tasks. A secondary goal of this study was to examine the connection between heart rate variability and its relation to aerobic fitness level and visual attention performance as a possible physiological mechanism.

Visuospatial Attention and Aerobic Fitness

The Multiple Object Tracking task (MOT) and Covert Visual Attention Task (CVAT) were chosen to assess visuospatial attention for this study because they require the utilization of several facets of visual attention for successful performance. The MOT task required divided attention amongst multiple targets, selective attention and sustained attention across spatial and temporal changes. The CVAT assessed selective attention, sustained attention, and attentional shifting. The MOT task is used extensively in the literature to assess both divided attention (Scholl, 2001) and attentional capacity (Pylyshyn & Storm, 1988).

Performances on the MOT task and CVAT used in the present study were significantly related. Both tasks were designed to assess visuospatial attention and required the use of similar facets of visual attention, and therefore, we would expect performances on these tasks to be related. For example, while the MOT task was primarily included in the study to assess divided attention, it cannot be successfully performed without the utilization of selective and sustained attention (facets required in the CVAT task) as well.

It was hypothesized in the present study that performance on the CVAT would correlate with aerobic fitness level. However, there were no significant findings supporting a relation between aerobic fitness level and performance on the CVAT while controlling for the influence of open skill activity. Several explanations for this result are worth discussing. Based on the range and distribution of scores, the difficulty level of the CVAT task may have been exceedingly high (Figure 6). The score of 13 of the 36 participants was less than or approximately at chance. There are two types of errors that can be made during the CVAT. The participant may not perceive the cue letter (‘A’, ‘B’, ‘C’, or ‘D’) in the central letter stream. This error should have been greatly reduced by the practice trials prior to beginning the task. During practice trials, participants recited each cue letter and ‘X’ when presented. Data collection did not begin until at least 75% of the letters were reported, and the participant felt confident to start. The other potential error was no perception of the ‘X’ in the peripheral letter streams. The occurrence of this error may have been magnified by the fact that two parameters were changed from the original task used in the Visuomotor Lab. The speed of letter presentation for the task used in this study was changed from 5 Hz to 8 Hz. The 8 Hz was selected for this task following pilot data collection because it showed a strong range of scores yet all scores remained above chance (50%). Pilot data was collected on three subjects. Pilot data may have revealed a much lower average score for the 125 ms speed had more subjects been collected. The visual angle of the CVAT was also modified from 10 degrees to 12 degrees to match the visual angle of the MOT task. However, this modification should not necessarily degrade performance, because performance at 12 degrees eccentricity on an attention task has been shown to exceed performance at both 6 and 18 degrees (Sekuler, Bennett, & Mamelak, 2000). The CVAT parameters used in this study did not allow for an accurate performance measure on this task for all participants and therefore, the CVAT did not necessarily provide a clear indication of selective, sustained, and shifting attention.

Contrary to our expectations, performance on the MOT task also did not correlate with aerobic fitness level. The existing studies on the younger adult population in the literature have mixed results. Results from studies on aerobic fitness and visual attention in young adults appear to be highly task-specific. For instance, Hillman, Kramer, Belopolsky and Smith (2006) found physical activity related to performance using a task switching paradigm. Yet, the relation was not supported when a stimulus discrimination task was used (Hillman et al., 2002). Similarly to older adults, the relation between aerobic fitness and cognitive performance in young adults may be more pronounced in certain cognitive domains (e.g., executive function, spatial processing) than in others. For example, tasks in which performance requirements include executive control processes such as planning, task switching, and working memory (Chan, Shum, Toulopoulou, & Chen, 2008) may elicit greater fitness-related differences in young adults than tasks that require visuospatial processing (Hillman et al., 2006). The present study does not support the relation between aerobic fitness and visuospatial attention. More research is needed to determine how aerobic fitness relates to various cognitive domains in the young adult population.

The results from the current study are consistent with some studies conducted on the young adult population. Shay and Roth (1992) compared performance of high- and low-fit participants in three age groups (young, middle, and old) on several cognitive tasks. They found that high-fit older adults performed better than low-fit older adults on visuospatial processing tasks, but no evidence supported enhanced performance on verbal memory, attention or simple sensorimotor functions. Differences in performance between the high- and low-fit participants of the middle and young age group on the visuospatial tasks were smaller and non-significant. Cognitive processes, such as visuospatial processing, may be particularly susceptible to age-related decline. Physical activity appears to preserve certain cognitive functions and/or delay cognitive decline in older adults; the fitness effect was not observed in the young and middle age groups in Shay and Roth (1992) nor in the present study because these populations may not yet experience comparable cognitive declines on visuospatial processing. Although the relation between aerobic exercise and cognition is widely supported in the literature regarding children and older adults, results from the present study did not support this relation in young adults. Several reasons exist as to why there may be a selective age-related effect of physical conditioning and attention. Sibley and Etnier (2003) conducted a meta-analysis on physical activity and cognition in children and found that the beneficial effects of aerobic exercise were greater for younger participants (4-13 years of age) compared to older children or adolescents. The authors suggest that some of the benefit may be attributed to a decrease in social anxiety and/or an increase in self-esteem. Therefore, the effects of aerobic exercise on cognition may be more pronounced in children and adolescents than in young adults because of this indirect benefit to the level of social anxiety and self-esteem. Older adults may also be especially susceptible to exercise-induced enhancements because of the protective influence of exercise against the progression of age-related cognitive decline. Specifically, aerobic exercise seems to attenuate tissue loss in brain regions involved in executive function tasks (Colcombe & Kramer, 2003). Therefore, the effects of exercise on cognition may be more apparent in older adults than in young adults because young adults do not have a cognitive deficit or loss of function from which to improve.

Open skill activity influence

Open skill activity information was collected from each participant in this study to account for the known beneficial influence of open skill activity on visual attention. Several studies have examined the effects of open skill sport participation on visual attention and other cognitive abilities. Researchers have shown that soccer players (Williams et al., 1998; 1994), volleyball players (Adolphe, 1997), tennis players (Farrow & Abernethy, 2002; Scott et al., 1998), and squash players (Abernethy, 1990) are superior at visual attention tasks when compared to novices or non-athletes. The relation between open skill experiences and performance on the attention tasks differed between the two tasks in the present study. Participants who engaged in open skill activities performed better on the CVAT than participants who did not engage in open skill activities. Conversely, open skill activity did not significantly correlate with performance on the MOT task. Memmert, Simons, and Grimme (2009) found that performance of expert open skill athletes did not significantly differ from performance of novice athletes or non-athletes on multiple attention tasks, including a variation of the MOT task. Shifting attention and rapid responses are unique aspects to the CVAT that the MOT task does not utilize. Individuals who engage in open skill activities may have an advantage in that open skill activities require rapid responses and frequent shifts in attention. An example would be when a volleyball player at the net rapidly shifts attention from the ball to the opposing hitter to prepare her optimal blocking position at the net. This finding may provide some insight into how open skill athletes attend to multiple sources of information. In certain activities or situations, it may be advantageous in terms of maximal processing to rapidly shift attention rather than divide attention amongst targets or sources of information.

Motivation

Motivation orientation was included in the present study to ensure that any relation between aerobic fitness and visual attention could not be confounded by motivational factors. Although the relation between aerobic fitness and visual attention was not significant, it is important to note that task orientation was significantly related to performance on the MOT task. Participants with higher task orientation scores performed better on the MOT task than participants with lower task orientation scores. This may be related to the feedback given on this task. After each trial of the MOT, the participant was shown his or her score (percent correct) for the previous trial as well as the average score for all completed trials. Task-oriented individuals perceive their success and competence in terms their effort and improvement, whereas ego-oriented individuals perceive success as superior performance relative to others (Nichols, 1989). Task-oriented participants were likely motivated to improve their own score after each trial. Feedback regarding the performance of other participants was not provided to the participant performing the task, and thus possibly detracting from the ego-oriented participant's motivation to perform well. Additionally, task-oriented individuals generally seek feedback because it is a means of continued effort and improvement, whereas ego-oriented individuals are less inclined to seek feedback because of the risk of suffering from negative feedback about the self (VandeWalle & Cummings, 1997). Performance feedback was given after each run (every 18 trials) for the CVAT task. All but one of the 36 participants had a task score greater than or equal to the ego score regardless of open skill activity involvement. This skewed distribution of the task scores and relatively normal distribution of the ego scores follow the norms (Duda, 1989). Future studies that include multiple cognitive tests should ensure that the frequency and type of feedback provided is consistent across tasks to minimize the effect of motivational orientations on task performance. Future research on exercise and cognition should address motivation because the present study provides evidence for its influence on performance of an attentional task.

Heart rate variability related to aerobic fitness and cognitive performance

As a possible physiological mechanism responsible for exercise-induced cognitive enhancements, we investigated a potential linkage between heart rate variability and performance. Two analyses were conducted, a temporal domain and a frequency domain analysis, to encompass multiple measures of HRV. In the present study, heart rate variability, as measured by the SD of R-R interval, was not significantly related to aerobic fitness level (VO_{2max} percentile). This finding is inconsistent with other studies that have found aerobic exercise related to increased HRV in athletes (Boutcher, Nugent, McLaren, & Weltman, 1998) and sedentary individuals introduced to aerobic training interventions (Levy et al., 1998). Levy et al. (1998) found increased HRV (as measured by SD of the R-R interval) at rest associated with increased VO_{2max} following a six month period of intense aerobic exercise training. This effect was more pronounced in older men than in younger men, 68% increase in HRV compared to 17% increase respectively. This suggests that the beneficial effects of aerobic exercise on cardiac activity may be greater for older individuals who experience age-related cardiac impairment and may be less apparent in the young adult population). However, other studies have not found a significant relation between aerobic fitness level and HRV when using the SD of R-R interval as a measure of HRV (Gregoire et al., 1996). Gregoire et al. (1996) found that trained and untrained young adults did not significantly differ in terms of SD of R-R interval. The authors' rationale is that the untrained group, consisting of mainly undergraduate kinesiology students, was atypically active and fit and not representative of an untrained control group. The majority of the participants in the present study also were undergraduate kinesiology students.

While the temporal domain analysis did not suggest a correlation, the frequency domain analysis did support a link between the low and high frequency components of HRV and aerobic fitness. The LF/HF was significantly related to VO_{2max} percentile suggesting a relation between aerobic fitness level and the balance of parasympathetic and sympathetic activity. Several studies in the literature support a relation between aerobic fitness level and LF/HF (Dixon, Kamath, McCartney, & Fallen, 1992; Gregoire et al., 1996). Gregoire et al. (1996) found regular aerobic exercise was related to decreased sympathetic and increased parasympathetic activity in middle age adults. This effect was not observed however in the young adult group. Other studies provide evidence for this relation in the young adult population when comparing endurance athletes and sedentary controls (Dixon et al., 1992).

Although the present study did not find HRV to be significantly related to performance on the CVAT, a trend did exist. A decreased LF/HF during the CVAT tended to result in superior performance on the CVAT. An elevated LF/HF has been observed during highly stressful mental tasks (Nater et al., 2006); therefore, the trend observed in the current study suggests that participants who experienced high stress or anxiety during the CVAT did not perform as well. Future studies that administer cognitive tasks as a measure of a cognitive function may consider addressing stress or anxiety as a possible influence on task performance. We expected HRV to relate to performance on the CVAT; given the previous literature, we predicted a higher CVAT score to be associated with a lower SD and a higher LF/HF value which would indicate that the participant had low HRV and sympathetic nervous system dominance during the task. The insignificant findings relating HRV to visual attention performance in the present study may be due to the negatively skewed distribution of scores on the CVAT task and the high percentage of participants who scored at or below chance. Several studies that have examined HRV during a cognitive task have not measured performance accuracy on the task. Therefore, more studies are needed to determine what aspect of performance (e.g., response time, accuracy) correlates with HRV during a cognitive task in young adults.

The difference in the findings from the two analyses regarding HRV and aerobic fitness may be explained by the fact that the SD of the R-R interval does assess the overall HRV; however, in regards to changes in sympathetic and parasympathetic balance, it is limited (Malliani et al., 1994). The SD measure cannot capture the frequency components hidden within the signal that reflect autonomic neural control of the heart (Malliani et al., 1994). Additionally, there are some physiological or pathophysiological conditions during which the balance between sympathetic and parasympathetic control can shift without changes SD of R-R interval (Malliani et al., 1991). The results from the current study suggest that aerobic fitness level in young adults may be related to the balance between the sympathetic and parasympathetic regulation of the heart but not necessarily to the variation in heart rate during an attention task.

Limitations

Results of this study can only be generalized to healthy young adults in the age range of 18 to 29 years who are free from neurological or psychological disorders and who have not suffered from a lower extremity or spinal injury in the six months prior to participating. Individuals who play action video games more than four hours a week may also respond differently to the study protocol.

A submaximal fitness test was used in this study to predict VO_{2max} rather than measure VO_{2max} through a maximal test. Some studies have shown that the submaximal cycle ergometer test underestimates measured VO_{2max} (Grant, Corbett, Amjad, Wilson, & Aitchison, 1995; Dabney & Butler, 2006).

The effect of open skill activity experience on visual attention is robust. To control for this statistically, we had to quantify this influence. Participants were scored based on whether they were currently, previously, or never involved in open skill activities. This scoring method did not account for duration of involvement, types of activities, frequency of participation or level of competition. Initial recruitment efforts sought individuals who did not have experience with open skill activities to eliminate this potential confound; however, that recruitment proved to be difficult, and thus, individuals with open skill experience were recruited and accounted for statistically.

Only two tasks were used in this study to assess visual attention. It is possible that had a battery of tasks been utilized, the findings may have been different. The vast majority of studies on cognition and attention incorporate a variety of tests to better index the function of interest and to reduce any method bias (Shay & Roth, 1992).

The heart rate variability analysis conducted in this study had several limitations. The timestamps on the R-R files did not coincide with the elapsed time axis when viewed among software packages; therefore, the occurrence of CVAT trials was determined by visual inspection. Baseline measures were taken prior to performing the attention tasks while the instructions were given. Ideally, the baseline measure would not be taken immediately before testing when the participant may be anxious about testing. Additionally, eight of the participants were excluded from this analysis because the CVAT trials could not be visually discerned.

Future Research

Findings from this study suggest that future research address the following:

1. Decrease the speed of the CVAT task to bring successful performance above chance.
2. Investigate the difference in visual attention performance of high-fit and low-fit closed skill athletes.

3. Investigate the visual attention effects of a pre- and post exercise training program on previously inactive young adults.

4. Investigate multiple time domain and frequency domain measures of HRV in aerobically-fit and unfit individuals.

Summary

The primary hypothesis was not supported as aerobic fitness level was not significantly related to performance on the visual attention tasks when open skill activity participation was controlled. Although performances on the two attention tasks were significantly correlated, the average and range of scores on the CVAT suggested that the particular parameters used in this study made the task exceedingly difficult and not appropriate as an accurate measure of visual attention.

It may be that the effects of exercise on cognition may be more apparent in school-age children and older adults who are still cognitively developing or are experiencing age-related cognitive declines than in the young adult population. In addition, aerobic fitness was related to autonomic cardiac control (as measured by the LF/HF). Although HRV was not significantly related to visual attention, a trend did exist suggesting a partial influence or interaction. The strength of this trend may have been greater had the parameters of the CVAT been modified to produce a more desirable distribution of accuracy scores. The SD of R-R interval was not related to aerobic fitness level or visual attention performance. This provides evidence that certain measures of

HRV, like certain cognitive functions, may be more sensitive to the benefits of aerobic exercise than others.

To improve visual attention, young adults are directed to action video games. Researchers investigating the effect of action video game playing on various cognitive functions have found strong support for a beneficial enhancement when comparing non-video game players to video game players (Green & Bavelier, 2003) and when introducing non-video game players to an action video game training program (Green & Bavelier, 2006). These effects have been observed following as few as 10 hours of training (Green & Bavelier, 2003; Feng, Spence, & Pratt, 2007). Additionally, the transfer of video game training appears broad, with improved performance on tasks such as the attentional blink, useful field of view, and the MOT (Green & Bavelier, 2003; 2006; Feng et al., 2007). A difference between action video games and the recently popular brain- and visual-training programs is the use of complex parallel processing. Action video games simultaneously employ visual attention tasks (e.g., multiple object tracking, ignoring distracters), visoumotor tasks (e.g., steering, maneuvering), rapid object identification (e.g., recognizing an enemy), and memory tasks (e.g., spatial memory for the location of an enemy and/or weapon, remembering a sequence of events required to achieve an outcome) and executive tasks (e.g., switching between several tasks) (Green & Bavelier, 2008). Conversly, most brain-training programs use block training where cognitive functions are trained separately. Block training may lead to fast acquisition; however, researchers have shown it does not lead to strong retention or transfer to other tasks (Schmidt & Bjork, 1992).

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Appendix A

Pre-Screen Questionnaire

Title of Research Project: The effect of aerobic fitness on visuospatial attention in young adults

The following questions will help determine if you meet the criteria for inclusion into this study. It is important that you answer each question accurately. Please indicate your response to each question by circling Yes or No.

1. Are you between the ages of 18 and 29 years old? Yes No
2. Do you have normal to corrected vision? Yes No
3. Do you have a neurological or psychological disorder? Yes No
4. Do you have a hearing deficit? Yes No
5. Have you suffered a lower extremity or spinal injury in the last 6 months? Yes No
6. Do you play action video games more than 4 hours a week? Yes No

If you answered YES to questions 1-2 **AND** you answered NO to questions 3-6, you are eligible to participate in this study!

Appendix B

<u>IRBManager Protocol Form</u>

Instructions: Each Section must be completed unless directed otherwise. Incomplete forms will delay the IRB review process and may be returned to you. Enter your information in the **colored boxes** or place an **"X"** in front of the appropriate response(s). If the question does not apply, write **"N/A."**

SECTION A: Title

A1. Full Study Title: The Effect of Aerobic Fitness on Visuospatial Attention in Young Adults

SECTION B: Study Duration

B1. What is the expected start date? *Data collection, screening, recruitment, enrollment, or consenting activities may not begin until IRB approval has been granted. Format: 07/05/2011*

03/01/2012

B2. What is the expected end date? *Expected end date should take into account data analysis, queries, and paper write-up. Format: 07/05/2014*

12/30/2014

SECTION C: Summary

C1. Write a brief descriptive summary of this study in Layman Terms (non-technical language):

The purpose of this study is to learn more about the relationship between physical fitness and visual attention. Specifically, the goal is to determine the extent to which aerobic fitness associated with elite sport performance affects performance on visual attention tasks.

This research is being done because we know that expert athletes outperform novices and non-athletes at tasks of perception, memory, and attention, but we do not know if fitness plays a part, because these studies did not control for physical fitness. Additionally, researchers have not previously controlled for video game playing. Research shows that video game playing enhances attention skills. Therefore, the present study will control for these two factors (physical fitness and video game playing) when comparing visual attention abilities of elite athletes and non-athletes.

This study will be conducted at UW-Milwaukee. The visual attention tasks will be done in the Visuomotor Lab, and the physical fitness test will be done in the Human Performance and Sport Physiology Lab. Approximately 25 elite athletes and 25 non-athletes will participate in this study. This study will take approximately 1.5-2 hours for each participant.

C2. Describe the purpose/objective and the significance of the research:

The purpose of this study is to determine the extent to which aerobic fitness in young adults is related to performance on visuospatial attention tasks. This study will fill the gaps in the existing literature on sport expertise and cognition. These studies have not controlled for aerobic fitness level or other confounding influences (e.g., video game playing).

C3. Cite any relevant literature pertaining to the proposed research

Castiello, U., & Umilta, C. (1992). Orienting of Attention in Volleyball Players. *International Journal of Sport Psychology, 23*(4), 301-310.

Colcombe, S., & Kramer, A. F. (2003). Fitness effects on the cognitive function of older adults: A meta-analytic study. *Psychological Science, 14*(2), 125-130.

Green, C. S., & Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature, 423*(6939), 534-537.

Kramer, A. F. (1999). Ageing, fitness and neurocognitive function (vol 400, pg 418, 1999). *Nature, 402*(6763), 750-750.

Shay, K. A., & Roth, D. L. (1992). Association between Aerobic Fitness and Visuospatial Performance in Healthy Older Adults. *Psychology and Aging, 7*(1), 15-24.

Sibley, B. A., & Etnier, J. L. (2003). The relationship between physical activity and cognition in children: A meta-analysis. *Pediatric Exercise Science, 15*(3), 243-256.

SECTION D: Subject Population
Section Notes… • D1. If this study involves analysis of de-identified data only (i.e., no human subject interaction), IRB submission/review may not be necessary. Visit the Pre-Submission section in the IRB website for more information.

D1. Identify any population(s) that you will be specifically targeting for the study. Check all that apply: (Place an "X" in the column next to the name of the special population.)

	Not Applicable (e.g., de-identified datasets)		Institutionalized/ Nursing home residents recruited in the nursing home
X	UWM Students of PI or study staff		Diagnosable Psychological Disorder/Psychiatrically impaired
	Non-UWM students to be recruited in their educational setting, i.e. in class or at school		Decisionally/Cognitively Impaired
	UWM Staff or Faculty		Economically/Educationally Disadvantaged
	Pregnant Women/Neonates		Prisoners
	Minors under 18 and ARE NOT wards of the State		Non-English Speaking
	Minors under 18 and ARE wards of the State		Terminally ill
X	Other (Please identify): Elite athletes recruited from local running, cycling, swimming, and skating clubs; UWM		

	students recruited from various social clubs/organizations; non-UWM students recruited from local social clubs/organizations

D2. Describe the subject group and enter the total number to be enrolled for each group. For example: teachers-50, students-200, parents-25, parent's children-25, student control-30, student experimental-30, medical charts-500, dataset of 1500, etc. Enter the total number of subjects below.

Describe subject group:	**Number:**
UWM students and non-students between the ages of 18-29 who do not play action video games more than 4 hours a week.	25
Elite athletes between the ages of 18-29 presently engaged in competitive closed skill sports (swimming, running, cycling, skating). These athletes will not play action video games more than 4 hours a week.	25
TOTAL # OF SUBJECTS:	50
TOTAL # OF SUBJECTS (If UWM is a collaborating site):	50

D3. List any major inclusion and exclusion criteria (e.g., age, gender, health status/condition, ethnicity, location, English speaking, etc.) and state the justification for the inclusion and exclusion:

Inclusion criteria: between age18 to 29 years old, healthy & free from injury in past 6 months as indicated by all negative responses on the modified PARQ form, normal to corrected-to-normal vision, free from neurological/psychological disorders, free from a hearing deficit.

Exclusion criteria: plays action video games more than 4 hours a week

SECTION E: Informed Consent
Section Notes… • E1. Make sure to attach any recruitment materials for IRB approval. • E3. The privacy of the participants must be maintained throughout the consent process.

E1. Describe how the subjects will be recruited. (E.g., through flyers, beginning announcement for X class, referrals, random telephone sampling, etc.). If this study involves secondary analysis of data/charts/specimens only, provide information on the source of the data, whether the data is publicly available and whether the data contains direct or indirect identifiers.

Announcements will be made in various UWM classes. Emails will be sent to local running, skating, swimming, and cycling clubs. Flyers will be placed in UWM dorms, and announcements will be made to various social clubs/organizations at UWM.

E2. Describe the forms that will be used for each subject group (e.g., short version, combined parent/child consent form, child assent form, verbal script, information sheet): If data from failed eligibility screenings will be used as part of your "research data", then these individuals **are** considered research subjects and consent will need to be obtained. Copies of all forms should be attached for approval. If requesting to waive documentation (not collecting subject's signature) or to waive consent all together, state so and complete the "Waiver to Obtain-Document-Alter Consent" and attach:

The standard adult consent form will be used for this study.

E3. Describe who will obtain consent and where and when consent will be obtained. When appropriate (for higher risk and complex study activities), a process should be mentioned to assure that participants understand the information. For example, in addition to the signed consent form, describing the study procedures verbally or visually**:**

Each participant who has completed the pre-screen questionnaire, and PARQ, and satisfies the inclusion and exclusion criteria will be fully informed of the study and will fill out an informed consent form upon arriving at the Visuomotor Lab at UWM.

SECTION F: Data Collection and Design
Section Notes… • F1. Reminder, all data collection instruments should be attached for IRB review. • F1. The IRB welcomes the use of flowcharts and tables in the consent form for complex/ multiple study activities.

F1. In the table below, chronologically describe all study activities where human subjects are involved.

- In **column A**, give the activity a short name. E.g., Obtaining Dataset, Records Review, Recruiting, Consenting, Screening, Interview, Online Survey, Lab Visit 1, 4 Week Follow-Up, Debriefing, etc.
- In **column B**, describe in greater detail the activities (surveys, audiotaped interviews, tasks, etc.) research participants will be engaged in. Address where, how long, and when each activity takes place.
- In **column C,** describe any possible risks (e.g., physical, psychological, social, economic, legal, etc.) the subject may ***reasonably*** encounter. Describe the **safeguards** that will be put into place to minimize possible risks (e.g., interviews are in a private location, data is anonymous, assigning pseudonyms, where data is stored, coded data, etc.) and what happens if the participant gets hurt or upset (e.g., referred to Norris Health Center, PI will stop the interview and assess, given referral, etc.).

A. Activity Name:	**B. Activity Description:**	**C. Activity Risks and Safeguards:**
Screening	Potential participants will be electronically sent a pre-screen questionnaire, and a modified Physical Activity Readiness Questionnaire to ensure that participants meet the inclusion criteria for this study. Potential participants will be instructed to notify the investigator if inclusion criteria are met. These forms will take approximately 5 minutes to complete.	There are no risks in filling out these questionnaires.

Fill out questionnaire	Qualified participants will also be asked to fill out a modified Task and Ego Orientation in Sport Questionnaire in the Visuomotor Lab. This will tell us about their motivation. This form will take approximately 5 minutes to complete.	There are no risks in filling out this questionnaire.
Visuospatial attention tasks	The participants will be asked to perform two visual attention tasks in the Visuomotor Lab, room 359 in the Pavilion on the UWM campus. For both tasks the participant will be looking at a large computer screen while we monitor eye position. These tasks will provide information on visual attention abilities. Each task will take 20-30 minutes and will be counterbalanced. Multiple Object Tracking: Participants will be asked to track 4 of 12 randomly moving dots for periods of ten seconds while staring at a fixed point in the middle of the screen. After each trial, they will be asked to indicate if one of the dots was or was not one of the dots being tracked that trial.	The risks for the visual attention tasks are minimal. The participant may become fatigued from staring at the screen, but an opportunity will be given to rest between these tasks. The risk is no greater than spending time on the computer.

	Covert Visuospatial Attention Task: Participants will be asked to stare at a letter stream in the middle of the screen. When cue letters are shown, the participant will be asked to shift attention to a different set of letters towards the edge of the screen. Once the letter "X" is shown, the participant will click the computer mouse and return attention to the center letter stream.	
YMCA submaximal ergometer test	Participants will be asked to perform a submaximal bicycle test in the Human Performance and Sport Physiology Lab, room 365 in the Pavilion on the UWM campus. This involves pedaling at a constant rate (50 rpm) with a gradually increasing workload and while wearing a heart rate monitor. This activity will last about 20-30 minutes. We will determine the workload based on the participant's heart rate. The participant will not be asked to exert maximal effort.	The potential risks for participating in the submaximal fitness test are minimal as the participant will never be asked to exert maximal effort. The duration and intensity of this test minimize the risk for injury, but the participant may experience some physical fatigue or soreness. Should the participant become fatigued or injured, testing will stop immediately and the participant will be referred to the Norris Health Center.

F2. Explain how the privacy and confidentiality of the participants' data will be maintained after study closure:

> The participant's name will not appear anywhere. Instead, each participant will be given a subject code. The questionnaires will be stored in a locked cabinet in the faculty advisor's office (Pavilion 361), and electronic data will be stored on a password-protected computer. Data will be securely stored for ten years for future use.

F3. Explain how the data will be analyzed or studied (i.e. quantitatively or qualitatively) and how the data will be reported (i.e. aggregated, anonymously, pseudonyms for participants, etc.):

> The de-identified data will be quantitatively analyzed. The data will be reported in aggregated form with no identifying of the participants.

SECTION G: Benefits and Risk/Benefit Analysis
Section Notes… • Do not include Incentives/ Compensations in this section.

G1. Describe any benefits to the individual participants. If there are no anticipated benefits to the subject directly, state so. Describe potential benefits to society (i.e., further knowledge to the area of study) or a specific group of individuals (i.e., teachers, foster children). Describe the ratio of risks to benefits.

> There are no direct benefits to the participants. This study will add to the literature regarding the effect of exercise on cognitive functions.

G2. Risks to research participants should be justified by the anticipated benefits to the participants or society. Provide your assessment of how the anticipated risks to participants and steps taken to minimize these risks, balance against anticipated benefits to the individual or to society.

Because there are minimal risks to participating in this study, the anticipated benefits outweigh the risks.

SECTION H: Subject Incentives/ Compensations
Section Notes… • H2 & H3. The IRB recognizes the potential for undue influence and coercion when extra credit is offered. The UWM IRB, as also recommended by OHRP and APA Code of Ethics, agrees when extra credit is offered or required, prospective subjects should be given the choice of an equitable alternative. In instances where the researcher does not know whether extra credit will be accepted and its worth, such information should be conveyed to the subject in the recruitment materials and the consent form. For example, "The awarding of extra credit and its amount is dependent upon your instructor. Please contact your instructor before participating if you have any questions. If extra credit is awarded and you choose to not participate, the instructor will offer an equitable alternative." • H4. If you intend to submit to the Travel Management Office for reimbursement purposes make sure you understand what each level of payment confidentiality means **(click here for additional information).**

H1. Does this study involve incentives or compensation to the subjects? For example cash, class extra credit, gift cards, or items.

[__] **Yes**

[_X_] **No [SKIP THIS SECTION]**

H2. Explain what (a) the item is, (b) the amount or approximate value of the item, and (c) when it will be given. For extra credit, state the number of credit hours and/or points. (e.g., $5 after completing each survey, subject will receive [item] even if they do not complete the procedure, extra credit will be award at the end of the semester)**:**

N/A

H3. If extra credit is offered as compensation/incentive, an alternative activity (which can be another research study or class assignment) should be offered. The alternative activity (either class assignment or another research study) should be similar in the amount of time involved to complete and worth the same extra credit.

N/A

H4. If cash or gift cards, select the appropriate confidentiality level for payments (see section notes):

[___] **Level 1** indicates that confidentiality of the subjects is not a serious issue, e.g., providing a social security number or other identifying information for payment would not pose a serious risk to subjects.

- Choosing a Level 1 requires the researcher to maintain a record of the following: The payee's name, address, and social security number and the amount paid.
- When Level 1 is selected, a formal notice is not issued by the IRB and the Travel Management Office assumes Level 1.
- Level 1 payment information will be retained in the extramural account folder at UWM/Research Services and attached to the voucher in Accounts Payable. These are public documents, potentially open to public review.

[__] **Level 2** indicates that confidentiality is an issue, but is not paramount to the study, e.g., the participant will be involved in a study researching sensitive, yet not illegal issues.

- Choosing a Level 2 requires the researcher to maintain a record of the following: A list of names, social security numbers, home addresses and amounts paid.
- When Level 2 is selected, a formal notice will be issued by the IRB.
- Level 2 payment information, including the names, are attached to the PIR and become part of the voucher in Accounts Payable. The records retained by Accounts Payable are not considered public record.

[__] **Level 3** indicates that confidentiality of the subjects must be guaranteed. In this category, identifying information such as a social security number would put a subject at increased risk.

- Choosing a Level 3 requires the researcher to maintain a record of the following: research subject's name and corresponding coded identification. This will be the only record of payee names, and it will stay in the control of the PI.
- Payments are made to the research subjects by either personal check or cash.
- Gift cards are considered cash.
- If a cash payment is made, the PI must obtain signed receipts.

SECTION I: Deception/ Incomplete Disclosure (INSERT "NA" IF NOT APPLICABLE)
Section Notes… • If you cannot adequately state the true purpose of the study to the subject in the informed consent, deception/ incomplete disclosure is involved.

I1. Describe (a) what information will be withheld from the subject (b) why such deception/ incomplete disclosure is necessary, and (c) when the subjects will be debriefed about the deception/ incomplete disclosure.

N/A

IMPORTANT – Make sure all sections are complete and attach this document to your IRBManager web submission in the Attachment Page (Y1).

UNIVERSITY OF WISCONSIN – MILWAUKEE
CONSENT TO PARTICIPATE IN RESEARCH
PARTICIPANT CONSENT FORM

THIS CONSENT FORM HAS BEEN APPROVED BY THE IRB FOR A ONE YEAR PERIOD

1. General Information

Study title: The Effect of Aerobic Fitness on Visuospatial Attention in Young Adults
Person in Charge of Study (Principal Investigator):

Wendy Huddleston, PhD
Assistant Professor, Department of Kinesiology
College of Health Sciences

2. Study Description

You are being asked to participate in a research study. Your participation is completely voluntary. You do not have to participate if you do not want to.

Study description:
The purpose of this study is to learn more about the relationship between physical fitness and visual attention. Specifically, the goal is to determine the extent to which aerobic fitness associated with elite sport performance affects performance on visual attention tasks.

This research is being done because we know that expert athletes outperform novices and non-athletes at tasks of perception, memory, and attention, but we do not know if fitness plays a part, because these studies did not control for physical fitness. Additionally, researchers have not previously controlled for video game playing. Research shows that video game playing enhances attention skills. Therefore, the present study will control for these two factors (physical fitness and video game playing) when comparing visual attention abilities of elite athletes and non-athletes.

This study will be conducted at UW-Milwaukee. The visual attention tasks will be done in the Visuomotor Lab, and the physical fitness test will be done in the Human Performance and Sport Physiology Lab. Approximately 25 elite athletes and 25 non-athletes will participate in this study. Your participation in the study today will take about 1.5-2 hours.

3. Study Procedures

What will I be asked to do if I participate in the study?
If you agree to participate you will be asked to meet with me in the Visuomotor Lab, room 359 in the Pavilion, on the UWM campus. You will then take part in several activities that will help us learn how exercise affects visual attention. This meeting will last approximately 1.5-2 hours and will consist of:

1.) **Filling out questionnaires:** You will be asked to fill out a modified Physical Activity Readiness Questionnaire to make sure it is safe for you to participate in physical fitness testing. You will also be asked to fill out a modified Task and Ego Orientation in Sport Questionnaire. This will tell us about your motivation. These forms will take approximately 5 minutes to fill out.
2.) **Performing visual attention tasks:** You will perform two visual attention tasks. For both tasks you will be looking at a large computer screen while we monitor your eye position. These tasks will provide information on your visual attention abilities. Each task will take 20-30 minutes and will not necessarily be in the order listed.
    a. Multiple Object Tracking: You will be asked to track 4 of 12 randomly moving dots for periods of ten seconds while staring at a fixed point in the middle of the screen. After each trial, you will be asked to indicate if one of the dots was or was not one of the dots being tracked that trial.
    b. Covert Visuospatial Attention Task: You will stare at some letters changing in the middle of the screen. When some letters are shown, you will be asked to shift your attention to a different set of letters towards the edge of the screen. Once the letter 'X' is shown, you will click the computer mouse and return your attention to the center letter stream.
3.) **Physical Fitness Test:** Lastly, you will be asked to perform a submaximal bicycle test in the Human Performance and Sport Physiology Lab, room 365 in the Pavilion on the UWM campus. This involves pedaling at a constant rate with a gradually increasing workload and while wearing a heart rate monitor. This activity will last about 20-30 minutes. We will determine how hard you will have to pedal depending on your heartrate. You will never be asked to bicycle as hard as you can.

4. Risks and Minimizing Risks

What risks will I face by participating in this study?

The potential risks for participating in this study are minimal. Your eyes may become fatigued from staring at the screen during visual attention tasks, but you will be allowed an opportunity to rest your eyes between these tasks. This risk is no greater than spending time on your computer. Risks in performing the submaximal bicycle test are minimal as you will never exercise as hard as you can, but you may experience some physical fatigue.

5. Benefits

Will I receive any benefit from my participation in this study?
There are no benefits to you other than to further research.

6. Study Costs and Compensation

Will I be charged anything for participating in this study?
You will not be responsible for any of the costs from taking part in this research study.
Are subjects paid or given anything for being in the study?
You will not be compensated for taking part in this research study.

7. Confidentiality

What happens to the information collected?
All information collected about you during the course of this study will be kept confidential to the extent permitted by law. We may decide to present what we find to others, or publish our results in scientific journals or at scientific conferences. Information that identifies you personally will not be released without your written permission. Only the PI and her faculty advisor will have access to the information. However, the Institutional Review Board at UW-Milwaukee or appropriate federal agencies like the Office for Human Research Protections may review this study's records.

Your name will not appear anywhere. Instead, you will be given a subject code.

The questionnaires will be stored in a locked room, and data will be stored on a password-protected computer.

The data will be stored in a locked file cabinet for ten years for future use.

8. Alternatives

Are there alternatives to participating in the study?

There are no alternatives available to you other than not taking part in this study.

9. Voluntary Participation and Withdrawal

What happens if I decide not to be in this study?
Your participation in this study is entirely voluntary. You may choose not to take part in this study. If you decide to take part, you can change your mind later and withdraw from the study. You are free to not answer any questions or withdraw at any time. Your decision will not change any present or future relationships with the University of Wisconsin Milwaukee. The investigator may stop your participation in this study if she feels it is necessary to do so.

If you decide to withdraw or if you are withdrawn from the study before it ends, we will use the data we have collected up to that time. Refusal to take part in the study will not affect any grade or class standing.

10. Questions

Who do I contact for questions about this study?
For more information about the study or the study procedures or treatments, or to withdraw from the study, contact:

Wendy Huddleston, PhD
University of Wisconsin-Milwaukee
PT-PAV 351
P.O. BOX 413
Milwaukee, WI 53201
414-229-3368
huddlest@uwm.edu

Who do I contact for questions about my rights or complaints towards my treatment as a research subject?
The Institutional Review Board may ask your name, but all complaints are kept in confidence.

Institutional Review Board
Human Research Protection Program
Department of University Safety and Assurances
University of Wisconsin – Milwaukee
P.O. Box 413
Milwaukee, WI 53201
(414) 229-3173

11. Signatures

Research Subject's Consent to Participate in Research:
To voluntarily agree to take part in this study, you must sign on the line below. If you choose to take part in this study, you may withdraw at any time. You are not giving up any of your legal rights by signing this form. Your signature below indicates that you have read or had read to you this entire consent form, including the risks and benefits, and have had all of your questions answered, and that you are 18 years of age or older.

____

Printed Name of Subject/ Legally Authorized Representative

____ ______________________

Signature of Subject/Legally Authorized Representative Date

Principal Investigator (or Designee)
I have given this research subject information on the study that is accurate and sufficient for the subject to fully understand the nature, risks and benefits of the study.

____ ______________________

Printed Name of Person Obtaining Consent Study Role

____ ______________________

Signature of Person Obtaining Consent Date

Appendix C

Physical Activity Readiness Questionnaire

Title of Research Project: The effect of aerobic fitness on visuospatial attention in young adults

The following questions will help determine if you meet the criteria for inclusion into the study. It is important that you accurately answer each question.

Please answer the following questions with a YES or NO response.	**YES**	**NO**
1. Has a physician or any other health care provider ever told you to NOT exercise?		
2. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?		
3. Do you feel pain in your chest when you do physical activity?		
4. Do you know of any reason why you should not do physical activity?		
5. Do currently take any prescribed medications for treatment of a symptomatic illness or condition?		
6. Do you currently have OR have a history of a blood clot disorder?		
7. Do you have any bone, joint, or muscle abnormalities (ie. arthritis, muscle pain)?		
8. Do you have any symptomatic ankle, knee, or hip trauma requiring medical attention within the last year?		
9. Do you lose your balance because of dizziness or do you ever lose consciousness?		

Appendix D

Modified Task and Ego Orientation in Sport Questionnaire
(original developed by Joan Duda and John Nicholls)

Directions: Please read each of the statements listed below and indicate how much you personally agree with each statement by circling the appropriate response.

Think of an activity that you enjoy doing and write it on the line below. When do you feel most successful in this activity?
In other words, when do you feel this activity has gone really well for you?

I feel most successful in _____________ when….

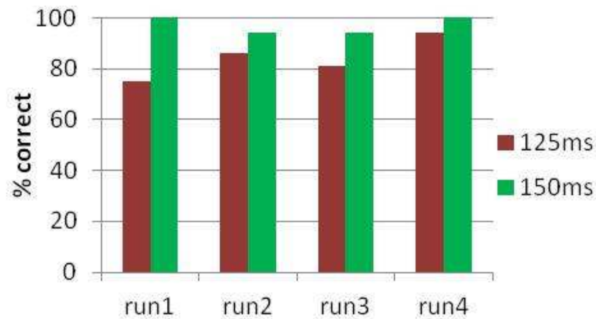
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. I'm the only one who can do the activity or skill.	1	2	3	4	5
2. I learn a new skill and it makes me want to practice more.	1	2	3	4	5
3. I can do better than my friends.	1	2	3	4	5
4. The others can't do as well as me.	1	2	3	4	5
5. I learn something that is fun to do.	1	2	3	4	5
6. Others mess up and I don't.	1	2	3	4	5
7. I learn a new skill by trying hard.	1	2	3	4	5
8. I work really hard.	1	2	3	4	5
9. I get the most compliments.	1	2	3	4	5
10. Something I learn makes me want to practice more.	1	2	3	4	5
11. I'm the best.	1	2	3	4	5
12. A skill I learn really feels right.	1	2	3	4	5
13. I do my very best.	1	2	3	4	5

Appendix E

CVAT pilot data

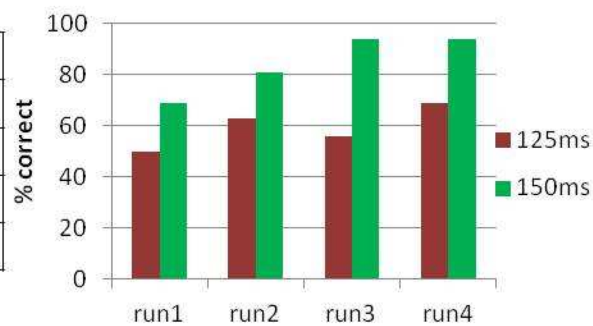
111212A

	125ms	150ms
run1	75	100
run2	86	94
run3	81	94
run4	94	100



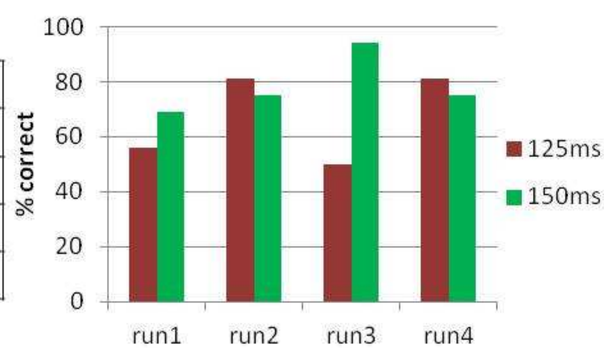
111213A

	125ms	150ms
run1	50	69
run2	63	81
run3	56	94
run4	69	94



111213B

	125ms	150ms
run1	56	69
run2	81	75
run3	50	94
run4	81	75



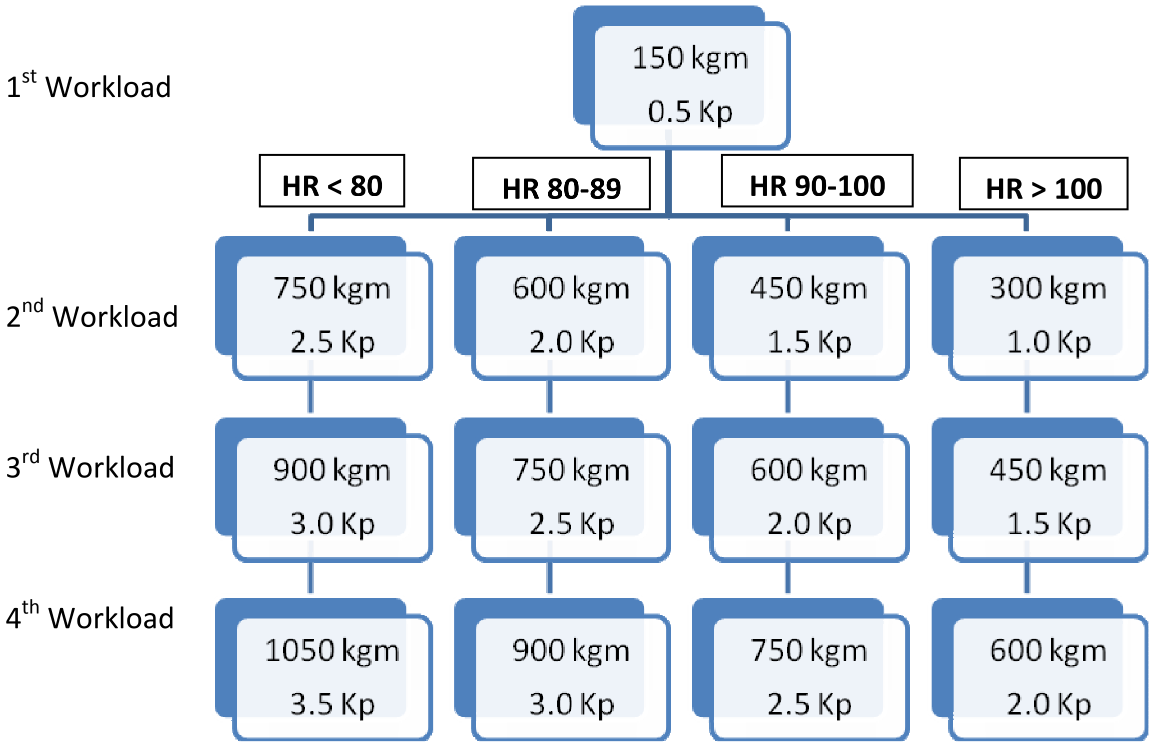
To determine the letter presentation duration of the Covert Visuospatial Attention Task, pilot data were collected. Three participants volunteered to perform four runs of the CVAT in the Visuomotor Lab. Data from each participant are shown above in both tabular and graphic formats. Participant 111212A was familiar with the task. The other two participants were naïve observers. Each participant was allowed to practice with each speed until 75% of the cue letters in the central letter stream were reported. The speed setting was counterbalanced such that participants 111212A and 111213B performed the CVAT at 150 ms first, and participant 111213A performed at 125 ms first. All three participants performed the task on a laptop, and eye tracking data were not collected. Based on the results of these three participants, the 125 ms speed, which corresponds to 8 letters per second, was selected for the proposed study because it yielded a greater performance range (50 to 94% correct) among naïve and experienced participants.

Appendix F

YMCA Bicycle Ergometer Procedure

1. To familiarize the participant with the 50 rpm pedal rate, the metronome is started, and the participant is allowed to pedal with little or no resistance.
2. Set the first workload at 0.5 Kp (150 kg m/min) and start the stop watch.
3. Take heart rate readings near the end of the second and third minutes of the first stage. A steady-state heart rate must be reached before progressing to the next workload. If the difference between the second and third minute heart rate is greater than 5 bpm, the heart rate is not at a steady-state, and a fourth minute should be added.
4. The steady-state heart rate of the first stage will determine the workload of the second stage (see guide to setting workloads below).
5. Repeat the heart rate monitoring (step 3) for the second and subsequent stages.
6. Stop the test when two steady-state heart rates between 110-150 bpm have been recorded for two separate stages.
7. Reduce the resistance on the ergometer to 0.5-1.0 Kp and allow the participant to cool down (heart rate should drop below 100 bpm).
8. Perform the following calculations to determine the predicted $VO_{2max:}$
    a. HR_1 = HR at second-last workload (bpm)
    b. HR_1 = HR at last workload (bpm)
    c. Calculate the oxygen cost in mL/kg·min for second-last and last workloads
        i. VO_2 = (Workload (W)/body mass (kg))*10.8+7
        ii. SM_1 = VO_2 at second-last workload
        iii. SM_2 = VO_2 at last workload
    d. Slope (m) = $(SM_2 - SM_1)/(HR_2-HR_1)$
    e. $VO_{2max} = m * (HR_{max} – HR_2) + SM_2$

Guide to setting workloads



Source: Y's Way to Physical Fitness (1989, p. 91), by Golding, Myers, and Sinning.

Appendix G

VO_{2max} to Percentile Conversion

Males: Percentile = $- 1.62*10^{-6} x^6 + 4.46*10^{-4} (VO_{2max})^5 - 0.05 (VO_{2max})^4 + 2.95 (VO_{2max})^3 – 95.43 (VO_{2max})^2 + 1606.82 (VO_{2max}) – 11004.02$

Females: Percentile = $- 1.31*10^{-6} (VO_{2max})^6 + 3.12*10^{-4} (VO_{2max})^5 – 0.03 (VO_{2max})^4 + 1.53 (VO_{2max})^3 – 41.91 (VO_{2max})^2 + 590.13 (VO_{2max}) – 3351.54$