

The Use of a Hockey Specific Stimulus to  
Measure the Efficiency of the Attention Networks

by

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**Abstract**

Attention is an important component to successful participation in a variety of sports and activities. Attention can be thought of as three separate but functionally interrelated networks; Alerting, Orienting and Executive Control. The Attention Network Test (ANT) can be used to examine the efficiency of the three networks. Many real life situations such as sport and physical activity involve more complex stimuli. The purpose of this study is to examine the relationship between the scores on the three attention networks using arrow stimuli and using sport specific stimuli (i.e., an image of a hockey player with the stick indicating direction). Thirty-two participants completed two versions of the ANT; one with arrows as stimuli and one with hockey players inserted as the stimuli. As a control, participants were surveyed as to their previous experience in the game of hockey. There were significant orienting, alerting, and executive function for both versions of the ANT (i.e., arrows and hockey stimuli). The only significant difference between the two versions of the test was found with executive function. When using hockey player stimuli, the estimate of executive function was less than that when using arrows. Overall, the results suggest that the use of real life stimuli can be used with the ANT.

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## CHAPTER ONE: INTRODUCTION

### Introduction

Attention is an important mental process required to initiate all cognitive functions. We use attention to process information originating from our sensory systems as well as information stored in memory (Posner & Petersen, 1990). For example, one must be able to attend to the letters printed in a book to be able to remember the story or attend to an object in order to locate that object in a cluttered array (e.g., finding a pen on a cluttered desk) and respond accordingly (Kastner, 2004). Attention is a key component to participation in many activities including the game of hockey. Hockey players use attention to process where their opponents are located, the location of the goal, and to retrieve motor programs necessary to complete all the complex actions involved in the game.

The different mechanisms of attention are needed to select relevant information and to filter out irrelevant information (Kastner, 2004). Being able to filter out irrelevant information is important in defining goals and initiating the appropriate motor program. Attention may be captured by certain features of a stimuli or a sudden onset of an event or it may also be controlled and moved toward a certain location or expected target. Attention can also be divided into three separate but functionally interrelated networks; alerting, orienting, and executive control (Fan, McCandliss, Flombaum, Thomas, & Posner, 2003; Posner & Petersen, 1990; Fan, McCandliss, Sommer, Raz, & Posner, 2002). The alerting network is responsible for maintaining arousal and being prepared, or vigilant, to an upcoming stimulus. The orienting network is responsible for the ability to quickly disengage, move and re-engage attention to a specific location. This task can be

accomplished overtly, without movement of the eyes or covertly, with movement. The executive control of attention network is responsible for the decision making processes between information that is relevant for a specific task and which information is irrelevant. Executive control helps initiate more complex cognitive functions such as memory, recognition and initiating a motor program (Giesbrecht et al., 2001).

The Posner Cueing Paradigm (1980) is a popular attention task requiring the subject to orient their attention between two locations when alerted to the possible stimulus location. The Attention Network Test (ANT) is a combination of the cued reaction time task (RT) (Posner, 1980) and the flanker task (Eriksen & Eriksen, 1974). The flanker task involves the presentation of central imperative stimuli with irrelevant stimuli located on either side of (or 'flank') the central stimuli. The 'flankers' are either congruent or incongruent with the central stimuli. This is an example of a choice reaction time task, where two choices of stimuli are presented and the participant responds by pressing a different key on a keyboard depending on the stimuli presented. The flanker task is simple and effective method in triggering separate brain networks that require conflict resolution. The ANT is a choice reaction time task designed to quantify the processing efficiency of the three attention networks in a single computerized task. The ANT requires participants to determine whether a central arrow points left or right by pressing the appropriate response key as quickly and accurately as possible. The ANT has been found to be adaptable and has been used in studies to assess attention in individuals with schizophrenia, Attention Deficit Hyperactivity Disorder (ADHD), and mild traumatic brain injuries (mTBIs) (Keightley et al., 2009; Kastner, 2004). In addition, new versions of the test have been developed to explore the attention networks in different populations.

For example, Rueda et al. (2004) used fish as the stimuli (i.e., children were to press the appropriate key to denote the direction that the fish would be ‘swimming’) to examine the development of the attention networks in children.

For the most part, previous work on attention and athletes, using various attentional cueing paradigms, has been restricted to examining athlete vs. non-athlete differences as well as differences between athletes in different sports (e.g., Nougier, Ripoll, & Stein 1989; Casteillo & Umilta 1992; Enns & Richards, 1997; Lum, Enns & Pratt, 2002; McAuliffe, 2004). Although the ANT has been used with athlete populations (see Keightley et al. 2009; Halterman et al. 2005) research has yet to be completed that examines the relationship between scores on the three networks in the ANT when using stimuli specific to the sport.

### **Purpose**

The purpose of this study is to examine the relationship between the scores on the three attention networks using arrow stimuli and using sport specific stimuli (i.e., an image of a hockey player with the stick indicating direction). As a control measure, the participants will be grouped according to hockey experience as repeated exposure (i.e., familiarity) to stimuli may have an effect on the results (Cycowicz & Friendman, 2006).

### **Hypotheses**

The present study aims to test the following hypotheses; first, we should find significant alerting, orienting, and executive functions for both versions of the ANT (i.e., arrows and hockey player stimuli) based on the difference between certain cue and target conditions. Secondly, the magnitude of the alerting, orienting, and executive functions will be similar for both versions of the ANT. Finally, as previous research has found a

difference in orienting of attention with hockey players, the hockey player group may show different, such as a smaller affects on the orienting network (Enns & Richards, 1997).

## CHAPTER TWO: REVIEW OF LITERATURE

Attention is the foundation for many cognitive processes in the human brain and this concept of attention has many facets. Attention has been studied for well over a century, from behaviourally to biologically. It is a broad term that subsumes a variety of cognitive mechanisms. It is the ability to select stimuli, responses, memories and thoughts that are behaviourally relevant among a host of others that are behaviourally irrelevant (Raz, 2004 & Kastner, 2004). It also relies on the brain's ability to integrate that information by perceiving and using it to think, memorize, recall, feel, plan and act in the world (Baars, 2007).

The following review examines some of the research on attention and the various tasks that have been used to measure it. A review of different populations, such as athletes, and how they have responded to similar attention tasks is highlighted.

### **Attention**

William James was a pioneer in attention research. In his *Principles of Psychology* he remarked: "Everyone knows what attention is. It is the taking possession of the mind in clear and vivid form, of one out of what seem several simultaneous possible objects or trains of thought... It implies withdrawal from some things in order to deal effectively with others" (James, 1890, pp. 403-404).

In the 1950s, Cherry and then Broadbent, whose contributions focused on auditory attention or dichotic listening, suggested that attention can be selective. From this, an early- vs. late selection of attention debate began and the *attentional bottleneck* theory arose (Broadbent, 1954). The early selection of attention implied that out of two different streams of information available, only one stream can be fully processed at any one time

and that information is lost if the other stream is attempted to be attended to, attention therefore, has a limited capacity. The late selection of attention implied that both streams are initially processed but one is thus regarded as more relevant and the other irrelevant and thus disregarded. Both theories are still being debated. Research in attentional capacity has been used to examine the efficiency of attention in occupations that require high attentional demands. Occupations such as bus drivers and air traffic controllers are constantly switching between different stimuli within their environment and require high attentional capacities (Nougier, Stein & Bonnel, 1991).

In visual, just as in auditory attention, the target or distractor stimuli are not processed independently of each other. They compete for limited processing resources by means of competitive interaction. This competition between stimuli is resolved based on the saliency or abrupt capture an object can create in our visual field when suddenly presented (Chanon & Hopfinger, 2007). According to the *Feature-Integration* Theory (Treisman & Gelade, 1980) different types of attention bind different features of an object or stimulus (such as colour, shape, size or orientation, etc.) into a consciously experienced whole. This theory has been one of the most influential in the field of visual attention.

Models and metaphors were soon proposed to help explain how visual attention functions and how it moves across a visual field or field of view. Posner, Snyder & Davidson (1980) proposed the “spotlight model” of attention that described one’s focus of attention as having set parameters. The spotlight consisted of a focus, fringe and margin. The focus is the area in the centre of spotlight where information is extracted and processed at its greatest capacity. The fringe is an area of extracting and processing

information but more crudely and extended to a finite cut-off point, the margin. Information outside of the margin in the field of view would not be processed and thus have no bearing on the outcome of the decision making process.

An extension of this model was the “zoom-lens model” of attention. Studies by LaBerge (1983) and Eriksen & St. James (1986) suggested that the spotlight could be adjusted to the demands of the task at hand. They suggested the spotlight could be spread out over a larger area to accommodate the task but may not come without a cost. The larger the spotlight, the fewer resources for processing information there is and the greater for potential distracting information to impede an appropriate response.

Visual attention can be captured by intense or sudden stimuli, or unexpected events in general (Baars, 2007). Two neural processes underlie goal-directed behavior to our visual environment, *bottom-up processing* and *top-down modulation*. Bottom-up processing is the cognitive process and reaction to an external stimulus, while top-down modulation underlies our ability to selectively focus on relevant stimuli; establishing a foundation for the allocation of attention and memory (Gazzaley & D’Esposito, 2007). Bottom-up processing occurs first, as a reflexive mechanism as cognitive initiation to the attention process.

#### *Bottom-up Processing*

Bottom-up processing draws attention automatically in a reflexive manner. It is done by means of an exogeneous, location-specific cue or stimulus-driven mechanism (Kastner, 2004). It cannot be suppressed, nor can we consciously or intentionally control it. It alerts us to an upcoming event and orients our attention to the location, such as a flash of light or a loud noise (Baars, 2007).

Bottom-up processing is externally driven by a synaptic threshold of neural activity in the sensory and parietal regions of the brain based on the novelty or saliency of the stimulus (Baars, 2007).

#### *Top-down modulation*

Top-down modulation is our voluntary control of attention. This mechanism is involved in controlling where we allocate attention within our environment. It is internally driven to a goal-directed decision and is responsible for activating our higher-order processes of cognition including the decision making processes of executive control, working memory, and long term memory (Gazzaley & D'Esposito, 2007 & Giesbrecht, Kingstone, Handy, Hopfinger & Mangun, 2001). Top down modulation allows us to use information to quickly formulate an appropriate response to a situation. For example, in sports, the location, speed, and movement patterns of both opponents and teammates must be processed and responded to continuously however; prior knowledge and experience can aid us greatly in the process. Moscovitch, Chein, Talmi & Cohn (2007) established connective measures to predict cognitive performance related to top-down modulation and long-term memory (Gazzaley & D'Esposito, 2007). Top-down processing of this kind can speed up the analysis of the retinal image when a familiar scene or object is encountered and can help fill in, or complete, details that are missing in the optic array (Zhang & Srinivasan, 2004).

#### **Attention Networks**

Visual processing may be affected by visual attention in several ways. One way is by facilitating neural processing in the brain which enhances neural responses to attended stimuli by filtering out unwanted information. It may also bias neural signals in favour of

an attended location or stimulus by increasing baseline activity in the absence of visual input (Kastner, 2004). Visual attention is generated from a distributed network of areas in the frontal and parietal cortex and is transmitted via feedback projections to the visual cortex (Raz, 2004). Current research has examined selective visual attention as an organ system, with its own functional anatomy, circuitry, cellular structure and specific neurotransmitters that modulates neural activity in visual cortex in the presence of visual stimulation (Posner & Fan, 2002; Baars, 2007). These neural activities are measured more precisely by the use of technology. Positron Emission Tomography scans (PETs) are now commonly being used to identify specific structures and neurotransmitters in the brain associated with each network involved in the attention process (Posner & Petersen, 1990). This neural activity occurs in a variety of areas in the brain that help perform interrelated functions such as *(a)* maintaining a vigilant or alert state; *(b)* orienting to sensory events, and *(c)* detecting signals for conscious processing (Posner & Petersen, 1990), which allow us to efficiently examine our environment. These interrelated functions are network subsystems of attention.

Maintaining a vigilant or alert state is referred to as the alerting network, which is responsible for achieving and maintaining high sensitivity to incoming stimuli. The orienting network is involved in the allocation of attention to selecting information from sensory input (Posner & Petersen, 1990 & Fan, Posner et al., 2002). The executive control network is defined as the mechanism for resolving conflict or the decision making process between two choices in stimuli (Fossella et al., 2001).

These subsystems have been determined by the research of Posner and colleagues (Posner, 1980; Posner & Cohen, 1984 & Posner & Peterson, 1990) and have been found

in different brain areas and function independently of each other, but interact to perform a complete visual search. Posner and colleagues focused on the orienting and vigilance components of attention by using computerized tests with illuminating lights as different cue and target conditions. The executive control network has been studied using a variety of “flanker tasks”. These activities used multiple target types and conditions that activated conscious processing and decision making skills. Most recently Fan, Posner et al., (2002) created the Attention Network Test (ANT) that uses a choice reaction time, which is a combination of the Posner’s cueing paradigm and the flanker tests by Eriksen and colleagues (1974), to evaluate the alerting, orienting and executive control networks of attention. The main purpose of this study is to examine the use of a specific modified version of the ANT. This research could allow for adaptations of the test for different cohorts (further discussion on the ANT is provided on page 36).

### *Alerting*

An important function of attention is the ability to prepare and sustain alertness to process high priority signals (Posner & Petersen, 1990). Alerting involves a change in the internal state in preparation for perceiving a stimulus. This alert state is critical for optimal performance in tasks involving higher cognitive functions such as responding appropriately and discriminating between targets (Raz, 2004).

Chemically, the neurotransmitter norepinephrine (NE) produces these changes in arousal and vigilance (Raz, 2004). Functionally, the activation of NE works through the posterior attention system to increase the rate at which high priority visual information can be selected (Posner & Petersen, 1990). As well, the alerting network has been associated with frontal and parietal regions of the right hemisphere (Fan, McCandliss,

Sommer, Raz, & Posner, 2002). This was a significant finding when examining patients with lesions to the right parietal region. These lesions can be from a number of causes including sports injury.

Alerting also effects attention orientation by improving the effect of the visual cue on target responses (Fuentes & Campoy, 2008), which is the ability to quickly respond to a stimulus when given warning to an event. However, this more rapid selection often produces higher error rates (Posner & Petersen, 1990). This suggests that there is a strong interaction between visual orienting and alerting networks by being more prepared to move attention to an expected location (Posner & Badgaiyan, 1998).

### *Orienting*

The shift of attention, called the orienting response, is a fundamental biological mechanism. The term orienting means the aligning of attention with a source of sensory input or an internal semantic structure stored in memory (Posner, 1980). Orienting occurs (1) in response to an event that was never before encountered, and (2) to a familiar event that is unexpected within a given context (Cycowicz & Friedman, 2007).

When stimulus input controls the shift of attention towards an internal structure it has been found that benefits occur before costs (Posner, 1980). This refers to the interaction between the alerting and orienting networks. When alerted to an upcoming stimulus, one would be more prepared to respond and would benefit from this state. However, responding incorrectly or a delay in the response when the target is presented at an unexpected location would be considered the cost.

Posner (1980) determined that responses to clear luminance would occur more quickly when subjects knew where the stimulus would occur. This is often referred to as

the “cuing effect”, in which the onset of the stimulus will draw our attention to that location. He used differences in reaction time to a stimulus at expected and unexpected positions in the visual field to measure the efficiency of detection due to turning attention towards an expected position. A fixation point, in computerized attention tasks, is the location in which attention is directed at the beginning of the test. Reaction time to a cued location nearer the fixation point is generally faster than farther away from fixation point, when separated by short stimulus onset asynchrony (SOA). SOA is the difference in time between the initial cueing signal and the target event. Their research also examined the response time when oriented to a valid trial (cue and target appearing in the same location), or invalid trials (cue and target appearing in different locations).

The orienting network of attention is responsible for drawing the attention of the participant to a specific location overtly, without eye movement, or covertly, with eye movement. Anatomically, the orienting system relies on the Superior Parietal Lobe, Temporo-Parietal Junction (Raz, 2004), and the frontal eye fields (Fan et al., 2005). Posner and Petersen (1990) suggest these areas perform separate but interrelated functions to complete the task of orienting. Patients with brain lesions have difficulty either disengaging, moving or re-engaging attention depending on what area is affected. The effect of orienting, in computerized attention tasks, can be examined and manipulated by presenting a cue indicating where in space a person should attend and varying the location and SOA to the target. This could have implications on properly scanning the environment and could be detrimental in a fast-paced game of hockey.

### *Executive Control*

The executive control network is responsible in more complex operations resolving conflict among stimuli, and is more active when the task involves complex discrimination or when the number of targets is increased within the visual field (Posner & Badgaiyan, 1998). Discriminating fine details or searching a crowded room or hockey rink requires an increase of the executive control function. The 'spotlight' theory of attention (discussed earlier) suggests that focusing attention on an area in the visual field sensitizes a circular area of about 1° of visual angle around the target (Posner, 1980). Pan & Eriksen (1993) found attention to be more elliptical in shape where information within the attention area was more rapidly processed than that in the periphery. This elliptical area is oriented horizontally as humans developed search strategies scanning their environment.

The research of Eriksen and Eriksen (1974) compared response time to stimuli based on the location and response-competition to irrelevant distracters or "flankers". The basic method is to present a fixation point to the subject, and then to present the target, along with stimuli that 'flank' the target. Their research varied the size of the attended area by varying the separation of the distractor stimuli. Their results showed a decrease in reaction time (RT) by increasing the spacing of distractors within the visual field. Therefore, as distractors were moved further apart it became easier to respond to the proper target. This experiment demonstrated that as the distractors moved outside a certain visual field they were no longer processed in parallel with the target. Pan & Eriksen (1993) examined the extent to which information in the visual field is selected and available for detailed processing. The selection of stimuli within our visual field during conflicting processes is based on colour, size, orientation, shape, or velocity of an

object which enhances activity in regions of the visual cortex (Corbetta et al., 1991). The flanker task is simple and effective in triggering separate brain networks, and is very adaptable (Kastner, 2004). Adaptations of the test allow us to explore how the brain pays attention to different events (Posner & Petersen, 1990).

### **Athletes & Attention**

Ice hockey is recognized as Canada's national sport, with over 500,000 youth registered in a minor hockey league each year (Hagel, Marko, Dryen, et al., 2006). Hockey is the activity of choice for over 2 million, and an estimated 4.5 million Canadians are involved in hockey as coaches, players, officials, administrators or direct volunteers (Hockey Canada Annual Report, 2008). These individuals are exposure to hockey and various stimulus several times a week over the course of a season. Additionally, over 150,000 people attended Hockey Canada's national team events and National Championships during the 2007-08 season with millions more watching at least one professional game televised each week. This hockey culture has allowed for a lot of visual exposure to the sport, resulting in visual representation and memories to form in both fans and players alike.

In all sports, including hockey, changes in the environment occur frequently and search strategies are adjusted to match the probabilities of occurrence. These probabilities can be based on the location of objects within the environment, such as location and direction of defending players that can be incorporated into search strategies. Nougier, Ripoll, and Stein (1989) and Casteillo and Umilta (1992) used informative central cues and found smaller cuing effects for athletes (volleyball, players, boxers, fencers and pentathletes) than they did for non-athletes. The results from both studies showed that

athletes had approximately the same RTs on valid trials, but had much faster RTs on invalid trials. Nougier et al. (1989) suggested this pattern of results was due to athletes adopting an optimized strategy in which they did not commit as many attentional resources to the cue and expanded their attention over a greater area. Contrary, Casteillo and Umilta (1992) concluded athletes were able to more rapidly allocate attention to invalidly cued targets, by quickly moving their attention from one location to another.

The ability to efficiently allocate attention is an important determinant of success in sport (McAuliffe, 2004). This would be especially true for athletes who compete at higher skill levels, as limited team positions tend to favour those athletes with the best physical and mental abilities suited to the sport. McAuliffe (2004) has suggested that athletes and non-athletes differ in the manner in which they allocate attention. The study examined attentional capture in volleyball players. The participants performed a discrimination task in which they determined whether a target object is a plus sign (+) or an equal sign (=). The results found greater cuing effects for athletes when the cues matched the targets. It was concluded that athletes must be able to process changes more rapidly from the visual information provided by their environment and are able to orient their attention more efficiently.

It is believed that hockey players are able to orient more efficiently than non-athletes. For instance, a skilled hockey forward may use information from the torso of a defenseman to decide whether to go around his opponent on the left or the right. Enns & Richards (1997) compared covert visual orienting in different age groups and skill levels of hockey players along with a control group in two types of cuing tasks. Their results support an association between hockey skill and several important aspects of visual

attention: efficient processing of abrupt stimulus events, sustained alertness, and efficient voluntary orienting. They concluded that high-skilled players were better able to diffuse their attention over a larger area in their visual field when responding to a stimulus.

Secondly, high-skill players tended to have smaller informational cue-orienting effects than low-skill players. The responses of high-skilled players were the fastest overall, and more importantly, their response time did not increase with longer cue-target intervals. This group thus showed the ability to sustain a high level of alertness over the longest SOA. Hockey players seem to have both a delayed onset of voluntary orienting and a smaller degree of commitment to a single target location (Enns & Richards, 1997). This has a number of interpretations, for example that hockey players are better at disengaging from one location to respond to another or they are better able to diffuse their attention over a larger area in their visual field when responding to a stimulus (Enns & Richards, 1997).

### **Memory and Recognition**

Semantic memories involve facts about the world, ourselves and the knowledge we share with the community (Moscovitch, Chein, Talmi & Cohn, 2007, p. 274). Visual working memory is the mechanism by which humans actively retain relevant information and ignore irrelevant visual information for a task (Olivers, Meijer & Theeuwes, 2006). There is a large overlap in the connection between attention and memory along with an overlap in brain areas involved in attention and working memory. Working memory is our short term ability to recall information within our environment, whereas the retrieval of long term memory is not as well understood but can be defined as a lasting representation that is reflected in thought, experience or behaviour (Moscovitch, Chein,

Talmi & Cohn, 2007). There is a great deal of evidence suggesting that memory is stored in the same areas that support active moment-to-moment brain functions

Recognition is the feeling that someone or something present has been encountered before (Chanon & Hopfinger, 2007). Evidence from primate studies suggests that the recognition process may contain several distinct phases. Early and late selection of attention produces top-down modulation signals that can influence the processing of visual information. Early is usually considered before executive functions in discrimination occur, whereas late selection occurs after the object has been discriminated.

Sayres and Grill-Spector (2005) found identification for a familiar object, at a correct rate of 85%, of presented stimuli occurring in early selection from 67 – 101ms.

According to them, prior experience can therefore play an important role in the search process. Targets within our environment may appear more frequently than others, and search strategies can be adjusted based on these recurrences to efficiently search the environment. Therefore, better recognition to more familiar symbols and processing novel events depends on whether stimuli have a pre-existing representation in long-term processing (Cycowicz & Friedman, 2006). In their study, memory performance was above chance and reaction times (RT) for old items were faster than those to new symbols, providing evidence that long-term recognition for these stimuli was established.

A late selection theory suggests that this selection occurs after stimulus identification or semantic encoding. Chanon & Hopfinger (2007) believe that sets of items within long-term memory would be too large to expect all items to receive voluntary object-based attention enhancement. Meaning, the reaction to a stimuli and the

processing in a reflexive manner does not include the processing of a recognized object, and that other processes must occur to retrieve that memory before a response can be made.

The surrounding environment may contain repetition that can be incorporated into search strategies and the act of search itself may become more refined with experience. In other words, search efficiency can be enhanced by knowing what to look for, what not to look for, and how to look (Mruczek & Sheinberg, 2005). One of the major problems that must be solved by a visual system is the building of a representation of visual information which allows recognition to occur relatively independent of size, contrast, spatial frequency, position on the retina, and angle of view. This is required so that with receiving information about one view, position, or size of the object, it is possible to generalize correctly to other views, positions, and sizes of the object (Rolls, 2004).

Sensitivity to the unexpected stimuli changes over time. Studying the orienting response is useful in understanding how sensory information is processed and coded when items repeat and are presented under different instructional conditions (Cycowicz & Friedman, 2007). This suggests that the orienting or shifting of attention to a specific location depends on the type and amount a stimulus is presented. According to this model, both encoding and retrieval of information occurs in related structures of the brain. These experimental investigations by Cycowicz & Friedman (2007) suggest that we have a measure of control over what we encode and what we retrieve from memory. The use of a familiar stimulus may help retrieve information from memory and have an effect on attention networks scores. For example, Rueda et al. (2004) used fish as the stimuli to examine the development of the attention networks in children.

For the most part, previous work on attention and athletes, using various attentional cueing paradigms, has been restricted to examining the differences between athletes and non-athletes as well as differences between athletes in different sports. We should be able to secure estimates of each of the attention networks with more ecologically valid stimuli. Hockey players have a higher exposure level of viewing other hockey players they may use information such as; where their opponents are located, the location of the goal, and to retrieve motor programs necessary to complete all the complex actions involved in the game.

Although the ANT has been used with athlete populations (see Keightley et al. 2009; Halterman et al. 2005) research has yet to be completed that examines the relationship between scores on the three networks in the ANT when using stimuli specific to the sport.

## CHAPTER THREE: METHODOLOGY AND PROCEDURES

### Participants

Thirty-six, undergraduate and graduate students, from Lakehead University were recruited as the sample for this study. Participants were males between the age of 18 and 35 ( $M=23.2$   $SD=3.6$ ) with normal or corrected to normal vision. Each participant signed an informed consent and volunteered his time for two sessions that lasted between 15 and 20 minutes each. Participants were only excluded from this study if they have had previously been evaluated on the ANT, allowing them a practice effect, or if they have had a diagnosed concussion, which would alter their responses on the test. The participants were free to withdraw from the study at any time.

Recruitment was conducted through classroom announcements, communication bulletins and posters placed around the university campus. Participants were separated according to their current hockey playing status in the 2008/2009 season (see Appendix C). There was no significant difference in age between the two groups.

The participants were allocated to one of two groups: “Hockey Players” or “Non-Hockey Players” based on their enrolment in an organized hockey league for the 2008/2009 season. The timeline was based on Richmond, Colombo & Hayne (2007), which examined the recognition of young adults. They determined that participants in the 3-month to 6-month retest groups correctly identified familiar stimuli more rapidly than did participants in a 12-month retest group. Their findings suggest that participants who played ice hockey over the past season may have a better recognition for the hockey stimulus and that participants who did not play would be less able to recognize the hockey stimulus.

## **The Attention Network Tests**

### *The Attention Network Test (Fan, Posner et al.)*

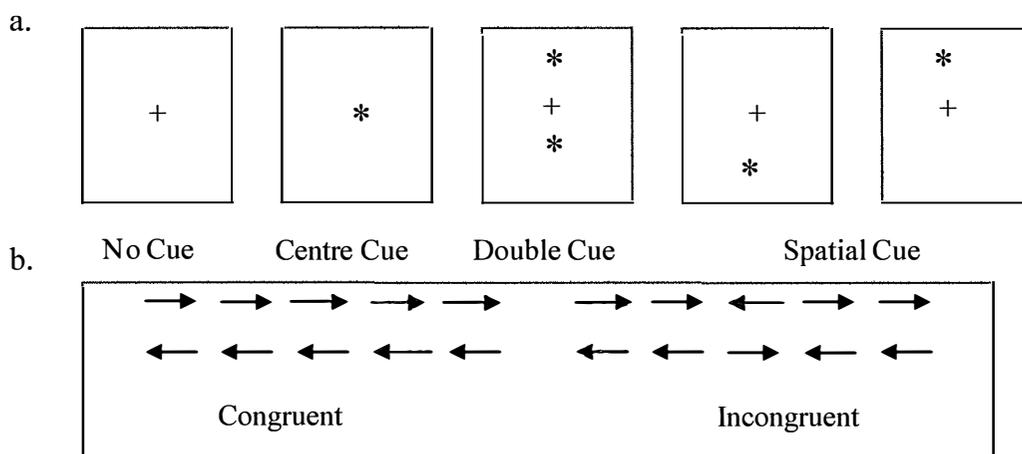
The Attention Network Test (ANT) was developed in 2002 by Fan, Posner and colleagues. It is a choice reaction time task, which is a combination of the Posner's cueing paradigm and the flanker tests by Eriksen and colleagues, to evaluate the alerting, orienting and executive control networks of attention, in a single computerized test. It was developed as a behavioural task which (1) clearly involves all three attentional networks, (2) could be used to obtain a measure of the efficiency of each of the networks, and (3) is simple enough to obtain data from children, patients and animals (Fan et al., 2002). In all versions of the ANT targets are 100% valid, meaning the target always appears in the spatial location as the spatial cue. Modified versions of this test, such as the child ANT, were created to examine the development of the attention networks in children. It is a modified version of the attention network test that uses a picture of a fish, as opposed to an arrow, to help sustain attention and increase the motivation in children to complete the ANT. Research using a highly recognizable image helped the children sustain attention throughout the test by giving them a story or purpose for completing the test (Raz, 2004). In other versions of the test, such as in the work of Greene, Barnea, Herzberg, Rassis, Neta, Raz & Zaidel (2008) on the lateralized attention network test (LANT) and Fan et al. (2005) the activation of attentional networks the neutral conditions were not used. In this research they have been removed since they are not directly involved in calculating the network scores and result in a shortened test which is intended to reduce the variability in response time within the conditions.

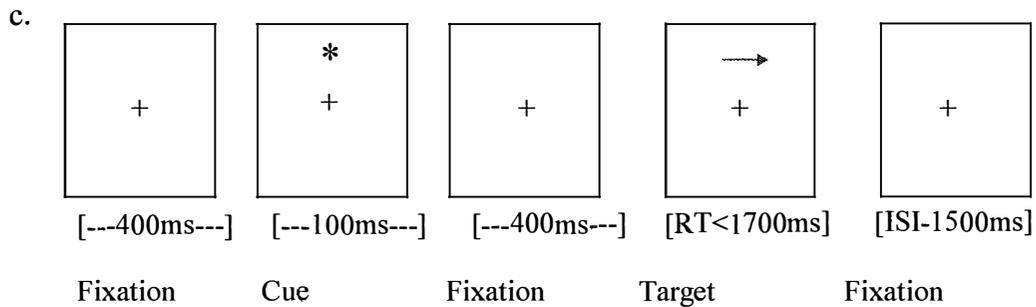
For both tests used in this study, the target was flanked on each side by two distracting stimuli in the same direction (congruent condition), in the opposite direction (incongruent condition) with the participants responding to the direction of the centre target. The original ANT includes neutral trials, which is when a single stimulus is presented; however, to try and maintain an alert state to the test and sustain attention in this experiment, the neutral trials have been removed to reduce the length of time to complete the test.

#### *Modified Attention Network Test (ANT)*

The target stimuli for the modified ANT were black horizontal lines with arrow heads similar to that of the original ANT (Figure 1b), pointing to the left or right. The image was mirrored in both directions and the size and spacing of the image were enhanced using Microsoft PowerPoint 2003©. The target was presented as a row of five arrows. These images were then converted to a Bitmap image and used with SuperLab Pro on a gray background. For the ANT, a single arrow was presented with the adjacent arrows separated by  $0.11^\circ$  of visual angle. The stimuli in the flanker conditions (centre arrow and four flankers) consisted of a total of  $3.11^\circ$  of visual angle and were presented  $0.91^\circ$  of visual angle either above or below fixation.

Figure 1: Experimental Design for the SuperLab Pro Version of the ANT





For both tests, the four warning cue conditions associated with the presented stimuli were no cue (NC), centre cue (CC), double cue (DBLC), or spatial cue (SPC) (see Appendix D). The cue was presented as an asterisk located  $0.92^\circ$  of visual angle above and/or below fixation. In the no cue condition, the participant saw only the fixation cross therefore involving no alerting or orienting (awareness of spatial location) effect. The centre cue was presented over the fixation cross which gives an alerting effect but no spatial cue. The double cue was presented both above and below fixation simultaneously, providing an alerting effect, and expands the field of attention, but gives no indication of spatial location of the stimuli. The spatial cue was presented either above or below fixation prior to the presentation of the stimuli in the same location as the cue therefore providing both alerting and orienting.

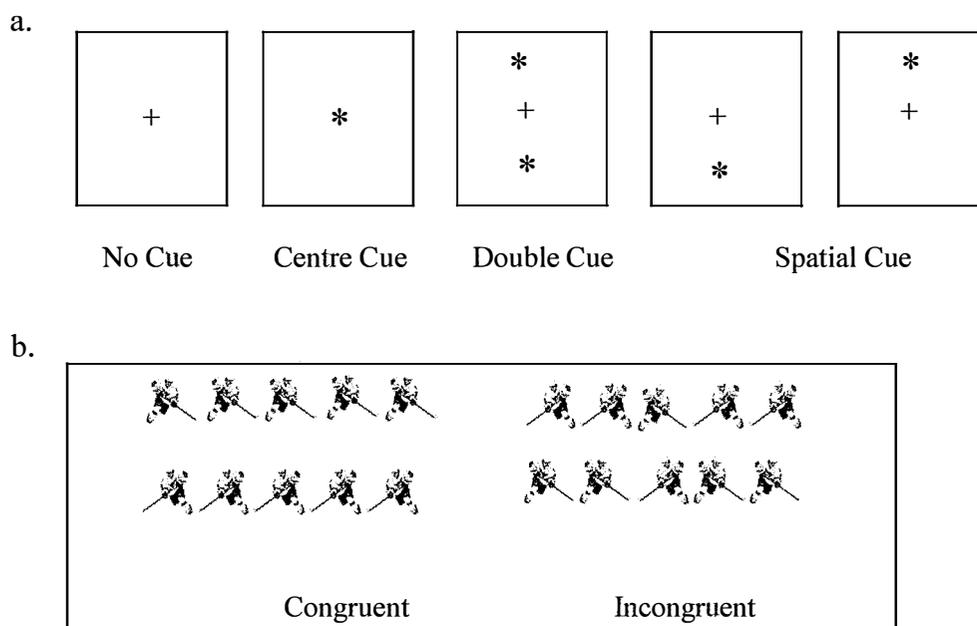
The testing session for each test consisted of one practice block of 16 randomly chosen trials and three experimental blocks of 64 trials (4 cue conditions x 2 target locations x 2 target directions x 2 flanker conditions x 2 repetitions) that were randomly presented for a total of 192 trials.

### *Hockey Attention Network Test (HANT)*

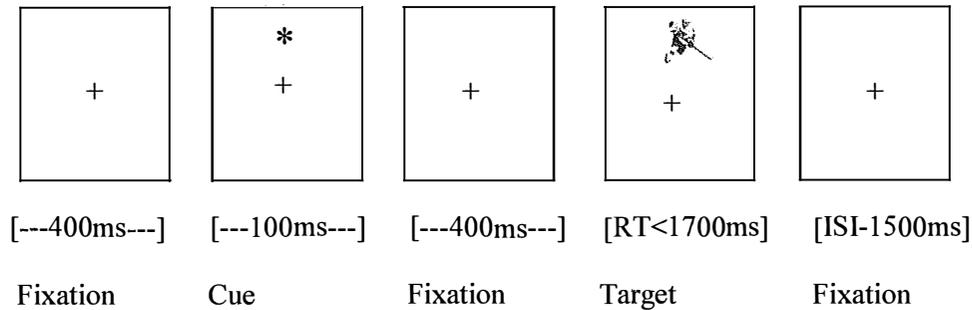
Target stimuli for the HANT were constructed from a photograph taken with permission (Jon Swenson, Personal Communication, Feb. 10<sup>th</sup>, 2009) of a hockey player and modified using Windows Paint 2003© to clearly show direction and be mirrored in both directions. The target stimuli were converted in Microsoft PowerPoint 2003© and transferred to SuperLab Pro alike the modified version.

Figure 2 shows the experimental design of the HANT. Target stimuli for the HANT consisted of a player skating toward the left or right with the blade of a hockey stick as the target pointing to the left or to the right and presented on a gray background. For the HANT a single player was presented with the adjacent hockey player figures separated by 0.08° of visual angle. The stimuli in the flanker conditions (central player and four flankers) consisted of a total of 3.44° of visual angle and were presented 0.82° of visual angle either above or below fixation.

Figure 2: Experimental Design for the SuperLab Pro Version of the HSANT



c.



### Procedure

Each participant completed the experimental sessions on two consecutive days in a quiet, dimly lit room of the Motor Control Lab at Lakehead University. Stimuli for both tests were presented on a 17 inch PC monitor at a resolution of 1280 x 960. The participants were seated at a distance of 70cm away from the monitor keeping their arms comfortably in front of them so they were able to respond to the task using two keys on the keyboard. The response was made by the participant pressing the 'z' key on the keyboard with the preferred digit on their left hand if the centre target pointed to the left or by pressing the '/' key on the keyboard with the preferred digit on their right hand if the centre target pointed to the right. The length of time to complete the test was approximately one minute for the practice block and four minutes for each of the experimental blocks. Including time to read the instructions and break time between each experimental block, the total time to complete the test was approximately 15 - 20 minutes. During the course of the study, participants were free to withdraw from the study at any time.

Stimuli and display of both the modified ANT and HANT was presented with a visual angle larger than the original version but remained within the visual field indicated

by Eriksen & Eriksen (1974). This ensured a similar network effects and response times would be produced. The visual angle was also kept similar between both tests.

Each trial consisted of five events (see Appendix D). First, the fixation cross was presented for a fixed duration of 400 ms. A warning cue was then presented for 100 ms. The no cue trial involved fixating on the cross for an additional 100 ms. The cue was followed by the fixation cross for a set SOA of 400 ms. The target stimulus was then presented for no more than 1700 ms in which the participant was to respond as quickly as possible. The response was then followed by the fixation cross for a fixed duration of 1500 ms as the inter-stimulus interval (ISI) before the next trial began.

Half the participants were asked to complete the Hockey Attention Network Test (HANT) on one day and the modified Attention Network Test (ANT) another. The other half of the participants completed the tests in the opposite order to counter balance groups. This study was approved by the Lakehead University Research Ethics Board.

### **Dependent Variable and Analyses**

The data was collected as a '.dat' file and transferred into SPSS Version 15.0 statistical analysis program. The reaction time was recorded (in milliseconds) from the time the target is presented until the time the correct response is pressed on the keypad. The trials were grouped by cue and target trials. From each target type the median reaction time of the different cue conditions was determined. The median is used due to the skewed distribution of the trial responses. The mean of the median scores of correct responses from each cue condition was determined for congruent and incongruent groups.

Error scores were not included in the overall calculations and occurred if, (1) the participant did not respond within the allotted 1700ms (2) the participant responded faster

than 100ms (3) the participant input the incorrect response. The error rate ranged from 1% – 7% in each target condition in both ANT and HANT, and overall error rate was 4% for each of the two tests. Four participants were removed from data analysis, two of which did not complete both tests and two recording over a 40% error rate on incongruent trials.

The alerting, orienting and executive control network scores for each participant is calculated by measuring the difference between specific cue or target conditions. The alerting network is calculated by the differences in RT between conditions with a warning to an upcoming target (double cue), and no warning to an upcoming target (no cue). This measures the speed at which the participant responded following a warning or not. The orienting network is measured as the difference between a cue capturing your attention and one that directs it. The difference in RT between centre and spatial cue conditions depicts the amount of time to disengage from the centre location and respond to a target. The executive control network is the difference between congruent and incongruent target conditions. These target conditions differ; in the amount of processing required to differentiate between irrelevant distracters. Alerting, orienting, and executive control effects are calculated using the following formulas that are consistent with the original version of the ANT:

- $Alerting = RT \text{ in the no cue condition} - RT \text{ in the double cue condition};$
- $Orienting = RT \text{ in the centre cue condition} - RT \text{ in the spatial cue condition};$
- $Executive Control = RT \text{ in the congruent conditions} - RT \text{ in the incongruent conditions}.$

The mean, variance and standard deviation were calculated using a SPSS version 15.0 for the two versions of the Attention Network Test (ANT). These descriptive statistics were analyzed separately between the two tests.

A Pearson product-moment correlation was used to examine the relationship of the network scores between the two tests. This correlation examines the bivariate relationship between the two tests. An intraclass correlation was also used to effectively show the differences between each individual's score of each test.

A paired t-test was performed between tests to examine the differences between the networks scores of attention on each test. The alpha level was adjusted to take this into account. Additionally, even though a division between groups was not distinct in recruitment of the participants a 2(Group: Hockey Players, Non-Hockey Players) x 2(Test Type: ANT, HSANT) mixed factorial ANOVA of each network score and overall reaction time in the three attention networks was performed to determine if there is differences between the tests and groups.

## CHAPTER FOUR: RESULTS AND DISCUSSION

### Results

The average reaction times (RTs) for correct responses of each cue and target condition are presented in Table 1 with the standard deviations in parentheses.

Table 1: Mean Reaction Time (RT) for cue and target conditions

Group	Flanker Type	Cue Type			
		No Cue (NC)	Centre Cue (CC)	Double Cue (DBLC)	Spatial Cue (SPC)
<b>ANT</b>					
Hockey	Congruent	450 (46.8)	430 (53.0)	426 (47.1)	393 (39.6)
Players	Incongruent	536 (44.2)	507 (46.1)	517 (42.5)	461 (42.0)
Non-Hockey	Congruent	461 (60.7)	436 (75.4)	438 (70.4)	408 (74.0)
Players	Incongruent	529 (65.8)	525 (69.6)	519 (57.7)	485 (78.4)
No Grouping	Congruent	456 (53.6)	433 (64.2)	432 (59.2)	400 (58.9)
	Incongruent	533 (55.3)	516 (58.8)	518 (49.9)	473 (63.1)
<b>HANT</b>					
Hockey	Congruent	477 (44.8)	447 (49.1)	452 (37.5)	421 (45.7)
Players	Incongruent	540 (38.5)	521 (48.4)	526 (42.3)	473 (41.4)
Non-Hockey	Congruent	485 (62.8)	453 (58.5)	458 (60.9)	432 (71.3)
Players	Incongruent	560 (63.6)	535 (61.3)	538 (60.3)	493 (67.7)
No Grouping	Congruent	481 (53.9)	450 (53.2)	455 (49.9)	426 (59.2)
	Incongruent	550 (52.7)	529 (54.8)	532 (51.7)	483 (56.2)

Table 1 shows the reaction times for each group by cue and target condition used in this analysis.

The average and standard deviations of the network scores and overall reaction time for both, ANT and HANT, are shown in Table 2. These network scores are similar to the findings of Fan et al. (2002). They showed average and standard deviations of network effects to be: alerting, 47(18), orienting, 51(21), and executive control, 84(25) networks of attention. In this experiment network scores on the modified ANT for the alerting, orienting and executive control scores are 20(22), 38(23), -80(21) and for the HANT 27(19), 36(29), -70(21) respectively.

Table 2: Network scores - Test by Group

	<b>No Grouping (N = 32)</b>	<b>Hockey Players (N=16)</b>	<b>Non-Hockey Players (N=16)</b>
<b>ANT</b>			
Alerting	20 (22.4)	25 (17.2)	14 (24.4)
Orienting	38 (22.5)	45 (15.2)	32 (26.4)
Executive Control	-80 (20.8)	-80 (18.4)	-79 (23.2)
Total Reaction Time (ms)	470 (54.1)	465 (41.8)	475 (64.6)
<b>HANT</b>			
Alerting	27 (18.9)	24 (19.1)	29 (20.3)
Orienting	36 (28.9)	42 (29.3)	30 (27.1)
Executive Control	-70 (20.7)	-66 (17.7)	-74 (23.0)
Total Reaction Time (ms)	488 (49.7)	482 (38.3)	494 (60.0)

Table 3 illustrates the result of the paired t-test performed between test conditions in both the ANT and HSANT to ensure there is a significant network effect. If these attention networks are functioning properly there should be a significant difference between reaction time when comparing the reaction times between conditions.

The difference between NC and DBLC for the HANT ( $t(31) = 7.9, p = .01$ ) and ANT ( $t(31) = 4.9, p = .01$ ) showed significant results. This result suggests there was an alerting effect occurring in both versions. The differences between CC and SPC in both the HANT ( $t(31) = 7.0, p = .01$ ) and ANT ( $t(31) = 9.6, p = .01$ ) also demonstrated significant results, that suggests an orienting effect occurred on both of the tests. The difference between the congruent (CONG) and incongruent (INCO) target conditions showed significant results for both the HANT ( $t(31) = -19.2, p < .01$ ) and ANT ( $t(31) = -21.7, p < .01$ ). Therefore, all network scores produced significant effects between cue conditions.

Table 3: Paired difference between target and trial conditions

	Mean	Std. Deviation	Std. Error	C.I. 95%		t	Sig.
				Upper	Lower		
NCa - DBLCa	19.53	22.44	3.97	11.44	27.62	4.9	.01
CCa - SPCa	38.44	22.57	3.99	30.30	46.58	9.6	.01
NCh - DBLCh	26.59	18.99	3.36	19.75	33.44	7.9	.01
CCh - SPCh	35.59	28.93	5.11	25.16	46.02	7.0	.01
CONGa - INCOa	-79.59	20.74	3.68	-87.07	-72.12	-21.7	.01
CONGh - INCOh	-70.28	20.72	3.66	-77.75	-62.81	-19.2	.01

\* The “a” suffix indicates the score is taken from the modified ANT. The “h” suffix indicates the score is from the HANT

A Pearson product-moment correlation was used using these network scores to calculate the independence of the network from each other for both versions of the test. These results are displayed in Table 4. There are significant correlations between the alerting network and both orienting and overall reaction time.

Alerting is positive and moderately correlated with orienting ( $r = .530, p < .01$ ). Although alerting and orienting have been identified as having separate anatomical areas they are interrelated in activity, which is likely the reason for the moderate relationship. There is also negative and weak correlation between the alerting network score and overall reaction time that is statistically significant ( $r = -.387, p < .05$ ). This also suggests an interaction between maintaining alertness and overall speed in responding to the stimuli. An individual with a large alerting effect is more prepared and responds faster than someone who is not alerted by the cue effect.

Table 4: Correlations between network scores and Reaction Time (RT) on the ANT

	<b>Alerting</b>	<b>Orienting</b>	<b>Executive Control</b>
<b>Orienting</b>	.530(**)		
<b>Executive Control</b>	-.269	-.112	
<b>Overall RT</b>	-.387(*)	-.162	.188

A Pearson product-moment correlation was used to calculate the independence of the network scores from each other within the HANT. These results, shown in Table 5, are similar to that of the Modified ANT used in this experiment. It shows a significant moderate correlation between Alerting and Orienting as well as a negative and weak correlation between alerting and overall reaction time.

Table 5: Correlations between network scores and Reaction Time (RT) on the HANT

	<b>Alerting</b>	<b>Orienting</b>	<b>Executive Control</b>
<b>Orienting</b>	.141		
<b>Executive Control</b>	.186	.222	
<b>Overall RT</b>	-.155	-.136	.025

The Pearson product-moment correlation was also used to measure the relationship between tests to produce similar network effects and overall reaction time between two test times.

Table 6 shows that the overall reaction time was strongly correlated ( $r = .844, p < .01$ ), suggesting that the overall reaction time had a strong relationship between each test. The orienting and executive control networks also showed a moderate correlation suggesting there was a relationship between the scores and the participants were shifting their attention and processing response selection similarly in both versions of the test. There is however, almost no correlation, or relationship between the alerting scores between tests ( $r = -.007$ ), suggesting a difference in the cue effect and/or response speed between each of the tests.

Table 6: Network Correlations between Tests

	<b>Alerting</b>	<b>Orienting</b>	<b>Executive Control</b>	<b>Overall RT</b>
<b>ANT * HANT</b>	-.007	.575**	.670**	.844**

\*\* represents significant difference at  $p < .05$

The intraclass correlations (ICC), Table 7, were used to determine the overall variance of the scores between each individual and within the two tests. The ICC showed results similar to that of the Pearson product-moment correlation for alerting, orienting,

executive control and overall reaction time  $-.007$ ,  $.588$ ,  $.670$ ,  $.842$ , respectively. The correlations are represented in Figure 3 – 6. This is a visual representation to show the strength of the correlations and the similarity between the Pearson correlation and the Intra-class correlation (ICC).

Figure 3: Alerting Network Correlations

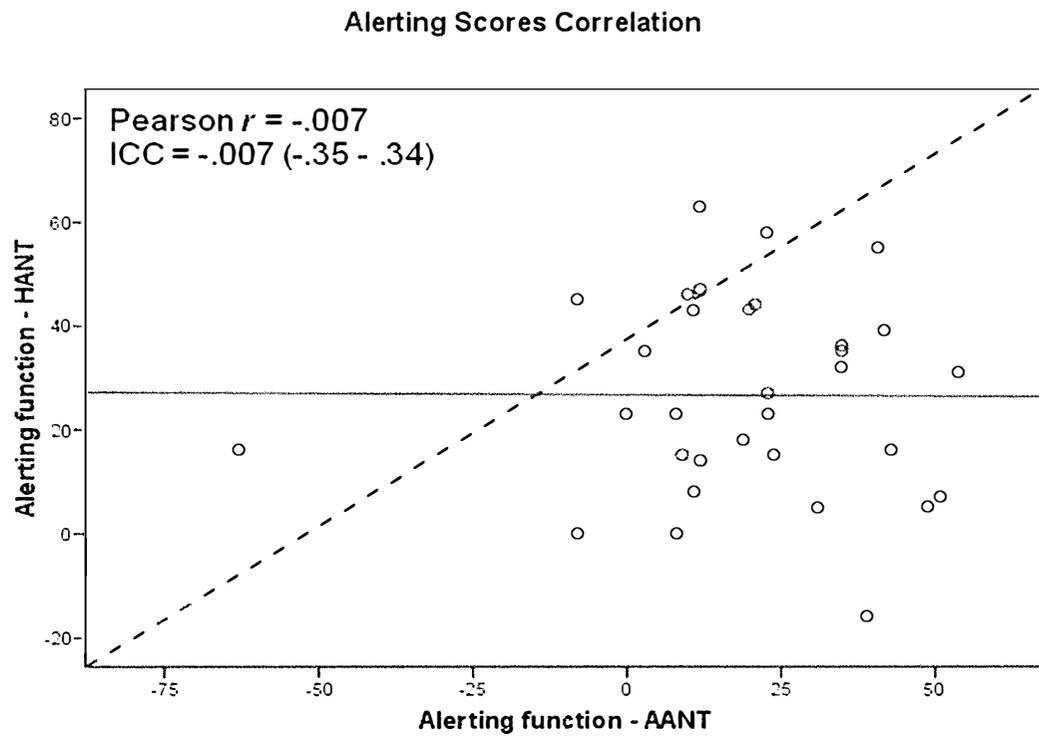


Figure 4: Orienting correlation between tests

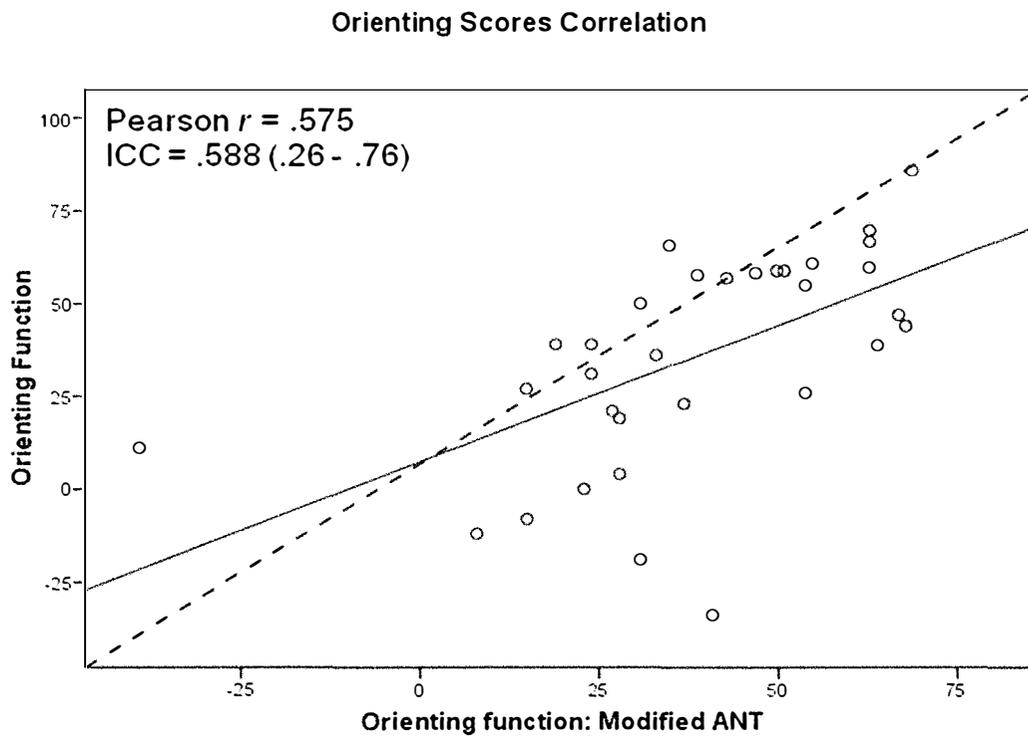


Figure 5: Executive control correlation

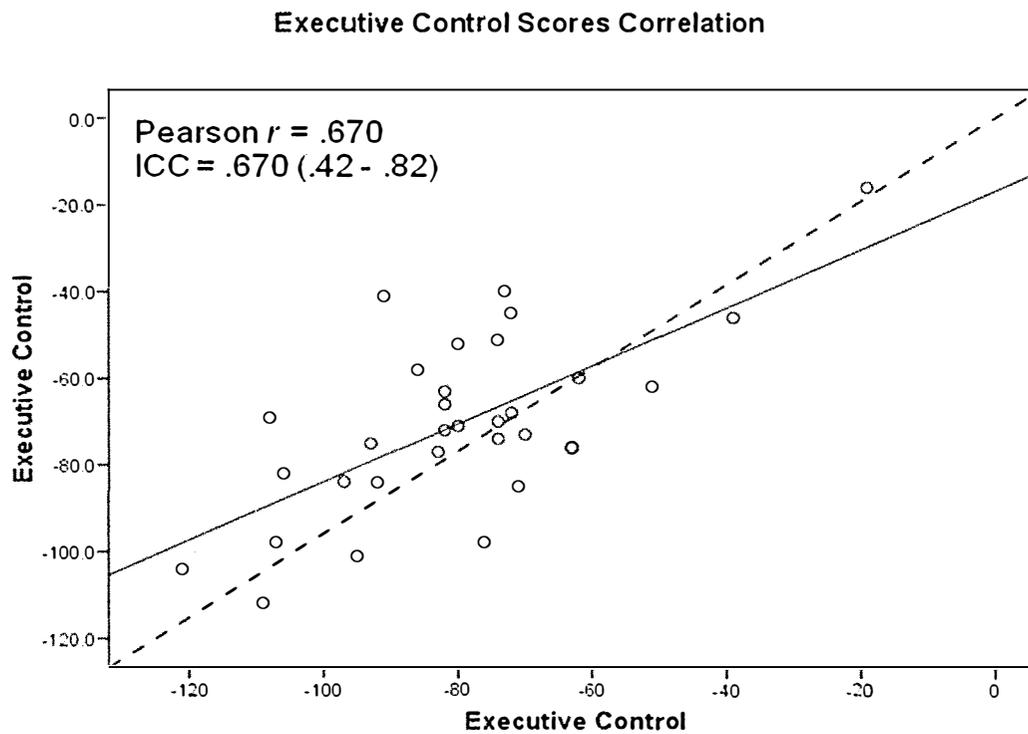


Figure 6: Overall Reaction Time correlation

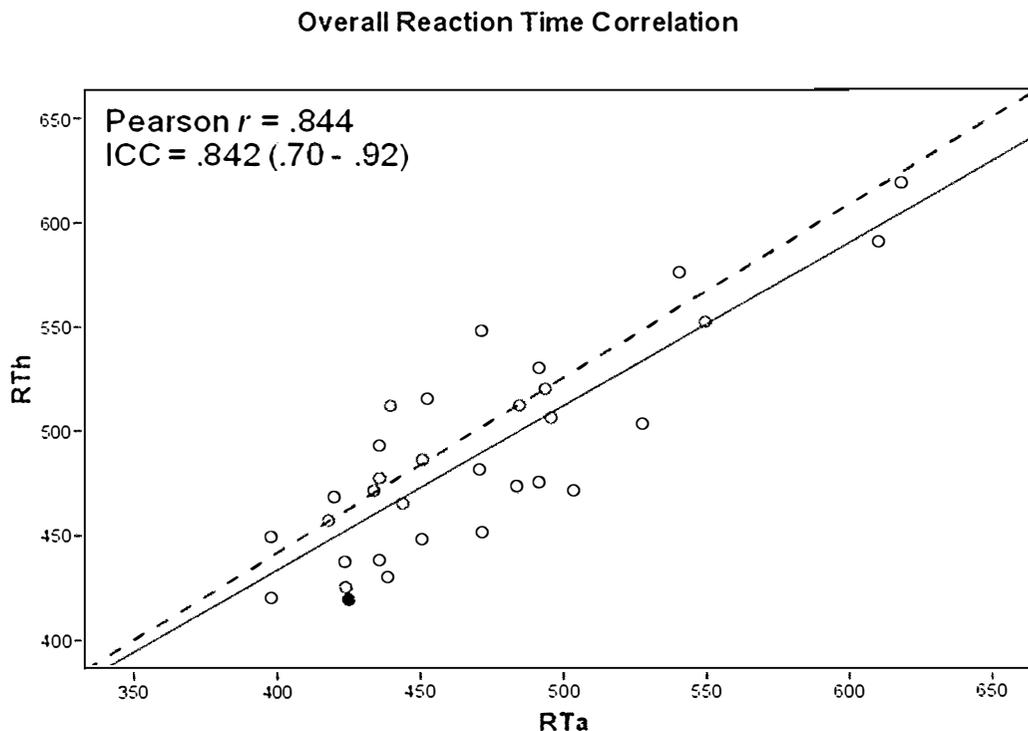


Table 7: Intraclass correlation of network scores and Reaction Time

	Intraclass Correlation	95% Confidence Interval		Value	Sig
		Lower	Upper		
<b>Alerting</b>	-.007	-.350	.338	.986	.515
<b>Orienting</b>	.558	.264	.756	3.520	.01
<b>Executive Control</b>	.670	.424	.824	5.065	.01
<b>Reaction Time</b>	.842	.700	.919	11.627	.01

The paired t-test, shown in Table 8, is used to examine the difference in network scores and overall reaction time between test types. The only significance differences appeared between the executive control network and overall reaction time. The executive

control network showed significant difference ( $t(31) = -3.129, p < 0.01$ ) suggesting there was less conflict in responding between the congruent and incongruent trials involved for the HANT. Overall reaction time also produced a significant difference ( $t(31) = -3.493, p < 0.01$ ). Overall it took longer to react to the hockey stimuli, but proved to be easier to distinguish between congruent and incongruent conditions on the executive control network in the HANT.

These results show that resolving conflict between distracting stimuli had less of an effect in the HANT, this in turn is accompanied by slower overall reaction time producing the correct response.

Table 8: Paired T-test of network scores, reaction time and error rates between the Modified ANT and the HANT

	Paired Differences				t	Sig.	
	Mean	Std. Deviation	Std. Error	95% Confidence Interval			
				Upper	Lower		
<b>Alerting Function</b>	-7.06	29.50	5.22	-17.699	3.574	-1.35	.185
<b>Orienting Function</b>	2.84	24.41	4.32	-5.957	11.644	.66	.515
<b>Executive Control</b>	-9.313	16.83	2.976	-15.382	-3.243	-3.13	.004
<b>Reaction Time</b>	18.13	29.35	5.19	-28.708	-7.54	3.49	.001
<b>Percent Total Error</b>	-.0069	.0257	.0045	-.0161	.0024	-1.51	.140

<b>Percent Error</b>							
<b>Congruent Trials</b>	-.0009	.0163	.0029	-.0068	.0050	-.33	.748
<b>Percent Error</b>							
<b>Incongruent Trials</b>	-.0131	.0476	.0084	-.03029	.0040	-1.56	.129

The segregation of groups was based on the current hockey playing status of the participant. The mean network scores were analyzed in a series 2 (Group: Player, Non-player) by 2 (Test Type: ANT, HANT) ANOVA, dividing the sample by participants who currently play in an organized hockey league to those who do not currently play does not take into effect additional exposure, such as watching or participating recreationally. The only effect was significant for the alerting network. There were significant main effect between Groups ( $F(1, 28) = 5.00, MS_e = 1.19, p < .05$ ), however no other statistical significance occurred. These results were possibly due to the grouping process, which involved grouping participants based on current hockey playing status, rather than taking into account other involvement with hockey such as spectators, coaches, or officials that may have given equal ability to recognition and response accordingly to a hockey stimulus.

## Discussion

The Attention Network Test (ANT) was developed as a measure that would evaluate the three networks of attention: alerting, orienting and executive control. The ANT uses the differences between specific cue and target conditions within a single reaction time task to provide a score and the means of exploring the efficiency of the three networks involved with attention (Fan et al., 2005). These networks are widely thought to be relatively independent aspects of attention that are linked to separate brain regions but

function and interact to perform the entire process of attention. Fan et al. (2005) suggests the networks function independently of each other. However, when functioning as part of an entire process some interaction must occur. The ANT is a highly adaptable tool to measure the efficiency in network scores of different populations. Versions such as Rueda et al. (2004) child ANT used fish stimuli to increase motivation to complete the task. This research used hockey stimuli to create an ecologically relevant stimulus to the participants responding. The results suggest that the use of a real life stimulus can be used to estimate the functioning of the attention networks.

This study supports an interaction between alerting and orienting networks. Posner & Badgaiyan (1998) suggest that there is a strong interaction between visual orienting and the alerting network. This research indicates that the two networks may function separately but interact and were found significantly correlated. Overall, the differences between the two test types using correlations and t-tests, it has been shown that the HANT can activate and assess the functions of the attention networks similarly to the original ANT.

### *Correlations*

A Pearson product-moment correlation was used to test the relationship between network scores as a function of operating independently. With the exception of the alerting network, the networks and overall reaction time showed moderate to strong correlations between the two tests. These results are consistent with the original findings on testing the efficiency and independence of attention networks (Fan et al., 2002). Orienting and executive control were positive and moderately correlated ( $r = .575, p =$

.001,  $r = .670$ ,  $p = .001$ ) and overall reaction time was positive and strongly correlated ( $r = .844$ ,  $p = .001$ ) between the two tests.

These correlations indicate that since these tests were intended to measure the same effect, they are viewed as having a moderate to strong relationship between one another. These correlations are comparable to findings on the ANT (Fan et al., 2002), orienting ( $r = .61$ ), executive control ( $r = .77$ ), and overall reaction time ( $r = .87$ ). The poor correlation between the alerting networks could be associated with the participant's motivation to complete the second day at the same state of mind as the first. Many may have felt inclined to continue the testing sessions and did not give an optimal performance both days. However, the poor correlation may have resulted in the use of only valid target conditions and the adaptation of a response strategy to the target. This could be responsible for the difference between tests.

Most of the research in this field including Rueda et al. (2004), and Greene et al. (2008) had participants complete both tests during a single testing session with a brief break, which may have resulted differences between tests. However, previous research also had difficulty finding a correlation between test sessions for the alerting network.

Intraclass correlations were performed to measure the overall variance of scores within each individual and between the two test types. These results support the results of the Pearson product-moment correlation used with alerting, orienting, executive control and overall reaction time. The ICC results were  $-.007$ ,  $.558$ ,  $.670$ , and  $.842$  for the networks and overall reaction time respectively. The poor correlation for the alerting network is shown again suggesting the group had difficulty attending, or the cue was not

adequately preparing the participants for the upcoming target. Participants may also have adapted search strategies causing a change in score between the tests.

A Pearson product-moment correlation was then used to determine the nature of the interaction of the attention networks of each test separately to measure the independence of each network score. This measure could also support and explain the low correlation between the alerting networks for the two tests. As expected, the alerting score showed a moderate and positive correlation with the orienting network ( $r = .530, p = .002$ ) and a weak but significant negative correlation with overall RT ( $r = -.387, p = .03$ ). These results suggest that the alerting network was not operating solely independent and were moderately correlated to the orienting network and overall reaction time while completing the task.

The findings in this study are supported by a report from Callejas et al. (2004) that suggest alerting exerts an influence on orienting and that the nature of it is not that of enhancing its effect but accelerating it. When measuring the functioning of the three networks in complex tasks, interactions between the attention networks have been observed. Therefore, even though their functions and neural substrates are different, the three attention networks act under the constant influence of each other in order to produce an efficient visual search. This means the functions of searching efficiently to a given location and being prepared for the upcoming event could help direct attention around the environment.

These correlations are also interesting to speculate the research design and nature of the test that only uses one SOA on a test with all valid trials. This could benefit the participant to predict the timing between cue and target and better prepare them for a

response. As reported by Fan et al. (2005), the alerting network is measured by “centre cue” minus “no cue” conditions. Since the ANT uses 100% valid cues to prepare the participant to respond, and in the case of a spatial cue, direct the participant to the location of the target, these results suggests that the cue was used to predict the time of the target and thus also served as a temporal orienting cue. Overall, alerting cues prepare the participant for an upcoming target. They also may also produce temporal timing to response and is supported by correlation between alerting network and overall reaction time.

### *Network Scores*

The differences between the network scores and overall reaction times of the ANT and HANT were examined. These tests were compared between each other and intended to measure and produce similar effects in the attention networks. Both tests produced significant difference between cue and target conditions to produce sufficient network scores for alerting, orienting and executive control ( $p < 0.01$ ). This means the directional image of a hockey player was simple enough to alert the participant to it, shift attention to its location, and was clear enough to make a decision and response properly to its direction. This application of the using a sport relevant image may also be used as a more practical and precise estimate of a hockey players network efficiency while playing.

To obtain scores for each network, the appropriate mathematical equations from the original ANT were performed. Alerting scores were 20 and 27, orienting 38 and 36, executive control -80 and -70 and overall reaction time 470ms and 488ms for the ANT and HANT respectively. These results, fall within the range originally reported by Fan et al. (2002) on the alerting ( $47 \pm 18$ ), orienting ( $51 \pm 21$ ), and executive control ( $84 \pm 25$ )

networks of attention. The alerting scores were low in comparison to the original findings. However, networks and overall reaction time (RT) meet the range reported by Rueda et al. (2004).

The child ANT is a modified version of the attention network test that uses a symbol of a fish to increase motivation and help to maintain and hold the attention span of children in order to complete the ANT. With this test, Rueda et al. (2004) found network scores for alerting ( $30 \pm 32$ ), orienting ( $32 \pm 30$ ), executive control ( $61 \pm 26$ ), and overall reaction time ( $483 \pm 36$ ). Even though the child ANT was intended to improve the response variance and accuracy in children, their study noted significant differences showing smaller effects with the simpler fish stimuli than the arrow stimuli. These similarities in network scores and overall reaction time of the modified versions of the tests, along with being compared to the original findings, suggest that the HANT is accurate at producing the expected attention network effects.

#### *Test and Group Differences*

Due to the cultural and geographical effects of hockey on the community of Thunder Bay, Ontario, this study examined the difference between participants who played in the 2008/2009 season in an organized hockey league to those who do not currently play. All participants had some prior experience in watching live or televised hockey. Nearly all participants had participated in hockey at some point in their life, but only half of the participants were currently playing hockey in the 2008/2009 season. Therefore, these divisions should not have made a significant difference to the overall network scores between groups or test.

When examining the sample of participants as a whole there were significant differences between the tests in executive control ( $t(31) = -3.129, p < 0.01$ ) and overall reaction time ( $t(31) = -3.493, p < 0.01$ ). These effects are consistent with the results from the work of Rueda et al. (2004) in comparison of the ANT and the children ANT. These results can be interpreted in a number of ways. Firstly, the use of a more stimulating image, hockey compared to arrow, can improve the efficiency of the attention networks. It may increase arousal and motivation to complete the task by using a hockey image and affect the alerting network.

The interaction between the alerting and orienting network, as well as the use of this test on a hockey playing population could alter the relative range of orienting network scores. As well, the executive control network is being manipulated by adding colour to the stimulus and using a familiar image to respond to. Research regarding object recognition suggests there is better recognition for more familiar symbols (Cycowicz & Friedman, 2006). The response time for these familiar symbols can aid in distinguishing between the target and distracting flankers.

The early selection theory of attention suggested by Sayres & Grill-Spector (2005) found recognition for familiar stimuli within 100ms of being displayed with high accuracy rates. This suggests that familiar stimuli are processed in the early stage of selection. The accuracy rate and overall reaction time of this experiment demonstrates that recognition and proper response to a stimulus can occur very early in the cognitive process. In addition, the use of a more complex shape, compared to that of an arrow, and use of a coloured image may have increased the arousal (Giesbrecht, 2001; Corbetta, 1991) in providing a more efficient response to the symbol.

For the interest of the researcher, a comparison was made between the groups of current and non-current hockey players to examine the interaction of the attention networks between the two test types. The only significant interaction produced was for the alerting network on the modified ANT between the groups ( $F(1, 28) = 5.00, MS_e = 1.19, p < .05$ ). When examining the network scores between groups non-hockey players display a smaller alerting effect. This finding is in contrast to the findings of Enns and Richards (1997) that suggest athletes are better able to distribute their attention more effectively over multiple locations, which assisted in their fast reaction time due to being alert to all incoming stimuli. This may suggest the non-hockey players in this study were motivated and prepared to correctly response to the target regardless if a cue was presented.

## CHAPTER FIVE: CONCLUSION

### Conclusions

Previous studies have examined attention as an organ system (Posner & Fan, 2002). Technologies have been used such as the use of Positron Emission Tomography (PETs) (Posner & Petersen, 1990), and the study of genetic differences in relation to attention (Fossella, Sommer, Fan et al., 2002; Fossella, Posner, Fan, Swanson & Pfaff, 2002) to examine the efficiency or deficits to the alerting, orienting and executive control network of attention. The present study created a sport specific version of the attention network test that is more relevant to hockey. The purpose was to examine the affects of a recognizable image to produce network scores on the Attention Network Test (ANT). The network effects produced were similar to the findings in the literature, suggesting that this modified version could be used to examine the efficiency of the attention networks in hockey players or individuals who are familiar with the sport. This research will add to present literature of attention and athletes. It examined the weak relationship between alerting scores when comparing results between modified tests, which has been found in other research as well (Fan et al., 2002; Rueda et al., 2004). This finding is likely due to the test design of the ANT. However, this research has demonstrated comparable network scores for orienting, executive control, and overall reaction time which may be used for further research in assessing those networks after sport injuries, such as concussion, and the implications on the deficits of the attention networks for a return to play guidelines in the sport of hockey.

## **Recommendations and Future Research**

These findings show appropriate methods for measuring the efficiency of the attention networking using hockey relevant stimuli. However, these results may only apply to this specific geographical region and culture.

Grouping of participants for this study was based on current hockey playing status. All participants had some prior experience to hockey images and almost all participants have at one time participated in an organized hockey league. This test used in a Canadian culture maybe able to assess accurate values of the attention networks, as the work of Rueda et al. (2004) has created for children. This test, like many other psychological tests, provides a practical utility that promotes the development and use of increasingly situational and population specific measures over a general psychological test (Gauvin and Russell, 1993).

These results can then be viewed in two possible manners in order to further the research in this area. One application for further research could be a more in depth study of attention in athletes within the sport of hockey. From this perspective, the HANT could be used as a tool to determine the efficiency of the attention networks for hockey players, which could benefit in the selection of athletes of an individual's network score in a hockey related situation and choosing players based on their efficiency.

These results could also assist in creating other modified tests that would be specific to other sports for the same purpose. This may allow researchers to better understand the range of cultural influences and geographical regions based on sport popularity. This specific test can be used, as originally intended by this research, to examine elite hockey players and the differences in efficiency of these networks.

The ANT has shown to be a convenient and useful procedure in evaluating attention abnormalities associated with cases of schizophrenia, attention deficit disorders and cases of brain injury (Fan et al., 2002). The three attention networks have been defined neurologically and functionally. Reaction time measures can be used to quantify the processing efficiency within each of these three networks. This tool could then be used in the detection and progressions of cognitive deficits.

Further research using this HANT has practical implications on the process of selecting elite hockey players by examining processing of different networks within a more realistic environment and using stimuli that occur frequently in their sport. This test could also be used to examine the networks of attention in a hockey based culture using a more familiar image to sustain attention and produce more representative effects in the executive control network. The HANT produced similar overall RTs and less conflict with decision making. When using cognitive tests to examine performance and the ability to return to play in a particular sport there needs to be a comprehensive understanding of the test and its results. Then by using a test that would be more relevant to the sport would help in assessing and recovering from sport related injuries.

### **Limitations**

The major limitations to this study included the recruitment and grouping procedure of the participants, which did not give a good representation of elite hockey players compared to those with little experience. The recruitment of a more specific cohort, such as a single team, representing similar skill level and age would be ideal.

The test design of the ANT also proved to be a limitation to the interpretation of the results. The main evidence, as suggested by Redick and Engle (2006), for the

independence of attention networks is based on the absence of significant correlation between the respective difference scores. These overall difference scores are between group comparisons of within-subjects variables, which make it difficult to interpret. This means that the scores may not be a true value of average since a network score can be variable between individuals. The problem interpreting these results arises from the lack of a true baseline condition in the ANT.

The ANT is a new paradigm created in 2002 with increasing number of studies and variations being created. Rueda et al. (2004) also found no significant correlations between the original network scores and their repetition 6 months later. In this study, specific changes were made to the ANT paradigm: using a sport specific image and removing neutral target conditions to shorten the test. This created changes in the activation of the executive control network and reduced the variability between the scores. Shortening the test would allow participants to hold their attention throughout the entire test with these modifications, which may in turn change their alerting network effects.

The current study is similar to the findings of Fan et al. (2002), who indicated the orienting and executive control networks to be moderately correlated, as well, overall reaction time being highly correlated between two testing sessions. Fan et al. (2002) also reported the alerting network has the least reliable test-retest correlation (.52). The alerting network appears to be the least reliable when completing this test as well as in other studies (Rueda et al., 2004). This could be due to a number of intrinsic factors such as motivation or fatigue and extrinsic factors such as time of day or distractions. The design of the ANT may also effect the overall poor correlation in the alerting network.

Since the paradigm only uses valid trials, the participant may adapt a strategy for responding to the stimulus, which would be of interest in further research.

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### **Appendix A: Cover Letter**

Dear Prospective Participant:

The Lakehead University Kinesiology research program is conducting a study to measure Stimulus Familiarity in Sports Specific Attention Network Test (ANT). To date, research is limited with respect to the alerting, orienting, and executive function of visual attention using a sports specific stimulus. This study will use the Attention Network Test (ANT), to study a hockey specific stimulus in visual attention for males.

This study invites the prospective participants to complete 2 computer-based tests. The tests will take approximately 30 minutes each to complete and will be done in a quiet room to minimize distractions.

This testing procedure is completely safe and will be administered by trained university personnel. All the information received will be obtainable only by the researchers involved in the study.

Your participation is voluntary and you may withdraw from the study at any time without any recourse.

All personal data will be kept strictly confidential and all information will be coded so that your name is not associated with your answers. Only the researcher listed below, as well as Dr. William J. Montelpare, Ph.D., Dr. Jim McAuliffe, Ph.D., and Tracey Larocque MSc. will have access to the data, and it will be stored securely at Lakehead University for five (5) years.

I sincerely appreciate your co-operation. If you would like to receive more information about the study, please contact

Researcher:

Adam Claus at 807-766-7198  
8481

or

[aclaus@lakeheadu.ca](mailto:aclaus@lakeheadu.ca)

Supervisor:

William Montelpare at 807-343-  
8481

or

[william.montelpare@lakeheadu.ca](mailto:william.montelpare@lakeheadu.ca)

Lakehead University Research Ethics Board  
343-8283

Thank you for your interest as a prospective participant.

Sincerely,

Adam Claus  
Enc. Consent form

**Appendix B: Consent Form****CONSENT FORM**

My signature on this form indicates that I agree to participate in the research project of Mr. Adam Claus and Dr. William Montelpare conducted at Lakehead University, on the use of a sport relevant test to examine the efficiency of attentional networks. I understand that my participation in this study is conditional upon the following:

- 1) I have read and understood the cover letter and thus, understand the basis of the study.
- 2) I fully understand what I will be required to do as a participant in the study.
- 3) I am a volunteer participant and I may withdraw from the study at any time without consequence.
- 4) I understand that there are no physical or psychological risks involved with this study.
- 5) My data will be confidential and stored at Lakehead University for a period of five (5) years.
- 6) I will receive a summary of the project, upon request, following the completion of the project.
- 7) In any publication, you will remain anonymous, unless explicitly agreed to.

I agree to participate in this study

---

Signature of Participant

---

Date

**Appendix C: Questionnaire**Group Allocation Questionnaire

- (1) Have you ever played in an organized hockey league? Yes / No
- (b) Do you currently play in an organized hockey league? Yes / No
- (c) At what level do you currently play hockey? \_\_\_\_\_
- (d) What is the most elite level you have ever played? \_\_\_\_\_
- (e) How many years have you participated in Organized hockey? \_\_\_\_\_
- (f) What was your primary position while playing hockey? \_\_\_\_\_
- (2) Do you ever watch Hockey? Yes / No
- On average, how many games do you watch per week? Live: \_\_\_\_\_
- Televised: \_\_\_\_\_
- (3) Have you ever been clinically diagnosed with a concussion? Yes / No
- (b) How long ago was your last clinically diagnosed concussion? \_\_\_\_\_

## Appendix D: Experimental Design

Figure 1: Experimental Design for the SuperLab Pro Version of the ANT

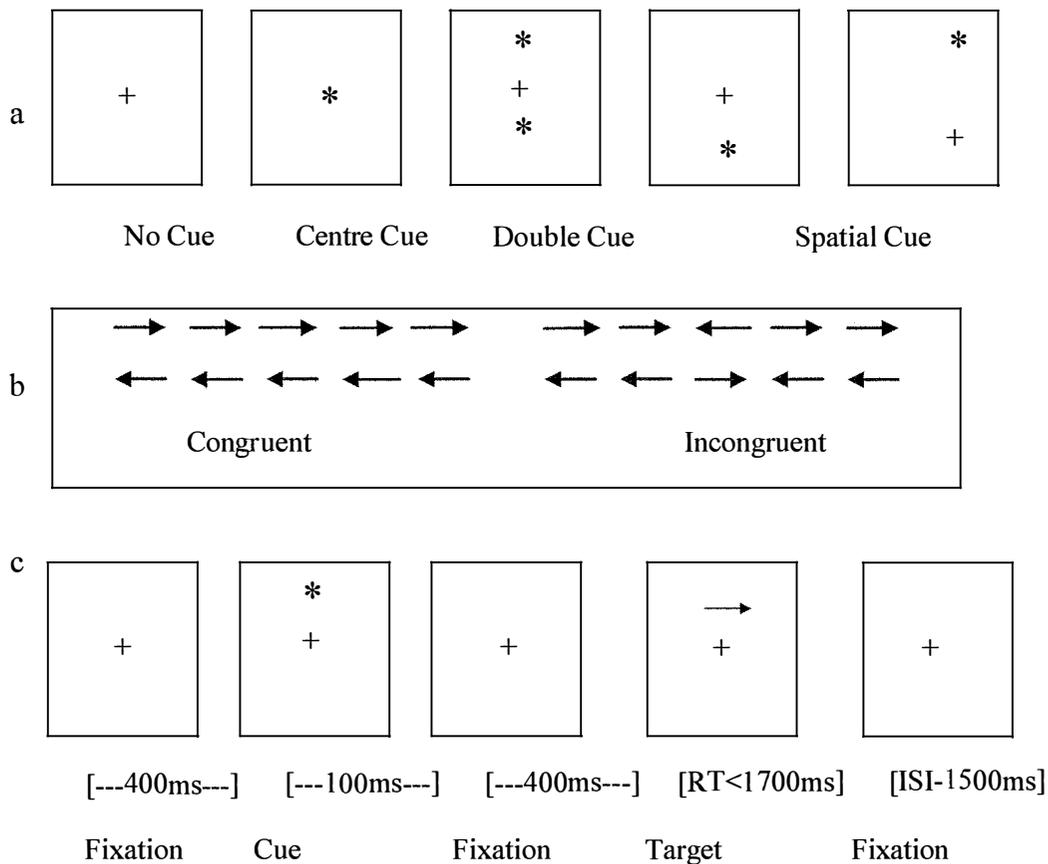


Figure 2: Experimental Design for the SuperLab Pro Version of the HSANT

