Head’s Up! Examining the Relationship between Field of View and Head Position in Ice Hockey Players

Kristine E. Walker, The University of Western Ontario

Supervisor: Wilson, Timothy D., The University of Western Ontario
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Abstract

Ice hockey is a dynamic, fast-paced game where players need to be aware of multiple factors, devoting appropriate attention to varying salient aspects to enhance performance. The term “keep your head up” is ubiquitous encouragement because if players do not, their visual field (what they can see) is compromised, performance (what they can do) decreases, and likelihood of injury increases. Head-down behaviour is problematic and is observed at all skill levels. Head position (HP) behaviour has not been quantified objectively in any sport. Through collaboration with an NHL player development coach, their practice-based knowledge and tacit experience informed the direction of the research objectives. The overall question of this dissertation was “How does head position effect game vision and skill demonstration in ice hockey players?” Objective one utilized a 3-week coaching intervention that incorporated helmet-mounted player point of view (PPOV) video and specialized training drills to provide post-practice feedback regarding HP and vision (n=18). It was hypothesized that these training sessions combined with video feedback would alter head position behaviours (Chapter 2). Results revealed this approach did not refine behaviour. Objective two simultaneously quantified multiple players’ HPs during small area games (SAG). The HP were measured in 2-on-2, and 3-on-3 SAGs (commonly used in practice). Players’ HPs (n=25) were measured with accelerometry during each on-ice shift and categorized further into HP during stickhandling or skating during offensive and defensive play (Chapter 3). The range of HP were portrayed as frequency distributions indicating player HP behaviours changed with respect to the number of players involved and the skills exhibited. Objective three quantified how players’ on-ice field of view (FOV) changed as HP decreased from the horizon, both with and without a half visor (Chapter 4). The results illustrated that head down positions severely impact FOV and it becomes dominated by immediate ice area, reducing game visibility regardless of eye movements. This dissertation, the approaches, and the results, suggests how closer collaboration of coach and performance scientist afford better blending of practice-based knowledge derived from experience with evidence-based knowledge derived from research for coaches to enhance team performance.
Keywords

Ice hockey, head position, situational awareness, skill development, coaching, practice-based knowledge, field of view
Summary for Lay Audience

Ice hockey is a fast-paced game where players always need an awareness of their surroundings. If you watch any hockey game, there are times you can point to and wonder what the athlete was thinking. Often when hockey players drop their head and look down at the ice, their ability to see is impacted potentially limiting their performance and leading to injury. Three studies were conducted to address the overall question of “How does head position affect the players ability to see and their performance on the ice?” A device was attached to the players’ helmets measuring head movements, and a small helmet camera attached above the visor to record players’ views. The first study attempts to change player’s head behaviour using drills that stress vision, here players completed drills over a 3-week period. At the end of each training session, players were provided with video feedback from their helmet camera as they performed the drills on the ice (Chapter 2). Further research is required with a focus on player skill development and how to enhance player head positioning during training. The second study simultaneously measured multiple hockey players’ head positions during 2-on-2 and 3-on-3 small area games, designed to mimic game play. The head positions measured were further grouped into skill categories identified in the game (stickhandling and skating) while the players were on offense and defense positions (Chapter 3). Players displayed a wide range of head positions for different skills, generally, as the number of players increased (2-on-2 to 3-on-3) each players’ head position dropped down towards the ice. The final study determined how a player’s vision changed as their head position dropped towards the ice, with and without a half visor on their helmet (Chapter 4). As players’ heads drop toward the ice, their ability to see decreased, and we quantify the proportion of vision dominated with ice. In order to better understand player performance and behaviour, sport scientists need to work closer together with the sport coaches. Incorporating the coaches’ knowledge can help inform the direction to conduct future research that is meaningful to the coach.
Co-Authorship Statement

This dissertation contains material from three manuscripts that are being prepared for submission (Chapter 2, Chapter 3, and Chapter 4) that encompass the collaborative work of researchers and co-authors. Kristine Walker is the primary author of all the chapters contained in this dissertation. Dr. Timothy D. Wilson (Schulich School of Medicine and Dentistry, Department of Anatomy and Cell Biology, Western University) co-authored Chapters 2-4. Dr. Bert M. Chesworth (Emeritus, School of Physical Therapy, Health and Rehabilitation Science) co-authored Chapters 2 and Chapter 3. Sebastian Vanin Moreno (PhD student, Schulich School of Medicine and Dentistry, Department of Pharmacology and Physiology) co-authored Chapter 2 and Chapter 3. Kevin Santiago (MSc, Department of Anatomy and Cell Biology) co-authored Chapter 4.
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Glossary of Terms

Cumulative Distribution Function (CDF) – describe the frequency of a phenomenon. In this case the angle of the head. Thus, CDF provides probabilities of a HP behaviour (less than or equal to the specific position) expressed during a single shift or drill (Filliben & Heckert, 2012)

Field of View – the image players can see in one glance without moving their eyes and head (Woutersen et al., 2017). It can be envisioned as a non-uniform, slightly flattened, cone extending from the eyes, encompassing a volume approximately 135° vertically and 200° horizontally (Davids et al., 1999; Leigh & Zee, 2015).

First-person vantage – a unique perspective to observe and understand the task through the eyes of another individual (Fiorella et al., 2017).

Head Position (HP) – defined as the angle between 0° at the horizon (the athlete was looking straight ahead with their helmet and visor on), and a head forward flexed position (looking down toward the ice).

Hockey Sense – player’s ability to read the gameplay within the context or surroundings and make high probability decisions on the ice with the puck, and find or create openings without the puck to gain advantage over their opponents (Malloy, 2011)

Situational Awareness (SA) – “the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future” (Endsley, 1995, 2000, 2012, 2015)

Third-person vantage – global observations of the task often from the side or in front of the individual (Fiorella et al., 2017) akin to being a spectator.
Abbreviations

2-on-2 – two players playing against two players on diminished ice surface

3-on-3 – three players playing against three players on diminished ice surface

AHL – American Hockey League

CDF – Cumulative Distribution Function

FOV – Field of View

HP – Head Position

HUP – Head up

IO – Inferior Oblique eye muscle

IR – Inferior Rectus eye muscle

LHP – Low Head Position

LR – Lateral Rectus eye muscle

LTPD – Long Term Player Development

MHP – Medium Head Position

MR – Medial Rectus eye muscle

NHL – National Hockey League

OHL – Ontario Hockey League

PDHP – Potentially Dangerous Head Position

POV – Point of View
PPOV – Player Point of View

SA – Situational Awareness

SAG – Small Area Games

SO – Superior Oblique eye muscle

SR – Superior Rectus eye muscle

VOR – Vestibular Ocular Reflex
Chapter 1

1 Introduction

1.1 Ice Hockey

Ice hockey is an intense, fast-paced sport, occurring in a dynamic environment that requires players to blend their technical and tactical skills together to perform. Games are normally an hour in duration (three periods of 20 minutes each with an intermission between periods) with player (on-ice) shifts lasting from 30 to 90 seconds in duration, followed by off-ice time of 2-5 minutes of recovery (Nightingale & Douglas, 2018). There are typically six players on the ice surface at a time for each team: three forwards, two defencemen and one goaltender. The forwards and defence are required to move around the ice surface on thin skate blades, with or without the puck (a small piece of frozen black rubber) manipulated dexterously at the end of their hockey stick. A coach can have 18 players on the roster for each game, not including the goaltenders. When possible, coaches normally assign 12 forwards to play four player line ups or lines (each line consists of three forward positioned players, left wing, center, and right wing) and six defencemen in pairs, for three lines. The defensive and offensive player lines play together as a unit. The coach’s perception of quality throughout the year enables them to categorize their lines based on skill and performance. This categorization creates a hierarchy and a player’s position in the hierarchy is related usually to amount of time they play during a game. The first and second (quality) lines of forwards will have the most on-ice shifts, accumulating an average of 18-21 minutes, followed by the third line with 14-17 minutes and the fourth line with 6-11 minutes (Wyshynski, 2015). The forwards are generally responsible for puck possession in the centre to offensive end of the ice (zone), maintaining good position for creating plays in the offensive zone and scoring (Hansen & Reed, 1979). The first pair of defencemen will have the most on-ice shifts (accumulating an average of 22-26 minutes) followed by the second pair with 19-22 minutes and the third with 15-18 minutes (Wyshynski, 2015). The defencemen are primarily responsible for preventing the opposition from shooting and scoring on their goaltender (Hansen & Reed, 1979) and are often in the most physical contact with players in the defensive zone.
As players develop their hockey skills and progress through more advanced leagues, the speed of the game increases, reducing the amount of decision-making or processing time the player has available to make play decisions. Players at the junior levels, ages 16-21, have roughly two seconds to make successful decisions, termed a play while in the American Hockey League, one of the development leagues for the professional league (National Hockey League (“NHL”)) player’s processing time is halved, while at the top professional level (NHL) they have half a second (Malloy, 2011). Giving perspective to the speed of the professional game, some players can skate one lap around the 200’x85’ ice surface (rink) in under 14 seconds, equivalent to roughly 27 mph and many players can shoot the puck over 100 mph (NHL.com, 2019) with excellent accuracy. Notwithstanding the requisite ability to be a skilled skater and shooter of the puck, players need hockey sense to encapsulate the entirety of the game; to be aware of their surroundings and activity on the ice, the puck location with respect to the positions of teammates and opponents, line changes, goaltending, score, and time left on the count down clock in each of the three periods of the game.

Mike Sullivan is the Head Coach of the Pittsburgh Penguins, winning back-to-back Stanley Cup Championships in 2016 and 2017 (Associated Press, 2019). At the start of Coach Sullivan’s presentation at the 2019 NHL Global Coaches Clinic, he explains the four characteristics of what he thinks make up an elite ice hockey player (Competitive spirit, functional intelligence, speed, and puck possession skills) (Sullivan, 2019). Two important characteristics of that definition involve hockey sense: functional intelligence and speed. Functional intelligence includes hockey sense, game sense and situational awareness (see below). Hockey sense is loosely defined as a player’s ability to fully comprehend or “read” the gameplay within the context of the opponents play and make high probability decisions on the ice with the puck, and find or create openings without the puck to gain advantage over their opponents (Malloy, 2011). Hockey Canada defines hockey sense as the “ability to make decisions that affect the play, ability to understand the tactics necessary to compete at this level, and adaptability (Hockey Canada, 2019)”. Coach Sullivan explains that “hockey sense is difficult to measure or evaluate because one must observe the player’s decisions with and without the puck”, making it an intangible skill that is highly sought after by hockey coaches and scouts alike. Another important element that Coach Sullivan mentions is speed; not just physical speed but also the team speed and a player’s decision-making capabilities.
which he describes as “mind speed,” which includes recognition, awareness, and the player’s ability to think quickly during game play. Multiple hockey coaching books highlight ways to develop physical speed (Bertagna, 2016; Davidson, 2017; Donskov, 2016; Johnston & Walter, 2019; Skahan, 2016; Twist, 2007; Walter & Johnston, 2010), however, if a player cannot cognitively process what is occurring during the game quickly enough, their performance will be limited. Coach Sullivan believes that understanding the brain will be the next frontier in the NHL [as the development of hockey sense] is an area of player performance that we know little about (Sullivan, 2019).

A parallel concept to hockey sense in the literature is the wider term, situational awareness (SA). Endsley defines situational awareness as “the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future” (Endsley, 1995, 2000, 2012, 2015). There are 3 levels of SA. Level 1 is perception of the elements in the environment within a volume of time and space. In hockey, this might be considered recognition opponents and teammates with respect to the puck and to a goal line or net. Level 2 concerns the comprehension of the meaning of these elements, here comprehension of offense or defensive play and possession of the puck are deeper than Level I. Finally, Level 3 is the projection of elemental status into the near future enabling individuals to attend to, and make, predictions regarding their immediate environment (Endsley, 2012). In hockey, this might be the player’s ability to change the course of game play quickly from defensive to offensive play by making an unanticipated pass or a stick handling manoeuvre that enacts an advantage. In skillful hockey play, all three levels of SA (perception, comprehension, and projection) must occur to provide the player with a comprehensive view of the game, allowing them to utilize their perceptual-cognitive skills to recognize, and anticipate the play, making the best decision in the shortest time possible. As the sporting environment is dominated by visual perception, vision is the factor by which the majority of SA is achieved. In Figure 1-1, the player view is recorded and exemplifies how SA must be modified based on head position. In panel A, a head up posture promotes the ability to view of the game environment (Level 1), enabling the potential for further levels of SA to develop. However, in panel B, the adoption of a head down posture reduces the player’s ability to attend to the maximum elements on the ice, the
player’s SA will be hindered, and their effectiveness will fall as they lose time and space as they simply cannot perceive elements they cannot visualize. Level 2 and 3 of the player’s SA can be altered by their perception of time and space within the play to play context (Endsley, 2000).

Due to a limited research focusing on the framework of situational awareness specifically in relation to sport, supporting literature needs to be pulled from other fields where it is conducted more frequently (Huffman et al., 2022). Two studies exploring situational awareness and vision were performed either in a highly stressful and trained scenario or in a simple day to day set of activities (Jones & Endsley, 1996; Lim et al., 2015). In highly trained air traffic controllers and pilots, Endsley and Jones (1996) conducted a search of 143 incidents recorded in the Aviation Safety Reporting System to examine the reasons behind SA errors. Within the incidents recorded, 262 different SA errors were observed with ~76% occurring in Level 1 (failure to perceive or misperceive the information), ~20% in Level 2 (improper comprehension of the information) and ~4% in Level 3 (incorrect projection of events). In a more mundane example, Lim et al. (2015) evaluated 20 individual’s SA as they walked on a treadmill and texted on their mobile phone. As the participants performed this dual task, they were asked to identify cues in their immediate visual field. Participants missed about half (~48%) of the presented cues in comparison to the number of visual cues perceived during the visual task alone. These studies demonstrate that without immediate acquisition of knowledge of elements in the environment, (SA -Level 1) simple awareness is severely hampered severely reducing the effectiveness of decision making for even simple tasks. Since the predominance

Figure 1-1. On-Ice Hockey Vision during two different game situations.  
**Panel A** – more time and space are available to the player to read the play.  
**Panel B** – less time and space available to the player.
of SA errors occur with a failure to perceive the information, we suggest the degree of perception in hockey is key to performance. Thus, it is important to quantify how head position influences vision of the game. Through better understanding of how hockey players acquire and incorporate visual information coaches are provided better opportunities to modify behaviours that affect the player’s ability to process the game and perform which may be equal to, or greater in importance, than good skills alone.

To perform at high levels, players must devote visual attention to their surroundings by keeping their “head on a swivel” (Figure 1-1) to visually attend to game cues and outplay their opponents (Peterson & Zaichkowsky, 2020). Fundamentally, good hockey player positioning on the ice is described as feet shoulder width apart, knees bent, hips low, chest square, and head up (Davidson, 2017; Francisco, 2012; Mell et al., 2017). Bending the legs, lowers the athlete’s center of gravity enabling better balance. Balance allows players to efficiently execute their skating techniques, integrate stickhandling skills and perceive their surroundings (Davidson, 2017). Player development models take an athlete-centered approach providing recommendations for age-appropriate training to create a foundation for the player to develop and grow. In the USA Hockey Athlete Development Model for 8 and under athletes, attention is devoted to coaching athletes on the importance of head-up play and highlighting the ability to perceive their surroundings (USA Hockey, 2021). In comparison, as the players develop within the Hockey Canada system, little regard is given to the importance of proper head positioning until they reach under 15 and 18 (U15/U18) (Hockey Canada, 2021). By the time players reach this age level, they could spend a minimum of 920 formal hours of training prior to ever reaching this stage without reinforcement of the importance of head position.

Professional coach and skills consultant, Mike Ellis, currently the Tampa Bay Lightning Director of Skill Development is involved in elite ice hockey training and coaching for over 40 years, in a variety of roles from athlete to head coach. Through his practical knowledge and experience, he recognizes the disconnect between skill execution without proper head positioning. Coach Ellis’s methodology focuses on the role of head position as he teaches players specific skills and how best to apply them in game situations. In every training drill, the importance of head position and its effect on the players’ ability to perceive the game is stressed. He uses the analogy of the 10ft, 20ft and 30ft game consistently.
1.2 Vision in Sport

1.2.1 Field of View

For this dissertation’s context, field of view (FOV) is defined as the visual image players can see in without moving their eyes and head (Woutersen et al., 2017). The FOV can be envisioned as a non-uniform, slightly flattened, cone extending from each eye, together encompassing a volume approximately 135° vertically and 200° horizontally (Davids et al., 1999; Leigh & Zee, 2015). This volume encompasses both central (foveal) and peripheral vision, as illustrated in Figure 1-2. Due to the small size of the fovea (1.5mm) (B. T. Carter & Luke, 2020) central vision, vision of the sharpest resolution, represents less than 2° of the field of view (Zaichkowsky & Peterson, 2018) (Figure 1-2). Despite the relatively small area, approximately 25% of the visual cortex is dedicated to processing visual input perceived from foveal vision (Fisch, 2017; Holmqvist & Andersson, 2017). Peripheral vision then encompasses the remaining 98% of the visual field (B. T. Carter & Luke, 2020; Holmqvist & Andersson, 2017). Peripheral vision is not uniform, a detailed peripheral visual zone represents the area between central vision and increasingly blurry peripheral vision (Peters, 2012). It appears detailed peripheral vision is plastic, elite athletes may have detailed vision zones extending from 20 degrees up to 80 degrees from the edge of the foveal vision (Peters, 2012). Despite peripheral vision having lower resolution than foveal vision, elite athletes may detect up to 220 degrees at the extremes of their horizontal periphery (Peters, 2012). Although still a matter of debate (Poltavski & Biberdorf, 2015), game play requires the athlete to attend to peripheral vision.

Figure 1-2. Human Field of View.

Panel A – Conical image of a single human eye field of view, 135° vertical and 200° horizontal. When both eyes are side by side, the cones overlap in the middle.

Panel B – The small, lighter circle represents central vision (less than 2°). The dark grey area surrounding represents the athlete’s peripheral vision.
extensively for what is termed, course visual information and presumably Level 1 situational awareness. For hockey players, the horizontal periphery possesses the majority of cues like personal orientation on the ice, location and direction of themselves in relation to moving teammates and opponents, and the puck (Holmqvist & Andersson, 2017). This is beneficial for hockey players as the game of hockey is predominantly horizontal in nature (Peters, 2012). This disadvantages those who keep their head down, as it directs their FOV downwards to a position dominated by immediate surroundings. Furthermore, the head down position forces players to use contrast sensitivity vertically as opposed to our evolutionary advantage of horizontal sensitivity. Despite this general knowledge of field of view, Williams et al., (2005) and Hodges et al., (2021) lament the need for further research in relation to sports performance as it represents a viable area for sport science and coaches to collaborate to enhance athletic performance.

1.2.2 Eye Musculature

The human eye has 3 degrees of rotational freedom in which both eyes move in unison, however the eyes normally return to the center of the orbit where all extrinsic eye musculature is relaxed without any forces pulling it horizontally or vertically (Leigh & Zee, 2015). In order for the extraocular muscles to rotate the eye, two primary forces must be overcome for movement to occur: viscous drag of the eye moving within the orbit and elastic restoring force of the opposing (antagonist) musculature (Leigh & Zee, 2015). Once the eye has rotated to its new position, a continual contraction of the extraocular muscle must be maintained otherwise the elastic restoring forces will pull the eye back to its center, or resting position (Leigh & Zee, 2015). The six extraocular muscles that rotate the eye attach to the sclera (the white element of the eye) (Davids et al., 1999; Mulvey, 2012). The muscles work in agonist/antagonistic pairs to rotate the eye in three different orientations: vertical, horizontal, and torsional (Goldberg et al., 2012). The superior rectus (SR) and inferior rectus (IR) are responsible for vertical eye movements: the SR rotates the pupil above the neutral plane (look up) while IR rotates the pupil below the neutral plane (look down) (Goldberg et al., 2012). The lateral rectus (LR) and medial rectus (MR) muscles are responsible for horizontal movements: the LR the eye outwards, and the MR the eye inwards (Goldberg et al., 2012). The superior oblique (SO) and inferior oblique (IO) are muscles with different insertions on the eye that are not as linear as the rectus groups. The oblique musculature is
responsible for torsional movements: the SO is responsible for intorsion (inward rotation) and the inferior is responsible for extorsion (outward rotation) (Goldberg et al., 2012). Since humans are binocular and the eye musculature is a mirror image of itself bilaterally, the coordination of muscle contractions to both eyes in parallel, in torsion, within the same velocity is important to vision. Both horizontal (LR and MR) and vertical (SR, IR, SO and IO) eye movements are responsible for keeping the field of view centered over the fovea, the specialized retinal area, at the back of the eye, that supports the highest visual acuity (Holmqvist & Andersson, 2017; Purves et al., 2001). Three different cranial nerves are responsible for innervating the extraocular eye muscles: oculomotor (cranial nerve III) innervates the SR, IR, MR and IO, trochlear (cranial nerve IV) innervates SO, and abducens (cranial nerve VI) innervates the LR (Goldberg et al., 2012; Purves et al., 2001).

1.2.3 Visual Input and Processing

How does a player perceive visual information from their surroundings? The process begins with the eyes. There are three layers of the eye: the outer, the middle and innermost (Fisch, 2017). The outer layer comprises the cornea, lens, and sclera, the outer visible parts of the eye which are responsible for the transmission of light to the retina (Fisch, 2017). The cornea and lens are transparent to allow the passage of light (Mulvey, 2012; Zhu et al., 2012). The sclera is opaque to block the transmission of light and serves as the attachment point for the six extraocular muscles involved in rotating the eye (Fisch, 2017). The middle layer comprises the iris, choroid, and ciliary body and is responsible for focusing the light onto the retina. Light is funneled through the pupil as the pigmented iris blocks light transmission (Litzinger & Del Rio-Tsonis, 2002; Mulvey, 2012; Zhu et al., 2012). The choroid and ciliary body balance the size of the pupil depending on the depth of the object (near or far), and the ambient light through which the object is viewed (brightness). The innermost layer comprises the retina (Fisch, 2017). On the retina, the fovea is a depression at the back of the eye, and it is responsible for highly detailed visual acuity (B. T. Carter & Luke, 2020). If the image is greater than 2° away from the fovea, acuity decreases by 50% (Leigh & Zee, 2015).

Light enters through the cornea and the lens, and it is altered and bent on its way to the fovea through the gelatinous vitreous fluid. The image on the fovea is two dimensional and upside down (Davids et al., 1999). The light must go all the way to the back of the retina
where it is translated back through three different layers of cells before it becomes a neural signal (Kandel et al., 2013). The three different layers (from back to front) through which the light must pass are the outer nuclear layer where the photoreceptor cells are located, the inner nuclear layer where horizontal cells, bipolar cells, and amacrine cells are located and lastly the ganglion layer where the retinal ganglion cells are located (Kandel et al., 2013). When light reaches the outer nuclear layer, it interacts with two main photoreceptors (rods and cones) that are responsible for converting light into a neural signal through a process called phototransduction (Kandel et al., 2013). Both of the photoreceptors serve very different purposes and are dispersed differently throughout the retina. Rods are low resolution, small and narrow in shape, perform better in dim lighting and they can be found in the periphery of the retina (Fisch, 2017). Cones are high resolution, conical in shape, perform best in bright light, used for colour vision (they recognize red, green and blue) and they are located in the central foveal vision (Fisch, 2017). Rod cells outnumber cones 15:1 (Fisch, 2017). From the sensory apparatus at the back of the eye, the neural signal is carried to the lateral geniculate nucleus on its way to the primary visual cortex. The left lateral geniculate nucleus receives input from both eyes about the right visual field and the right lateral geniculate nucleus receives input for both eyes about the left visual field (Kandel et al., 2013). By the time the signal reaches the primary visual cortex, information about line orientation, colour, contrast, disparity and movement direction are known (Kandel et al., 2013).

From the primary visual cortex, visual processing breaks into two separate streams; the dorsal (where) and ventral (what) stream. Visual processing at the level of these two streams focuses on enhancing and combining the smaller details such as contour integration, surface properties, shape discrimination, surface depth, surface segmentation, objection motion and shape from kinematic cues (Kandel et al., 2013). The dorsal stream runs from the primary visual cortex (also known as V1) to the posterior parietal lobe (Fisch, 2017). It processes information quicker of the two streams and it is responsible for determining orientation in space and time, and directing attention to locations in space (Vickers, 2007). The ventral stream runs from the primary visual cortex to the temporal lobe and it is involved in information processing and incorporating high order cognitions such as decision making (Vickers, 2007). The streams then send their information to the frontal cortex where all of the information gathered is assembled back together (Vickers, 2007). There are two types of
processing for visual input: bottom-up and top-down and they vary in the information they process.

Bottom-up processing occurs when the athlete processes the salient stimuli immediately (Erickson, 2021; Vickers et al., 2016). Salient features can be colour, texture, motion, edges or other properties that “pop,” or stand out without the need for conscious processing (Vickers, 2007). Salient features in relation to hockey could be the lie of the opponent’s hockey stick or the direction the player’s skates are moving when they are being chased, or when an opponent skates toward another player, posing an immediate threat decreasing the amount of time and space for the player to make decisions. Once the salient stimuli are perceived by the retina, neuronal signals travel through the lateral geniculate nucleus to the primary visual cortex, splitting into the two sensory streams (dorsal and ventral) before converging at the prefrontal and posterior parietal cortex (Corbetta & Shulman, 2002; Erickson, 2021). Top-down processing occurs when the athlete uses past experience and knowledge to inform their decision (Corbetta & Shulman, 2002; Erickson, 2021). This form of processing typically occurs faster and leads to a decision informed through their intuition and their on-the-ice training, experience, and knowledge (Vickers, 2007). Both top-down and bottom-up processing play key roles and are important to take into consideration in terms of skill development (Vickers, 2007).

1.2.4 Eye-Head Connection

When the head is stationary, the eyes rotate to create a field of view approximately 135° vertically and 200° horizontally (Davids et al., 1999; Leigh & Zee, 2015). The eye musculature is limited to a range of motion, in this case rolling the eye within the orbit. During a hockey game, players need to have their head unrestrained to perform and perceive input from their surroundings. The head can move in 3 planes: rotations laterally, left to right; sagittally, up and down; and rotationally, keeping the head in upright position while cornering sharply. For coaches, it is important to understand the connection between eye and head movement.

How does player head position in the head up/down plane (sagittal) affect player performance when the game is horizontal in nature (Peters, 2012)? Head movements occur for three reasons; to assist in bringing the eyes back to the central position in their orbit, to
make compensatory movements that maintain a stable image when body position is altered, and for communication and expression (Proudlock & Gottlob, 2007). Human oculomotor range limits eye rotation to a maximum of ~50° before head movement must be initiated (Ing et al., 2002). The eye influences head position (Fang et al., 2015) as visual processing occurs best when head/eyes are in alignment (Nakashima & Shioiri, 2014) as opposed to the eye being held in an eccentric (off-center) position. When eccentric positions occur, unconscious decisions are quickly made to determine if eye or head movement will occur (Nakashima & Shioiri, 2014) as the situation dictates. In hockey training environments, coaches emphasize the importance of head position to their players, explaining that their eyes will lead their head and ultimately determine the size of field of view they can perceive (Corneil, 2011; Holmqvist & Andersson, 2017) and the magnitude of situational awareness that can be achieved.

Head movement is perceived through three sensory pathways that intersect to inform individuals of their location and orientation. Vision normally provides context to our position in relation to the overall environment while neck proprioception informs the individual of the interplay between the sensing organs (eyes and vestibular system) with respect to the body. The vestibular system is composed of 2 primary sensory organs bilaterally. The vestibular organs are subdivided into 3 semicircular canals and a two-component otolith. The semicircular canals indicate angular accelerations of the head while the otoliths are reactive to linear accelerations (Somisetty & M Das, 2021; Vilis & et al, 2013). Located within the inner ear and fully encased in petrous portions of the temporal bone, these endolymph-filled organs relay information to the brain via cranial nerve VIII, the vestibulocochlear nerve (Armstrong et al., 2008; Goldberg et al., 2012; Leigh & Zee, 2015). The utricle is larger in size, containing ~30,000 hair cells (Brain Made Simple, 2021; E. R. Kandel et al., 2013). When the head is in an upright, neutral orientation, the utricular macula is sensitive to movement in the horizontal plane (Brain Made Simple, 2021; E. R. Kandel et al., 2013). In comparison, the saccule is smaller in size, containing ~16,000 hair cells and is sensitive to movement in the vertical plane (Brain Made Simple, 2021; E. R. Kandel et al., 2013). The macula, in both the utricle and saccula, is the region in each organ where hair cell movement is detected allowing the perception of head tilt and orientation (Brain Made Simple, 2021; E. R. Kandel et al., 2013; Purves et al., 2001b). The semicircular canals are 3 orthogonal canal
loops (horizontal, superior, and posterior) that detect angular acceleration in all directions. Both left and right semicircular canals are rotated within the head away from the horizon and away from a purely anterior plane. Thus, when the head is in a neutral position with the eyes to the horizon, the horizontal semicircular canals are tilted upward approximately 30° and the anterior canal is rotated roughly 45° laterally from the sagittal plane. This orientation suggests that most everyday rotational movements are accurately interpreted through the integration of input from all 6 semicircular canals (E. Kandel et al., 2013). Although significant neural integration is achieved to discern rotation, each canal has a predominant plane of activation. The horizontal canal is most sensitive to horizontal rotations while the anterior and posterior canals are more sensitive to sagittal and coronal (lateral head) rotations. The posterior canals are activated with neck extension, and head tilt. The anterior canals are most activated with neck flexion and head tilt (Canadian Neuro-Ophthalmology Group, 2021). The canals work in three agonist/antagonistic pairs like the extraocular muscles; the left and right horizontal canals, the left anterior and right posterior canals, and the right anterior/left posterior canals to discern the most accurate representation of head and body rotation. If accelerations are sensed in the right or left horizontal canal, the lateral and medial rectus extraocular muscles are pulled causing the eyes to rotate in a clockwise direction (right side horizontal canal stimulation) or counterclockwise direction (left side horizontal canal stimulated) (Fisch, 2017). Accelerations in the anterior canal pull the eyes in an upward direction, and accelerations in the posterior canals pull the eyes in a downward direction (Fisch, 2017; Leigh & Zee, 2015).

1.3 Coaching

1.3.1 Deliberate Practice

The theory of deliberate practice proposed by Ericsson (1993), explains that in order to become an expert, an individual must spend significant time, 10,000 hours or 10 years, performing a skill, while maintaining an emphasis on both the quality of practice and quantity of repetitions (Harwell & Southwick, 2021). Ericsson further classified practice into three styles: naïve, purposeful, and deliberate. Naïve practice revolves around the thought that repeatedly performing the skill will lead to an improvement and occurs without a coach. Purposeful practice is designed by the athlete and has a defined goal allowing the outcome to
provide feedback to the athlete. For example, a hockey player wanting to improve their shot on net. The puck will either go in the net or miss, providing the athlete the opportunity to critique their performance. Deliberate practice requires the athlete to focus on specific details of their skills and make binary decisions, “did I achieve my desired outcome yes/no,” during the practice about tasks they may not enjoy but are perceived to enhance their performance (Ford & Coughlan, 2020). This style of practice is designed by the coach with the inclusion of feedback provided by the coach on how the athlete can improve their performance (Harwell & Southwick, 2021). As players age, finer refinements of a skill may need to occur for a few reasons such as a change in sports equipment, the player’s kinematic movement patterns (may not be as efficient causing a decrease in performance outcome), or for injury prevention (Carson & Collins, 2014; Sperl & Cañal-Bruland, 2019). Pertinent to this discussion, if the player has learned to stickhandle the puck with their head down for a significant amount of time, how can a coach refine their technique?

1.3.2 Practice Design

   There are two approaches coaches can take when designing their practice plan: a traditional skills-based, or a games-based approach. Both approaches can complement each other depending on the targeted outcome for the practice. Traditional skills-based approach practice plans follow the structure of warm-up, isolated skill-based drill work then a scrimmage to finish. Games-based approaches take a whole-part-whole approach where the structure of practice is warm-up, game play, drills focused on game play then back into scrimmage or game play (Martens, 2012). Coach Sullivan alludes to enhancing player skill acquisition through the incorporation of top-down and bottom-up approaches in coaching (USA Hockey, 2015). In the book Decision Training in Ice Hockey by John Bales and Joan Vickers (1996), both top-down and bottom-up visual processes are emphasized and broken down in terms of how they can help with the development of decision making. Incorporating both traditional and games-based approaches to coaching, allow the athlete to develop the way they visually process the game; relying on the bottom-up processing to register immediate, salient stimuli and on top-down to recognize team patterns of play and goal-oriented strategies with their teammates (Erickson, 2021).
The traditional skills-based practice approach emphasizes players’ bottom-up visual processing, focuses on developing a strong technical foundation, resulting in quick improvements in practice but does not produce a skill that holds up in a game (Bowker, 1996). Athletes perform their drill repetitions in a blocked style design, with little variation where they only focus on one skill before building and advancing onto the next (Pill, 2016). For example, a player may be able to perfectly stickhandle the puck with their head up in the absence of teammates or opponents, however that skill may deteriorate in a game as they have not practiced it in the same environment.

A games-based approach incorporates both top-down and bottom-up visual processing as the drills resemble the game, requiring players to use and develop the tactical and cognitive skills they will need to succeed. Instead of performing drills in isolation, competition-like drills and variability that encourages a player to use their technical skills under pressure are utilized (Pill, 2016). For example, instead of a hockey player stickhandling solo, a pair of players, each with their own puck, can skate down the ice passing the two pucks back and forth between each other. This adds a layer of anticipation and cognition to the drill as the teammates need to work together as they would in a game. Athletes are provided feedback but always in terms of relation to a game situation. Despite the benefits of top-down style approach, it takes longer for the athlete to develop and retain the skills (Bowker, 1996).

1.3.3 Incorporation of Video for Player Development

Aside from practice-design, another way to enhance player’s learning is through the incorporation of video (Bowker, 1996). The use of video is thought to provide the player with a repeated view of their play. Classically, we may assume video takes the form of the way we watch the game, the third-person vantage, where players may concentrate on themselves in relation to the team play to better understand their skills in relation to their situational awareness. The first-person vantage records video of players’ actions at the level of the playing surface where a different perspective of their skill and situational awareness are demonstrated (Figure 1-3). Very limited research has investigated the importance of which perspective the video should take to provide players with effective feedback on their performance. The first-person vantage or point of view (POV)(Figure 1-3A) provides a unique perspective for the player to observe and understand the task through the eyes of
another individual or team mate (Fiorella et al., 2017). For example, if a player is missing important visual cues during a drill or game, a coach or teammate could record their POV as they perform certain drills or shifts within training or gameplay. The same player struggling could also wear a POV camera to record themselves performing the task, enabling them to watch the drills back from their POV with a coach, utilizing the video to receive feedback to enhance performance. Third-person vantage or point of view (POV) (Figure 1-3B) provides global observations of the task often from the side or in front of the individual (Fiorella et al., 2017) akin to being a spectator. Viewing video from third-person vantage results in slower learning as the process requires the athlete to utilize more working memory capacity to develop their own mental representations (Fiorella et al., 2017). Coaches utilize video to scout their opponents in various games and observing drills and set play configurations during practice from a bird’s eye perspective. Currently, the implementation of POV cameras into sport training is not common practice in the scientific literature but has been incorporated amongst a few athletes training regimes in elite skiing, snowboarding and cycling (B. Carter, 2012). If the coach is trying to develop a player’s game awareness on the ice, implementing the use of POV cameras into practice and games would enhance the player’s learning (as they do not have to spend extra time performing mental rotations trying to figure out what they should see). This approach may lead to better understanding of the coach’s feedback as the POV video allows coaches to see what the player was/was not seeing during their shift or practice drill. For example, what if a hockey player missed an opportunity to pass to their open teammate but instead turned the puck over to their opponent? What was happening in that situation that caused them to miss that. Was
their head down not allowing them to see the opportunity or were they looking somewhere else on the ice? By enabling players with a way to re-watch their performance, their decision-making and performance may be enhanced or altered as it allows them with feedback to understand errors/mistakes. As the player’s top-down processing relies on past experience and knowledge to inform their performance (Erickson, 2021), this could provide a way to augment their knowledge and modify their behaviour the next time a similar play occurs.

1.3.4 Science-Coach Interaction

The gap in the literature on skill refinement in sport could be illustrative of the existing disconnect between science and coaching practices (Anderson, 2020; Farrow et al., 2013). As Dr. Zaichkowsky (2018) explained in the Playmakers Advantage “To control variables and isolate a finding, a lab experiment breaks down sport into simpler components. However, the intricacy and interrelationships of multiple moving players in a real game add another dimension of analysis that an isolated task in a lab can’t capture.” It is very hard to replicate and understand the dynamic nature of ice hockey skills in a lab setting, as the skills being studied may differ from those during a game, in terms of the way they are expressed and the context in which they are expressed (Fullagar et al., 2019; Woods et al., 2020). For example, an athlete may be able to stickhandle the puck easily with no one around them, however, if an opponent or teammate was involved to pass the puck too, another level of complexity would be added.

Hockey coaches have innate, tacit knowledge based on their experience within the sport (Mell et al., 2017). When coaches seek knowledge and answers on best practices, their preferred methods are often conversations with other coaches, or coaching conferences (Fullagar et al., 2019; Reade et al., 2008). With the disconnect of where to source scientific information, and a lack of skill refinement research in sport being conducted, how does a coach incorporate evidence to support their training design? It has been inferred that “Innovation and progression of coaching methods are often in advance of scientific rationale and understanding (i.e. coaches use drills and exercises to affect performance long before there is a body of evidence to support or refute their use)” (French & Ronda, 2022; Gamble, 2021; Thompson et al., 2020). Collaborating with sport coaches to conduct practice-based research in areas they are interested in (technical and tactical behaviour, and skill acquisition)
provides a potential solution to start bridging the two fields (Fullagar et al., 2019; Gamble, 2021; Sullivan, 2019, 2020; Waller, 2020). Coach Brett Bartholomew, a well-known strength and conditioning coach, author, and Founder of Art of Coaching™, has written “in our science-centric world – where scientific research is seen as the ultimate validation of an idea – other forms of evidence are becoming marginalized” (Bartholomew, 2016). Practice-based studies are conducted in real-world environments with less control and structure as labs (French & Ronda, 2022). Due to the dynamic nature of an ice hockey game, studying skills in a lab setting would limit the ecological validity and application of results, as the skills required differ from those on the ice, and further the disconnection between the fields of coaching and science (Fullagar et al., 2019). The knowledge and insight gained can inform the direction on conducting more rigorous studies in the laboratory (Gamble, 2021). This would enable coaches and scientists to work together, striving to attain the same goal of enhancing performance (Waller, 2020). Unfortunately, funding and grant agencies regard highly controlled, rigorous studies as the gold standard over real-world application research (Keegan et al., 2017). This limits and under-values the amount of practice-based research being conducted and published (Langford & Bird, 2020).

1.3.5 Representative Design Learning

Conducting sport research in environments that are conducive to performance is important (Kredel et al., 2017; Robertson & Farrow, 2018). Understanding sport performance in natural settings is often difficult as it is challenging to mimic the constraints of the sport (Pinder et al., 2011; Woods et al., 2020). A representative learning design reflects the ability of the constraints to replicate the natural sport in training (Pinder et al., 2011). This enables athletes to perform their sport, the same way they would during competition. Players are able to pick up on contextual cues from opponents, and teammates to make their decisions (Pinder et al., 2011; Woods et al., 2020).

Incorporating game-based elements into practice for individual and team development, plays an important role for several reasons. First, it enables players to learn in an environmental context that represents competition (Kredel et al., 2017; Pill, 2016; Robertson & Farrow, 2018). Pittsburgh Penguins Head Coach Mike Sullivan explained at NHL coaching conferences that “in a false environment (one lacking competition) the skill won’t
transfer effectively. Players need to learn the skill when fatigue and pressures of the opponent are absent, but coaches aim to simulate elements of a game scenario. In practice, this can be done by pushing players into tighter spaces with limited time. Sullivan suggests that the athletes need to “struggle and practice with purpose to learn and grow” (Sullivan, 2019). Second, game-based elemental approaches enable athletes to practice their skills sequentially, over multiple iterations, developing permanency of the patterns that endure temporally (Bowker, 1996). Lastly, including game-based elements provides athletes with enhanced ability to rehearse and enhance their perceptual-cognitive and decision-making skills. As Coach Sullivan said in the book, The Playmaker’s Advantage, “if you want to practice or train decision-making, awareness, anticipation, and those types of intellectual skills, you have to create activities in practice that closely resemble the demands of the game itself (Zaichkowsky & Peterson, 2018).” Since situational awareness develops quietly in conjunction with skill training (Endsley, 2012), coaches can assist in the development of the player’s hockey sense (ability to see and process game events) through game like drills and scrimmages.

1.4 Purpose

With only intuition-based knowledge on the importance of ice hockey player head positioning, the overall research question this dissertation will address is How does head position effect game vision and skill demonstration in elite ice hockey players? The research question will be addressed through three objectives.

The first objective was to evaluate a 3-week head-up training intervention that provided player-based point of view (PPOV) video feedback while performing on-ice drills in elite hockey players. The aim of the drills was to provide players the ability to self-monitor and modify head position to higher head positions during hockey drills. It was hypothesized that individual head positions could be altered through practice-based intervention.

The second objective was to simultaneously quantify multiple players’ head positions (HP) during small area games (SAG). More specifically, to quantify HP in a 2-on-2 and 3-on-3 SAG commonly used in practice, and quantify HP during expressions of the most commonly used skills (stickhandling and skating) in both offensive and defensive play.
The third objective was to quantify how players’ on-ice field of view (FOV) changed as their head position decreased from the horizon, with and without a half visor use.
1.5 References


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Chapter 2

2 Refinement of Head Position in Elite Ice Hockey Players

2.1 Introduction

Ice hockey players spend hours practicing and developing their skill in the hopes of playing for a team in the National Hockey League. Fundamentally, good hockey player positioning is described as feet shoulder width apart, knees bent, hips low, chest square, and head up (Davidson, 2017; Francisco, 2012; Mell et al., 2017). As young players learn the sport, little attention is paid to proper head positioning anecdotally nor in the Hockey Canada Long Term Player Development (LTPD) model (Hockey Canada, 2013). The LTPD model takes an athlete centered-approach providing recommendations for age-appropriate training to create a foundation for the player to develop and grow (Hockey Canada, 2013). As the players develop, they learn more advanced technical skills, individual and team tactics, team play and strategy (Hockey Canada, 2013). The LTPD recommendation is for players 5-6 years old (yo) to participate in 35-40 practice (50 minutes) that place an emphasis on technical skill 85% of the time and compete in 15-20 simulated games. For 8-9 (females)/9-10 yo (males) the number of practices increases to 45-50 that focus on technical skill 50% of the time and compete in 45-50 games. In the 11-15yo (females)/12-16yo (males) they have 55-60 practices (80 minutes) spending only 35-40% on technical skill and compete in 50-55 games (Hockey Canada, 2013). In a six-year timespan, an athlete might only spend a minimum of 186 formal hours focusing on technical skill development by the time they are 11 years old. As head position is not prioritized until the team play/offensive skills category in the U15/U18 Train to Train level, players could spend a minimum of 920 formal hours training prior to reaching this stage without reinforcement of the importance of head position (Hockey Canada, 2013). In comparison, the USA Hockey Athlete Development Model for 8 and under athletes, suggests head-up play is important highlighting the ability to perceive their surroundings (USA Hockey, 2021).

Perception of the individual’s surroundings has been described by various hockey personnel as an important quality of hockey sense they seek when scouting athletes (Malloy,
Hockey sense is loosely defined as “player’s ability to read the gameplay within the context or surroundings and make high probability decisions on the ice with the puck and find or create openings without the puck to gain advantage over their opponents” (Malloy, 2011). The closest construct to hockey sense in the scientific literature is Situational Awareness as proposed by Endsley (1995). It is defined as “the perception of the elements in the environment within a volume of time and space (level 1), the comprehension of their meaning (level 2) and the projection of their status in the near future (level 3)” (Endsley, 1995, 2000, 2012, 2015). If a player plays with their head up, they can perceive their surroundings and incorporate various perceptual-cognitive skills of anticipation, deception, and pattern recognition to enhance their performance. A player’s situational awareness can influence their decision making ability and performance on the ice (Huffman et al., 2022). For example, in a hockey game, if a player has a breakaway opportunity and they are skating down the ice with the puck, they need to perceive the defender’s location. If the player outskates the defender, the player needs to comprehend what this means in relation to them shooting the puck at the net. Lastly the player needs to predict what move the goaltender is going to perform to try and stop the puck from going in the net. Will they come out of the net towards the player or stay in net, watching the player to see if they can anticipate what the player is about to do. If the player misperceives their surroundings through the adoption of a head down position, they may not have been afforded that shot on net or worse they might turn the puck over to their opponent who consecutively scores. In the situational awareness literature, it has been found that errors are more likely to occur in perception (level 1) (Jones & Endsley, 1996, Mason 2020). Gaining an understanding of how head position influences the player’s ability to perceive their surroundings provides the coach with an opportunity in training to potentially modify the behaviour. Situational awareness develops quietly with practice (Endsley, 2012). As the player becomes better at perceiving their surroundings, their performance should improve.

The theory of deliberate practice proposed by Ericsson (1993), explains that in order to become an expert, an individual must spend 10,000 hours or 10 years performing a skill, while maintaining an emphasis on both the quality of practice and quantity of repetitions (Harwell & Southwick, 2021). Ericsson further classified practice into three styles: naïve, purposeful, and deliberate. Naïve practice revolves around the thought that repeatedly
performing the skill will lead to an improvement and occurs without a coach. Purposeful practice is designed by the athlete and has a defined goal allowing the outcome to provide feedback to the athlete. For example, a hockey player wanting to improve their shot on net. The puck will either go in the net or miss, providing the athlete the opportunity to critique their performance. Deliberate practice requires the athlete to focus on specific details of their skills and make binary decisions, “did I achieve my desired outcome yes/no,” during the practice about tasks they may not enjoy but are perceived to enhance their performance (Ford & Coughlan, 2020). This style of practice is designed by the coach with the inclusion of feedback provided by the coach on how the athlete can improve their performance (Harwell & Southwick, 2021). As players age, finer refinements of a skill may need to occur for a few reasons such as a change in sports equipment, the player’s kinematic movement patterns (may not be as efficient causing a decrease in performance outcome), or for injury prevention (Carson & Collins, 2014; Sperl & Cañal-Bruland, 2019). Pertinent to this discussion, if the player has learned to stickhandle the puck with their head down for a significant amount of time, how can a coach refine their technique?

Skill acquisition research focuses on the development of a new skill and through training, the subcomponents of the skill become automatic (Sperl & Cañal-Bruland, 2019). In ice hockey for example, this could be a player learning to skate. Once this basic skill has been acquired, complexities are added commencing with learning to skate with a stick, followed by a stick and puck, progressing into control of the puck. As players reach the elite level, they are no longer at the stage of acquiring a new skill but refining their previously learned or automatic skills. A dilemma presents itself however as there is a gap in the literature that focuses on the refinement of an already developed, automatic skill (Carson & Collins, 2014; Sperl & Cañal-Bruland, 2019; Toner et al., 2020). Often in the literature, the term changing automated movement patterns is interchanged with technical refinement (Sperl & Cañal-Bruland, 2019) but they are different aspects. The definition for changing automated movement patterns is “the relatively permanent modification of an already acquired movement pattern while the overall task goal remains the same” (Sperl & Cañal-Bruland, 2019). In comparison, technical refinement is defined as “the evolution of technique in a way that is new (emphasis added) to the athlete” (Carson et al., 2014) and it is specific to each individual player in terms of speed and ability (Carson & Collins, 2014). Factors such as
previous experience (knowledge and skills), traits (genetic and maturation rate), motivation and coachability play into this timeline (Rose & Christina, 2006). When refining a skill, an athlete often experiences a decrement in their performance caused by interference from the old way of performance (Carson et al., 2016; Carson & Collins, 2014, 2018; Kearney et al., 2018; Sperl & Cañal-Bruland, 2019; Toner et al., 2020). Often coaching staff and training concentrate on the mechanical components of skill leaving the perceptual components of skill application to develop simultaneously with the experience of the players (Hockey Canada, 2013).

MacAskill (2016) aimed to train athlete’s upward gaze and on-ice performance in a cross-over design study in young hockey players. The participants (10-year-old hockey players) either received the off-ice computer-based training designed by Quickstickz for 30 minutes, four times a week, for four weeks, or no additional training (control) prior to switching groups. Unfortunately, the study had a high dropout rate which compromised the quality of the study. One limitation of the study was caused by athletes undergoing training in an environment that was not representative of their sport (MacAskill, 2016). The computer monitor provided feedback to the players on puck location, however in a real-game situation, there are various visual cues for them to pick up on such as opponents and teammates; the puck will not be in their direct line of sight if they have an upright head position. Through the incorporation of training in representative (on-ice) settings, there are better opportunities to understand player skill in relation to gaze and further extrapolated, their head position, as the eye processes visual information quicker when it is in alignment with the head orientation (Fang et al., 2015; Nakashima & Shioiri, 2014).

One important perceptual skill for player’s to have is their ability to be vigilant of the ice surface and the developing play. Video can be a useful tool for coaches to implement to scout their opponents in various games (developing the team’s ability to recognize patterns), observing drills and set play configurations during practice, and as a way to enhance player learning (Bowker, 1996). Here, coaching staff may debrief the athlete at key moments of play or often, the athlete self-studies the video and intrinsically critiques their performance. Often the athlete concentrates on the overall performance rather than the integral components of modifiable skills that ultimately support the performance. Very limited research has been done on the importance of which perspective the model video should have while performing
the task, first or third. First-person vantage or point of view (POV) provides a unique perspective for the player to observe and understand the task through the eyes of another individual (Fiorella et al., 2017). Third-person vantage or POV provides observations of the task often from the side or in front of the individual (Fiorella et al., 2017). Viewing video from third person POV results in slower learning as the process requires the athlete to utilize more working memory capacity to develop their own mental representations (Fiorella et al., 2017). The implementation of POV cameras into sport training is not common practice in the scientific literature but has been incorporated amongst a few athletes training in elite skiing, snowboarding and cycling (Carter, 2012). Two real-world studies that implemented video modelling and feedback to enhance performance were conducted by Boyer at al (2009) and Anderson et al (2015). Video feedback refers to the player observing video of themselves performing the skill, and video modelling is the player observing an expert perform the skill (Boyer et al., 2009). Boyer et al. (2009), studied four competitive gymnasts (7-10 yo) that received video feedback and modelling during skill training. The athletes performed a set skill, then received video feedback of themselves, observed an elite model perform the skill, followed by a side-by-side comparison of the two prior to completing two more repetitions on their own without video. The authors found that the exposure to video feedback and modelling improved the skill refinement quicker than training alone. Anderson and Campbell (2015) conducted a similar study with 16 novice rowers, providing them with concurrent real-time video feedback of themselves performing the skill with an expert model video layered on top of their video. The authors found this accelerated their acquisition of proper rowing technique as it allowed the novice rowers to observe and correct their mistakes with feedback from the layering of the expert video. Both these studies found improvement in the athletes with video feedback and modelling, however a limitation exists as they are both being conducted with younger, more novice populations (Ford & Coughlan, 2020).

Professional coach and trainer, Mike Ellis, currently the Tampa Bay Lightning Director of Skill Development has been involved in elite ice hockey training and coaching for over 40 years, in a variety of roles from athlete to head coach. Through knowledge and experience, the importance of head position and its effect on an athlete’s ability to see 10ft, 20ft and 30ft in a game is reiterated to the athlete. Though collaboration with Coach Ellis, the objective of this study was to undertake a 3-week head-up training intervention that provides player-based
point of view video feedback while performing on-ice drills in elite hockey players. The aim of the drills was to encourage players to modify head position to higher head positions being adopted during hockey drills. It was hypothesized that individual head positions could be altered through practice-based intervention.

2.2 Methodology

2.2.1 Participants

Thirty-one male university ice hockey players (M age = 22±1 yrs.) from the 2015-2020 teams were recruited from the intercollegiate mens ice hockey team at the institution. As the study took place during the team’s regular season of games, 18 players completed the study, 6 did not complete the study due to COVID-19 shutdowns, and 7 were withdrawn due to injury obtained outside of the study. All players were accomplished athletes with an average of 17±2 yrs. experience in competitive hockey play. All the players had normal, or corrected to normal vision, they were injury free, and had undergone prior on-ice training and conditioning at moderate to intense levels. All players were volunteers and their participation in the study had no impact on their status on the team or their academics. Informed and written consent to participate and utilization of images was provided prior to the commencement of baseline testing. The protocol was approved by The University of Western Ontario Research Ethics Board (#108285) (see appendix A).

2.2.2 Determination of Player Point of View (PPOV) and Head Position (HP)

To capture simultaneous multiplayer PPOV, small cameras (HWKI Inc., Waterloo, Ontario) were firmly affixed to the forehead of players’ helmets. The lightweight cameras (1.2oz/34g) were affixed above the player’s ½ visor to continuously capture PPOV during testing and training sessions and was not perceivable by the players. The camera lens had a 150° wide field of view. Digital video was captured at 60Hz and stored on an integrated SD card on each camera. At the end of each practice session, the PPOV video was downloaded to a digital storage device for off-line analysis.

Players’ HPs were recorded with an inertial measurement unit (MBIENTLAB Inc., San Francisco, Ca). The small device (0.2oz/7g) was affixed to the right side of the helmet just
above the ear. Here, data was captured using a continuous stream of the x, y and z acceleration vectors (measuring accelerations in all directions), the device proved to be robust to the challenge. A validation study conducted at the University of Ottawa found the MetaMotionR to perform reliably in relation to angle orientation and motion tracking, with a measurement error in these devices to be $\leq 1.54^\circ$ (Beange, 2019). In the current experiment, HP was recorded with a reference of $0^\circ$ as horizontal (head up) and negative angles indicating downwards HPs. Positional data was captured at 33 Hz with onboard SD cards in each accelerometer. At the end of baseline and follow-up testing sessions, the HP recordings were downloaded for off-line analysis.

2.3 Procedure

Experimental data collection took place during the men’s hockey team season. Baseline testing was conducted prior to the players being randomized into two groups: the training intervention or the control. Players in the training intervention were on the ice for an additional 4.5 hours and received video feedback following each session. Players in the control group did not receive any additional training or feedback. Follow-up testing was conducted 4 days after the last training session. During baseline/follow-up testing, 4 or 6 players wore both player point of view (PPOV) cameras and head position (HP) devices simultaneously. During the training component, 4-6 players wore only the PPOV camera. For all sessions, players wore full regulation hockey gear and a Canadian Safety Association (CSA)-certified ice hockey helmet and ½ visor.

2.3.1 Baseline and Follow-Up Testing

Prior to testing, the players performed a 5-minute self-directed skate to warm-up. The players participated in 5 drills in various locations on the ice (Figure 2-1 A-E), with the objective of performing the drills as quickly and accurately as possible. The drills were not arranged in any specific order and were designed with varying degrees of complexity. If the player lost the puck, the trial did not count, and it was repeated. Total time for testing the 5 drills and warm-up was 30 minutes or less.
2.3.2 On-Ice Intervention

**Training Group.** Experimental training sessions were conducted over a 3-week period, half an hour prior to their regularly scheduled practice, 4 days a week (Monday to Thursday). The additional training did not interfere with player practice, strength training, or academic schedules. The training sessions consisted of drills targeted at maintaining a head-up position, provided by an experienced hockey coach. Prior to the start of each new drill, the athlete was shown a pre-recorded video of the drill on an iPad demonstrating expertise, based on an expert first-person perspective (NHL caliber). The video demonstrated the drill from a helmet-based point of view on the expert. The total time for the on-ice session and off-ice video review took 35 minutes per session.

**Control Group.** Players did not receive any additional on-ice training or video feedback.

2.4 Calibration

**Baseline and Follow-Up Testing.** Prior to the commencement of the testing session, the recording equipment on each player was field calibrated. The PPOV camera and accelerometers on each player were activated and time synchronized by directing athletes to observe a central clock on the researchers iPad. To calibrate the accelerometer for HP, the athlete was instructed to look straight ahead, while their helmet and attached recording devices were adjusted to 0° at ice level. Following each testing session, video recordings were temporally aligned with the time at the start of each session. Despite the different collection rates of PPOV and HP, the data was binned into second-by-second time frames.

**On-Ice Intervention.** Prior to the commencement of each on-ice training session, the PPOV camera was attached to each player’s helmet, and activated. Following each training session, the PPOV video was downloaded and emailed to each athlete in the treatment group. The video was only the player’s POV during training and did not include any additional coaching commentary. The video observation by player’s following the training session was not tracked.
<table>
<thead>
<tr>
<th>Drill</th>
<th>Explanation</th>
<th>Diagram of Drill</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Participant skates down the ice with a mix of skating and stickhandling.</td>
<td></td>
</tr>
<tr>
<td>Stickhandle + Skate</td>
<td>The participant cutbacks (curve turn) and stickhandles 5 times in the middle before they cutback again.</td>
<td>![Diagram of Stickhandle + Skate]</td>
</tr>
<tr>
<td></td>
<td>1 turn and 5 stickhandles in the middle = 1 repetition (pink). Participant performed 7 repetitions in total.</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Two teammates stand on the ice (A and B)</td>
<td></td>
</tr>
<tr>
<td>Forehand Pass in Tight Space</td>
<td>The participant passes the puck to teammate A, then skates around on the inside of the circle past teammate B to the top of the circle.</td>
<td>![Diagram of Forehand Pass in Tight Space]</td>
</tr>
<tr>
<td></td>
<td>The participant receives the puck from teammate B and passes it to teammate D, then skates around on the inside of the circle past teammate B to starting point.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 pass and receive = 1 repetition (pink). The participant skated around the circle 4 times.</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>The participant repeats the same drill as above, this time skating in the opposite direction, while passing and receiving the puck with their backhand.</td>
<td>![Diagram of Backhand Pass in Tight Space]</td>
</tr>
<tr>
<td>D</td>
<td>The participant skates as fast as possible down the ice carrying a puck, weaving in and out between the dots and the wall.</td>
<td>![Diagram of Weave]</td>
</tr>
<tr>
<td>Weave</td>
<td>1 repetition = 1 skate down the ice</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>The participant is skating in front of their teammate.</td>
<td></td>
</tr>
<tr>
<td>Quick cuts + Pass backs</td>
<td>Each time the participant returns to the middle (in front of their teammate), they must receive the puck and pass it back before they make a quick cut around.</td>
<td>![Diagram of Quick cuts + Pass backs]</td>
</tr>
<tr>
<td></td>
<td>The teammate follows the participant down the ice.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 turn and puck receive/pass in the middle = 1 repetition (pink). Participant performed 7 repetitions in total.</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2-1 Explanation and diagram of drills used for baseline and follow-up testing.

Players performed each drill once.
2.5 Head Position Data Filtering

**Head Position.** The accelerometer delivered HP data and was analyzed as a continuous data stream for each drill from the start to the end (Figure 2-2). A challenge is presented in analyzing the behaviours displayed not only between drills, but also between players. Head position was defined in terms of degrees down from the horizon or 0°. For simplification, a single sagittal (head up/down) position was calculated from the extraction of the x, y and z acceleration vectors. In order to move from time-based HP, the accelerometry sagittal plane data was analyzed in the frequency realm by creating individual cumulative distribution functions (CDF) for each player and for each drill (Figure 2-3). Individual player CDF curves represented HP performed over the entire duration of each drill. The average CDF curves of the “exp” and “control” represent the average HP of that group during the entirety of the drill duration.

Cumulative distribution functions (CDF) (Figure 2-3) describe the frequencies of a phenomenon, in this case head position, over a period of time, in this case the entire duration of each player’s drill. When the frequencies of HP are expressed as a cumulative percentage vs the percentage of time on the ice, mean CDF curves are created for each player, an overall view of head position behaviours emerges, and comparisons may be made as time is now expressed in percentages. Thus, CDF provides a probability of a HP behaviour (less than or equal to the specific position) expressed during a single shift or drill (Filliben & Heckert, 2012). In sport research, CDFs are used to generate reference curves for coaches to compare individual players against the team averages in fitness (e.g. heart rate) and speed metrics, (Ravindranathan et al., 2017) and to generate predictive curves to compare in blood doping...
profiles (Faiss et al., 2020; Sottas et al., 2011). The novel utilization of the CDF approach here enables HP behaviour profile comparisons across each player, regardless of shift durations. This approach creates a comprehensive method to visualize HP data over the entire epoch of play, providing a stronger, unbiased assessment of overall player behaviours.

The CDF represent actual HP angle probabilities from 0 to 100% (Figure 2-3). Average CDF curves for each player were created to enable a categorization of 4 head positions: head up (HUP), medium HP (MHP), low HP (LHP), and potentially dangerous HP (PDHP) corresponding to 0.1, 0.5, 0.9 and 0.99 probabilities across all measured head angles respectively in a CDF for all players’ drills (Jackson, 2006; Jonsson, 1982). It is important to note that it is the displayed probability percentage, not to be confused with the percentage of time. For example, at the 0.1 probability level, there is a 10% probability the player’s head will be between 0° and the corresponding HP. Accordingly, the probability level of 0.5 represents 50% of the data, meaning there is a 50% probability the player’s head will be between 0° and the corresponding head angle. Alternatively, the CDF may also be interpreted as the displayed HP behaviours expressed as probabilities. The probability level from 0.91–0.99 is useful information for the coaching staff as it represents the extreme head down positions the player is likely to display during practice.

**Hockey Skills Characterization during Drills.** Two independent researchers (SVM, KW) analyzed the PPOV video of each player, determining the start and stop points of each drill. Furthermore, determination of the hockey skill was verified during the video to
ensure the drill was performed correctly and the number of repetitions was achieved. In a couple instances, a player would lose the puck and have to restart the drill.

2.6 Analysis

Statistical analyses were performed using SPSS software release 27.0 (IMB Corp., Chicago, Illinois, USA). Data normality was checked using the Shapiro-Wilk test as the sample size was less than 50, using a significance level of \( p < 0.05 \). Since the assumption of normality was violated, Friedmann non-parametric tests were used to analyze each hockey drill (one, two, three, four and five) by HP category (HUP, MHP, LHP and PDHP) by training group (control or treatment). The median, minimum, IQR, and maximum were reported for each of the head position categories for each drill. A Bonferroni correction factor for multiple comparison tests was used to adjust alpha from <0.05 to <0.00625 to be considered significant.

2.7 Results

2.7.1 Head Position

The median HP values (in degrees down from the horizon) for control players vs. the players who participated in the head refinement training sessions (Table 2-1) and the minimum, interquartile range and maximum HP values are listed in Table 2-2.
Table 2-1. Control and Treatment Group Pre- and Post- Player Median values for Head Positions (HP) adopted during each Drill and Head Position Category.

<table>
<thead>
<tr>
<th>Drill</th>
<th>HP Category</th>
<th>CONTROL GROUP (n = 9)</th>
<th></th>
<th>TREATMENT GROUP (n = 9)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>p-value</td>
<td>Pre</td>
</tr>
<tr>
<td>A</td>
<td>HUP</td>
<td>2.0°</td>
<td>3.0°</td>
<td>.102</td>
<td>2.0°</td>
</tr>
<tr>
<td></td>
<td>MHP</td>
<td>9.7°</td>
<td>13.0°</td>
<td>.096</td>
<td>8.0°</td>
</tr>
<tr>
<td></td>
<td>LHP</td>
<td>25.4°</td>
<td>30.0°</td>
<td>.317</td>
<td>22.0°</td>
</tr>
<tr>
<td></td>
<td>PDHP</td>
<td>35.4°</td>
<td>50.0°</td>
<td>.317</td>
<td>30.0°</td>
</tr>
<tr>
<td>B</td>
<td>HUP</td>
<td>2.0°</td>
<td>2.0°</td>
<td>1.00</td>
<td>2.0°</td>
</tr>
<tr>
<td></td>
<td>MHP</td>
<td>12.5°</td>
<td>12.0°</td>
<td>1.00</td>
<td>11.0°</td>
</tr>
<tr>
<td></td>
<td>LHP</td>
<td>30.0°</td>
<td>32.0°</td>
<td>.480</td>
<td>27.0°</td>
</tr>
<tr>
<td></td>
<td>PDHP</td>
<td>43.0°</td>
<td>56.0°</td>
<td>.034</td>
<td>49.6°</td>
</tr>
<tr>
<td>C</td>
<td>HUP</td>
<td>2.0°</td>
<td>2.0°</td>
<td>.180</td>
<td>2.0°</td>
</tr>
<tr>
<td></td>
<td>MHP</td>
<td>11.0°</td>
<td>10.0°</td>
<td>.157</td>
<td>10.0°</td>
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<tr>
<td></td>
<td>LHP</td>
<td>28.0°</td>
<td>30.0°</td>
<td>.739</td>
<td>30.0°</td>
</tr>
<tr>
<td></td>
<td>PDHP</td>
<td>42.0°</td>
<td>51.0°</td>
<td>.317</td>
<td>47.0°</td>
</tr>
<tr>
<td>D</td>
<td>HUP</td>
<td>3.0°</td>
<td>3.0°</td>
<td>.257</td>
<td>2.0°</td>
</tr>
<tr>
<td></td>
<td>MHP</td>
<td>15.0°</td>
<td>12.0°</td>
<td>.102</td>
<td>8.0°</td>
</tr>
<tr>
<td></td>
<td>LHP</td>
<td>39.0°</td>
<td>33.50°</td>
<td>.480</td>
<td>21.0°</td>
</tr>
<tr>
<td></td>
<td>PDHP</td>
<td>54.0°</td>
<td>55.0°</td>
<td>.480</td>
<td>37.0°</td>
</tr>
<tr>
<td>E</td>
<td>HUP</td>
<td>2.0°</td>
<td>3.0°</td>
<td>.480</td>
<td>2.0°</td>
</tr>
<tr>
<td></td>
<td>MHP</td>
<td>11.4°</td>
<td>12.0°</td>
<td>.739</td>
<td>9.0°</td>
</tr>
<tr>
<td></td>
<td>LHP</td>
<td>28.9°</td>
<td>31.0°</td>
<td>.257</td>
<td>22.0°</td>
</tr>
<tr>
<td></td>
<td>PDHP</td>
<td>51.0°</td>
<td>47.0°</td>
<td>.317</td>
<td>41.0°</td>
</tr>
</tbody>
</table>

HP is expressed in absolute degrees down from horizontal.
Table 2-2. Variability of Drill Data.

<table>
<thead>
<tr>
<th>Drill</th>
<th>HP Category</th>
<th>PRE IQR</th>
<th>Max</th>
<th>POST IQR</th>
<th>Max</th>
<th>PRE IQR</th>
<th>Max</th>
<th>POST IQR</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>HUP</td>
<td>1.0°</td>
<td>1.2-3.0°</td>
<td>6.0°</td>
<td>2.0°</td>
<td>2.0-5.0°</td>
<td>8.0°</td>
<td>1.0°</td>
<td>1.0-4.0°</td>
</tr>
<tr>
<td></td>
<td>MHP</td>
<td>3.0°</td>
<td>6.0-13.0°</td>
<td>76.0°</td>
<td>10.0°</td>
<td>12.5-15.5°</td>
<td>27.0°</td>
<td>5.0°</td>
<td>7.1-12.0°</td>
</tr>
<tr>
<td></td>
<td>LHP</td>
<td>13.0°</td>
<td>17.0-36.0°</td>
<td>82.0°</td>
<td>26.0°</td>
<td>27.0-35.0°</td>
<td>46.0°</td>
<td>14.0°</td>
<td>18.0-26.0°</td>
</tr>
<tr>
<td></td>
<td>PDHP</td>
<td>24.0°</td>
<td>25.5-60.0°</td>
<td>86.0°</td>
<td>44.0°</td>
<td>45.5-53.5°</td>
<td>61.0°</td>
<td>21.0°</td>
<td>22.0-46.1°</td>
</tr>
<tr>
<td>B</td>
<td>HUP</td>
<td>1.0°</td>
<td>1.9-5.3°</td>
<td>6.0°</td>
<td>2.0°</td>
<td>2.0-3.0°</td>
<td>5.0°</td>
<td>1.0°</td>
<td>1.0-3.0°</td>
</tr>
<tr>
<td></td>
<td>MHP</td>
<td>9.0°</td>
<td>9.0-16.0°</td>
<td>19.0°</td>
<td>10.0°</td>
<td>10.5-13.5°</td>
<td>17.0°</td>
<td>5.0°</td>
<td>7.0-13.0°</td>
</tr>
<tr>
<td></td>
<td>LHP</td>
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<td>23.3-35.5°</td>
<td>58.0°</td>
<td>29.0°</td>
<td>30.5-35.5°</td>
<td>46.0°</td>
<td>16.0°</td>
<td>20.0-34.3°</td>
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<tr>
<td></td>
<td>PDHP</td>
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<td>36.0-54.7°</td>
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<td>34.0-57.0°</td>
</tr>
<tr>
<td>C</td>
<td>HUP</td>
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<td>1.0-2.0°</td>
<td>2.0°</td>
<td>1.0°</td>
<td>1.5-2.5°</td>
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<td>0.9°</td>
<td>1.0-3.0°</td>
</tr>
<tr>
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<td>MHP</td>
<td>6.0°</td>
<td>7.5-13.0°</td>
<td>14.0°</td>
<td>7.0°</td>
<td>8.5-15.0°</td>
<td>18.0°</td>
<td>3.3°</td>
<td>8.00-12.50°</td>
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<tr>
<td></td>
<td>LHP</td>
<td>21.0°</td>
<td>23.5-38.7°</td>
<td>45.0°</td>
<td>22.0°</td>
<td>23.0-34.5°</td>
<td>35.0°</td>
<td>8.1°</td>
<td>20.5-35.5°</td>
</tr>
<tr>
<td></td>
<td>PDHP</td>
<td>30.0°</td>
<td>37.0-51.2°</td>
<td>56.0°</td>
<td>36.0°</td>
<td>41.0-54.0°</td>
<td>56.0°</td>
<td>12.1°</td>
<td>35.0-57.0°</td>
</tr>
</tbody>
</table>

CONTROL GROUP (n = 9)  |  TREATMENT GROUP (n = 9)
<table>
<thead>
<tr>
<th></th>
<th>HUP</th>
<th>1.0°</th>
<th>2.5-4.5°</th>
<th>8.0°</th>
<th>1.0°</th>
<th>2.0-3.8°</th>
<th>4.0°</th>
<th>1.0°</th>
<th>1.0-2.5°</th>
<th>11.0°</th>
<th>1.0°</th>
<th>2.0-3.5°</th>
<th>4.0°</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>MHP</td>
<td>5.0°</td>
<td>14.0-18.1°</td>
<td>27.0°</td>
<td>6.0°</td>
<td>8.3-15.8°</td>
<td>17.0°</td>
<td>5.0°</td>
<td>5.8-11.5°</td>
<td>21.0°</td>
<td>5.0°</td>
<td>7.0-16.5°</td>
<td>18.0°</td>
</tr>
<tr>
<td></td>
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<td>44.0°</td>
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<td>17.0-30.0°</td>
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<td>32.0°</td>
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<td>23.0-44.5°</td>
<td>49.0°</td>
<td>45.0°</td>
<td>51.0-67.5°</td>
<td>74.0°</td>
</tr>
</tbody>
</table>

HP is expressed in absolute degrees down from horizontal. The outlier data remained in the table. The minimum (min) represents the lowest HP (in ° down from the horizon) observed. The interquartile range (IQR) represents the middle 50% of the HPs observed. The maximum (max) represents the highest HP (in °) observed.
2.7.2 Baseline and Follow-Up Testing Drills.

With the Bonferroni correction factor applied, there were two statistically significant differences between HPs from pre to post in defined HP categories, both found in the treatment group (Table 2-1). Head positions in the LHP category for the treatment group in drill 4 were significantly different at the pre and post testing points, $\chi^2 (1) = 9.00, p = .003$. Head positions in the PDHP category for the treatment group in drill 5 were significantly different at the pre and post testing points, $\chi^2 (1) = 9.00, p = .003$.

2.7.3 Variability.

The minimum, maximum and interquartile range (IQR) for HPs adopted during each CDF categorization can be found in Table 2-2. Figure 2-4 is a visual representation of the variability of data at each respective CDF HP categorization for Drill E. The control group (blue) is on the left-hand side, with the treatment group (green) on the right. At each categorization, the variability of the data varies as seen by the size of the boxes and the length of the whiskers.
Figure 2-4 Variability of data at each respective CDF HP categorization for Drill E. The box represents the middle 50% of the data. The line in the middle of the box represents the median value. The top whisker represents the minimum HP adopted by a player. The bottom whisker represents the maximum HP adopted by a player.

2.8 Discussion

This study represents the first on-ice field study in collaboration of varsity athletes with an NHL skills development coach to quantify hockey player’s head positions during specific training drills aimed at training head position. At the elite level, there are very small margins that exist to differentiate athletes (Carson & Collins, 2014). Once players reach the university level, they have become experts developing their skill habits (good and bad) and personal nuances from various hockey exposures (coaches, experiences, and level of competition). An athlete may still experience success with poor habits but they may be compromising their performance and increase their chance for injury (Milanese et al., 2016). Despite the training drills being designed with an emphasis on maintenance of an upright HP, player behaviour was not refined during the 3 weeks (4.5 hours) of additional training, rejecting the research hypothesis.

Conducting research with high performance athletes has a few known issues: experimental control, training interference and randomization issues (Fullagar et al., 2019).
As seen in the literature, performance decrements often result at the beginning of refinement due to the old pattern interfering with the new (refined) pattern being learned (Carson et al., 2016; Carson & Collins, 2014, 2018; Kearney et al., 2018). This lack of change in behaviour could potentially be explained by a few factors; the timing as the study was conducted during season, the duration of the training component, or the level of hockey experience of the instructor providing the players with the drills. To become an expert, athletes need to spend 10 years or 10,000 hours training (Harwell & Southwick, 2021). Using deliberate practice elements (video feedback) and top-down coaching methodology (game-like elements), 4.5 hours may not have been long enough to facilitate a refinement in a skill that has accumulated over an average of 17 years thus far. As the graduate student was limited in NHL hockey experience, providing the players with side-by-side video comparison of their POV and the experts POV, may have assisted with the players ability to learn and pick up on errors in their video.

### 2.8.1 Variability

In order to maintain ecological validity, players completed the drills in testing and training with their current teammates as players are not allowed to select from whom they receive a pass during a game. As seen in figure 2-4, players completed the drill with varying degrees of HP behaviours. The whiskers are the lines extending above and below the box, to the lowest and highest HPs (in ° down from the horizon) in each HP category. When looking at the whiskers, the lengths vary between each HP category, from pre to post. The whisker length tended to be shorter in the HUP and MHP category indicating less variability amongst HPs adopted by the athletes. The whiskers length in the LHP and PDHP categories get longer as there is more variability amongst the player’s behaviours. For example, in treatment group LHP category, there is a longer line extending from the top of the box (pre-condition) and a longer line extending from the bottom of the box (post-condition). Some of this variability might be explained by the player’s skill development background, and some by individual player nuances such as their motivation and willingness to refine their skills with a more upright HP position.

Based on observation of the variability in the LHP and PDHP, a technical refinement study with elite athletes might be better suited as a case study as opposed to a group study.
(Carson & Collins, 2014). The case-study approach would allow the coach to work one-on-one with the player, creating individual CDFs for the athlete to see and focus on the specific elements that need to be changed. With the player nuances, one coaching strategy may work for one player but not necessarily another. Carson and Collins (2014) explore the notion of whether or not conducting retention tests on elite athletes is the best way to assess skill refinement. Knowing that players will experience a decrement in performance at the elite level, there may be hesitancy to try refining a skill in season. Conducting a saving score retention test as suggested by Carson and Collins (2014) may provide a more meaningful way to monitor the refined technique and measure the stability. Saving score tests would be conducted on a more consistent interval during the intervention as opposed to only at baseline and follow-up. This would take on a case study approach allowing more individualization in training program design to occur.

2.8.2 Limitations

Despite this study being conducted in a field environment, both the practice and competition schedule, and player nuances may have limited the results. In order to capture a larger sample size, the study took place during regular season, as there are limited number of players that remain available during the summer. As a mix of starters and developmental roster players participated in the study, both academic and training schedules, in addition to team commitments being added last minute prior to practice meant that timing of the on-ice training was limited. However, the duration (3 weeks) may not have been long enough to see a change in the player’s head position, and the timing of the study (in season) may have limited individual player’s motivation or focus on the target outcome of the study. As there was no additional coaching feedback provided with the PPOV video and the inability to ensure the players watched their video each evening may have limited the ability to elicit a change in behaviour. With the inherent risk of injury during competition, 7 players were removed from the study as a result of injury incurred from regular season games. Head position training is important to incorporate and apply at all levels of competition: from house league to university and the NHL. Due to the short time frame of this study, it would be more appropriate to conduct this research with youth athletes. The shape of the performance curve for youth athletes should be steeper, as the athletes see improvement
quicker with practice, in comparison to athletes with 17 years of prior experience and training (Rose & Christina, 2006).

2.8.3 Future Directions

With the gap in translation of research into practice, teams and organizations have started to hire sport scientists to connect with coaches to further their knowledge (French & Ronda, 2022; Fullagar et al., 2019). Further studies focusing on the incorporation of video feedback from both first person and third POV may assist players in their comprehension and implementation of concepts being taught by their coaches in both training and game situations. Depending on the head position adopted by the player, first person video may provide the player with the opportunity to observe what they misperceived or did not perceive at all during game situations in training. This could aid in the development of the player’s hockey sense or situational awareness as it focuses on the perception of their surroundings (level 1) and their comprehension of the situation (level 2). More field studies should be conducted to better understand how coaches can assist elite athletes in enhancing their performance (Malone et al., 2019). Specifically focusing on case studies as they may provide more insight into assisting and accommodating the individual player differences (Carson & Collins, 2014).

2.9 Acknowledgements

The authors would like to thank Mike Ellis for his knowledge, expertise and time in developing the training intervention; Shea Kewin at UHK for the equipment; John Chibuk at KIWI for assistance with the accelerometers and determining head position; and Jim Dickey for assistance with the cumulative density functions. Our thanks are also extended to the University of Western Ontario men’s varsity hockey team, and Head Coach Clarke Singer.

2.10 Disclosure statement

No potential conflict of interest was reported by the authors.
2.11 References


AND PREDICTIVE ANALYTICS. MFPT.


Chapter 3

3 Head Position Behaviours of Ice Hockey Players during Game Simulations

3.1 Introduction

Ice hockey is a fast-paced sport, it encompasses both technical and tactical skills, exhibited individually and as a team. Men’s hockey also incorporates various forms of body checking that may put relatively inattentive athletes at risk of injury. The sport requires the athletes to move around the ice on thin skate blades, chasing after a puck with a stick and 9 other players. The player combines physical prowess with the various perceptual-cognitive skills of anticipation, deception, pattern recognition and cue utilization throughout the game to gain an advantage over their opponent and effectively utilize their teammates (Zaichkowsky & Peterson, 2018). Effective posture on the ice can be defined as one that places the feet shoulder width apart, knees bent, hips low, and head up (Davidson, 2017; Francisco, 2012; Mell et al., 2017). By teaching athletes to play in a head up position, they maximize viewable ice surface during the game with a better opportunity to anticipate play and react to recognized team patterns and individual postural cues. As the level of play and competition increase, the pace of the game and physicality increases, leaving players less time to react and make decisions. In the Ontario Hockey League (OHL), a large semi-professional hockey league, players have on average, 2 seconds to make game decisions. In the American Hockey League (AHL) the decision-making time falls to 1s, and 0.5 seconds in the National Hockey League (NHL) (Malloy, 2011). If a head down position is adopted during the game, it is presumed that vision is compromised and key information from the surroundings is missed increasing the risk of making poor game decisions, or worse, injury. In order to prepare players for the speed of the game, coaches teach players to maximize personal time and space on the ice, through body positions, drill work and the incorporation of small area games into practice. Small area games provide the coach with the ability to manipulate the space
(ice-surface size) and time constraints (player number) at all levels of play (Sullivan, 2020; USA Hockey, 2018, 2019). The spatial and temporal adjustments assist in the development of players as they simulate game-like speed and space, as well as enabling the player to touch and shoot the puck more frequently (Hockey Canada, 2019). Players have the ability to practice and incorporate various technical skills (ie. puck control and protection, angling, and stick checking), tactical skills and perceptual-cognitive skills (reading the play, anticipation and decision making) (Hockey Canada, 2019). Game awareness, is an individually defined, but abstract concept that involves integration of personal skill and athleticism with their teammates’ versions of the same. In practice drills, athleticism and individual skills can be repeated and anticipation and pace is achieved. However, the last component of game awareness is hard to practice and that is the responses of the opposing team. Here, appreciation of the ice surface, teammates, and opponents all must be attended to in order to make the highest probability game play. As age and skill levels rise, players have less time and space at the higher levels, meaning their head posture on the ice is critical for realizing personal skill and expertise within the confines of the game.

Despite tacit coaching experience and player knowledge, how does player head position in the head up/down plane (sagittal) affect player performance when the game is horizontal in nature (Peters, 2012)? Head movements occur for three reasons; to assist in bringing the eyes back to the central position in their orbit, to make compensatory movements that maintain a stable image when body position is altered, and for communication and expression (Proudlock & Gottlob, 2007). When the head is stationary, the eyes rotate to create a field of view up to 135° vertically and 200° horizontally (Davids et al., 1999; Leigh & Zee, 2015). Figure 3-1 illustrates an athlete’s neutral line of sight at the head up position (HP at 0°). The red arrows represent the
optimum range of superior/inferior eye rotation of ~60° (~25° upwards from neutral and ~35° below) (Tilley & Henry Dreyfuss Associates., 1993; van der Zanden, 2014). With the head stationary, the eyes can rotate maximally ~50° from neutral before head movement must compensate or visual attention on any target is lost (Proudlock & Gottlob, 2007). It is important to note that eye movements are not the focus of this study, however since eye position is inherently related to head position, on-ice vision is captured.

Briefly, research defines two types of vision: central and peripheral. Central vision enables the athlete to see ~2° degrees of sharp, high resolution images within the field of view (Davids et al., 1999). Humans normally maintain their eyes centrally in the orbit to allow for maximal peripheral vision in relation to their body location (Proudlock & Gottlob, 2007). Although still a matter of debate (Poltavski & Biberdorf, 2015), game play requires the athlete to attend to their peripheral vision extensively for course visual information. In the context of hockey, course visual information would include a multitude of cues like personal orientation on the ice, location and direction of themselves in relation to moving teammates and opponents, and puck location. Peripheral vision also enables orientation and game awareness of stationary items like the boards, blue line, bench and nets. Athletes use both central and peripheral vision to enhance their performance (Ryu et al., 2013). If the athlete’s head is lowered, the view of the entire game surface is decreased and they are not able to utilize their full peripheral vision to inform decisions in game play and personal safety.

Understanding how hockey players incorporate visual information from evolving game play while performing various hockey skills is important for skill development and understanding how game awareness is developed. Leavitt (1979) evaluated hockey abilities using a multitasking paradigm requiring players to identify shapes while they skated or stickhandled through a series of 5 pylons in a straight line. The author quantified how adding additional tasks to university hockey player drills increased their completion times from 0.1 seconds while skating and identifying the shapes, to 0.9 seconds with the addition of stickhandling. Fait et al. (2011), expanded on Leavitt’s study
and evaluated how a hockey player’s performance during hockey skills changed as task complexity increased in combination with a visual task and obstacle avoidance. They found that player’s cognition (the number of errors made on the Stroop task) and the speed at which the drills were performed decreased as the hockey skills became more complex. The results from this study demonstrated a degradation of performance (increased time and error) of automated skills when new visual information is introduced. A similar study to the obstacle avoidance and visual task was performed recently outside of the hockey context (Lim et al., 2015). They evaluated individual’s situational awareness as they walked on a treadmill and texted on their mobile phone. As the participants performed dual tasks, they were asked to identify cues in their immediate visual field. While participants performed the dual tasks, half (48.3%) of the visual cues presented were not perceived, in comparison to the visual task alone. The magnitude of this loss of situational awareness was dependent upon the nature of visual information provided. As hockey is a game of multiple tasks, where players perform while attending to and making rapid decisions using the visual field to make decisions, it is important to quantify how head and body position affect vision in the game.

Despite coaching practices worldwide, there is limited information regarding head position in hockey, in real-world settings (Ste-Marie et al., 2012). Only two hockey-related studies refer to head position in relation to the performance of various practice drills. Vickers et al. (2016) evaluated how a 1m orange warning line around the outside of a hockey rink causes athletes to position their head compared to a traditional rink. Head angle was calculated with two electrogoniometers attached to the back of the head and the cervical spine. They measured head flexion-extension angle, head angle during fixation and tracking gaze location, and head angle by quiet eye location. The study found athletes did not keep their head up more on the rink with the orange warning line. The results of the study are challenging to interpret as the head angle data was unclear due to a lack of definition, particularly in relation to a starting point of 0°. In another study of head position, MacAskill (2016) evaluated if training off-ice using Quickstickz (a computer program) to maintain an upright gaze, would transfer to on-ice drill performance. The main outcome measures in the study were the percentage of time where
players maintained their gaze above the horizon (defined as 0°), the average gaze angle and the drill completion time. In order to determine gaze angle, an accelerometer was affixed to the top of the athlete’s helmet and it was synchronized with video from a GoPro camera directed at the athlete’s eye and attached to the wire facemask. The study found a significant difference in drill completion time from pre- to post-intervention, with athletes completing drills faster at post testing. There were, however, no differences between the athletes’ drill success or importantly, the average gaze angle or the percentage of time with gaze above the horizon. Both studies conducted by Vickers and MacAskill were performed in a controlled environment, and suggested the need for the research to occur in a game-like setting.

Coaches and scientists recognize the important role the visual system plays in an athlete’s ability to perceive the game, however focusing only on studying the athlete’s gaze is important but not easily performed scientifically in game play and impractical as a coaching tool. Nonetheless, the visual information available to the athlete must change with head position. Head position behaviour remains unstudied nor quantified in natural, game-like settings for ice hockey. Gaining insight into these player behaviours would be a key component for coaching applications and player performance.

The primary objective for this study was to simultaneously quantify multiple player’s head positions (HP) during small area games (SAG). More specifically, to quantify HP in a 2-on-2 and 3-on-3 SAG (as they are commonly used in practice) and quantify HP through expression of the most commonly used skill (stickhandling and skating) while playing both offensively and defensively in free hockey scrimmage.

3.2 Methodology

3.2.1 Participants

Thirty-one male university ice hockey players (M age = 22±1 yrs.) from the 2015-2019 teams were recruited from the intercollegiate mens ice hockey team at the institution. All players were accomplished athletes averaging 17±2 yrs. experience in competitive hockey play. All the players had normal, or corrected-to-normal vision, they
were injury free, and had undergone prior on-ice training and conditioning at moderate to intense levels. All players were volunteers and their participation in the study had no impact on their status on the team or their academics. At any time, 4 or 6 players wore both player point of view (PPOV) cameras and head position (HP) devices simultaneously during small area game play. Of the 31 players: 9 competed in the 2-on-2 SAG, and 16 in the 3-on-3 SAG. Six players data were removed from the 2-on-2 SAG due to severe movement of their helmet in the game making the signal unintelligible. Informed and written consent to participate and utilization of images was provided prior to the commencement of the small area game. The protocol was approved by The University of Western Ontario Research Ethics Board (#108285) (see appendix A).

3.2.2 Determination of Player Point of View (PPOV) and Head Position (HP)

To capture simultaneous multiplayer PPOV, small cameras (HWKI Inc., Waterloo, Ontario) were firmly affixed to the players’ helmets. The lightweight camera (1.2oz/34g) was affixed above the player’s ½ visor to continuously capture PPOV during the SAGs and was not perceivable by the players. The camera lens angle was 150° wide field of view. The digital video was captured at 60Hz and stored on an integrated SD card on each camera. At the end of each SAG, the PPOV video was downloaded to a digital storage device for off-line analysis.

Players’ HPs were recorded with a MetaMotionR inertial measurement unit (MBIENTLAB Inc., San Francisco, Ca). The small device (0.2oz/7g) was affixed to the right side of the helmet above the ear. HP was recorded with 0° as horizontal (head up) and negative angles (degrees down from the horizontal) implying further downward HPs. The accelerometer measured accelerations in all directions. HP data was captured at 33 Hz with an onboard SD card in each accelerometer. At the end of each SAG, the HP recordings were downloaded to a digital storage device for off-line analysis. The MetaMotionR sensors are validated, producing reliable metrics in relation to angle orientation and motion tracking, and a measurement error of ≤ 1.54° (Beange, 2019).
3.3 Procedure

Data collection took place during the men’s hockey team season, and data was collected over 7 different practice times to accommodate the numbers of players with their practice and academic schedules. Players wore regulation hockey gear and a Canadian Safety Association (CSA)-certified ice hockey helmet and ½ visor. The players participated in a small area game (SAG) that was played on a half ice surface between the blue line and end boards (Figure 3-2). Each SAG followed normal hockey rules and if the puck crossed the blueline borders a change of possession occurred. This was followed by team selections in a play-like scrimmage. The players participated in one variation of the small-area game: 15 players competed in the 2-on-2 SAG with 1 goalie and 1 net, and 16 players competed in the 3-on-3 SAG with 2 goalies and 2 nets. To mimic natural playing conditions, players completed a total of 7 shifts lasting approximately 45 seconds to 60 seconds in duration with 1 minute to 2 minutes recovery time (Nightingale & Douglas, 2018). Total time for the SAG and warm-up was 30 minutes. The SAG mimicked game play thus body checking was in effect.

2-on-2 Small Area Game (SAG)  
3-on-3 Small Area Game (SAG)

Figure 3-2. Small Area Game Scenarios.
In the left panel, 2-on-2 SAG, the light grey shaded area represents out of bounds and change of puck possession. Upon puck dispossession (turnover), the athlete with the new puck possession must return to the blue line to commence offense. In the right panel, 3-on-3 SAG, the athletes played across the width of the ice. In both scenarios, the numbers represent the teammates, and the light grey shaded area represents out of bounds. If athletes or errant puck cross this line, puck possession is given to the opposing team.
3.4 Calibration

Prior to the commencement of the SAG, the recording equipment on each player was field calibrated. The UHWK camera and accelerometers on each player were activated, and the athlete was asked to observe a central clock on the researcher’s (KW) iPad to synchronize time between the video camera and the accelerometer. To calibrate the accelerometer for HP, the athlete was instructed to look straight ahead, while their helmet and attached recording devices were adjusted to 0° at ice level.

Following each SAG, the UHWK camera recording was temporally aligned with the time at the start of each shift. This ensured the video and accelerometer times were aligned and the correct data was analyzed. Despite the different collection rates from the PPOV and HP devices the data was extrapolated and binned into second-by-second time frames.

3.5 Data Filtering

**Head Position.** Accelerometery measured all head positions. The HP data was collected as a continuous data stream for each shift from the start to the end. Offline, HP was calculated in degrees down from the horizontal, here the x, y, z acceleration vector was extracted to calculate a single sagittal (head up/down) position for the entirety of the shift. In order to move from time-based HP, the accelerometry sagittal plane data was analyzed in the frequency realm by creating individual cumulative distribution functions (CDF) for each player and for each shift. Individual player CDF curves represent an average of 6 shifts in each SAG scenario. The 2-on-2 and 3-on-3 average CDF curves are representative of 25 individual players comprising 150 shifts on the ice for 45-60 sec each. The CDF presents HP angles as percentages of each shift from 0 to 100%. Utilizing the CDF approach enables comparisons across different lengths of individual shifts and creating HP behaviour profiles. An average CDF curve for each player enabled a categorization of 4 head positions: head up (HUP), medium HP (MHP), low HP (LHP), and potentially dangerous HP (PDHP) corresponding to 0.1, 0.5, 0.9 and 0.99 probabilities across all measured head angles respectively in a CDF for all players’ shifts.
(Jackson, 2006; Jonsson, 1982). The HP percentage, not to be confused with the percentage of time but rather the percentage of head position behaviour being expressed regardless of time it was expressed, thus a stronger and less biased assessment of overall player behaviours can be achieved. For example, at 0.1 probability, there is a 10% likelihood the player’s head position will be between 0° and the corresponding HP of the CDF. Alternatively, the CDF may also be interpreted as the displayed HP behaviours expressed as probabilities. The probability level from 0.91-0.99 is useful information for the coaching staff as it represents likelihood of a player putting themselves into extreme head down positions the player is likely to display in game situations.

**Hockey Skill.** As no shift in a hockey game is the same, the skills the athlete displays vary based on team strategy and number of players on the ice. The individual shifts were further dissected into the various skills displayed during SAG. Reporting HP behaviour data without the skills associated does not provide meaningful information for the coach. Two independent researchers (SVM, KW) analyzed the PPOV video of each player, categorizing the skills used within each of the shifts. Using predefined hockey terminology (Hockey Canada Player Development), skills were classified into 4 different categories: offensive play, defensive play, stickhandling, and skating. Offensive play was defined when the player was trying to score a goal and defence was defined when the player was protecting their net from being scored upon. Stickhandling was defined as time when the player had possession of the puck, or they were battling for the puck. It is representative of both offensive and defensive play, however for the purposes of this study, it was categorized separately regardless of the style of play to observe how the player’s HP changed when they had possession of the puck. Skating was defined as the time when the player was not involved in offense or defence. The corresponding skills were selected from each shift and processed into a cumulative distribution function and compared to HP.

### 3.6 Analysis

Descriptive statistics (mean, standard deviation and confidence intervals) were calculated for head positions in each simulation (2-on-2 and 3-on-3 SAG). Head
positions were further delineated by categorizing a cadre of skills displayed within each simulation and the percentage of time spent displaying said skills. All statistical analyses were performed using SPSS software release 27.0 (IBM Corp., Chicago, Illinois, USA). Normality was verified with the Shapiro-Wilk test. The level of significance for all statistical tests was \( p < 0.05 \) unless otherwise noted. An overall analysis of HP in SAG was conducted with a two-way analysis of variance (ANOVA) comparing the head positions (HUP, MHP, LHP and PDHP) observed in each SAG (2-on-2 and 3-on-3). Deeper analysis of hockey skills displayed was undertaken, a three-way mixed method ANOVA was conducted to examine players’ head positions (HUP, MHP, LHP and PDHP) while demonstrating different skills (offense, defense, stickhandling and skating) in each SAG (2-on-2 and 3-on-3). Statistical significance of a simple two-way interaction was accepted at a Bonferroni-adjusted alpha level of 0.025. To sample whether the display of hockey skills changed in either simulation, a two-way ANOVA was conducted. Tukey post hoc comparisons were performed following significant effects. A Greenhouse-Geisser \( \varepsilon \) was used to adjust for violations of sphericity. The above approaches were performed on the 10%, 50% and 90% probabilities, not the 99% probability. The 99% probability was demonstrative for coaching application.

### 3.7 Results

#### 3.7.1 Head Position (HP)

The mean, standard deviation (±1 SD), and confidence intervals for cumulative HP at the four a priori categories are listed in Table 3-1. The analysis of HPxSAG indicated no interactions between HP and the number of players in each SAG, \( F(1.102, 25.339) = 3.157, p = .084 \). Head positions (HUP, MHP, LHP and PDHP) were consistently and significantly lower in the 3-on-3 vs the 2-on-2 SAG scenarios, \( F(1, 23) = 5.104, p = .034 \).
Table 3-1. Overall mean and standard deviation of cumulative head position (HP) in small area games (SAG).

<table>
<thead>
<tr>
<th></th>
<th>10% Probability (HUP)</th>
<th>50% Probability (MHP)</th>
<th>90% Probability (LHP)</th>
<th>99% Probability (PDHP)</th>
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<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>95% Confidence Interval</td>
<td>Mean ± SD</td>
<td>95% Confidence Interval</td>
</tr>
<tr>
<td>HP in 2-on-2 SAG</td>
<td>1.9° ± 0.6°</td>
<td>1.4°-2.4°</td>
<td>9.6° ± 2.3°</td>
<td>7.8°-11.3°</td>
</tr>
<tr>
<td>HP in 3-on-3 SAG</td>
<td>2.3° ± 0.7°</td>
<td>2.0°-2.7°</td>
<td>12.5° ± 2.9°</td>
<td>11.0°-14.0°</td>
</tr>
</tbody>
</table>

HP is expressed in absolute degrees down from horizontal.

3.7.2 Head Position and Hockey Skills

The mean, standard deviation (±1 SD), and confidence interval for player HPs during each skill displayed during each SAG is listed in Table 3-2. A significant three-way interaction between HP, hockey skill, and number of players, F (2.664, 61.264) = 3.062, p = .040 was found. Statistical significance of a simple two-way interaction was accepted at a Bonferroni-adjusted alpha level of 0.025. The simple two-way interaction between HP and hockey skill was not significant for the 2-on-2 SAG, F (2.117, 16.933) = 3.709, p = .250, or for the 3-on-3 SAG, F (1.984, 29.766) = 3.709, p = .037.
Table 3-2. Mean and standard deviation for player head position (HP) during each skill demonstrated in small area games (SAG).

<table>
<thead>
<tr>
<th>Skill</th>
<th>10% Probability (HUP)</th>
<th>50% Probability (MHP)</th>
<th>90% Probability (LHP)</th>
<th>99% Probability (PDHP)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>95% Confidence Interval</td>
<td>Mean ± SD</td>
<td>95% Confidence Interval</td>
</tr>
<tr>
<td>HP in</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Defence</td>
<td>1.8° ±0.6°</td>
<td>1.4°-2.2°</td>
<td>9.6° ±2.5°</td>
<td>7.7°-11.5°</td>
</tr>
<tr>
<td>2-on-2</td>
<td>2.3° ±0.8°</td>
<td>1.7°-2.9°</td>
<td>10.7° ±3.1°</td>
<td>8.3°-13.0°</td>
</tr>
<tr>
<td>SAG Stickhandling</td>
<td>2.2° ±1.3°</td>
<td>1.2°-3.2°</td>
<td>9.4° ±3.7°</td>
<td>6.5°-12.3°</td>
</tr>
<tr>
<td>Skating</td>
<td>2.0° ±0.6°</td>
<td>1.5°-2.4°</td>
<td>9.0° ±2.5°</td>
<td>7.1°-10.9°</td>
</tr>
<tr>
<td>HP in</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Defence</td>
<td>2.4° ±0.8°</td>
<td>1.9°-2.8°</td>
<td>12.4° ±3.2°</td>
<td>10.7°-14.1°</td>
</tr>
<tr>
<td>3-on-3</td>
<td>2.2° ±0.6°</td>
<td>1.9°-2.6°</td>
<td>11.9° ±2.7°</td>
<td>10.4°-13.3°</td>
</tr>
<tr>
<td>SAG Stickhandling</td>
<td>2.5° ±1.0°</td>
<td>2.0°-3.0°</td>
<td>13.7° ±5.2°</td>
<td>11.0°-16.5°</td>
</tr>
<tr>
<td>Skating</td>
<td>2.5° ±0.6°</td>
<td>2.2°-2.8°</td>
<td>13.5° ±2.0°</td>
<td>12.5°-14.6°</td>
</tr>
</tbody>
</table>

* Significant difference (p < 0.05) between skills within the respective SAG. HP is expressed in absolute degrees down from horizontal.
3.7.3 Percentage of Shift and Hockey Skills

Descriptive data of means, standard deviation (±1 SD), and confidence intervals for time, represented as the percentage of each shift spent on each skill during each SAG (Table 3-3). A two-way ANOVA was conducted to compare the relative time spent on each skill in each SAG. The test indicates a significant interaction between the SAG and the percentage of time spent on each skill, F (2.191, 50.386) = 7.774, p = .001. Players spent 8.6% (95% CI [5.3 to 12.0], p < .005) more time on offense in the 3-on-3 SAG compared to the 2-on-2 SAG. Players spent 6.8% (95% CI [2.3 to 11.3], p = .005) more time stickhandling and 6.7% (95% CI [.3 to 13.1], p = .043) more time skating in the 2-on-2 SAG compared to the 3-on-3 SAG. There was no difference for the skill of defence (p = .087). Tukey post hoc test comparisons (Table 3-4) were performed following significant effects to determine where the relative time spent on each skill differed in each SAG.

2-on-2 SAG: There was a significant effect of skill percentage expression on the players’ shifts, F (2.074, 16.594) = 9.538, p = .002. Tukey’s post-hoc comparisons for each skill by number of players on the ice was undertaken (Table 3-4). Players spent a significantly greater percentage of the shift on defence compared to offence (M = 18.3%, 95% CI [3.0 to 33.7], p = .019), and stickhandling (M = 17.1%, 95% CI [2.3 to 31.9], p = .023).

3-on-3 SAG: There was a significant effect of skill percentage expression on the players’ shifts, F (1.565, 23.482) = 67.620, p < .005. Tukey’s post-hoc comparisons (Table 3-4) indicated players spent a significantly greater percentage of the shift on defence compared to offence (M = 14.5%, 95% CI [10.3 to 18.7], p < .001), stickhandling (M = 28.7%, 95% CI [24.8 to 32.6], p < .001), and skating (M = 21.9%, 95% CI [12.7 to 31.2], p < .001). The players also spent a significantly greater percentage on offense compared to stickhandling (M = 14.2%, 95% CI [10.2 to 18.2], p < .001), and skating (M = 7.4%, 95% CI [.3 to 14.6], p = .040).
### Table 3-3. Mean and standard deviation of percentage of shift by skill by number of players in small area games (SAG).

<table>
<thead>
<tr>
<th></th>
<th>Defence</th>
<th>Offence</th>
<th>Stickhandling</th>
<th>Skating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>95% Confidence Interval</td>
<td>Mean ± SD</td>
<td>95% Confidence Interval</td>
</tr>
<tr>
<td>2-on-2 SAG</td>
<td>36.4% ± 8.6%</td>
<td>29.9% - 43.0%</td>
<td>18.1% ± 4.9% *</td>
<td>14.3% - 21.9%</td>
</tr>
<tr>
<td>3-on-3 SAG</td>
<td>41.3% ± 5.0%</td>
<td>38.6% - 43.9%</td>
<td>26.8% ± 3.2% *</td>
<td>25.1% - 28.4%</td>
</tr>
</tbody>
</table>

* Significant difference (p < 0.05) between percentage of time spent on skills between the SAGs.

### Table 3-4. Percentage of shift time and hockey skill during both small area games.

<table>
<thead>
<tr>
<th></th>
<th>2-on-2 SAG</th>
<th>3-on-3 SAG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defence</td>
<td>Offence</td>
<td>Stickhandle</td>
</tr>
<tr>
<td></td>
<td>.019</td>
<td>.023</td>
</tr>
<tr>
<td></td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

Post-Hoc Pairwise Comparisons with P value listed. Green cells represent skills that are different between 2-on-2 vs 3-on-3 SAG. White cells represent no difference.
3.8 Discussion

This study represents the first on-ice field study to quantify multiple hockey player’s head positions simultaneously during simulated game play. It provides an objective and comparable overview of individual and team play head position behaviours expressed in high calibre varsity hockey players. Head position was defined and categorized through 4 a priori cumulative probabilities to illustrate the differing ranges of HPs players adopted during game play. The percentage values of each categorization (0.1, 0.5, 0.9 and 0.99) correspond to classifications in the literature (Jackson, 2006; Jonsson, 1982). The categories are adapted to ice hockey terminology providing coaching staff a comprehensive and hands-on understanding of player behaviour with respect to HP and vision of the ice surface. Generally, players who participated in the 2-on-2 SAG had higher HPs than those in the 3-on-3 SAG when comparing medium HP (10° vs 12°), low HP (29° and 34°) and potentially dangerous HP categories (52° and 59°) (Table 3-1). Head positions were further explored by the skill expression while adopting these head positions.

3.8.1 Head Position and Hockey Skills

When the four hockey skills were compared in play environments created by differing SAG, players maintained a higher HP while performing all skills in the 2-on-2 game (Table 3-2). From a skill development perspective, it is of interest to observe the difference in HPs at the potentially dangerous (PDHP) category for all skills in the 2-on-2 and 3-on-3 SAG respectively: Offense (54°, 58°), Defence (50°, 58°), Stickhandling (47°, 59°), and skating (48°, 57°). The HPs measured during all skills were lower when there were more players on the ice at one time, 3-on-3 SAG. Understanding how a player’s HP changes within the varying time and space constraints in practice environments, provides opportunities for coaching staff to monitor and modify a players’ HP in relation to specific skills. The most notable difference in HP was 12° between the SAGs occurs when the players are stickhandling. With this knowledge, coaches can modify the effects very easily in SAG while emphasizing the importance of HP during the stickhandling drills incorporated into practices. Although not addressed in the current study, the effects
of the mix of differing SAG with drills would be a potential avenue for young player
development where many good or bad “habits” are formed (Ice Hockey Systems, 2021;
Pollard, 2018).

Technical skills are defined by Hockey Canada as fundamental skills that the players
require to compete in the game (Bertagna, 2016; Malloy, 2011). In the 2-on-2 SAG
(Table 3-2), the players generally adopted higher HPs while skating versus stickhandling,
with the exception occurring during the 2-on-2 SAG potentially dangerous HP category.
In both SAGs, the players head should be up more as they are skating around, paying
attention to where their teammates and opponents are. Stickhandling adds another
element of complexity for the players, in addition to skating and an awareness of their
surroundings.

Tactical skills can be sub-divided into individual and team elements, with both
tactics combining the technical skills to gain an offensive or defensive advantage
(Macaskill, 2016). In the 2-on-2 SAG (Table 3-2), in the PDHP category, players adopted
higher HPs during offensive skill expression. In the 3-on-3 SAG, players only expressed
higher HPs while on offense during the low HP category. Despite the number of players
included in the SAG, the players had similar HPs for both skills.

3.8.2 Percentage of Shift and Hockey Skills

During games, the majority of time is spent on offense, or defence. In the 2-on-2
SAG, players spent a total of 54% of the shifts on offense or defence, compared to 68%
in the 3-on-3 SAG. The 14% difference could be explained by the amount of space
available to the players. In the 3-on-3 game, there is less space available to the players,
meaning they are always involved in offense or defence, with little time to not be
involved in the play. This result is similar to a study examining heart rate and intensity of
varying SAGs with youth hockey players, that illustrated the 3-on-3 game with
transitions from offense to defence and back, had the highest intensity of all 6 SAG
variations they studied (Lachau et al., 2017).
Another element to note, is the amount of time a player spends stickhandling the puck. During a game, players spend more time on the ice without the puck than they do with it on their stick (Vickers et al., 2016). As more players are incorporated in the SAG, there is less opportunity to receive the puck and less space and time to stickhandle before the opponents converge. This effect was found in the 3-on-3 SAG where the players had the puck 13% of the shift compared to 19% in the 2-on-2 SAG (Table 3-3). Despite limited puck possession, players adopted more unfavourable HPs while they were stickhandling in the 3-on-3 SAG (Table 3-2). This result highlights an area for a coaching intervention.

3.8.3 Coaching Application

Despite the tacit knowledge and experience of the coach in teaching athletes to maintain an upright HP, this area has been under studied. There are two key findings from the current study that can be applied to coaching. The first is an understanding of player HP and on-ice vision during SAG and the second relates to skill development. Adopting a head up, or medium HP isn’t a cause for concern, however a potentially dangerous HP may be an area for coaching and game behaviour intervention. Overall, as the player’s head drops further down from the horizon, there is a strong likelihood their overall performance will decrease as their view of the game is severely inhibited. Whether HP and chance of injury is related is yet to be determined.

Using images from the PPOV cameras, Figure 3-3 illustrates the effects of progressively lower HP. In the HUP images, the player has a HP of ~0° enabling them to have a full view of the ice. In the MHP, LHP and PDHP images, as the player’s head tilts down, the field of view progressively becomes dominated by increasingly proximal ice. In the PDHP image, the player’s performance will be severely impacted as they cannot see beyond ~2m or the reach of their stick. As eye rotation was not measured in this study, line of sight is directly inferred from HP. Fang et al. (2015) found eye position biased HP direction supporting the notion of the line of sight inference. In the current study, when HP fell to ~50°, there is a high probability that the athletes were looking down, in the direction of their head orientation, and not rolling their eyes upwards to look.
ahead. Further, Nakashima et al. (2014) demonstrate a higher visual processing ability when the eyes and HP are aligned, supporting the notion of coaching athletes to maintain an upright head position to “see” the game better.

![Figure 3-3. On-ice field of view at various head position (HP) cumulative density function (CDF) levels.](image)

Row A represents player head positions. The black dotted arrow represents the neutral line of sight at 0°. The red arrows represent the upper and lower maximum eye rotation and the space between represents the optimum eye rotation range. The solid black arrows represent the upper and lower visual limits of the eye. Row B is on-ice view at that head position.

As the skill level of play increases, players have decreased time and space on the ice (Malloy, 2011). Observing HP and the corresponding on-ice vision in the two SAGs enables the coach to better understand visual information the player has available to them when they have time and space (2-on-2) compared to when it is limited (3-on-3). Through individualized coaching of HP and the emphasis of an elevated HP during each skill, overall team performance could rise. If player analytic statistics were applied to HP and skill in a longer term, player improvements could be tracked over the season. As stated earlier, examining overall HP during the game doesn’t enable coaches to determine targets for individual player skill development.

The second point relates to skill development for games as there was a difference in skills and HP depending on the number of players present. To develop players’ to adopt higher head positions during offensive and defensive skills, it is important to mimic behaviours akin to those in games so it would make sense to have the team compete in 3-
on-3 SAGs. In order to help players develop proper HP during their stickhandling skills, it is better to use 2-on-2 games as there is increased space and time to allow them to stickhandle the puck.

3.8.4 Limitations

Although this study was in a field study environment, both player idiosyncracies and seasonal tendencies may have limited the overall results. A smaller sample size was used in the 2-on-2 SAG because the data of 6 players data was removed due to severe movement of the helmet in the game rendering consistent video analysis impossible. The player’s helmets in this group tended to be have looser chin straps and although helmets fit well, there was significant rocking in the anterior/posterior and side-to-side during vigourous play. Further, the SAGs occurred amongst teammates during a single season. Conducting the field study at this time ensured that players were in mid season, and peak condition, but it may not fully reflect the true nature of the game as there was no overt risk of bodily contact to the same extent players would experience during a game against an opposing team.

3.8.5 Future Directions

Head position in the current study was defined as an angle between 0° at the horizon (the athlete was looking straight ahead with their helmet and visor on), and a head flexed position. More research is required to create a better working definition of player gaze and HP in ice hockey players. As the head and eyes synergistically enable players to capture pertinent visual information, the definition should include the incorporation of eye position with HP. MacAskill (2016) defined upward gaze as any vertical gaze data above the horizon (0°) while Vickers et al. (2016) defined looking up through the vertical head flexion angle. The current study demonstrates that, regardless of player eye position, the relationship between HP is also related to the type of game play and the skills demonstrated therein.

Time motion analysis of ice hockey games has been performed looking at low intensity (standing, gliding, slow forward and backward skating) and high-intensity (fast
forward skating, forward sprinting, and fast backward sprinting and skating) activities (Brocherie et al., 2018). It would be of interest to break down a hockey game by team skills and observe HP professional players adopt during the game. Furthermore, knowledge of “what is normal” in regards to HP to a skilled athlete has not yet been described until now.

### 3.9 Acknowledgements

The authors would like to thank Shea Kewin at UHWK for the equipment; John Chibuk at KIWI for assistance with the accelerometers and determining head position; and Jim Dickey for assistance with the cumulative density functions. Our thanks are also extended to the University of Western Ontario men’s varsity hockey team, and Head Coach Clarke Singer.

### 3.10 Disclosure statement

No potential conflict of interest was reported by the authors.
3.11 References


Ice Hockey Systems. (2021). *Keep your head up: Tips to coach this important hockey habit.* IHS. https://www.icehockeysystems.com/blog/keep-your-head-up-hockey-habit


Chapter 4

4 Using Head Position as a Proxy of On-Ice Hockey Field of View

4.1 Introduction

Ice hockey is a dynamic, fast paced game with a maximum of 16 bodies on the ice at any time: 12 players (5 players and 1 goalie on each team) and 4 officials. With this many dynamic bodies on the ice, players must devote visual attention to their surroundings by keeping their “head on a swivel” to attend to game cues to outplay their opponents. As players become more experienced, the level of skill increases, increasing the speed of the game, decreasing the time and space players have to make decisions (Malloy, 2011). Hockey sense is an intangible skill that is highly sought after by hockey coaches and scouts alike. It is loosely defined as a player’s ability to ‘read’ the play with the context to make high probability decisions on the ice with and without the puck, to find or create openings to gain advantage over their opponents (Malloy, 2011). The closest concept in the literature is termed situational awareness (SA). There are 3 levels of SA, first the perception of the elements in the environment within a volume of time and space, secondly, the comprehension of their meaning and finally the projection of their status in the near future enabling individuals to attend to, and make, predictions regarding their immediate environment (Endsley, 2012). In hockey, all three levels of SA (perception, comprehension, and projection) must occur to provide the player with a comprehensive view of the game to make the best decisions in that particular game play context. In hockey, the sporting environment is dominated by visual perception, if perception (level 1) is impacted through adoption of a head down posture on the ice, the player’s SA will be hindered, and the level of play will fall. As SA develops skill training (Endsley, 2012), coaches can develop the athlete’s hockey sense (ability to see and process game events) through game like drills and scrimmages.

But how is hockey visual input attained? Mechanistically, visual information is received by the human eye. The eye is positioned on salient visual stimuli through 6 ocular muscles
that pull the eye in 3 different directions: vertical, horizontal, and torsional. Both horizontal and vertical eye movements are responsible for keeping the field of vision centered over the fovea (Holmqvist & Andersson, 2017). The fovea is a retinal depression at the back of the eye, and it is responsible for highly detailed visual input (Carter & Luke, 2020). The term visual field has been interchanged with “functional field of view” and “useful field of view” in the literature (Holmqvist & Andersson, 2017). The field of view is defined as the image players can see in one glance without moving their eyes and head (Woutersen et al., 2017).

The field of view can be envisioned as a non-uniform cone extending from the eyes, the cone encompasses a volume approximately 135° vertically and 200° horizontally (Davids et al., 1999; Leigh & Zee, 2015). This volume encompasses both central (foveal) and peripheral vision (Dowler et al., 2009). Due to the small size of the fovea (1.5mm) (Carter & Luke, 2020) central vision represents less than 2° of the field of view (Zaichkowsky & Peterson, 2018). Despite this mechanical fact, approximately 25% of the visual cortex is dedicated to processing visual input perceived from foveal vision (Holmqvist & Andersson, 2017). Peripheral vision covers the remaining 98% of the visual field (Carter & Luke, 2020; Holmqvist & Andersson, 2017). Humans have better contrast sensitivity and detection in their horizontal periphery as opposed to the vertical (Holmqvist & Andersson, 2017) which is a benefit for hockey players as hockey is predominantly horizontal in nature (Peters, 2012) but disadvantages those that keep their head down as it directs the cone of visual attention to a position dominated by immediate surroundings and forces players to use contrast sensitivity vertically as opposed to our evolutionary advantage of horizontal sensitivity.

During a hockey game, players need to have their head unrestrained to perform and perceive input from their surroundings. For coaches, it is important to understand the connection between eye and head movement. Like any muscle, the eye musculature is limited to a range of motion, in this case rolling the eye within the orbit. Human oculomotor range limits eyes to rotating a maximum of ~50° before head movement is initiated (Ing et al., 2002). The eye influences head position (Fang et al., 2015) as visual processing occurs best when the head and eyes are in alignment (Nakashima & Shioiri, 2014) as opposed to the eye being held in an eccentric (off-center) position. When eccentric positions occur, unconscious decisions are quickly made to determine if eye or head movement will occur (Nakashima & Shioiri, 2014) as the situation dictates. In hockey training environments,
coaches emphasize the importance of head position to their players, explaining that their eyes will lead their head and ultimately determines the size of field of view they can perceive (Corneil, 2011; Holmqvist & Andersson, 2017) and the magnitude of situational awareness that can be achieved.

With the level of intensity and physicality present in games, players are required to wear certified equipment to ensure safety. Due to the number of facial and ocular injuries resulting in numerous games lost, the NHL and NHLPA mandated in the 2013-2014 season, all players entering the league and players with less than 25 NHL game experiences were to wear a visor (Dowler et al., 2009). The NHL is the only league providing the option to not wear the visor however it is in the process of being phased out (Associated Press, 2017; Seravalli, 2019). In leagues other than the NHL, players must wear facial protection (half visor, full visor, or cage). The plastic visor is made from translucent polycarbonate material with anti-fog and anti-scratch coating (Dowler et al., 2009). Despite players’ opposition to visors saying that it impedes their vision, over 97 percent (Micieli et al., 2014; Seravalli, 2019) of the league wear a visor to play with only a handful still playing without.

It is important to understand how, or whether, the visor effects an athlete’s performance. There is limited research studying the visor in ice hockey. Ing et al. (2002) performed a study investigating the effect of a visor compared to sports goggles on vision. Due to limitations in their paradigm, the visor was not attached to the helmet but held in place with fishing line and weights in front of the participant. A decrease in participant’s peripheral vision (greater than 60°) from a fixation was found. Ing et al. (2002) also make note that the superior visual field, that is visual elements that exceed 30° beyond the horizontal, is not used to its full extent. In relation to hockey, if the player adopts a head down position, their peripheral vision will be limited due to eccentricity (decreased perceptual capacity) and the volumetric cone of the visual field will be limited to objects closer to the player as their head will likely be lowered (Corneil, 2011; Holmqvist & Andersson, 2017).

Dowler et al. (2009) investigated how hockey visors effected the response and movement times of players across the horizontal plane. Participants were surrounded by motion capture cameras while looking at a horizontal 13-point light bar under three conditions (helmet, visor, and cage). While wearing the visor in comparison to the helmet only, response and
movement time increased by 12ms and 14ms with a cage in side-to-side head rotation. Although not tested, the authors highlighted the importance of the addition of a vertical component, as hockey utilizes the visual system in all planes of movement (Greenwood et al., 2012). The two prior studies were performed in a highly controlled, laboratory setting and not on the ice. This limits the external validity and application of the research for coaches.

Coaches have a wealth of experiential and tacit knowledge (Greenwood et al., 2012), however novel information to improve athlete performance is garnered through conversations with other coaches and coaching conferences (Fullagar et al., 2019; Reade et al., 2008). As research on conditioning and fitness has saturated the field and become mainstream, coaches have sought information on technical and tactical player behaviour and skill acquisition (Fullagar et al., 2019; Sullivan, 2019, 2020). One of the goals of conducting field research is to assist in the translation of science into applicable coaching outcomes with applicable language and methods of application. Engaging with the coach and incorporating their tacit knowledge, a more representative study can be conducted, providing value and insight for both science and the coach and athletes (Pinder et al., 2011).

Walker et al. (see Chapter 3), conducted a representative study in conjunction with hockey coaches to gain a better understanding of player head positions adopted during simulated games. Players competed in two iterations of a small area game (2-on-2 and 3-on-3) designed to mimic game situations in relation to time and space constraints. Accelerometers and a point of view cameras on each player provided game footage. Head positions were categorized into 4 positions based on each players’ cumulative probabilities. This approach enabled researchers to measure the full spectrum head position of each player during entire game. Despite the study being conducted in the field, one of the limitations was the inability to quantify the athlete’s field of view in connection with the HP adopted.

The objective of the current study was to quantify how a player’s on-ice field of view (on-ice FOV) changed as their head position decreased from the horizon, with and without the use of a half visor.
4.2 Methodology

4.2.1 Participants

Twelve male university ice hockey players (M age = 22±2 yrs., and M height = 72”±3”) were recruited from the intercollegiate men’s ice hockey team at the institution. All players were accomplished athletes with an average of 17±2 yrs. experience in competitive hockey play. All the players had normal, or corrected-to-normal vision, were injury free, and had undergone prior on-ice skill training. All players were volunteers and their participation in the study had no impact on their status on the team or their academics. The protocol was approved by The University of Western Ontario Research Ethics Board (REB # 115123) (see appendix B).

4.2.2 Equipment

**Head position.** Players’ head positions (HP) were recorded with a MetaMotionR inertial measurement unit (MBIENTLAB Inc., San Francisco, Ca). The small device (0.2oz/7g) was affixed to the right side of the helmet beside the ear to record head position. The accelerometer measured accelerations in all directions and the vertical pitch (head up/down rotation) value was extracted. Head position data was recorded with respect to 0° at the horizon where negative angles indicated head down positions. The data was captured at 50 Hz with onboard SD cards in each accelerometer.

**On-ice field of view.** Player’s on-ice field of view (FOV) at each head position was recorded with the Arrington Eye Tracker and ViewPoint Software (Arrington Research Inc., Scottsdale, AZ, USA). The eye tracking device was attached to a plastic set of eyeglass frames that the athlete wore, connected to a computer by a 10m cable. The unrestricted equipment allowed FOV calibration at each HP. The on-ice point of view (POV) camera (Arrington scene camera) was located on the center of the eyeglass frames, with an infrared camera and infrared light source pointed towards each eye (Figure 4-1). The eye tracking data was captured with a sampling rate of 30 Hz and stored digitally. The camera lens used for the on-ice POV camera had a wide angle (78°) as the horizontal FOV (96.9°) and vertical FOV (68.7°) dimensions were closest to the optimum human vertical FOV (~60°) (Nakashima & Shioiri, 2014).
Figure 4-1. Equipment orientation on the athlete.
The left image represents the no-visor condition. The right image represents the visor condition.

Helmet and Visor. All players wore a single CSA certified hockey helmet (Bauer 5100) to ensure both the eye tracker frame and cable fit comfortably underneath the helmet and the visor (when attached). A previous game-worn clear Bauer Pro Clip straight visor (Bauer) was clipped onto the helmet for the visor condition.

4.3 Procedure

Data collection took place around the men’s hockey team on-ice skill development sessions. Players wore regulation hockey gear (skates, stick and gloves) and a Canadian Safety Association (CSA)-certified ice hockey helmet.

Equipment set-up. Prior to stepping on the ice, the eye tracker was fitted on the athlete. The cable attached to the collection computer was clipped to the collar of the participant’s uniform. The helmet equipped with the back-up camera (UHWK) and accelerometer (metawear) was then placed on the athlete’s head. The helmet was adjusted to ensure it snugly fit the athlete’s head. The eye tracking camera and infrared light source were oriented at the player’s right eye. To calibrate the accelerometer for HP, the athlete was instructed to
look straight ahead, while their helmet and attached recording devices were adjusted to 0° at ice level.

Prior to the commencement of each trial, the recording equipment was field calibrated by asking the athlete to observe a central clock to synchronize time between the various devices. Two conditions were studied (no visor and visor) at four different head positions, for a total of eight trials. The athlete was allowed a break after the first condition to attach the visor to the helmet. For the duration of each trial, the athlete was asked to adopt their attack position stance, straddling the center (red) line, with their hips back against the boards, in front of the penalty box.

**On-ice Field of View.** To field calibrate the eye tracker at each head position, a 9-point grid was superimposed onto the on-ice POV camera image visible on the computer (Figure 4-2). Six orange pylons were placed in the approximate area of the corresponding points on the ice. Once the athlete’s head was positioned by the assistant (KS), they were asked to hold their position until the completion of each trial. A researcher remained on the ice beside the athlete to monitor head position maintenance. During each trial, the athlete’s eyes were directed to one of the nine points on the grid. The athlete’s eyes were directed to each point 3 times each to ensure accuracy of the field of view.

Following the session, the back-up camera, on-ice POV camera recording, and accelerometer were temporally aligned with the time at the start of each trial.

### 4.4 Data Filtering

**Head Position (HP).** The accelerometer delivers head orientation data as a continuous stream. Here, sagittal head position was resolved (Microsoft Excel) and converted to degrees
down from the horizon in both the visor conditions. As the HP data was collected at 50Hz it was binned to time in seconds. The on-ice POV camera video was analyzed to determine the start and stop points of each trial. This allowed for the alignment of time and analysis of HP during each trial.

4.4.1 Field of View

Percentage of field of view occupied by ice. Since the FOV is confined practically to the ice surface, a 75x75 square grid was super imposed on top of the corresponding static FOV images for each of the HPs. The number of squares were summed to determine the relative percentage of ice visible within the defined FOV. As the percentage of ice increases, the HP falls further from the horizon.

On-ice surface area visible within field of view. Using the static images, landmarks on the ice were used to calculate a trapezoid shaped area to estimate the area of ice visible within the defined FOV. Unlike the percentage of ice within the FOV, the on-ice surface area rises as the head rises towards the horizon.

Line of Sight. The human eyes return to a central position in the orbits. This normally is in alignment with that of the head. This line of sight was then determined as the center dot in a 9-point grid superimposed within the eye tracking system (Figure 4-2) and used to infer the player’s line of sight. As HP falls further from the horizon, the distance visible in front of the athlete decreases.

4.5 Analysis

Descriptive statistics (mean, standard deviation and confidence intervals) for head position (HP), percentage of field of view occupied by ice (%FOV), on-ice surface area and line of sight (LOS) was calculated individually for each visor condition. Normality was assessed with the Shapiro-Wilk test. Data was analyzed with two-way repeated measures ANOVAs using post-hoc Tukey tests to assess main effects and interactions between data. A two-way repeated measures ANOVA was conducted to determine if the head positions (HUP, MHP, LHP and PDHP) observed were significantly different between visor condition (no visor or visor). A two-way repeated measures ANOVA was conducted to determine if
more ice occupied the player’s field of view at each head position (HUP, MHP, LHP and PDHP) was significantly different between visor condition (no visor or visor). A two-way repeated measures ANOVA was conducted to determine if line of sight at each head position (HUP, MHP, LHP and PDHP) was significantly different between visor condition (no visor or visor). An alpha value of \( p < 0.05 \) was considered significant and a Greenhouse-Geisser \( \varepsilon \) was used to adjust for violations of sphericity. Statistical analyses were performed using SPSS software release 27.0 (IMB Corp., Chicago, Illinois, USA).

### 4.6 Results

#### 4.6.1 Head Position

Mean, standard deviation (±1 SD) and confidence intervals are listed in Table 4-1 for visor vs the no visor condition. The two-way repeated measures ANOVA found no interaction between the athlete’s HP and the visor condition, \( F(3, 33) = 0.548, p = .653 \). The visor condition had no main effect on HP, \( F(1, 11) = 0.015, p = .906 \).

<table>
<thead>
<tr>
<th></th>
<th>HUP Mean ± SD</th>
<th>95% Confidence Interval</th>
<th>MHP Mean ± SD</th>
<th>95% Confidence Interval</th>
<th>LHP Mean ± SD</th>
<th>95% Confidence Interval</th>
<th>PDHP Mean ± SD</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Visor</td>
<td>1.9° ± 1.2°</td>
<td>12.4° ± 1.0°</td>
<td>34.3° ± 1.8°</td>
<td>59.8° ± 1.4°</td>
<td>58.9° ± 2.1°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visor</td>
<td>2.3° ± 1.4°</td>
<td>12.3° ± 1.4°</td>
<td>34.6° ± 1.1°</td>
<td>59.4° ± 2.1°</td>
<td>58.1° ± 60.7°</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

HP is expressed in absolute degrees down from horizontal.

#### 4.6.2 Field of View

**Percentage of field of view occupied by ice.** The mean (±SD) for percentage of ice visible within the player’s field of view during each HP is listed in Figure 4-3. The two-way repeated measures ANOVA HPxVisor found there were no interaction between visor condition and Head Position, \( F(1.825, 20.074) = 1.870, p = .182 \). The visor condition had 2.9 % (95% CI, [1.0 to 4.8], \( p = .007 \)) more ice occupying their field of view.

**On-ice surface area visible within field of view.** The mean (±SD) for area visible on-ice within the player’s field of view during each HP is listed in Figure 4-3. The HPxVisor condition analysis found a significant two-way interaction between visor condition and Head
Position, $F(1.050, 11.555) = 5.667, p = .034$. When the player was in the HUP position, they were able to see a 101.8 ft$^2$ (95% CI [25.5 to 178.0], $p = .013$) more with the visor. There were no differences in the MHP ($p = .072$), LHP ($p = .052$) and PDHP ($p = .186$).

Line of Sight. The mean, standard deviation (±1 SD), and confidence intervals for player line of sight during each HP is listed in Table 4-2. A two-way repeated measures ANOVA was conducted to determine if line of sight at each head position (HUP, MHP, LHP and PDHP) was significantly different between visor condition (no visor or visor). There was a significant two-way interaction between visor condition and Line of Sight, $F(1.008, 11.1) = 8.915, p = .012$. Players were able to see a mean distance of 17.3 feet (95% CI [4.8 to 29.8], $p = .011$) further in the MHP without a visor on the helmet.

Figure 4-3. Percentage of ice by area within field of view. Circles represent the no visor condition. Triangles represent the visor condition. Dark grey lines represent the percentage of ice visible within field of view. Light grey lines represent the visible on-ice square footage. * Significant difference ($p < .05$) between conditions for square footage of ice within field of view.
Table 4-2. Line of sight at each head position.

<table>
<thead>
<tr>
<th></th>
<th>HUP</th>
<th>MHP</th>
<th>LHP</th>
<th>PDHP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
</tr>
<tr>
<td></td>
<td>95% Confidence Interval</td>
<td>95% Confidence Interval</td>
<td>95% Confidence Interval</td>
<td>95% Confidence Interval</td>
</tr>
<tr>
<td>No Visor</td>
<td>85 ± 0 ft 85-85 ft</td>
<td>68.3 ± 22.2 ft *</td>
<td>54.2-82.4 ft</td>
<td>11.1 ± 2.2 ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5.1 ± 0.9 ft</td>
<td>9.7-12.5 ft</td>
</tr>
<tr>
<td></td>
<td>95% Confidence Interval</td>
<td>4.5-5.7 ft</td>
<td>4.9 ± 0.9 ft</td>
<td>4.4-5.5 ft</td>
</tr>
<tr>
<td>Visor</td>
<td>85 ± 0 ft 85-85 ft</td>
<td>51.0 ± 23.0 ft</td>
<td>36.5-65.6 ft</td>
<td>10.5 ± 1.2 ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>9.7-11.2 ft</td>
<td>4.9 ± 0.9 ft</td>
</tr>
<tr>
<td></td>
<td>95% Confidence Interval</td>
<td>4.4-5.5 ft</td>
<td>4.4-5.5 ft</td>
<td></td>
</tr>
</tbody>
</table>

* Significant difference (p < .05) between conditions. HP is expressed in absolute degrees down from horizontal.

4.7 Discussion

This study represents the first on-ice field study to quantify player on-ice field of view at various head positions. The HP category values were extrapolated from the 3-on-3 SAG in Walker et al. (see Chapter 3) as the time and space constraints were closest to a regulation hockey game (Nightingale & Douglas, 2018). The HUP category represents a 10% probability that athletes could adopt a HP between 0° and 2° (in this study). The MHP category represents a 50% probability (0°-12°), the LHP represents a 90% probability (0°-34°), and the PDHP represents a 99% probability (0°-60°). From a coaching perspective, there is a 10% probability that the athlete will adopt a HP greater than 34°. In relation to a standard 45 second shift (Nightingale & Douglas, 2018), a 10% probability means there is a strong likelihood the athlete will have their head down lower than 34° for roughly 4.5 seconds. In a game where time and space constraints influence performance, adopting a LHP or PDHP may not result in a desirable outcome, such as a bad pass or turnover.

4.7.1 Field of View

Percentage of field of view occupied by ice. It was hypothesized that the field of view would become dominated with ice as the head position decreased in both conditions. In Figure 4-3, the left vertical axis and dark grey lines illustrate the percentage of ice visible within the field of view. The hypothesis is accepted as in both visor conditions the field of view becomes dominated by ice indicating a precipitous fall in game visibility and although speculative, situational awareness. It is of interest to note that the visor condition had 2.9% more ice within the field of view opposed to only the helmet. This notion may support the perception in the hockey world of visors impacting performance (Dowler et al., 2009).
Whether the athlete wears a visor or not, more ice in their field of view may lead to a limitation in their performance. As seen in Figure 4-4, a HUP position allows the athlete to see more of their surroundings (with a limited percentage of ice in their FOV) as opposed to a PDHP where their FOV is limited (and dominated with ice).

**On-ice surface area visible within field of view.** The area visible on-ice follows the opposite effect than the percentage of ice visible within the FOV. In figure 4-3, the right vertical axis and light grey lines illustrate the area visible on the ice. The data provides more rationale for the acceptance of the hypothesis. In the HUP position (figure 4-4), the athlete can see more of their surroundings denoted by the boards across the ice, and the various markings on the ice (blue lines on either side), equating to roughly 3825 square feet (no visor) and 3927 (visor) (figure 4-3). Visible area on-ice continues to decrease in the MHP (3825, 3927), the LHP (2218 and 1763) and PDHP (58 and 51), respectively (figure 4-3). It was of interest to note that when the athlete was wearing a visor, there was a significant amount more of on-ice square footage visible in the HUP than without a visor. This is almost reversed at the LHP, as the difference was approaching significance. Regardless of visor condition, as HP decreases, the area visible on ice decreases. This may limit the athlete’s performance as they are not able to see what is happening in their surroundings.

**Line of Sight.** In conversation with hockey coaches, the goal of improving athletes 10ft, 20ft and 30ft vision of the game is a priority. As the athlete’s HPs were lowered down from the horizon, line of sight decreased in both conditions. In this study, the athlete was able to see further across the ice at the MHP, LHP and PDHP when the athlete was not wearing the visor (Table 4-2). At the MHP, it was of interest to note that the player was able to see 17 feet further without the visor. As illustrated in figure 4-4, HPs in the HUP and MHP category, the athlete was able to see across the ice without stressing their visual system. However, in the LHP when the athlete is wearing a visor, their line of sight is around 10.5 feet ± 1.2 feet and roughly halfway across the ice if they roll their eyes up into their superior visual field. This eccentric eye position is not comfortable and cannot be maintained as the eyes want to remain centrally in their orbit (Duchowski, 2007; Moran et al., 2018). Tying in the information gained from Ing et al. (2002) the superior visual fields are not being used to their full extent and visual processing is not as efficient when the eye is not in alignment with
the head (Duchowski, 2007; Moran et al., 2018). Through knowledge of the athlete’s individual or team cumulative density function HP’s being adopted, the coach can utilize their tacit knowledge and various training drills to modify habits on the ice. As seen in Walker et al. (see Chapter 3), athletes adopted different HPs when performing technical skills and tactical game elements. Through emphasis of adopting higher HPs for all performance related elements, line of sight and in-game vision can be improved.

![Figure 4-4. On-ice field of view (FOV) at various head positions (HP).](image)
Row A represents the player head position during the visor condition. The black dotted arrow represents the neutral line of sight at 0°. The red arrows represent the upper and lower maximum eye rotation and the space between represents the optimum eye rotation range. Row B represents the on-ice FOV.

### 4.7.2 Limitations

Although this field study was performed within the training environment, there are a few limitations. The eye tracker is a great piece of equipment however it does not provide the ability to discern the difference between the user’s attention and gaze (Duchowski, 2007; Moran et al., 2018). It has been commonly stated in the literature that the gaze does not infer attention (Holmqvist & Andersson, 2017). Another limitation is the effect head movement has on the field of view calibration (Holmqvist & Andersson, 2017). The slightest head movement shifts the FOV calibration. This did not affect the study however, in future studies performed head position should be taken into consideration with eye tracking in a dynamic
sport. Despite the athlete adopting a common hockey posture (attack position), it is a snapshot from a static position that is not held very long within the sport itself. It is hard to draw generalizations about HPs while the athlete is performing various skills and adopting different stances of varying height during game play.

4.7.3 Future Directions

It would be of interest from a coaching perspective to determine if the knowledge gained (line of sight, percentage of ice visible, on-ice area) through this study could lead to the development or modification of training drills designed to improve HPs adopted on the ice. Through knowledge gained on the impact of the visor, a collaboration with hockey equipment companies to develop a visor that does not impede vision could serve as another direction. From a skill development perspective, the information garnered here could be utilized to illustrate and coach youth athletes on the importance of head position during training and games.

4.8 Acknowledgements

The authors would like to thank Dr. Kristine Dalton at the University of Waterloo for the eyetracking equipment and Shea Kewin at UHWK for the PPOV video camera equipment. Our thanks are also extended to the University of Western Ontario men’s varsity hockey team, and Head Coach Clarke Singer.

4.9 Disclosure

No potential conflict of interest was reported by the authors.
4.10 References


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Chapter 5

5 Discussion

This dissertation identified a gap in knowledge and understanding of proper head positioning in ice hockey players. As HP is not acknowledged as a core skill until players reach the Under-15 category in the Hockey Canada Development Model (Hockey Canada, 2013), players develop skills and habits that may compromise or limit their performance. Coaches have a wealth of knowledge and experience within the sport, however when they seek out alternative solutions to enhance their team’s performance, they often turn to other coaches to have conversations or attend coaching conferences (Fullagar et al., 2019; Reade et al., 2008) rather than coaching science. The disconnect between the fields of coaching and science, hinders a coach’s ability to base their training methodologies on evidence. As coaching methodologies are in advance of scientific literature (French & Ronda, 2022), developing studies in collaboration with coaches creates opportunities to gain practice-based evidence. Knowledge gained from practice-based studies can inform the direction to conduct research in order to garner support for the continued implementation of current practice methodologies or alternatively if refinement should occur. What started out as a collaboration with an NHL skills development coach, researching and developing a way to quantify an area of particular interest, has developed into a better understanding of the relationship between head positioning and field of view. The practice-based knowledge informed the basis of this dissertation with the evidence obtained being able to inform practice. This creates a cycle to evaluate and enhance performance. The overall question of this dissertation was “How does head position effect game vision and skill demonstration in ice hockey players?” Objective one utilized a 3-week coaching intervention that incorporated helmet-mounted player point of view (PPOV) video and specialized training drills to provide post-practice feedback regarding HP and vision (n=18). It was hypothesized that these training sessions combined with video feedback would alter head position behaviours (Chapter 2). Results revealed this approach did not refine behaviour. Objective two simultaneously quantified multiple players’ HPs during small area games (SAG). The HP were measured in 2-on-2, and 3-on-3 SAGs (commonly used in practice). Players’ HPs (n=25) were measured with accelerometry during each on-ice shift and categorized further into HP during stickhandling or skating during
offensive and defensive play (Chapter 3). The range of HP were portrayed as frequency distributions indicating player HP behaviours changed with respect to the number of players involved and the skills exhibited. Objective three quantified how players’ on-ice field of view (FOV) changed as HP decreased from the horizon, both with and without a half visor (Chapter 4). The results illustrated that head down positions severely impact FOV and it becomes dominated by immediate ice area, reducing game visibility regardless of eye movements.

Despite seemingly logical and immense anecdotal knowledge around the importance of head positioning, prior to this dissertation, HP had not been quantified in training or game simulations. This presented an opportunity to understand HP behaviours as they were displayed during both training and game situations and interpret the data through the lens of both science and coaching.

In sport research, cumulative distribution functions (CDF) have been used to generate a reference curve for coaches to compare individual players heart rate/speed metric against the team average (Ravindranathan et al., 2017) or generate predictive curves for comparison in blood doping profiles (Faiss et al., 2020; Sottas et al., 2011). Due to the dynamic nature of ice hockey, despite the same skill behaviours being expressed, no two shifts or drills that were performed by the players were exact replicates of each other. Utilizing the CDF approach enables comparisons across different lengths of individual shifts and creating HP behaviour profiles. This creates a simple way to visualize the data, and provides a stronger, less biased assessment of overall player behaviours.

Cumulative distribution functions (CDF) provide the probability of a specific HP behaviour (less than or equal to the specific value) being expressed during a single shift or drill (Filliben & Heckert, 2012). Head position was defined and categorized through 4, a priori cumulative probabilities to illustrate the differing ranges of HPs players adopted during game play. The percentage values of each categorization (0.1, 0.5, 0.9 and 0.99) correspond to classification categories in the literature (Jackson, 2006; Jonsson, 1982). The categories were adapted to ice hockey terminology providing coaching staff a comprehensive and hands-on understanding of player behaviour with respect to HP and vision of the ice surface.
Average CDF curves for each player’s HP behaviour were created for each drill (Chapter 2) and small area game shifts (Chapter 3).

Players spend years training and developing their skills to reach peak performance. With a gap in translation of research into practice, coaches are left to rely on anecdotal evidence and previously accepted practices (D. N. French & Ronda, 2022; Fullagar et al., 2019). Conducting studies in collaboration with coaches, enables their coaching knowledge and experience to be incorporated and inform the design, enabling and fostering the development of practice-based evidence (Swisher, 2010). Chapter 2 exemplifies a practice-based study developed in collaboration with Coach Mike Ellis (Tampa Bay Lightning Director of Skill Development) designed to target a skill that Coach Ellis selected as meaningful to performance enhancement based on his expertise. Video provides a unique opportunity for coaches and athletes to observe skills and behaviours during training and game simulations. Teams use video to scout their opponents and as a bird’s eye view of drills during practice (Wilson, 2008), however companies have developed smaller video cameras for players to wear, capturing video from their point of view (PPOV), as opposed to the side (third person perspective) (Carter, 2012). Implementing POV cameras into training is not common practice in the scientific literature but has been incorporated by a few athletes training in elite skiing, snowboarding and cycling (Carter, 2012). Previously, coaches had to rely on the information provided by the athlete and may not have made the same observations the athlete had. This allowed coaches the ability to view what the player is seeing as they perform tasks and enables another dimension of performance to be explored. Through the incorporation of POV cameras into the 3-week training intervention, players were able to passively re-watch their training sessions. Despite promising results on the use of POV video (Carter, 2012; Fiorella et al., 2017; G. French, 2016; Warrian et al., 2015), our findings did not support changes in new HP behaviour refinement. This finding aligns with previous research on athletes experiencing performance decrements prior to expressing the newly refined skill (Carson et al., 2016; Carson & Collins, 2014, 2018; Kearney et al., 2018; Sperl & Cañal-Bruland, 2019; Toner et al., 2020). However, if the players had received coaching feedback in addition to the video, results may have been more aligned with the studies by Boyer et al (2009) and Anderson and Campbell (2015). The results from the current study highlight the important
synergy that practice- and knowledge-based refinements must adopt in order to be meaningful to athletes and to incite measurable behaviour alterations.

With the finite differences between athletes (Carson et al., 2014), and minimal time coaches have developing their players, it is important to ensure that training is being reflected and transferring to performance. In order to strengthen the behavioural connection between training and performance, an understanding of HP during performance was first necessary. Chapter 3 simultaneously quantified multiple player’s head positions’ (HP) during small area games (SAG), more specifically, during 2-on-2 and 3-on-3 SAG. As the level of play intensity increases, players have decreased time and space on the ice (Malloy, 2011). Small area games have only been studied in relation to exercise physiology and biomechanics (Brocherie et al., 2018; Lachaume et al., 2017) identifying shift characteristics (playing time, number of shifts, and duration of each shift), time spent performing various locomotor activities (standing, skating, gliding) and SAG size that best resembled normal game play in relation to player heart rate and intensity. Biomechanics research has focused on player’s skating mechanics (stride and length) and how the equipment (stick and helmet) impacts performance. Some research has been conducted focusing on eye movement behaviours in ice hockey players (Martell & Vickers, 2004; Vickers et al., 2001, 2016) however the research is restricted. This could be in part due to the cost of the equipment (only one player at a time can wear the eye tracker) and the limited generalizability to normal game play as the drills performed have been controlled in terms of the number of teammates and opponents involved. The unique approach taken in chapter 3 to simultaneously measure group HP during two SAGs versions, with the same players enables coaching staff a better understanding of players’ situational awareness as it pertains to their ability to develop hockey vision. Regardless of skills expressed, players adopted higher head positions when they had greater time and space (2-on-2) compared to when it is limited (3-on-3). Head position behaviour was further analyzed through expression of the common skills of stickhandling and skating, while playing both offensively and defensively. To encourage players to adopt higher head positions during offensive and defensive skills, it is important to simulate team behaviours akin to those in games (Bowker, 1996; Sullivan, 2019). In order to aid player development of better HP during their stickhandling skills, the 2-on-2 games may be a better coaching choice as there is increased space and time to allow players to
stickhandle the puck. It is important to note that players also had the puck on their stick for a greater percentage of the shift in the 2-on-2 game. The results from this study provide an objective and comparable overview of individual, and team play head position behaviours expressed in high caliber varsity hockey players. Although outside the scope of the study, future endeavours could incorporate the current approach of team HP and skill interactions on a line-by-line approach. Here, coaches could combine the player lines normally used in games and compare real game efficacy across a variety of performance statistics. The approach of game statistics compared to HP in SAG would be a powerful tool that combines individual HP, with line HP, and integrate real game statistics. Furthermore, the use of the approach in chapter 3 could also be very valuable to coaching staff in younger player development and monitoring the amelioration of HP during skill expression across the season through the lens of the player, to assist in the development of their situational awareness and game vision.

In conversation with Coach Ellis and various hockey coaches, the ability to improve an athlete’s 10ft, 20ft and 30ft vision of the game is a priority. Chapter 4 demonstrated how a player’s on-ice field of view (FOV) changed in relation to head position as it decreased down from the horizon, with and without a half visor use. The specific HPs examined were informed by those adopted during the 3-on-3 SAG (chapter 3) as the time and space constraints were akin to a regulation hockey game. Evidence-based research needed to be conducted to gain a more meaningful understanding of what the HPs represented and if the values could be used as a proxy for on-ice FOV. Three metrics were used to define FOV: percentage of ice visible, on-ice surface area, and line of sight. The hypothesis was accepted as both visor conditions became dominated with visible ice. An interesting finding showed that the visor condition had ~3% more ice within the field of view, indicative of a lower HP, as opposed to only the helmet. This notion supports the suggestion in the hockey circles of visors impacting performance (Dowler et al., 2009). Regardless of visor condition, as HP decreases, the on-ice surface area and line of sight decreases. Although outside the scope here, decreasing the line of site will degrade the athlete’s performance as their situational awareness is negatively affected. Players are less likely to play with their head down and eyes rolled upward eccentrically as the eye position is not comfortable and the position is not maintained (Duchowski, 2007; Moran et al., 2018). Ing et al. (2002) have identified the
superior visual fields are not used to their full extent as visual processing is not as efficient when the eye is not in alignment with the head (Duchowski, 2007; Fang et al., 2015; Moran et al., 2018). Incorporating an eye tracker into training is not feasible for many teams. Understanding the relationship however between measuring HP and the player’s FOV provides an alternative way for coaches to train and track this element of performance.

Although “gold standard” does not necessarily incorporate practice-based approaches, these field approaches provide valuable information that can inform evidence-based research to enhance training methods implemented by coaches (D. N. French & Ronda, 2022; Swisher, 2010). Figure 5-1 provides a summary of images captured during small-area games (practice-based) from Chapter 3 and during the HP as a proxy (evidence-based) from Chapter 4. In the HUP position, the athlete can see more of their surroundings denoted by the boards across the ice, and the various markings on the ice (blue lines on either side) compared to the

![Figure 5-1. Summary of Head Position Images of on-ice field of view.](image)

The coloured lines emerging from the athlete’s face represent the head position angles (in degrees down from the horizon) of HUP, MHP, LHP and PDHP. The images that correspond with the HPs are outlined in the same colour. The images on the left are adapted from Chapter 4. The images on the right are adapted from Chapter 2.
PDHP, the athlete can see very little of their surroundings. This was the first-time quantifying and providing meaning to head position in ice hockey players. Even though these studies were conducted through a lens focused on ice hockey, the knowledge gained on head position and field of view can be implemented in other sports. Developing athletes with an emphasis on the role of proper head positioning should extend their careers (injury preventative strategy) and enhance their performance, individually and as a team. Due to the complexity of conducting studies focusing on the influence of situational awareness in sport, many studies are conducted studying individual perceptual-cognitive skills (i.e. visual search, anticipation, pattern recognition, etc.) as they relate to decision making (Huffman et al., 2022). A few examples of how this has been conducted in sport settings is through the use of occlusion glasses (Hadlow et al., 2018), chin up goggles (Dunton et al., 2019), and 1m orange lines painted around rinks (Vickers et al, 2016) to name a few. Although head position is not the only answer, it is a large and determinant component of the visual input modalities that influences athlete’s perception of the game.

5.1 Coaching Application

There are three approaches coaches may adopt based on the knowledge gained from the current research. The first applies to situational awareness expansion based on POV video perspective, the second refers to the player’s game vision, and lastly, training. As video is common practice for coaches and teams, this research suggests changing the perspective the video. By using athlete perspectives coupled with debriefing, the ameliorations in the athlete’s learning found in the literature (Fiorella et al., 2017) might be multiplied. Implementation of the POV cameras into practice or game simulations, provides a unique coaching opportunity where the coach can watch with the player after they are done performing the drill or during the game. The coach can ask the player questions and/or ask the player to reflect upon game play decisions based on these videos. Through the video, the coach and athlete may find some information was misperceived or not perceived at all, developing level 1 (perception) and level 2 (comprehension) of the player’s situational awareness or hockey sense. The reflection off-ice on decisions regarding situational awareness could increase the player’s self-awareness and ownership over their performance. The second takeaway relates to a player’s game vision. If the goal is to increase player’s
ability to see more ice surface, chapter 4 provides values and images at four varsity athlete, simulated game play-derived head positions. If an athlete isn’t understanding what it means to play with their head down, the coach can use the images to illustrate to the player what influence their head position will have on their performance. There are certain times in a game players need to have their head down, however learning to use their peripheral vision will allow them to play with better, potentially safer head positions. Lastly, this research will positively add to methods to incorporate head position into practice. During training and games, coaches can utilize their knowledge and skills to identify game situations where players that tend to look down at the puck more. Once identified, coaches can specifically watch the player as they perform the various drills or skills on the ice, providing feedback or adding in additional time during warm-up or cool down for the player to focus on that skill. Results from chapter 3, help prescribe which simulated game situations would be best to develop those skills. For example, if the player is struggling with their head up while stickhandling, it is best to have them compete in a 2-on-2 SAG as the player has more time and space, but also the puck on their stick for more time. Another way aside from utilizing what the coach can see, would be developing a team CDF for various skills, to identify one athlete against the team,. Figure 5-2 is an example where coaches can use practice data to identify individual player head positions in relation to the team position average while in defensive roles in the 3-on-3 SAG. The black line represents the forward player average HP, while coloured lines represent cumulative distributions of individual

![Cumulative distribution of head positions](image)

**Figure 5-2.** Cumulative distribution of head positions of forward position individuals versus a forward player average during defensive roles during a shift while competing in a 3-on-3 SAG. Error bars on the forward average line represents +1 SD.
players. With relative ease, the coach could identify players 2, 3 and 4; they require additional feedback on their head position while they are on defense. This tool would provide a tangible metric for coaches to track and identify if the player adopts different head positions.

5.2 Limitations and Future Directions

Conducting and observing the research with only one team can be viewed as a limitation, the results may not be generalizable to other teams or athletes of varying levels of experience. In Chapter 2, the inability to conduct the training study in conjunction with the small area game study (chapter 3) may have limited the effects of specialized training as it could interact in game play and influence performance. In Chapter 2, the coach was not present and supervising the adherence to training. Having a hockey coach present at all training sessions providing coaching and mentorship, could have garnered more buy-in from the athletes, potentially changing the motives or effort put forth in the various sessions. More field studies, specifically case studies with coaches present, across different ages and ranges of hockey player development spectrum, would offer deeper insights for the coaches that can assist both minor and elite athletes in enhancing their training and performance while accommodating individual player differences (Carson & Collins, 2014). Finally in Chapter 2, the athlete was provided the POV video of their individual performance in the drills but no attempts to query their adherence or account for athlete’s time spent on viewing their videos were undertaken. Although not the objective of Chapter 2, feedback and coach oversight may have inadvertently minimized potential alterations in HP patterns. Using hands on approaches like this would better marry practical-based expertise of coaching with experimentally based data to leverage athlete and team performance.

Future directions should concentrate on two important populations to implement themes from this research, namely youth and women athletes. Youth athletes observe and try to mimic skills they see their favourite players perform during NHL games. Our research approach concentrated on skilled players, but it may also be suited for training youth athletes who are in the beginning years of the sport where the greatest gains in performance are made. Furthermore, women’s hockey is played with non-contact rules and cages on their helmets. It would be of importance to study and compare how head position behaviours differ between
the men and women when the threat of physical injury is minimized yet the level of play is still “elite”. Do women exhibit the same head position behaviours as men or do they adopt different head positions when they expect little, or different, contact from their opponent.

5.3 Conclusion

In conclusion, the overall question of this dissertation was “Does head position effect field of view and skill demonstration in ice hockey players?” The measurement objectives have revealed three main findings that all point to the power of good coaching. A 3-week head-up training intervention that provided player-based point of view video feedback while performing on-ice drills did not refine a player’s head position behaviour. Players adopt different head positions and exhibit different skill and head position in games based on the size of ice and the number of players (opponents and teammates) present. Finally, we have demonstrated that as players adopt head down positions, their line of sight and field of view decrease, as their vision becomes dominated with ice through more proximal gaze. Through innovative thinking and collaboration with coaches, practice-based knowledge can inform research and research can be conducted gathering evidence-based knowledge to further inform practice. Although this dissertation is focused on ice hockey players, the applications adopted here could be extended for other team sports as their athletes are trying to achieve the same goal: creating more time and space for the offence to perform, while limiting the time and space of their opponent.
5.4 References


Appendix A

Appendix A: Chapter 2 and 3 Ethics Approval Notice

Western University Health Science Research Ethics Board
HSREB Delegated Initial Approval Notice

Principal Investigator: Dr. Bert Chesworth
Department & Institution: Schulich School of Medicine and Dentistry\Epidemiology & Biostatistics, Western University

Review Type: Delegated
HSREB File Number: 108285
Study Title: Heads Up Skill Acquisition in Ice Hockey Players

HSREB Initial Approval Date: August 12, 2016
HSREB Expiry Date: August 12, 2017

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The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above named study, as of the HSREB Initial Approval Date noted above.

HSREB approval for this study remains valid until the HSREB Expiry Date noted above, conditional to timely submission and acceptance of HSREB Continuing Ethics Review.

The Western University HSREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the International Conference on Harmonization of Technical Requirements for Registration of Pharmaceuticals for Human Use Guideline for Good Clinical Practice Practices (ICH E6 R1), the Ontario Personal Health Information Protection Act (PHIPA, 2004), Part 4 of the Natural Health Product Regulations, Health Canada Medical Device Regulations and Part C, Division 5, of the Food and Drug Regulations of Health Canada.

Members of the HSREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.
Appendix B

Appendix B: Chapter 4 Ethics Approval Notice

Date: 3 February 2020
To: Dr. Tim Wilson

Project ID: 115123

Study Title: Visual Field of View and Search Behaviours in Ice Hockey Players
Application Type: HSREB Initial Application
Review Type: Delegated

Full Board Reporting Date: 25 February 2020
Date Approval Issued: 03 Feb 2020 10:03
REB Approval Expiry Date: 03 Feb 2021

Dear Dr. Tim Wilson,

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above mentioned study as described in the WREX application form, as of the HSREB Initial Approval Date noted above. This research study is to be conducted by the investigator noted above. All other required institutional approvals must also be obtained prior to the conduct of the study.

Documents Approved:

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No deviations from, or changes to, the protocol or WREX application should be initiated without prior written approval of an appropriate amendment from Western HSREB, except when necessary to eliminate immediate hazard(s) to study participants or when the change(s) involves only administrative or logistical aspects of the trial.
Curriculum Vitae

Name: Kristine Walker

Post-secondary Education and Degrees:
The University of Western Ontario
London, Ontario, Canada
2008-2013 B.A. Honors Specialization in Kinesiology
Minor Health Sciences

2013-2015 M.Sc. Kinesiology

2015-2022 Ph.D. Health and Rehabilitation Sciences

Honours and Awards:
2021 – USPORTS Football Vanier Cup Champions – Assistant S&C Coach
2019 - NFL Women’s Forum Attendee (Nominated and Selected)
2018 – USPORTS National Silver Medalist Women’s Hockey – S&C Coach
2017 – USPORTS Football Vanier Cup Champions – S&C Coach

Related Work Experience:
Assistant Strength and Conditioning Coach (S&C)
The University of Western Ontario
2013 – Present

Teaching Assistant
The University of Western Ontario
2013 - 2020

Strength and Conditioning Intern
Gary Roberts High Performance
2018

Conferences:
