Amateur Ice Hockey Coaching and the Role of Video Feedback

by

Jason Procyk

B.Sc., Simon Fraser University, 2013

Thesis Submitted in Partial Fulfillment of the
Requirements for the Degree of
Master of Science

in the
School of Interactive Art and Technology
Faculty of Communication, Art, and Technology

SIMON FRASER UNIVERSITY

Spring 2015

Approval

Name:	**Jason Procyk**
Degree:	**Master of Science**
Title:	***Amateur Ice Hockey Coaching and the Role of Video Feedback***
Examining Committee:	**Chair:** Dr. Ron Wakkary

Dr. Carman Neustaedter
Senior Supervisor
Assistant Professor

Dr. Thecla Schiphorst
Co-Supervisor/Supervisor
Professor

Dr. Anthony Tang
External Examiner
Assistant Professor
Department of Computer Science
University of Calgary

Date Defended/Approved: May 14, 2015

Partial Copyright Licence

Ethics Statement

The author, whose name appears on the title page of this work, has obtained, for the research described in this work, either:

a. human research ethics approval from the Simon Fraser University Office of Research Ethics,

or

b. advance approval of the animal care protocol from the University Animal Care Committee of Simon Fraser University;

or has conducted the research

c. as a co-investigator, collaborator or research assistant in a research project approved in advance,

or

d. as a member of a course approved in advance for minimal risk human research, by the Office of Research Ethics.

A copy of the approval letter has been filed at the Theses Office of the University Library at the time of submission of this thesis or project.

The original application for approval and letter of approval are filed with the relevant offices. Inquiries may be directed to those authorities.

Simon Fraser University Library
Burnaby, British Columbia, Canada

update Spring 2010

Abstract

Amateur minor hockey coaches have recently begun to capture and play back video recordings as a teaching tool, but it is not clear is whether such video feedback is useful or how video feedback systems could be designed to suit coaches' and players' needs. I wanted to understand coaches' current practices for communicating and teaching and their current use of video. I observed games and practices and conducted *in situ* interviews with amateur coaches. I found that teaching and learning at competitive levels of minor hockey focuses on decision-making and comprehension rather than individual physical movement. One-on-one teaching happens opportunistically and in brief moments throughout games and practices. However, video feedback is currently used mostly away from the ice because of technological limitations. Based on these findings, I suggest video feedback systems be designed for use within the context of games and practices while balancing players' needs with coaches' goals.

Keywords: video feedback; amateur coaching; ice hockey; user-centered design

Dedication

To the friends and family who nurtured my love of hockey, to Carolyn for her constant love and support, and to Mom and Dad for their support throughout my (ongoing) education: thank you.

And to Noble the dog for his wisdom and patience: “you are the champion”.

Acknowledgements

I want to thank my senior supervisor, Carman Neustaedter for his guidance and patience. I feel I have taken greater strides as a student, as a professional, and as a person since we began to work together. I have learned from you, and I hope I can continue to learn from you in the future. Thank you for everything.

I also want to thank my committee member, Thecla Schiphorst for her influence and expertise. This research began to take shape in that first research methods class, and it has since grown into something truly rewarding.

Finally, I would like to recognize the camaraderie of my lab mates in the Connections Lab and in SIAT in general. Even before I started—in the lab and in Paris—I never felt out of place.

Table of Contents

List of Tables

List of Figures

1 Introduction

This work is motivated by what I know—through my own experiences and through the stories of my hockey-playing friends and colleagues—to be a very common and very eye-opening experience for many hockey players. The first time I saw myself playing hockey on video was after a recreational men's league game. My girlfriend had come to watch the game, and I had asked her to record some clips on her iPhone. Later that evening, I downloaded them to my laptop and queued them up. As a relative latecomer to the sport, I was keen on self-improvement. I wanted to critique my performance and pull out problems I could work on improving for next time. I was not, however, ready for what I saw—did I really look like that?

The recording showed me a version of that game that was completely different from the version I had in my own mind. My movements were slower and more awkward, and my decisions were more questionable. In hindsight, the game looked a lot different than it had felt. The feedback I received from the video was harsh. At this point, I began to become quite curious about how this seemingly revelatory feedback might be employed in more serious circles of the sport.

In minor hockey and in the extremely competitive adult professional associations, players have the benefit of coaches to help them develop their abilities. Coaches leverage their own expertise and experience to provide analysis, feedback, and guidance that helps players improve over time. Traditionally, coaches have relied on a modest arsenal of communication methods to teach their players: verbal description, physical demonstration, and hand-drawn diagrams. More recently, however, many coaches have begun to capture and play back video recordings to provide their teams with a different kind of feedback (e.g. Groom and Cushion, 2004). However, we know little about how coaches integrate video feedback with their teaching approaches or how effective it is. This thesis explores whether such video feedback is useful and how video

feedback systems could be designed to better suit the needs of amateur hockey coaches and players.

1.1 Background

In recent years, camera and display technology has increasingly become more affordable, powerful, and portable. The rising popularity of multipurpose devices like smartphones and tablets, alongside more specialized devices like GoPro cameras and Google Glass, has made it possible to record, play, and transmit high-quality video almost anywhere and in almost any context. Through anecdotally available evidence, we know that many professional clubs had the resources to capture video and incorporate it in their training and preparation routines well before this kind of technology was available. Sports broadcasters have provided crews and equipment and recorded professional hockey games for decades, and as a result, professional clubs had access to quality footage. At the amateur level, however, even highly competitive clubs have lacked the funding and resources to utilize video on a regular basis. Even today, broadcasters typically televise only select games from the most competitive amateur leagues, which means teams need to coordinate their own staff and equipment if they want to record games. As the technological barrier to entry shrinks, I am interested in researching how coaches' existing practice around teaching the game of hockey might evolve with greater access to video feedback.

From a Human-Computer Interaction (HCI) perspective, I see this as a problem of understanding how amateur coaches interact with their players and how future video feedback systems might be designed to support them. Within HCI, the field of video-mediated communication (VMC) encompasses a large body of work investigating the design, development, and use of video technology in both the workplace and the home. For example, Fish et al. (1990) and Bly et al. (1993) explored the use of early video-conferencing tools and showed how video supports awareness and informal interactions among distributed coworkers. More recently, researchers have investigated how video systems can be designed around gaze and gestures to provide better support for collaborative tasks (e.g. Gergle et al. 2004, Tang et al. 2007). Similarly, in domestic computing, researchers have studied how families use video technology to communicate

and stay in touch. For example, Judge and Neustaedter (2010) and Ames et al. (2010) have shown how distance-separated family members use video to enhance feelings of closeness over distance. However, competitive sport is different from the workplace and the home. Coaches and athletes set goals around competing, improving, and winning in a highly structured situation. Their activities are focused around the particular game they play and the contexts of leagues and seasons. Even the physical environments coaches and athletes act in are quite different. Sports facilities are often built around large, open spaces, are usually accessible to the public, and are often equipped with only basic technology.

While video has been studied extensively in HCI, there has been relatively little investigation of the intersection between video and sports training. A handful of experimental training systems have been designed around video feedback, and the most relevant work beyond training systems focuses on the use of video to create shared experiences of physical activities over distance. Hämäläinen (2004) designed an interactive video mirror for martial arts training. It leveraged large displays to enable martial artists to review actions that prevent the use of an ordinary mirror (e.g. a spin kick) (Hämäläinen, 2004). Marquardt et al. (2012) designed a similar Super Mirror prototype for ballet dancers. The Super Mirror used motion capture and computer vision to analyse the dancer's technique and provide instruction on top of video playback. Both of these systems involved stationary cameras and displays, and they were designed for *self-guided* training. In competitive amateur levels of a team sport like ice hockey, players practice and play together under the guidance of a coaching staff. It is common for players to train independently, but they usually receive the most instruction and practice in the context of the team. In this way, we have yet to understand how this kind of video feedback technology might interface with the routines of a team.

Outside of HCI, psychology and motor learning researchers have studied the effect of video feedback on athletes' development. Much of this work has focused on measuring the value and efficacy of video feedback as a training tool. Researchers have attempted to measure quantitatively the effect of video feedback on the performance of specific techniques in sports like tennis (Van Wieringen et al., 1989) , golf, (Guadagnoli et al., 2002), and gymnastics (Boyer et al., 2009). Both Van Wieringen et al. (1989) and

Guadagnoli et al. (2002) found no significant difference between video feedback and traditional feedback (i.e. verbal instruction). While these results might suggest that video feedback offers little advantage to athletes, Boyer et al (2009) found that video feedback did help young gymnasts improve certain techniques with a greater rate of success. Other research has shown that integrating video feedback with conventional soccer coaching was a valuable yet complex task (Groom and Cushion, 2011). Groom and Cushion (2004) conducted a case study around the perceptions of two experienced football coaches in England. They found that the coaches supported the use of video and felt it was beneficial for both players and coaches. However, the above studies relied heavily on existing video technologies, which may or may not have mapped well to coaches' needs, existing routines, and desired coaching goals. From a design perspective, this presents both an important limitation and a research opportunity. As such, my research goal is to understand what existing routines coaches have, how video feedback fits within these routines (if at all), and, how such video feedback systems should be best designed.

In this way, my research explores the gap between these different fields. The VMC literature offers a great deal of insight into how video technology should be designed to support workplace collaboration or family communication, but we know little about how this knowledge translates to the unique context of competitive sports. HCI researchers have explored interactions around physical activities and sports training, but they have not focused specifically on how coaches can use video to support their interactions with players. Outside of HCI, researchers have studied how athletes can use video to train, but again, the role of the coach is often understated. Additionally, many of these studies adopt a quantitative approach to try to validate the effectiveness of video as a training tool, while I am more interested in understanding the coach's experience and learning how video tools could be designed to improve their practice.

1.2 Thesis Problems

This thesis investigates how coaches perceive and use video technology in their teaching routines. It addresses the overarching research problem: *we do not know how a video feedback system should be designed to support amateur coaches in teaching*

sports skills to the players on their teams. This is further divided into the following sub-problems:

1) **We do not know what coaches' goals and needs are in directing player learning.** Minor hockey associations typically mandate a certain level of theory from the top down (e.g. Hockey Canada recommends a set of best practices). However, we do not know how closely amateur coaches subscribe to these standards or what other goals and needs they account for in their approach to teaching the game.

2) **We do not know how coaches put their teaching strategies into practice.** This problem specifically addresses amateur coaches' experience of existing video technologies. While not all amateur coaches use video, we can investigate how those that do currently interact with video technology in order to inform the design of future video feedback systems.

3) **We do not know how coaches currently use video technology or what limitations they encounter in their existing practice.** We do not know much about how amateur coaches use existing technology in their current practice. We need to understand how they currently interact with video feedback technology before we can fully understand how future systems should be designed.

4) **We do not know how to apply this knowledge to the design of interactive systems.** While the bulk of this work focuses on understanding amateur coaches' needs and behaviours around teaching and using video in hockey, the questions I ask are ultimately oriented to inform the design of new technology for these coaches. In this way, the final sub-problem is to take the insights and translate them into design recommendations.

1.3 Thesis Goals

My primary goal with this thesis is to provide an understanding of how video feedback systems should be designed to help coaches better communicate with and teach their players. To address this overarching goal, I seek to address the following objectives, which are aligned with the aforementioned thesis problems:

1. **I will investigate coaches' current needs and goals around directing player learning.** I will conduct a user study to collect data from coaches to better understand their current experience and the needs and goals they have in their roles.

2. **I will explore coaches' actual behaviour around directing player learning.** The user study will also seek to gather descriptions of amateur coaches' actual demonstrated behaviour.

3. **I will investigate coaches' current use of video technology**. When applicable, I will explore their use of video technology in order to better understand how existing systems address the needs of coaches and how they might be improved in the future.

4. **I will apply my understanding of coaches' current practice to generate user-centered design recommendations.** I will analyze the data collected through the study and synthesize the findings to extract guidelines to support the design of future video feedback systems for amateur coaches.

1.4 Methodological Approach

My research focuses on understanding how coaches might use video feedback for teaching in hockey. I am approaching this research through a human-computer interaction lens that is focused on gathering understanding and design requirements for technology that will support coaches' day-to-day teaching practices and the direction of

player learning. The Association for Computing Machinery defines HCI as “a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them” (ACM SIGCHI Curricula for Human-Computer Interaction, 2009). Accordingly, the research presented here seeks to understand needs, teaching strategies, and actual practice of hockey coaches so that we might design more valuable video feedback tools for them. M research falls at the intersection of three related bodies of work. Within HCI, I am building on existing research on video-mediated communication, which has focused heavily on the role of video in the workplace and in the home. Also within HCI, I am drawing on a smaller body of work around interactions for sports and physical activities, which has included both training tools and more social applications for shared experience. Outside of HCI, my research is influenced by work from psychology and motor learning that investigates the effects of video feedback on athletes in training.

This thesis addresses my exploration of amateur hockey coaches’ existing practice around teaching the game and directing player learning. I conducted an observational and interview study primarily involving highly competitive PeeWee (ages 11-12), Bantam (ages 13-14), and Midget (ages 15-17) minor hockey teams in first and second tier leagues. I targeted these kinds of competitive high-caliber teams because I wanted to understand teaching, learning, and video at a level where competition and skill development are just as important as fun. At lower levels, coaches and players might interact differently to achieve recreational goals. For the sake of breadth, the study did include a small number of ‘house’-level coaches and coaches who worked with younger age groups (e.g. ages 7-8). I adopted a purely qualitative approach because this research space is still very much in a discovery phase. Considering that the HCI community knows very little about how coaches interact with players or how those interactions might be mediated by technology, a qualitative approach seemed most appropriate to begin to characterize their current practice and their needs. I used field observation and semi-structured interviews to gather descriptions of the coaching process. I adopted semi-structured interviews as a method because they give both the interviewer and the interviewee the freedom to expand on open-ended questions or raise new topics entirely (Schensul et al., 1999). As somewhat of an outsider to the domain of hockey, this aspect of flexibility was very important. It allowed the participants to educate

me about their process and about the larger context of the 'hockey community' they belong to.

1.5 Organizational Overview

In Chapter 2, I present a literature review. I first review how people use video-mediated communication technology in the workplace and in the home. I then discuss how people have used video technology to share physical activities over distance. Finally, I discuss existing sports training technology from both the perspective of psychology and motor learning research and the perspective of human-computer interaction.

In Chapter 3, I discuss the methodology for a qualitative study that investigates coaches' current practices for communicating and teaching and explores their current use of video feedback. The study uses field observation and semi-structured interviews to gather descriptions of coaches' perceptions, strategies and behaviours for directing player learning in hockey. It aims to understand how current video feedback technology does or does not fit the teaching routines of coaches and how video feedback systems should be designed in the future to meet their needs.

In Chapter 4, I present the results of the qualitative study and identify a number of themes around how coaches approach teaching hockey, how they communicate in the rink, and how they currently use video.

In Chapter 5, I discuss the results and call out design implications for future video feedback systems centered around coaches. This discussion touches on challenges and trade-offs around providing feedback in a team environment, contextualizing feedback, curating content, and social sensitivity.

In Chapter 6, I conclude this thesis by revisiting my research goals and reflecting on how I achieved each one. I also reiterate my contributions and make recommendations for future work.

2 Related Work

In this chapter, I review literature related to my research. First, I describe the body of work around video-mediated communication in the workplace and in domestic and mobile contexts. Second, I review research on shared physical experiences and discuss systems that have used digital interactions to mediate athletic activities. Finally, I describe related work around sports training from both the psychology and motor learning and HCI fields.

2.1 Video-Mediated Communication

There is a large body of work exploring the use of video in the workplace and in the home. Sports could be considered a separate context aside from the workplace and the home, but this work remains an important part of the HCI lens I adopted for my research. This video-mediated communication literature provides an account of how people use video to communicate in day-to-day life as well as a starting point for understanding how video technology might be used in a sporting context.

2.1.1 In the Workplace

With respect to the workplace, researchers have explored how video might be used to support awareness and interaction between distance-separated colleagues and to improve communication and efficiency in collaborative tasks. The challenge is that it can be difficult to for distributed colleagues to communicate because they cannot see each other (Bly et al, 1993, Whittaker et al., 1994). It can also be difficult for distributed colleagues to work together on a specific task because the documents or artifacts they are working on may not be easily visible (Harrison, 2009). As a result, researchers have explored two main scenarios. The first explores how to connect offices or social spaces like kitchens or lounges through technology (e.g., Bly et al., 1993, Fish et al., 1990). In

these cases, there is a desire to have the same kind of casual access to or awareness of remote colleagues that one might have when collocated (Harrison, 2009).

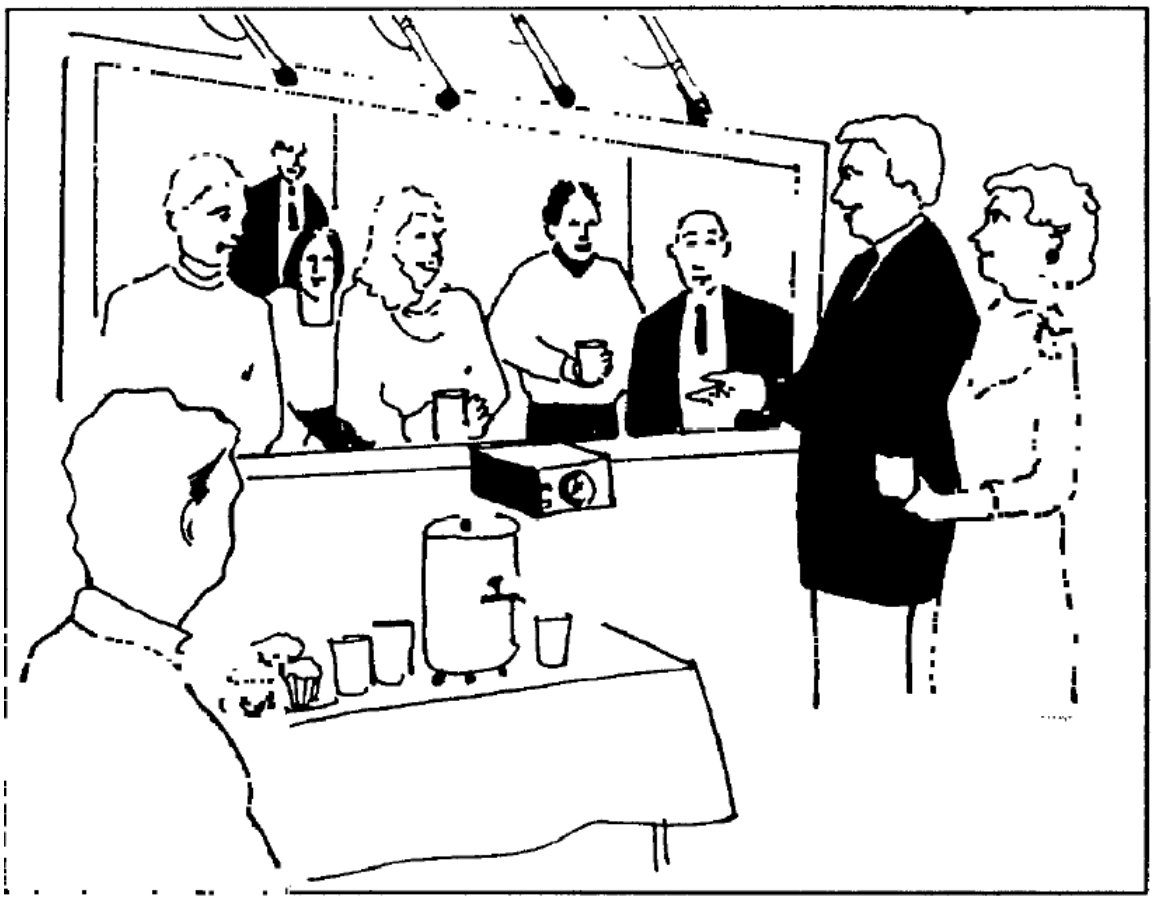

Figure 2.1 Figure 2.1 The Video Window system (image copied from Fish et al., 1990).

For example, Fish et al. (1990) created the Video Window system to understand how an always-on video connection could be used to create a shared space for distance-separated colleagues. Collocated colleagues often have chats or informal meetings in common areas, and the video window was designed to support this behaviour for distributed colleagues. The system used relatively high-definition cameras and two large displays to provide a reciprocal pair of 'windows' in two separate workplaces. The authors deployed the system for three months and studied the interactions that occurred around it. While they observed many similarities between interactions through the Video Window and ordinary face-to-face interactions, they also

identified a number of social and technical challenges that inhibited communication between separated users. They found that the fixed view of the camera lead to difficulty with social cues around initiating or avoiding conversations (e.g. perceiving body language, eye contact, gestures).

Similarly, Bly et al. (1993) reported on the use of a media space that connected twenty geographically-distributed colleagues with an always-on video and audio link. The link connected offices in Palo Alto and Portland. In some cases, it even connected the individual offices of colleagues located in the same building. The media space supported both “social and task-specific activities” over distance. They found that the media space supported collaboration over distance but also that it supported the informal social activities that collocated colleagues exhibit (e.g. chance encounters, awareness of availability, locating each other). At a high level, these works have shown video to support awareness amongst distributed colleagues so they know when others are available for interaction.

Second, researchers have explored how to connect more functional spaces like meeting rooms (Harrison, 2009). In these cases, there is a desire for more direct conversation or even for collaboration on specific tasks. This work offers an understanding of how people work together through video conferencing technology and provides insight into how cameras and displays can be configured (e.g. Kraut et al., 2003, Gergle et al., 2004, Tang et al., 2007).

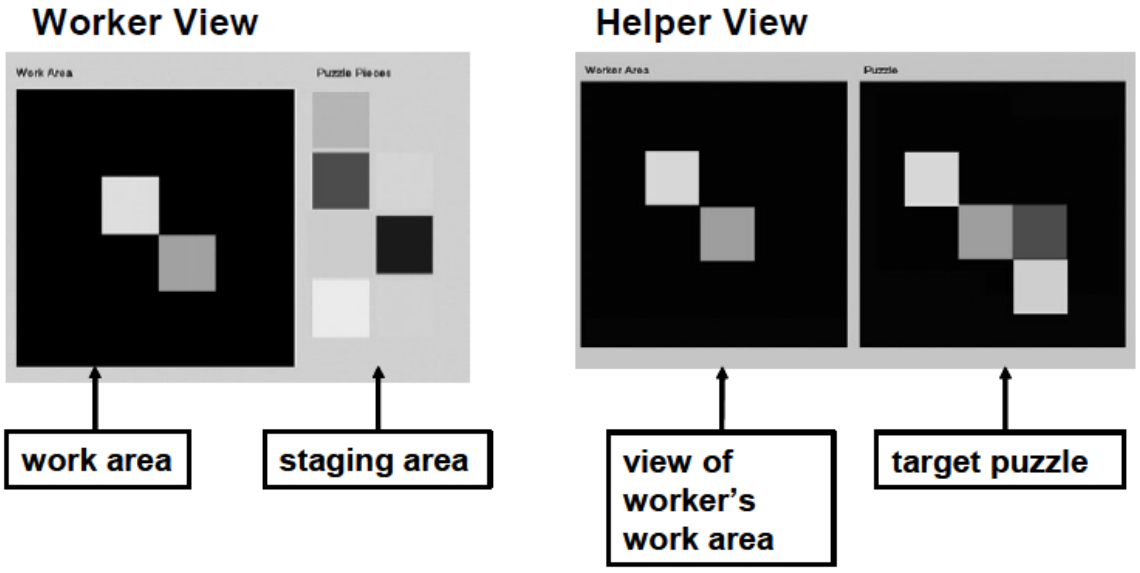

Figure 2.2 Screen captures of Gergle et al.'s puzzle task interface from the worker and helper perspectives (image copied from Gergle et al., 2004).

For example, video has been used as part of collaborative workspaces where distributed colleagues work on a shared artifact such as a drawing surface. This research has shown that the view of a remote collaborator's body and gaze becomes important for recognizing and anticipating workplace actions. Gergle et al. (2004) conducted an experiment to understand the value of visual information in distributed collaborative tasks. The experiment revolved around a collaborative puzzle task where a 'worker' had to arrange colored tiles on a grid with the aid of a 'helper' who could see the correct formation. The two were separated by distance, and the helper was required to provide instructions to help the worker match the puzzle solution. In one condition, both shared a view of the worker's space (the 'work area' in Figure 2.2). In the other condition, they did not share this view. The authors reported that participants in the former condition were able to communicate and complete the task more efficiently and achieve "a more efficient mechanism for establishing mutual understanding": with the shared view of the workspace, both partners could see understand the current state of the puzzle. In the other condition, the worker had to describe the current state to the helper. In another body of work, Tang et al (2007) designed a system to explore how distributed colleagues can work together on a shared surface while seeing each other's arms. The prototype allowed both collocated and remote collaborators to draw on a

shared drawing surface. At the same time, this so-called 'VideoArms' system integrated video from both locations with the drawing surface to enable collaborators in one location to see the arms of collaborators in the remote location. In an exploratory study, the authors found that people relied heavily on gestures to discuss the workspace with both collocated and remote collaborators. The integration of the purported 'video arms' with the workspace helped participants communicate more clearly and more efficiently with collaborators in both locations. The authors also recognized that camera placement and occlusion could be an issue: if participants leaned over the table, they sometimes obscured their arms from view and muddled the shared display.

While the above research all focuses on the use of video in distributed settings—which is unlike my focus on *collocated* players and coaches—it does highlight strategies for using video to show the position of a person's body and how to utilize one or more cameras to capture such views. In particular, the research points to the importance of top-down views along with broader contextual views of a location (e.g. Kraut et al., 2003). Of course, competitive sport is quite different from office workplaces. Coaches and athletes set goals around competing and improving, and winning in a highly structured situation. I imagine video in sport as an information resource—a tool a coach might draw on to communicate more clearly and share expert knowledge with a developing player.

2.1.2 In the Home

Outside of the workplace, people often use video chat to communicate with geographically-separated family members and friends. Other communication mediums such as email or telephones can feel impersonal because they do not allow people to see the person they are talking to. Video chat is more similar to a face-to-face conversation because it does allow people to see one another. Researchers have explored how video can be used to connect family or friends who separated by distance as well as to support a variety of shared experiences over distance. Much of this work has focused on understanding how video-mediated communication impacts the user experience and how it might support greater feelings of connectedness or intimacy. At the same time, researchers have also explored more technical aspects of video-

mediated communication and tried to understand how video chat systems should be designed to support domestic activities.

Figure 2.3 Examples of how families presented themselves to the camera on video chat calls (image copied from Ames et al., 2010).

For example, Ames et al. (2010) investigated the benefits and challenges of video chat for families. They conducted a field study of 22 different families and the ways they used video chat to interact with remote family members. The authors recognized a number of benefits for families including stronger feelings of connectedness. At the same time, they identified several kinds of "work" that families had to overcome to use the technology. Some of this work revolved around technical (e.g. poor internet connection) and social (e.g. scheduling times) challenges. The authors also described "presentation work", which involved coordinating and managing the view of the camera.

Figure 2.3 provides examples of how families positioned themselves in front of the camera. The authors found that the use of personal camera and display devices (e.g. a laptop) was often challenging. Families struggled to fit multiple people within the camera's narrow field of view, and the crowded call area also impeded their ability to use the computer controls. Similarly, Forghani and Neustaedter (2014) explored how grandparents communicate with grandchildren over distance. They conducted an interview and diary study with grandparents and parents, and they found that one of the challenges of conventional video chat was that children sometimes wandered out of the frame. They suggested that the use of multiple cameras could help to cover a broader area and address this problem.

Judge and Neustaedter (2010) also explored the use of video conferencing tools in the home. They interviewed 21 adults to learn about their experiences using video conferencing tools at home and to define a set of design considerations for future domestic video chat technologies. The authors reported that families enjoyed sharing activities and moments rather than just conversation. They recommended that video chat technologies should not limit calls to single devices or locations. They explained that this kind of design would afford more mobility within the home and, in turn, would better capture activities and moments. Judge, Neustaedter, and Kurtz (2010) designed and evaluated the Family Window to further explore the use of video conferencing tools in the home. The Family Window was a media space prototype intended to investigate how a video connection might be implemented to strengthen families' feelings of connectedness. The prototype consisted of a webcam and tablet PC running custom always-on video chat software with a number of experimental features (e.g. knocking and privacy blinds), and it was deployed with four families for five weeks. The authors found that the always-on video and the portability of the prototype helped families share more intimate, comprehensive views of their home lives by enabling them to capture more activities and moments.

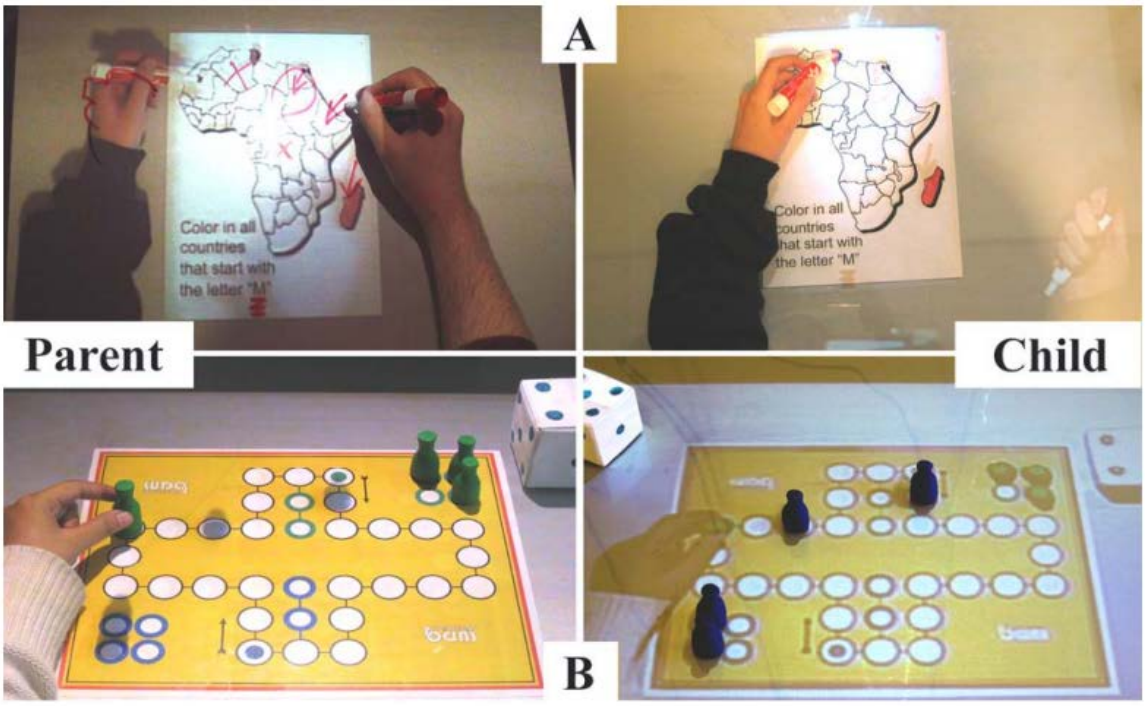

Figure 2.4 Parent and child perspective of two different tasks on the ShareTable system (image copied from Yarosh et al., 2009).

Much of the work I have described so far focused on the use of systems with a single camera and a single display. Researchers have also experimented with more complicated designs that involve combinations of multiple cameras, multiple displays, and other technology to capture and share domestic life. These systems often aim to support interactions that are more complex than an ordinary conversation.

For example, Yarosh et al. (2009) designed a media space called the ShareTable to support parent-child interactions in separated families where the child did not live with both parents. The prototype combined an overhead camera, a webcam, an ordinary monitor, and an overhead projector display to provide both face-to-face video chat and a shared physical table space. As a result, the system allowed parents and children to see each other face-to-face and share an activity (e.g. drawing, homework help) at the same time. Figure 2.4 illustrates how each tabletop presented the view captured by the opposite overhead camera. The authors compared the ShareTable to an ordinary video chat setup and found that the ShareTable made it easier and more enjoyable for parents and children to do things together. They also observed that the

shared tabletop view gave children a better understanding of what the parent could see. Yarosh, Inkpen, and Brush (2010) explored how children use video to play together over distance. They compared four different designs in order to understand how cameras and displays could be configured and controlled to support unstructured play. The designs they compared included: (1) standard video conferencing on a laptop, (2) a researcher-controlled pan-zoom-tilt camera with a large television display, (3) a tablet with a built-in camera and a stationary monitor, where the tablet acted as a handheld control for the remote party's view, and (4) a webcam and display combined with an overhead camera and projector similar to the ShareTable system. The authors recruited thirteen pairs of children to participate in a controlled comparison of the four configurations. Their findings highlight some of the challenges of mediating a complex activity through video. For example, in all conditions, they found that children struggled to comprehend what their partner could or could not see. In conditions (3) and (4), the authors found that children struggled to attend to multiple displays.

In contrast, Oduor and Neustaedter (2014) found multiple cameras and multiple views to be beneficial for some family communications. They prototyped a multi-camera, multi-device media space called the Family Room. The system allowed distributed family members to connect over video by joining a persistent virtual 'room', and instead of placing a call, a family member could join the room with a device of their choice (e.g. tablet, laptop) to begin sending and receiving synchronous video chat. In an autobiographical design trial, the authors discovered that the use of multiple cameras oriented at different positions, angles, and levels of detail helped to provide a more comprehensive viewing experience for distributed family members. For example, the authors reported that this kind of setup helped supported interactions between grandparents in one location and multiple grandchildren in another: as each child moved about a large room and played with toys, a broad overview provided context closer handheld cameras provided detailed views of the children and their toys.

2.1.3 In Mobile Contexts

As camera and display technology becomes more powerful, portable, and affordable, people are increasingly using video chat in mobile contexts as well. People

often want to connect with distant family members or friends when they are outside of the home. Many special occasions, recreational activities, or other meaningful experiences happen away from home, and mobile video chat provides a way to share those experiences. However, this application of video-mediated communication involves unique constraints relating to the public context, large spaces, and hand-held camerawork. Researchers have investigated how people use video in mobile contexts to understand these challenges and to learn how to improve the design of mobile video systems.

For example, O'Hara et al. (2006), studied the everyday use of mobile video chat to understand when and why people use it. They recruited 21 to keep diaries of all video calls made and received over a period of five weeks. The authors reported that people largely made video calls for social reasons such as keeping in touch with friends or coordinating plans. To a lesser extent, people made video calls when they wanted to show objects that they wanted to talk about. At the same time, the authors found that people were hesitant to make video calls when the display might be visible to others nearby. They also found that some people shied away from video calls because they felt that they provided too much visual information. These findings illustrate how privacy mechanisms may be needed to support discrete use of video in public settings. Furthermore, the matter of excess information could actually be seen as an advantage in a more practical application like sports training.

To investigate user needs around capturing kids' activities outside of the home, Inkpen et al. (2013) deployed two technology probes in a variety of scenarios. The first probe consisted only of an iPad. The second combined multiple cameras on a tripod to create a large yet portable device that could stream an activity (e.g. a soccer game) while supporting a face-to-face video call between the camera operator (usually a parent) and a remote family member. The results showed that the need to operate a camera (i.e. hold the device or adjust framing) interfered with the ability to participate in an activity. The authors also reported that people relied on the pan-tilt-zoom functionality of the camcorder to ensure that the stream captured an appropriate level of detail. With respect to my research, this work shows first that hands-free recording may be important when an observer has responsibilities beyond filming. Second, while the authors

recommend image stabilization to address the instability associated with zooming and panning the camera, I believe the work also suggests that multiple cameras could be used to capture different critical views.

Jones et al. (2015) conducted a study to understand how people actually control the camera when they capture mobile video. The studied involved nine pairs of adults who carried out a set of four tasks that emulated various mobile video scenarios. Each member of each pair played the part of either the mobile collaborator (MC) or the desktop (stationary) collaborator (DC). The task set included a collaborative puzzle task, a campus tour, a fine-grained searching task, and a cooperative shopping task. In the results, the authors categorized the different kinds of camera work participants used throughout these tasks. Notably, they identified four kinds of "overview shots": (1) a static overview, where the MC showed the subject (e.g. an object or a place) from far away, (2) an approach overview where the MC began to show the subject from far away and then slowly moved toward it to reveal greater detail, (3) a camera-moving overview where the MC panned or spun the camera to show multiple subjects (e.g. different objects) or multiple parts of a single subject (e.g. a location), and (4) a walkthrough overview where the MC. In general, the authors found that MCs used these overview shots to communicate high-level, contextual information about the environment such as "where landmarks were relative to each other" or the "space of possibilities" in a task. However, they reported that the DC struggled to form an accurate mental model or track subjects moving out of the frame when the MC captured moving overviews (2-4). These findings highlight the value of overviews, and they point to the limitations of single-camera configurations: even when the camera is mobile, it may not be able to present all required views at the same time. Similar to Inkpen et al. (2013) above, people might benefit from seeing combinations of views simultaneously. This kind of multi-camera view may not be suitable for mobile contexts, but it may be feasible in a more static environment, and I discuss this possibility in Chapter 5.

2.2 Exercise Games & Shared Physical Activities

Figure 2.5 The Houston prototype: a) pedometer, b) pedometer in use, c) mobile phone software for shared step counting (image copied from Consolvo et al., 2006).

Figure 2.6 Game screens from PiNiZoRo (image copied from Stanley et al., 2010).

People often engage in physical activities for health benefits, for social engagement, or simply for fun. For some people, a lack of motivation, social support, or enjoyment can be a barrier to participation these activities. Researchers have studied how two or more people might use video links, audio links, or other digital tools to overcome these obstacles and participate in physical activities together. For example, Consolvo et al. (2006) wanted to understand how technology could be used to encourage adults to adopt more active lifestyles. The authors prototyped and evaluated a shared-step-counting system called Houston (Figure 2.5) in order to understand how technology can encourage physical activity in adults. The system combined a pedometer and a mobile phone to enable users to exchange step counts, messages, fitness goals, and performance trends within a group of friends. They found that this kind of social approach helped participants become more active, and in particular, they identified "social influence" as a motivating factor. Similarly, Stanley et al (2010) designed a location-based game called PiNiZoRo (Figure 2.6) to encourage physical activity in children. The game included a digital interaction (e.g. fighting monsters), but the primary mechanic revolved around walking physical paths to complete game objectives. In a pilot study, the authors found that the combination of physical and digital game interactions

was a novel motivator. However, they also found that most participants expected additional digital mechanics would be required to maintain the interest of older children over time.

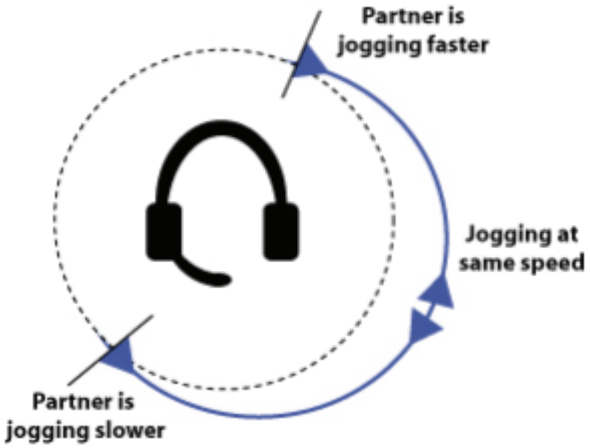

Figure 2.7 Diagram illustrating how sound was spatialized in shared jogging (image copied from Mueller et al., 2007).

Figure 2.8 The shared geocaching technology probe (image copied from Procyk et al., 2014).

Other research in this space has investigated how interactive systems can connect distributed partners over distance in a variety of activities such as soccer, jogging, and geocaching. This work provides insight into how people use technology to share in physical activity even when separated by distance. Typically, the aim of these kinds of systems is to establish a sense of social presence between geographically-separated partners. In shared jogging (Mueller et al., 2007), distance-separated partners communicated via audio link while jogging in different locations. The system measured each jogger's pace relative to their partner and spatialized the audio accordingly: if your partner was running faster than you, their voice would sound like it was coming from in front of you; if they were running slower than you, they would sound as if they were behind you. This example highlights how simple augmentations can drive meaningful interactions that add value to physical activities. In this case, the authors found the system strengthened participants' sense of social presence. Procyk et al. (2014) explored this kind of interaction with a more complex, visual activity. In shared

geocaching, geographically-separated partners geocached in different locations while a head-mounted video camera captured and broadcast video. In other words, pairs of participants were able to share a parallel experience of geocaching in separate locations—both partners were moving, navigating, searching, streaming, and receiving video at the same time. In a user study, the authors found that the point-of-view video was more useful for higher-level navigation tasks than for fine-grained searching tasks, and they noted that participants sometimes directed their view at objects of interest to show their partners. While this work explored distributed video, the manner in which participants tried to frame the video view for their partner's behalf illustrates the importance of first person views to show what a person sees in relation to their current task.

2.3 Sports Training

In sports psychology and motor learning research, there are seemingly conflicting studies around the value and efficacy of video feedback as a training tool. Researchers have attempted to measure quantitatively the effect of video feedback on the performance of specific techniques in sports like tennis, golf, and gymnastics. Guadagnoli et al. (2002) compared three groups of golfers to understand how video feedback could help them improve their swing technique. One group received no feedback, one received verbal feedback, and the third group received video feedback. The authors found that the latter two groups demonstrated significantly better swings than the former group, but there was no significant difference between the two types of feedback. Moreover, in both of the feedback conditions, participants worked with a coach—the feedback was a supplement to the coach's instruction and not a substitute for it. Van Wieringen et al. (1989) found similar results in a previous study of video feedback for tennis players. They compared video-feedback training to "traditional training" (i.e. verbal feedback from a coach) in a controlled study of tennis players. The experiment indicated that, compared to a control group, both traditional training and video-feedback training resulted in greater improvements in players' serve. However, neither of these studies found a significant difference between the effect of video

feedback and the effect of traditional feedback. These results seem to suggest that video feedback offers little advantage to athletes.

In contrast, Boyer et al (2009) found that video feedback did help young gymnasts improve certain techniques with a greater rate of success. They studied a sample of four young gymnasts before, during, and after training sessions that included video feedback. They found that video feedback helped athletes make significant improvements when presented in conjunction with “video models”, or exemplary footage of expert athletes. This feedback was presented as a complement to traditional instruction from a coach. Similarly, Groom and Cushion (2004) conducted a qualitative case study around the perceptions of two experienced football coaches in England. They found that the coaches supported the use of video and felt it was beneficial for both players and coaches. In particular, they identified improved technical skills, critical thinking, decision-making, and confidence as positive outcomes for players. They also suggested that the act of reviewing video provided allowed coaches to take a closer look at their players’ performances. In a later study, Groom and Cushion (2011) interviewed 14 elite youth soccer coaches to learn about the practices around using video feedback. All of their participants belonged to the English national youth soccer program and had a wealth of experience using video in their coaching practices. At a high level, the authors characterized the use of video feedback as a very valuable yet very complex task. At a low level, they identified a number of challenges coaches face in delivering video feedback. Coaches reported taking care not to wear on players’ confidence by showing them too many of their mistakes. They also reported taking care not to give players too much feedback.

These studies highlight some of the positive and negative aspects of video feedback. However, these studies do not discuss how these coaches captured and prepared video or how cameras and displays were. Because the research is focused on elite coaches working in national-level programs, it is possible that recruiting equipment and support staff for these tasks was not an issue for the participants. In Chapter 4, I describe how these tasks were problematic for the amateur hockey coaches I studied. Moreover, the above studies relied heavily on existing video technologies, which may or may not have mapped well to coaches’ needs, existing routines, and desired coaching

goals. From a design perspective, this presents both an important limitation and a research opportunity. As such, my goal is to understand what existing routines amateur hockey coaches have, how video feedback fits within these routines (if at all), and, how such video feedback systems should be best designed.

Figure 2.9 The video mirror prototype (image copied from Hämäläinen, 2004).

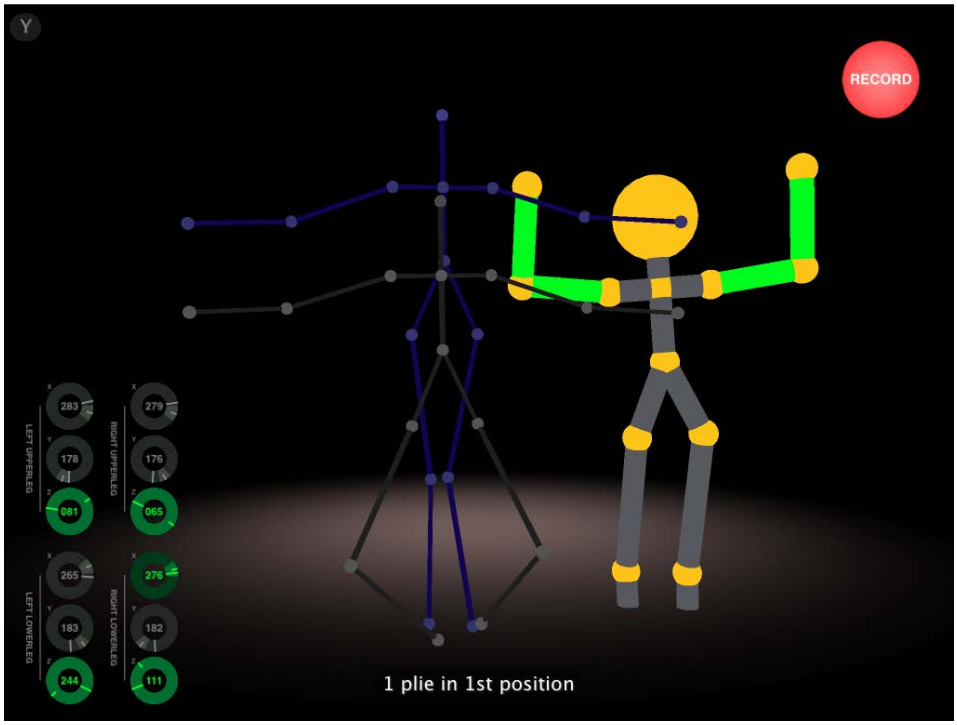

Figure 2.10 Feedback provided by the Super Mirror prototype (image copied from Marquardt et al. 2012).

In HCI, there has been a limited amount of exploration of different kinds of digital feedback for athletes. Hämäläinen (2004) designed an interactive video mirror for martial arts training. It leveraged large displays to enable martial artists to review actions that prevent the use of an ordinary mirror (e.g. a spin kick). Marquardt et al. (2012) designed a similar Super Mirror prototype for ballet dancers. The Super Mirror used motion capture and computer vision to analyse the dancer's technique and provide instruction on top of video playback. Both of these systems involved stationary cameras and displays, and they were designed for self-guided training. In competitive amateur levels of a team sport like ice hockey, players practice and play together under the guidance of a coaching staff. It is common for players to train independently, but they usually receive the most instruction and practice in the context of the team. In this way, we have yet to understand how this kind of video feedback technology might interface with the routines of a team.

Figure 2.11 Augmented climbing (image copied from Kajastila and Hämäläinen, 2014).

There are also training systems that leverage biomechanical sensors (e.g. Baca and Kornfeind, 2006, Marshall, 2013) or computer vision (e.g. Daiber et al., 2013, Kajastila and Hämäläinen, 2014) to support more structured feedback interactions. For example, Baca and Kornfeind (2006) present designs for rapid, digital feedback in rowing, table tennis, and biathlon. Their designs recruited motion sensors to track

velocity, force, and directionality as athletes performed, for example, a rowing stroke. This data was then compared to model data and presented back to athletes in real-time to provide rapid biomechanical feedback so they could adjust their technique on the fly. The BouldAR augmented-reality system enabled rock climbers to map indoor rock-climbing routes on their smartphones (Daiber et al., 2013). It used computer vision to enable climbers to mark specific holds on a real-time display on their smartphones. In a pilot study of six climbers, the authors found that the system helped participants create and describe routes. Kajastila and Hämäläinen (2014), prototyped a similar climbing system that used motion tracking and a projector to augment an indoor climbing wall. In a Wizard of Oz experiment, the authors demonstrated that climbers could feasibly interact with graphics projected on the physical climbing wall. They also discussed the potential advantages of the social elements of the system. For example, they explained that users could save routes and scores digitally to share with their peers, and they suggested that these features motivate training within a group of climbers.

Figure 2.12 The TacTowers prototype (image copied from Fogtmann et al., 2011).

Fogtmann et al. (2011) explored a more embodied approach to sports training with their TacTowers system. They designed customized physical feedback devices to help handball players develop their skills in a live practice simulation. This system was for self-training, and it used LED lights to guide training exercises. The authors deliberately moved away from screen-based technology in an effort to improve athletes' anticipation and decision making. Similarly, Jensen et al. (2014) designed a system for

soccer players that used light and sound in a customized enclosure to drive a set of training games. One of the training games—"Look Ahead"—was designed to improve "players' ability to look up, stay oriented and plan ahead during ball handling situations". When the game begins, targets in the training space begin to light up around the player. In order to score, the player has to identify active targets and kick the ball at them. The authors evaluated this system with nine adolescent soccer players, and they found that the players' performances improved over three weeks of practice with the prototype. However, they cautioned that they could only argue that players improved at the training game and not at soccer in general. Because their investigation did not encompass regular matches or team practices, they could not determine if players improved at soccer.

At a high level, these kinds of systems provide athletes with specialized training tools that may or may not translate into improved performance in actual sports. Systems designed to augment or motivate regular activities (e.g. Kajastila and Hämäläinen, 2014) seem to preserve more of the natural context of sports than more embodied systems (e.g. Fogtmann et al., 2011, Jenner et al., 2014). In all of these works, the role of the coach is either unclear or absent altogether, and many of these systems support individualistic (e.g. Hämäläinen, 2004, Jensen et al., 2014). In many sports, and especially in team sports, a player's training experience often involves teammates, coaches, or even training partners. As such, the goal of my work was to understand how video feedback as a training tool might fit within the interactions of hockey players and coaches.

2.4 Summary

This literature review has outlined three different areas that background my research on video feedback and amateur ice hockey coaching. First, I described work form the field of video-mediated communication, which examines how people use video to communicate and collaborate in work, home, and mobile contexts. Second, I discussed exercise games and shared physical activities. Some of these works investigated how interactive systems could drive participation in physical activities, and others explored how technology could foster a sense of shared experience between

remote partners. Finally, I reviewed existing research on sports training from both motor learning and HCI perspectives. Here, I discussed studies that have compared video feedback to conventional verbal feedback and attempted to measure its effect on athletes' performances. I also discussed a number of experimental systems that have explored how athletes might utilize technology like video, motion sensors, and augmented reality as training tools.

At a high level, this review has revealed a number of insights into how cameras and displays might be coordinated around a complex activity like ice hockey to capture and present meaningful views. First, a great deal of the video-mediated communication work has focused on connecting distributed colleagues, family members, or activity partners, but this research still provides some guidelines for how coaches might utilize video. For example, studies of video in the workplace reveal that gestures and shared views help colleagues come to a common understanding of video-based tasks. Inquiry into the use of video in the home and in mobile contexts reveals how broad overviews can help to capture a coherent view of complex activities or spaces. For example, when remote family members interact with children over video chat, a wide view of the children's location can address issues with keeping them in the frame. This overview technique can be included as part of a multi-camera setup to create a more comprehensive experience that captures details while preserving the larger context. In Chapter 5, I draw on some of these insights when I review my study findings and discuss their implications for the design of video feedback systems for hockey coaches.

Second, previous explorations of exercise games and shared physical activities point out how audio and video captured from a remote partner can provide valuable insight into their physical performance or their task-at-hand. They also reveal that the social component of doing something together—even with someone who is not physically present—can encourage participation. In Chapter 5, I discuss how the social dynamic might differ in a more competitive team context. Finally, the sports training literature supports the idea that video feedback has value as a training tool. However, there is little research that provides deep insight into coaches' experiences of implementing video feedback into their coaching practices. Many of the experimental training systems have been designed for "individualistic" training that largely ignores the

roles of coaches and teammates. Groom et al.'s (2011) study of elite soccer coaches does provide a deep, exploratory account of video feedback in a team sports context, but this account focuses on the *delivery* of video through existing technology that may or may not fit their needs and goals. We still need to understand how video feedback might be designed for amateur coaches to use and incorporate in their everyday practice. In the next chapter, I describe the study methods I used to address this question.

3 Methodology

I took a qualitative approach in my research. The problems and goals I outlined in Chapter 1 are very much exploratory problems and goals—they are aimed at developing a fundamental level of understanding in a space that has not been thoroughly explored through an HCI lens. I wanted to understand how coaches might incorporate video feedback for players into their teaching. Consequently, I conducted an exploratory study of a number of minor hockey coaches in the Greater Vancouver area. The specific goals of the study were to understand their strategies for teaching hockey, to see how they put those strategies into practice, and to investigate their current use of video (if at all). I aimed to synthesize the findings into requirements for the design of future video feedback systems.

At a high level, I sought to understand the coaches' experience of guiding player learning through practices and games. In my analysis of the study findings, I strove to adopt the language of the coaches who participated in the study. As a result, I borrow a particular way of looking at players' experience of the game—especially around defining mental versus physical aspects of performance—from the descriptions I gathered. When I report the findings in Chapter 4, I rely on this lens to explore coaches' approach to teaching and discuss some of the obstacles they face. There are certainly other lenses that could be applied to this research space. For example, theories of somatic practice or embodied interaction that focus on the role of emotional processes in decision making could offer valuable insight into players' perspectives.

This chapter describes the qualitative approach involved in the user study. The study relied heavily on field observation and semi-structured interviews. It also included a more hands-on co-creation method inspired by participatory design, but this method became less important as the study progressed. I first provide an overview of the study

participants before describing each of these study methods in detail. I conclude the chapter by outlining how data is collected and analyzed.

3.1 Participants and Recruitment

Through snowball sampling of personal contacts, I recruited eleven coaches to participate in my study. I sent potential participants a brief outline of the study requirements (Appendix A) via email, and if they agreed to participate, I scheduled a time to meet with them. I required that all participants held a coaching position with an organized hockey team within the past year to ensure that they had experience with the most current state of the sport. I did not require a minimum number of years coaching because I felt the experiences of newcomers would still be valid inputs to the design of future technology for coaches.

It was particularly challenging to recruit participants for this study because of a number of factors. First, the target role is very specific. While hockey is an extremely popular sport in Canada, 'minor hockey coach' is still relatively limited population. By targeting more competitive teams, I narrowed the number of potential participants even further. Very few minor hockey coaches are in the role full time. Of the eleven I recruited, only one was a full-time coach—the others were all on a volunteer or stipend basis and had full-time jobs as well. That said, I found that most participants were keen to participate if they had the time and if I was able to start a conversation and explain my interests. Consequently, I began to ask participants if they could recommend others who might be a good fit for the study (see Appendix B for a modified recruitment message for this case).

Participant #	Coaching Role	Current Level	Years Experience	Video Use
1	Assistant	Midget AAA	3-5	Yes
2	Assistant	Midget AAA	5-10	Yes
3	Goalie	Midget AAA	5-10	Yes
4	Head	Peewee House	1-3	No
5	Head	Bantam AA	3-5	No
6	Assistant	Peewee AA	3-5	No
7	Head	Major Midget	10-15	Yes
8	Assistant	Major Midget	10-15	Yes
9	Head	Bantam AAA	10-15	Yes
10	Assistant	Bantam AA	5-10	No
11	Head	H2 House	5-10	No

Table 3.1 Description of participants

Table 3.1 breaks down the role (head vs. assistant vs. goalie coach), age group (e.g. Peewee vs. Bantam vs. Midget) and level of competition (e.g. house through AAA) for each of the coaches who participated. The table also indicates how much experience each participant had as a coach and if they had used video as a coaching tool before. Three of the eleven participants were female, and all were between 25 and 51 years of

age. All participants coached in minor hockey associations in Greater Vancouver, Canada, and there were five head coaches, five assistant coaches, and goalie coach. A head coach is typically responsible for guiding a team as a whole while assistant coaches play more of a support role and may specialize in working with either forwards or defensemen. A goalie coach is an assistant coach who has specialized in coaching goaltenders and usually has a background in playing the position. A single team typically has three or four coaches and about fifteen to twenty players. The age groups of the players on these teams included PeeWee (ages 11-12), Bantam (ages 13-14), and Midget (ages 15-17) as well as one 'H4' team (ages 7-8). There were two 'house' or recreational teams, and the level of competition for the other teams ranged from 'AA' to 'AAA' to Major Midget, where Major Midget is the highest regional level out of seven levels for players in the midget age group. To put this information in perspective, a player must be at least 18 to enter the professional ranks in North America. While even the best players face long odds to become professionals, many of our participants coached teams where players were in a position to work towards that goal. In this way, we primarily targeted serious teams who practice and compete on a regular basis.

3.2 Study Protocol

Once participants had volunteered to participate in the study, they completed an Office of Research Ethics informed consent form. This form was available online on the Connections Lab website. Next, I arranged to meet with them after one of their regularly scheduled practices or games, which took place in various arenas across the Great Vancouver area. Each study session began at the start of one of these practices or games. I arrived just before the participant's team was scheduled to take to the ice. I brought a notebook and pen for recording field notes, an interview guide (Appendix C) and audio recorder for the semi-structured interview, and a copy of the informed consent form. For the first six sessions, I also brought a model ice rink and craft supplies (e.g. elastic bands, markers, colored sticky notes) to conduct a participatory design activity.

During the ice time, the participating coach went about his or her business as usual, and we did not make contact until after the ice time was over. I took detailed notes about what the coach said, what the coach did, where they went on the ice or on the

bench, what kinds of tools or props they used, and how they interacted with players and other coaches. I also kept a list of occurrences I wanted to ask the coach about afterwards. When the ice time concluded, I met the coach in the arena lobby, in an observation room, or in an office, depending on what was available at the facility. It was important to find a space that offered some privacy but also allowed for a view of the ice surface so that we could preserve as much of the context of coach's activities as possible. In cases where it was difficult to find such a space, we found an empty section of the stands and talked there. The semi-structured interview lasted between 30 and 60 minutes. The first six interviews tended to run shorter because I left time for the participatory design activity. For the remaining five participants, I removed the participatory design activity in favour of a longer interview. I discuss the rationale behind this method and the decision to remove it below.

Next, I will describe each of the study methods in detail. I will also discuss how we conceived the participatory design activity and why we decided to remove it part-way through the study.

3.2.1 Field Observation

In total, I observed participants for about twelve hours of ice time (six hours of games and eight hours of practices). I spent between an hour and three hours observing each participant depending on their team's schedule of games and practices and their level of enthusiasm for participating in the research. I used this time to study the on-ice interactions of coaches and players, and I focused on identifying communication and feedback patterns and on tracking balance between performance and instruction. I chose to include this method for two reasons. First, it helped to prime me and the participant for the following interview. As an outsider to minor hockey and a relative newcomer to the game itself, I did not have many common experiences to draw on in conversation with these participants (e.g. I did not have my own experiences as a player or as a coach). The observation portion of each session ensured that every interview took place in light of a recent experience shared to a certain extent between the two of us. In many cases, I was able to draw on my observations to generate questions or recall examples in the interview. The field observations allowed me to see the coaches

in action and develop my own account of their activities. I felt this was an important perspective to capture because one of the goals of my research is to identify any gaps between coaches' goals and strategies in teaching and their actual demonstrated practice.

3.2.2 Semi-structured Interview

Immediately after the field observation, I conducted a semi-structured interview with the participant. The interview took place in the same ice rink in order to preserve the context of the participants' practice and to provide visual and spatial reference material for the subject matter of the conversation. I encouraged coaches to point or otherwise make reference to the space, and I often did the same as I recalled my observations in the interview. Each interview lasted between 30 and 40 minutes. I asked coaches to discuss their communication habits around practices and to recall moments where they had difficulty communicating with other players and coaches. The interview questions prompted coaches to describe their teaching strategies (e.g. "how much do you rely on demonstration to teach?") and the obstacles they encounter (e.g. "how do you fail to communicate with players?"). These questions helped me collect detailed descriptions of coaches' experiences and understand the interactions I observed in the field.

3.2.3 Participatory Design Activity

With the field observations and semi-structured interviews helping me capture coaches' existing practices, I wanted to try to approach the problem from a different angle. Observations and interviews map to what Sanders and William (2001) describe as 'do' and 'say' methods respectively. They argue that both types of methods are valuable yet limited. 'Say' methods are limited "to what people are able to put into words", and 'do' methods are not able to "[access] people's underlying motivations or emotions". They argue that these kinds of methods can be complemented by 'make' or participatory design methods that help people "in expressing their current experiences and ideas and in generating new ideas". These 'make' methods encourage users to be creative with research tools designed to "stimulate creative exploration". Based on this

kind of participatory approach, I devised a hands-on activity to prompt participants to express their experiences and speculate on future possibilities in a creative manner.

Figure 3.1 The table hockey set used for the participatory design activity.

The tools I provided for this activity included a table hockey set (Figure 1) that served as a model hockey rink (37 x 19.75 in) and an assortment of office and craft supplies (e.g. markers, post-it notes, sticky tac, elastic bands). After the interview, the coach and I took a short break while I retrieved the model rink and craft supplies from my car. When I returned, I explained the activity to the participant: they had ten minutes to 'build' a perfect video setup in the rink. I challenged them to assume technological feasibility were not an issue and to show me what their rink would look like in a blue-sky scenario. I encouraged them to use the supplied materials to represent their vision and help me understand what they imagined. After ten minutes elapsed, we discussed what they had created before ultimately concluding the session.

Figure 3.2 Example of a participant's creation in the participatory design activity. In this case, blue flags indicated audio-linked players. Blue putty on top of the net represented a camera.

I used this method in my research because I wanted to give participants an opportunity to focus on the physical space they worked in and explore how they might change it to support their coaching practices. I wanted to see if participants could elaborate on the obstacles and limitations they encounter by approaching the rink from a 'what-if' perspective. I also felt that—as Sanders and William (2001) note—this kind of creative method would yield findings that could not be captured through interviews or observations. I employed this method through the first six study sessions with varying degrees of success (see Figure 3.2 for an example). Ultimately, it proved to be more of a stumbling block than an asset, and I removed it in the following five sessions in favour of longer interview (see Appendix D for an expanded interview guide). In Chapter 4, I report in greater detail on the data collected through this method, and in Chapter 6, I reflect on my experience with it as a researcher.

3.2.4 Limitations

This methodology was designed to capture the experiences and practices that occur on and around the playing surface. While this encompasses the bulk of interactions between coaches and players, it is not exhaustive. In hockey, the first point of contact between coaches and players is often in the dressing room where players

spend between fifteen and thirty minutes ‘getting dressed’, or putting on their equipment. Many coaches begin coaching or teaching in the dressing room, but I was not able to access this part of the experience. To do so would have required assent from all players on the team as well as consent from each player’s legal guardians. It would have also put the coaches, who are tasked with protecting the privacy and safety of their players at the rink, in a challenging position. In order to protect players, minor hockey associations often enforce restrictions on who can enter the dressing room and ban the use of any kind of recording device. On a positive note, I was able to collect data about interactions in the dressing room through descriptions provided by coaches in the semi-structured interviews.

I was also unable to record the practices and games I observed. It would have yielded richer data, but it was logistically unfeasible to obtain the consent of the entire team (and, potentially, of the team they were competing against). That said, the practices and games were open to the public, so I was able to attend and take detailed field notes.

3.3 Data Collection & Analysis

	Talking	Drawing	Pointing	Writing	Walkthrough
Individual player	x	x	x		
Group of players	x	x	x		x
Whole team	x	x	x		x
Other coaches	x		x		
Self				x	

Table 3.2 Map of observed interactions between coaches and various actors. Yellow rows and columns were expected in the design of the study while blue rows and columns were 'discovered' during the study.

I kept handwritten notes during both the observation sessions and the interviews. As part of the observation process, I classified any observed intersections between different modes of communication and different audiences. Table 3.2 illustrates how this classification began and how it grew to include unexpected interactions. The cells coded in yellow indicate interactions I expected to observe. For example, based on personal experience playing and watching hockey, I expected to find that coaches would talk, draw, and gesture with individuals, groups, and the whole team. The cells in blue indicate interactions that emerged during the study.

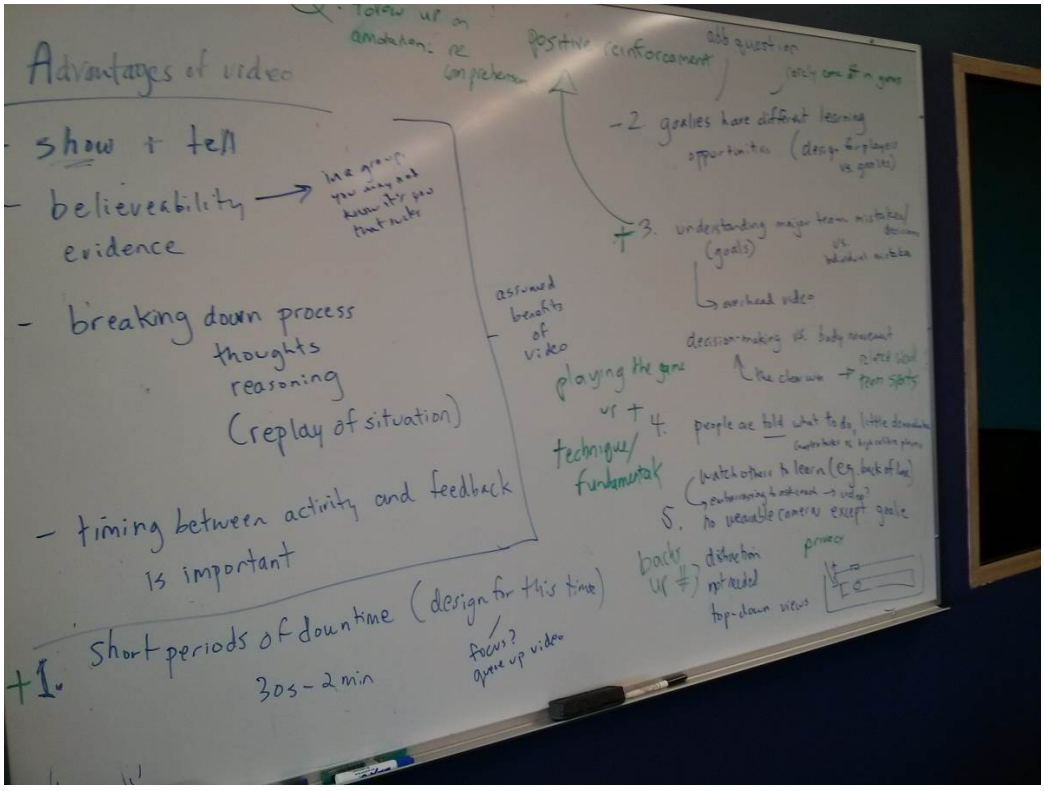

Figure 3.3 Grouping low-level findings.

All interviews were audio-recorded, and I analyzed the interview transcripts and notes using open and axial coding (Strauss and Corbin, 1998). Throughout the study, I periodically coded observations and interview responses to highlight seemingly important concepts and insights. When I had collected data from the first six participants, I began to categorize these findings into larger groups with input from my supervisor. We repeated this process once the first nine sessions had been completed and once again after eleven sessions had been completed. Figure 3.3 depicts a whiteboard session where we explored connections between low-level findings and began to identify larger groups.

DECISION MAKING SKILLS -Emphasis on understanding strategic mistakes -Ask players lots of questions (e.g. “what did you see”) -Players don’t always speak up when they don’t understand -How to tell simple mistake from lack of understanding?	**OPPORTUNISTIC TEACHING** -Give feedback after every shift/rep (hard to give feedback later) -Can’t give feedback on all events for all players -Downtime (e.g. on bench) is a good chance to talk, but limited duration	**GROUPS VS. INDIVIDUALS** -Better feedback 1 on 1 -Sometimes you need to address whole group -Try not to call a player out in front of a group (some don’t handle it well)
PHYSICAL SKILLS -Not very prominent -Important, but not something that happens a lot in team context (varies from coach to coach) -Very little physical demonstration in practices	**GOALIES ARE DIFFERENT** -Often separate activities in practices (different location, drills while skaters do something else) -Lots of 1on1 with goalie coach -On the ice all the time in games -Goalie view seen as important in PD activity	**VIDEO BENEFITS** -See things you didn’t notice during games/practices -Players more inclined to believe you -emotional boost
PRACTICES VS. GAMES -G: restricted to bench / P: on ice with players -G: teaching vs. running the team; easy to miss something -P: more time/flexibility, but flow is important -> don’t want to stop drills to teach	**TECHNICAL LIMITATIONS** -Self-trained on software -No standard software w/in associations -Equipment not provided; operated by volunteers -Exception, one association mandates webcasts, but quality varies from arena to arena	**VIDEO DRAWBACKS** -Takes a long time to go through everything and find out what to talk about -Players’ short attention spans -Don’t want to take away from ice time - Have to use volunteers or dedicate a coach to it. Quality/views are limited

Table 3.3 Coding map capturing main groupings.

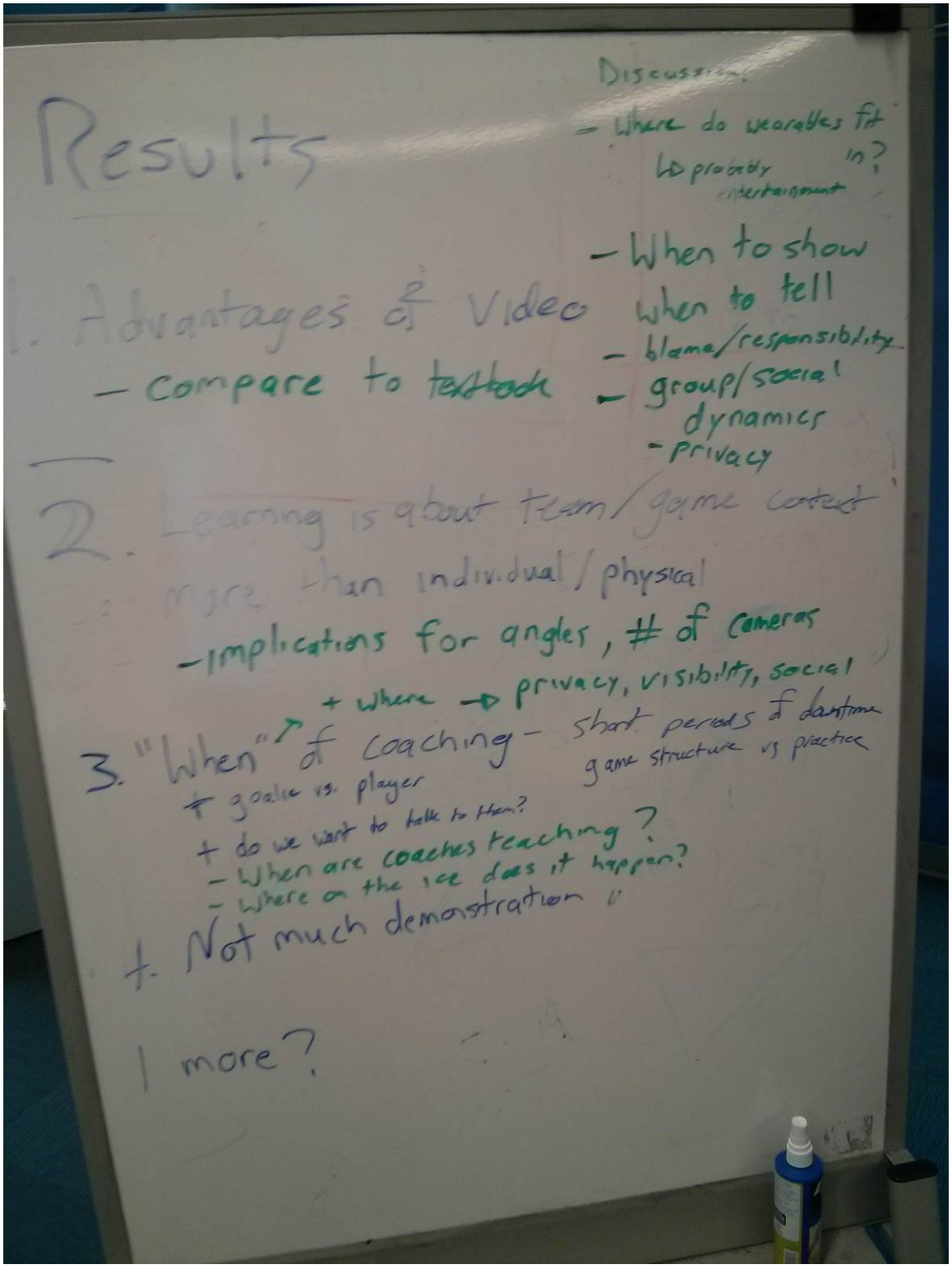

Figure 3.4 Whiteboard session for drawing out high-level themes.

In my analysis, I classified observations and interview data and then organized them into groups of related findings. Table 3.3 represents a digitized coding map that represents these groups and provides examples of the findings that constituted them. For example, in the center of the table, the “goalies are different” grouping gathers findings that related to special treatment for goaltenders. As we reviewed findings, we recognized that there were a number of field observations and interview data that contrasted goaltenders to the other players and formed this group. As another example, consider the “decision-making skills” label in the top-left corner of the table. This group took shape as we connected a number of findings that suggested tactics and obstacles relating to players’ thought processes. Ultimately, the related groups were further aligned to form the high-level themes that structure the findings I present in Chapter 4. Figure 3.4 recalls a whiteboard session where I explored the make-up of these themes with my supervisor.

3.4 Summary

In this chapter, I discussed the recruitment and backgrounds of participants as well as the methods used to collect and analyze data. In summary, the study involved a qualitative, exploratory methodology driven by field observations of participants’ practice and game sessions as well as semi-structured interviews. Initially, the study also included a hands-on participatory design activity, but I removed it part-way in favour of longer interviews. After data was collected, I used open, axial, and selective coding to organize findings, identify important patterns, and group the results into high-level themes. In the next chapter, I outline the main findings of our study where I learned that coaches focus their instruction around decision-making and strategy, that teaching occurs in a very opportunistic manner in the rink, and that preparation is currently a major obstacle to using video feedback. Following our presentation of the study findings, I draw out implications for the design of video feedback systems for hockey.

4 Results

In this chapter, I describe the study findings. These findings answer the first three sub-problems I identified in Chapter 1. First, we do not know what coaches' goals and needs are in directing player learning. Second, we do not know how coaches put their teaching strategies into practice. Third, we do not know how coaches currently use video technology or what limitations they encounter in their existing practice. Through the data analysis described in Chapter 3, I organized the findings into three broad themes. I begin by describing amateur coaches' approach to teaching hockey and some of the common concepts that emerged in the study. Next, I explain how coaches execute their approach in terms of how, when, and where they communicate in the rink. Finally, I explore how coaches currently use video feedback, how they perceive its value, and what limitations they encounter.

4.1 Teaching Understanding

Like most sports, ice hockey involves a number of skills that demand balance, coordination, and strength. Players have to be able to skate, control the puck with a stick, shoot, and pass. Given this array of complex intersecting physical skills, I expected to find that coaches would spend a great deal of time communicating about technique and individual body movements. In contrast, coaches almost always emphasised decision-making skills and strategy when they described their current approach to teaching. While the importance of individual skills development varied from coach to coach—some dedicated time to it while others felt it was something players should practice on their own--every participant stressed the importance of developing players' understanding of the decisions, patterns, and systems that make up the game.

In this section, I present the study findings that substantiate this comprehension-driven approach to teaching the game. First, I describe how coaches approach teaching

players to 'think the game', and I relate common concepts coaches reported and strategies they described for teaching those concepts. Second, I discuss some of the challenges coaches encounter in this kind of teaching.

4.1.1 Thinking the Game

When I probed participants about their role as a coach or their strategies for teaching, I found that coaches were focused on helping players improve their ability to understand and think about the game. They often described communication techniques that address a player's mental processes rather than their physical execution. For example, many coaches explained that they preferred to ask players questions rather than give them direct instructions. This strategy is intended to encourage reflection and to help players understand when they had made mistakes and what they might have done differently. One participant explained that her priority in many cases was to encourage her players to think critically about their performance:

> "I try to get them to describe why they're doing stuff. I try to get them to talk as much as they can, whether it's giving me feedback on what I just told them, asking them what just happened, or how did they feel about it. I'm really trying to get them to think for themselves." – P2

There is an emphasis on player agency in this approach. It is easy to think of a coach as an expert leader who sees mistakes and dispenses knowledge to correct them. However, this description illustrates the coach as more of a guide trying to help players see their own mistakes. Similarly, P1 suggested that it is more important to help players think more strategically than to judge decisions as either right or wrong:

> "Sometimes I'll ask them what they saw and why they made the decisions they did. You tend to get the best feedback when you're asking them what they saw, because then if they didn't see the whole ice or whatever, [the players] get feedback not based on whether it was the right or wrong decision, but you get them to open up and see more of the ice." – P1

When players 'see the ice' in hockey, they are cognizant of the larger flow of the game and aware of the position and movement of the other players. In each of the examples above, the coach is more concerned with how well a player is interpreting the

game and executing strategy than with how well he is skating or shooting. A different coach took this approach one step further and explained how he tried to improve his players' ability to learn:

> "You have to be able to communicate with your players and provide them with some guidance, but at the same time, you want them to be able to explore and learn on their own. So really, [coaching is] facilitating their ability to learn." – P6

This coach added that he tries not to stifle creativity by prescribing too much instruction. He offered his view on 'breaking out' (when a team moves the puck out of their defensive zone to transition to offense) as an example:

> "There's only so much you can teach because every situation is different, and teams may attack you differently. There are fundamentals you can teach: if you have a forward pinching down, you can chip off the boards. Or if you have the guy high, then you can come through the middle. But as coaches, we have to understand that there's some creativity as well, and we have to allow that." – P6

This notion of creativity speaks to the same kind of process-oriented teaching that P1 and P2 alluded to. For P6, coaching is about helping players develop a systemic understanding of the game. At a high level, these descriptions suggest that the growth of game comprehension, thinking skills, and learning skills is much more central in the interactions between players and coaches than I initially imagined. In fact, when I observed practices, I saw very little demonstration of individual techniques like skating or shooting. We expected coaches and players would rely on this kind of demonstration to communicate because of the physical aspect of the sport, but I learned that older, high-level players—even though they are considered amateurs—are often expected to be able to execute most technical skills already:

> "With our players, they're super high level, so [the room for improvement] is really more mental and understanding." – P2

Only two participants, P8 and P9, reported that physical skills development was a major part of their roles as coaches. P8 explained that he simply enjoyed the technique around stickhandling, skating, and other physical aspects of the game, so he tried to

include them regularly. P9 explained that his team would have dedicated skills practices early in the year but that these were phased out in favour of more team-oriented practices as the season developed. During my observations, many coaches' behaviours aligned more with P2's position. While there was little demonstration of individual movements, I often witnessed a higher-level kind of 'walkthrough' demonstration on the ice in practice. Coaches acted out larger strategic concepts by stepping through the positioning of drills, by re-enacting a mistake, or by simply directing players with verbal instructions and gestures—all while explaining the underlying logic to their players.

At a surface level, these findings suggest that video feedback may not play a large role in the team context when it comes to understanding one's body movements (at least at the ages and levels of competition I studied). Instead, the importance of video feedback for teams may lay in aiding cognition, decision-making, and one's overall understanding of plays. I discuss this idea in more detail in Chapter 5.

4.1.2 Challenges

During the interviews, I aimed to understand the obstacles coaches encounter in teaching players to think the game. Not surprisingly, I found that coaches' emphasis on teaching the mental side of the game came with a set of drawbacks. Participants told me that it can be difficult to differentiate a true lack of understanding from a one-off mistake. For example, P2 explained how it can be difficult to distinguish a momentary lapse from a real problem of comprehension:

> "Not knowing what they know [is an obstacle]. Sometimes they'll make a mistake, and [I try] to get them to tell me why they did that. Like, do you not know that it was wrong? Should I be teaching you this? Or did you just not think of it at that moment? Just figuring out the context of why they made a decision [is challenging]." – P2

This challenge highlights a need to understand the player's perspective in order to assess what kind of help that player needs. In the previous section, I explained how coaches ask players questions or otherwise prompt them to voice their own thoughts and feelings in coach-player dialogues. This inquisitive approach appears to be a common method for accessing the player's perspective in order to evaluate their level of

comprehension. P3 pointed out that the outcome of this obstacle is a more personal connection between coach and player that can be a challenge in its own right. She suggested that this kind of teaching requires the coach to get to know each player in order to gauge how well they grasp new information and feedback:

> "You can ask them right away, 'do you understand?', and depending on the person, you definitely have to build a rapport with them and understand them and how they react when you're trying to figure out if they actually understood." – P3

The need to develop this kind of familiarity with each individual player suggests a investment of time and attention on the coach's part. In order to understand the magnitude of this investment, consider that each age group spans only two or three years, and consequently, there is a fair amount of turnover each year. At the beginning of the season, older players graduate to the next group and younger players move up from the level below to fill their places. As a result, it is entirely possible for coaches to have several new faces on their team every year, and they must get to know each of them as both players and as people.

I also learned that players may exacerbate these challenges by concealing their own level of understanding. Several participants noted that players will sometimes be embarrassed to admit when they do not know something and reported that players have strategies for avoiding such situations. For example, rather than ask the coach for clarification, players may attempt to learn on-the-fly by watching their teammates. In practice, players who are unsure of a drill often discretely move to the back of the line

> "Last week, the whole group would say, 'Yeah we understand the drill', but then they're all scrambling to the lineups saying, 'You go first you go first', and then the whole drill falls apart. Some people just didn't want to ask the question even though they're not all shy."– P2

This kind of behaviour causes two challenges. First, it obscures whatever failure occurred in the initial communication of the drill. Second, it directly contradicts the coach's desire to help players "think for themselves".

These findings characterize the interaction between coaches and players at least in part as a complex, cognitive endeavor. There seems to be a tension between the need to optimize a player's performance in a structured approach to the game and, simultaneously, the need to understand a player's unique perspective, context, and thought process. This suggests that video feedback may need to be individually tailored to a particular player's needs, understanding, and the relationship that the coach has with that player. There are also potential implications around embarrassment if a player is singled out as part of a group when using video feedback systems.

4.2 Communicating in the Rink

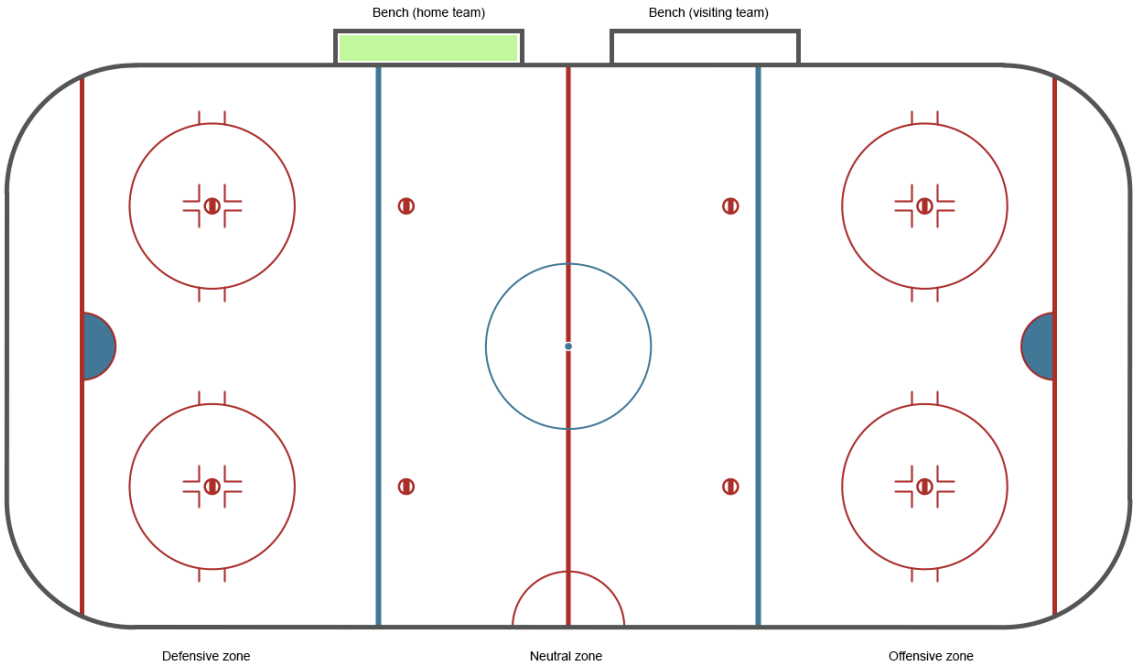

Table 4.1 Diagram depicting a typical ice rink, including players' benches. The green shaded area marks the space coaches are allowed to occupy during a game.

Through my field observations and through the descriptions gathered in the semi-structured interviews, I learned that coach-player interactions in hockey occur continuously in short exchanges throughout practices and games. These interactions vary according to who is involved, how much time is available, and where on the ice they

take place. In games, coaches are restricted to communicating with players on the bench or in the dressing room between periods (see Figure 4.1). In practices, coaches often stand on the ice with players as they do drills. Coaches relied heavily on face-to-face, verbal communication, but they also used demonstration, drawing boards, and video recordings to communicate with their players.

This section is broken down into three parts that capture the constraints we found coaches face as they communicate in the rink. First, I describe how their communication with players takes place across a number of brief moments that arise throughout practices and games. Second, I report on how coaches adapt their tactics when working with a group of players or with an individual. Finally, I describe the unique situation poised by goaltenders and the methods coaches use with them.

4.2.1 Brief Windows

In my observations, I noted that teaching occurs opportunistically and in brief moments throughout games and practices. Typically, coaches have increments of 30 seconds to a couple of minutes to speak to players while they are on the bench during a game. In a practice, there is a similar time constraint. Rather than stop drills and disrupt the flow, they speak to players who are waiting on the sidelines for their turn. They only gather the whole group together to deliver high-level instructions such as a new drill or general feedback that is relevant to a majority of the team. Even though coaches usually wait for an opportune moment, there is a high level of constancy in this feedback. One participant explained that he takes nearly every opportunity in a game to speak to his players:

> "During games, every single shift I'm giving guys feedback on their [performance], whether it's positive, negative, or indifferent." – P1

A 'shift' in hockey is a player's turn on the ice. Most teams carry three 'lines' or units of forwards and defencemen, and only one unit plays at a time. A shift usually lasts between 45 and 90 seconds, which means players spend between 90 and 180 seconds on the bench between shifts. This coach explained how he strives to capitalize on this downtime by providing feedback. Sometimes, however, the chance to give feedback is

simply too short, and time becomes a barrier to communication. Another participant explained how she struggled to form a thought fast enough to teach it properly before the moment passed:

> "Stuff happens really quickly, so sometimes it's hard to properly put a thought together and communicate it well for the person. Like, because it happened so quickly, you kind of just blurt it out instead of thinking about how to actually teach it to them better. Then you kind of back up, and between periods, I'll go talk to them again." – P2

In this way, these tight time constraints translate into communication problems. Practices and games generate a wealth of information for coaches, but they may not always have time to process it for their own understanding or package it as proper feedback for individual players. In order to understand the magnitude of this challenge, consider that teaching is only part of a coach's job. As teachers, they need to attend to all five players on the ice while simultaneously communicating with the players on the bench. In order to win the game, they must also track the events on the ice, watch the players on the other team, decide which lines to send out next, and modify the team's strategy. As P2 explained, there are bound to be missed opportunities for teaching. When I describe my findings around the current use of video feedback later in this chapter, I detail how some coaches use video to address these missed opportunities and revisit problems in the future. In addition to this, these results also highlight the role that video feedback could play *during* games and practices, *if* systems could be designed to be used during short, sporadic moments of interaction. This would map very closely to coaches' existing teaching strategies.

4.2.2 Group vs. Individual Teaching

A majority of the coaches explained that they are able to communicate more clearly when they are speaking to a single player. Coaches often reported giving more specific, direct feedback to players on an individual level:

> "If I'm talking to one guy, it's more personalized—noticing just about him and not about the group. So, he gets more tailored feedback." – P5

Most coaches were careful not to give too much specific or targeted feedback in front of the whole group. They explained that they do not want to embarrass a player by singling them out:

> "[Individual feedback] is way more specific because you don't want to call a kid out and make them feel dumb in front of everyone. It's way more direct when it's one-on-one. I would never say it the same way in front of the team. It would be more team-oriented instead of on the player." – P2

I often observed coaches demonstrating this social sensitivity by pulling a player off to the side before having a one-on-one conversation. However, it was also quite clear in my field observations and in the interviews that coaches do not have time to speak to every player individually throughout practices or games, and they often need to communicate the same concept to several players at the same time. In this way, social sensitivity can become a challenge in itself as coaches try to balance the need for discretion against time constraints and other responsibilities.

Coaches also found it harder to gauge understanding when they were speaking to the group. As I discussed in the previous section, getting a sense of the player's level of understanding is a critical point of communication. Participants reported feeling more able to judge comprehension when speaking directly to a single player:

> "I can explain better one-on-one for sure. You have the time to clarify, and you have the time to make sure they understand what you're saying." – P3

Again, these results illustrate the potential for video feedback systems that are focused on individual players. In Chapter 5, I revisit this issue and consider how the designers of video feedback systems might help coaches balance the needs of individuals with the needs of the team.

4.2.3 The Goalie Experience

So far, I have presented the study findings in terms of a coach and their players. In general, the players here are usually the skaters—the group of forwards and

defencemen who make up most of the team. Hockey teams also have goaltenders, and the goaltending position is somewhat special: the goalies wear different equipment, practice different skills, and play a different role than the other players. There are only two on a team that has twenty other skaters, and they have a very different experience of teaching and learning.

Spatially, a goalie is usually isolated from the rest of the team. In practices, I often observed skaters running through drills on one half of the ice while the goalies received separate instruction and separate drills with a specialized goaltending coach at the other end. It is common for the coaches to gather the team near the player's bench to give instructions on the next stage of the practice, but the goalies are not always expected to participate in this gathering. They might continue to work on something with the goaltending coach instead, and in this way, they sometimes operate on a different timeline than the rest of the team. Many participants explained that the goalie's perspective on a game situation (e.g. a defensive breakdown leading to a goal against) can provide extremely useful information about what was done right and what was done wrong for the whole team.

Overall, these results suggest that goalies are a unique case for video feedback systems, and a solution suitable for coaching skaters may not necessarily work for coaching goaltenders. At the same time, they also suggest thatthe location of a goalie also offers an interesting on-ice perspective that designers of video feedback systems may want to capitalize on. Additionally, these results suggest that a solution suitable for coaching skaters may not necessarily work for coaching goaltenders.

4.3 Current Use of Video Feedback

In this chapter, I have described how coaches take a comprehension-centered approach to teaching, and I have identified some of the constraints that shape how, when, and where they actually communicate in the ice rink. Next, I discuss what I learned about how coaches currently use video feedback and what obstacles they encounter in doing so. Six out of eleven participants (P4-P9) belonged to teams that used video at least occasionally as part of their training and preparation process. The

remaining participants belonged to teams that used video very rarely or not at all. Members of this latter group usually explained that they simply did not have time to include video in the team's regular schedule. In the former group, one participant, P7, belonged to a team that used video feedback on a weekly basis and considered himself an expert on the subject. While others scheduled separate video sessions away from the rink, his team spent a short time before each practice reviewing video in the dressing room. I asked him and the other participants who used video to describe their experience with it and to evaluate the benefits and drawbacks involved in using it. They all reported that preparation (i.e. capture, editing) and players' attention spans were obstacles, but they also suggested that video is a powerful teaching tool.

My findings around the current use of video fell into four categories: replayability, objectivity, psychological and emotional utility, and the limitations of off-ice sessions. The first three relate to advantages of video feedback, and the last describes some of the obstacles coaches currently face with it. I step through each next and draw particular attention to the contrast in the ways video feedback is being used when compared to the more typical non-video coaching strategies described in the previous sections. This suggests that while teams are making use of video feedback, the technology is limiting them to using it in somewhat constrained ways or with workarounds.

4.3.1 Replayability

I learned that video helps coaches extend the brief window for teaching by enabling them to track and review issues that get lost in the shuffle of a busy practice or game. Hockey is a fast-paced sport, and several coaches reported that it can be difficult to provide an adequate level of feedback on every event that merits it. This problem of missed opportunities reflects the way that coaching often has to work around brief windows of time. I found that some coaches currently use video as a way to revisit fleeting moments from past games and practices and teach around important scenarios that may be faded in the players' memories. For example, one coach recalled gathering the team in her living room to study video, and another participant reported using video to present concrete scenarios while travelling with the players:

> "Say you're on a road trip on a bus, and you're trying to explain something that happened in a game, like a goal that went in. That's one of the hardest scenarios. That's why I think video … is the most effective." – P3

> "When we're in a game, it's so limiting because I can't stop the play. I can't get on the ice, I can't show them. It's really hard [to teach] during a game." – P2

In these cases, playing back video recordings allows coaches and players to teach and learn 'off-ice' where it can be difficult to explore on-ice situations and strategies. While such practices offer coaches and players time to be reflective, the downside is that they occur outside the context of the hockey rink where players may easily be 'out of the mindset' that they have when playing. They may also fail to tie their leanings back to their actual play given the delay in seeing the video feedback. When players receive feedback during a practice or game, they usually have an opportunity to put that knowledge into practice in the very near future. For example, in practice, if a coach critiques the way a player executed a particular drill, the player can try the drill again. Two participants reported improvising this approach. P1 recalled simply using his personal smartphone to record a player and play the video back right away. P7 explained that he had at times used a tablet application to record video on the ice, annotate it with colored lines, and play it back for a group of players *during* a practice. In a video session held off-ice, players can see a concrete example of a scenario they need to improve on, but they cannot immediately apply what the coaches teach them.

4.3.2 Objectivity and 'Buying In'

Coaches reported that players tend to take criticism to heart more quickly when they see a recording of their mistakes played back. Coaches suggested that it is easier for a player to downplay or even ignore verbal feedback because it comes from the coach's subjective viewpoint. For example, P2 argued that video prompts the player to 'buy in' and accept the feedback:

> "Even as a player, I remember: it's so different seeing yourself. And you just notice what you do. Someone can tell you over and over what

you're doing wrong, but if you see it, it's way different. You totally buy into it." – P2

Similarly, P9 shared a story that reflected this idea of 'buying in':

"I had this one kid who was a great skater, but he always dogged it on the backcheck. I would always tell him, "[Name], you're not skating back hard enough", and he would always say, "I am, I am!". Eventually, we just recorded one of the games, then sat him down and showed him the video. You could just see in his face that he finally saw it, and he was just like, "I'm sorry!". After that, he was way better." – P9

In this way, video recordings provide a kind of factual evidence for players. This is not to suggest that players deliberately ignore the coach's perspective. According to P9, the player really did believe that was he was backchecking (returning to a defensive position when the opposition team acquires the puck) properly until he saw the video. P1 also had some experience with this phenomenon, and he explained how this problem might relate to a gap between what a player does on the ice and what that player *feels* they did on the ice. He described improvising video feedback during a game by using his smartphone to record one of his players:

"I've used my phone during a game to record players and show them what they did. Sometimes they don't even realize mistakes that they're making or habits that they have until you actually show them, like, 'I'm not bringing it up for no reason'." – P1

This question of the extent to which a player is able to perceive of a given problem speaks to the issue of mental skill development that we described previously. Improving the player's ability to play the game appears to hinge on both parties' ability to recognize, define, and discuss difficulties. In this way, video recordings might provide a concrete middle ground around which players and coaches can communicate.

Overall, this suggests that video recordings can help players build a more complete mental model of a specific play in order to improve their understanding of the decisions they made or could have made. I also see value in in-the-moment video recordings and annotations that occur within the context of the practice itself, rather than off-ice viewing sessions.

4.3.3 Psychological and Emotional Utility

My inquiry focused on performance as a product of teaching and practice, but I also discovered that video is used beyond just being a resource for learning. During the interview, P7 used his laptop to show me an example of this kind of video. The video combined audio and video clips from various sources to produce a motivational mashup: sports movies (e.g. Al Pacino's locker-room speech from "Any Given Sunday"), a Gatorade advertisement, professional hockey broadcasts, and highlight footage of his own team. The video is intended to be shown to players in the dressing room before a training camp or before an important game to help them prepare mentally and emotionally. While valuable, the obvious challenge in this application is finding the time to create such videos.

None of the other participants who had worked with video feedback reported using this kind of video, but P7 suggested they are fairly common on teams that regularly work with video. Moreover, I did find a similar use of music in my observations where I regularly witnessed teams playing music before games and during stoppages in order to raise the 'energy level' in the arena.

4.3.4 Limitations of Off-Ice Sessions

My study also revealed additional drawbacks with present-day video feedback systems that limited the way my participants were able to use video. First, when coaches hold off-ice 'video sessions' where players gather in a classroom setting to watch recordings, the players' attention span can be a major obstacle. Participants explained that players often lose interest during extended video sessions:

> "They get bored. It takes a lot of time to go through it. So their attention span is like 15 minutes, so it's like quickly show them what we can in 15 minutes." – P2

> "Five minutes or less. If it's beyond that, people are going to stop paying attention. So when we're talking about reviewing game video, it's very important that you're very selective in what you pick." – P7

P7 explained that he likes to share 'pre-scout' videos with players a few days before games. He annotates footage of an upcoming opposition team and posts it to an unlisted YouTube channel in hopes that his players will study it on their own time. However, he pointed out that player attention is an obstacle in this approach as well:

> "Are they going to look through it? It's hard to say. We didn't get a hundred percent compliance with the YouTube video. [This video] has 8 views. There's 20 kids on the team. This is going into playoffs. This is our semi-finals." – P7

While this method works around the coach's time constraints by giving players 'homework', their attention span becomes an issue. Even though the team was headed into an important game, less than half the team watched the video he assigned. This limitation suggests that there might be value in being able to capture and replay short video clips for players in order to maintain their attention.

Second, coaches described the time and energy required to capture and prepare video recordings as another major obstacle. For example, P7 talked about reviewing video recordings of his team and spending additional time analysing their performance and developing goals for their next ice time. Yet this constituted a large effort on his part that many coaches were not willing to put in.

> "A big part of video work is the analytical part. That would be analysing game footage and determining what you want to use and presenting that back to the team. We have a TV in the dressing room where we plug in a laptop and go through the video before practice." – P7

One team was only able to use video feedback because a mother of one of the players volunteered to record their games with her own camera. In this case, the coaching staff still did not have time to make use of a majority of the captured video.

> "We'll pick games where we know it's a good game for us to go over because we're going to play [the same team] again or whatever reason. We don't go through every game, that's for sure." – P3

The reliance on volunteers and personal recording equipment also limits the quality of information the coaches can gather. Participants explained that high-angle or

overhead views provide the best overview of the strategies at work and the decisions being made on the ice. However, in practice, they are usually limited to one camera positioned in the stands with a volunteer spectator or a scratched player. One participant even suggested that they might be able to address the attention span problem if they could spend the time necessary to gather more video recordings and the time required to then make use of those recordings. She suggested that players would pay more attention to individual, tailored video feedback:

> "If it was more specific to [a single player], like maybe 1-on-1 video, that would be awesome, because then they'd actually think, 'Oh it's all about me'. I think if you had unlimited time and the ability to edit really easily, you would do 1-on-1 sessions. But we don't have the resources." – P2

This limitation suggests the potential for cameras placed in various strategic locations throughout an arena. I elaborate on this idea in the following chapter.

4.4 Participatory Design Activity

Figure 4.1 Photo of P2's creation. P2 used small chunks of putty to mark the positioning of cameras, blue paper tabs to indicate audio-linked players, and square blue tabs to indicate monitors.

Figure 4.2 Photo of P3's creation. P3 created labels to indicate where cameras and displays would be located. Top-left: "cam above center ice"; top-right: "flatscreens on bench"; bottom: "cam behind net", "netcam".

There were three prominent patterns in the results of the participatory design study: fixed cameras, fixed displays visible from the ice surface, and audio links. First, participants often indicated that they would position multiple fixed cameras in positions that would capture the most important views of the ice. For example, Figure 4.2 depicts P2's creation where she used chunks of putty to map the location of cameras. She marked three top-down cameras spaced along the middle of the rink, four lower-angle corner cameras, and one camera for each net. She explained that each of the top-down

cameras would capture the defensive, neutral, and offensive zones respectively. She included corner cameras because she felt it would be useful to have a closer view of the sometimes messy 'battles' that occur when a player tries to fend off opposition defenders along the corner boards. P3 used labels to indicate cameras in the same locations as P2 (see Figure 4.3). P3 explained that the "net cams" would offer a valuable view of the goalie's perspective, which could help coaches understand how the opposition attacked to score a goal.

Figure 4.3 Photo of P4's creation. P4 combined a paper tab with a chunk of putty to indicate a camera. He also used large sticky notes to mark important areas of the rink that he wanted to discuss further.

In addition to these fixed views, I found that participants experimented with displays near the ice surface. For example, Figure 4.4 depicts the player's bench area from P4's model. He used sticky notes to flag important areas of the ice for discussion. He explained that the yellow note on the right represented his computer: he imagined having a laptop connected to a large screen so he could load video on-the-fly to show

his players. Similarly, P2 and P3 added multiple displays to their models. P2 (Figure 4.2) used small white tabs to represent monitors positioned along the players' bench and along the glass in the corners of the rink. P3 (Figure 4.3) provided less description and simply added a label that read "flag screens on bench".

Lastly, P2 and P3 both included some form of audio link for their players. P2 used blue flags to indicate that the players on her team was joined by a shared audio link (Figure 4.2). These designs blur the boundary between feedback and real-time instruction, and I probed both participants to share any concerns about distracting players while they were on the ice. While P2 felt all players could be linked without providing too much distraction, P3 suggested that she would limit the link to the goaltender and the center—players at these positions are typically expected to carry greater responsibilities than other players on the team..

Despite the valuable findings described above, I felt that this method was not generating enough creative discussion to warrant the time and effort involved. In two of the six sessions, the participant only spent a minute or two engaging with the activity (e.g. looking at the model or sorting through the materials), and they offered little in the way of discussion around the prototype. In other sessions, the discussion quickly moved away from the activity and returned to concepts discussed beforehand in the interview. At the same time, I noticed that many of the cues provided by the model rink were present during the in-situ interviews—by interviewing coaches in an ice rink, they were already able to point and make reference to different parts of the arena while we spoke. As a result, I opted to simplify the process by removing the activity and extending the interview portion of the remaining sessions. In Chapter 6, I reflect on my experience using this method and discuss how it might be improved for use in future research.

4.5 Summary

In this chapter, I presented the study findings to address the first three sub-problems I outlined in Chapter 1. I began by exploring findings around how coaches focus on teaching understanding of the game. Participants often reported exchanges with players that revolved around players' decision-making process or their ability to

comprehend patterns and systems in the game. In this approach, coaches struggled to perceive players' level of comprehension. Next, I explained how coaches communicate with their players: where, when, and how they teach. I found that time is a major constraint for coaches as the pace of the game and their multitude of responsibilities inevitably leads to missed opportunities for teaching. I also found that negotiating group versus individual communication can be a challenge where one-on-one communication is more effective but distracts from the overall direction of the team. This issue also highlighted the unique challenge posed by goaltenders—they play a completely different role and often require different a different treatment from the coaching staff in practices. I concluded by exploring the advantages and limitations present in coaches' current use of video feedback. I detailed the value of replayability, the perceived objectivity of video feedback and its resulting persuasiveness, and the application of video as an emotional motivator. At the same time, I also discussed how coaches struggle to retain players' attention in video sessions and to capture, review, and prepare video for use as feedback. In the next chapter, I revisit these findings to develop additional insights and discuss the implications for how future video feedback systems could be designed to provide better support for amateur coaches.

5 Design Implications

In this chapter, I summarize and discuss my findings and draw out the lessons I learned for the design of new video feedback systems for amateur hockey. Specifically, this chapter answers the final sub-problem outlined in Chapter 1: we do not know how to apply this knowledge to the design of interactive video feedback systems.

5.1 Tailoring Feedback for Team Sports

Much of the related work around video feedback for sports focuses on individual body movements. For example, Hämäläinen (2004) and Marquardt et al. (2012) both explored mirror-like setups that were designed to help a single, independent athlete analyze his or her own body movements. These were self-training systems for martial arts and dance respectively, and they focused on low-angle views that allowed the user to reflect on body movements. Compared to a team sport like hockey, these activities involve fewer 'moving parts'. While I initially imagined that coaches and players would want to see close, detailed views of their physical actions, I found the opposite. The study findings suggest that although hockey, and perhaps team sports in general, still demand a high level of individual, physical skill, they may require feedback from a broader perspective that encompasses multiple players and exposes decision making, causality, and strategy in the game space. I believe video feedback systems for hockey need to be designed to privilege this kind of top-down view. Imagine a defenceman reviewing a recording where he turned over the puck to the other team by passing through the middle on a breakout in his defensive zone. This 'first pass' on a breakout is a crucial decision point for a defenceman, and passing the puck through the middle of the ice is an often tantalizing yet risky option—if an opposition player intercepts the pass, he usually has a dangerous scoring chance. A low angle view of the play might offer a detailed view of how the defenceman moved to make the pass, but it would not expose the trajectory of the opposition player who intercepted the pass. From the top-down, the

defenceman would be able to see both himself and the other player as well as the positions and trajectories of his teammates.

However, I feel that there is a tension between conceptualizing a player as one of many moving parts in a larger system and privileging the player's point of view, context, and thought process. I found on one hand that many coaches aspired to help players understand the system of the game and to make better decisions from a team perspective. On the other hand, coaches often asked questions of their players to prompt them to reflect on their personal experience of a given scenario on the ice. If a video feedback system presents a top-down view of the ice surface, it allows both players and coaches to see how a scenario played out, where everyone was, and how it should have been played out. A top down view does not tell them much about what the player in question saw, how he felt, or what he was thinking. While I recognize that the top-down view might be extremely useful on its own for building a greater understanding of the game, designers should consider how it might be supplemented with additional data. This data might be visual (e.g. first-person view from a wearable camera) or biometric (e.g. heart rate) or even purely auditory. All of these possibilities would provide a contextualized glimpse of the player's perspective. I can imagine that this kind of data presented side-by-side with the 'big-picture' view might help to synthesize the player's experience with a systematic understanding of the game. In the study, I learned that coaches currently use questions to prompt players to think back about what they saw and felt on the ice and how it affected their decisions. Currently this process is almost entirely conversational. Imagine if a player were able to look back at a play and see the top-down view showing the behaviour of all the players on the ice and, at the same time, low-angle video recorded from his or her own perspective. I imagine that this kind of side-by-side display might help coaches illustrate more explicit, objective comparisons between 'what you saw' and 'what I saw'.

Overall, I am not suggesting that low-angle views focusing on individual body movements are completely irrelevant to hockey or to team sports. I found that amateur coaches displayed varying interest in skills development in a team setting, and even those that did not attend to it still suggested it was important—even necessary—for their players. However, it was seen as something players could improve on their own. Van

Wieringen et al. (1989) and Guadagnoli et al. (2002) studied the use of video feedback for developing specific physical skills, and while they did not find it to be better or worse than conventional feedback from a coach, they did find it was an improvement on practicing without a coach. As a result, I believe systems that prioritize low-angle camera views and mirror-like displays could be valuable as a self-training tool or as a complement to team training activities..

5.2 Contextualizing Feedback

We found that most conventional teaching in both practices and games happens opportunistically in brief, face-to-face moments. During games, these moments occur on the bench (the sidelines) with the players who are not on the ice. During practices, these moments occur at various locations on the ice as players execute drills. The obvious benefit of this kind of instruction is that it minimizes disruption to the player's activities, preserves the on-ice context, and allows the player to apply feedback immediately towards improved performance.

However, only two participants reported using video feedback in this manner, and it was not a typical tactic for either one. As described, one coach simply recorded a video on his smartphone and then played it back for a single player. In another case, the coach described using a tablet application to provide a group of players with annotated feedback on a drill after they completed it. This behaviour aligns more closely with the pattern of opportunistic teaching we found in coaches' regular routines, but it is not without limitations. In both cases, the coach had to capture the video manually at ice level. Coaches are already taxed for attention during on-ice sessions, and the ground-level view may not be ideal. Designers should consider how coaches might use video feedback in-context, with greater control over the view, and without distracting from on-ice activities. For example, eliminating the need for hand-held or manually operated cameras would lighten the burden on the coach or on volunteer support staff. One of the few consistent findings in the participatory design activity was the use of fixed cameras to capture important views of the ice (e.g. top-down view of each of three zones). Allowing coaches to select from a number of fixed views rather than coordinating the capture themselves is a trade-off that would save considerable effort and still produce

valuable recordings. With respect to display, monitors could be integrated into the existing structure of the rink to create opportunities to review recordings during games and practices. For games, coaches are restricted to the player's bench area, and displays would likely need to be embedded in the wall of the bench. For practices, there would need to be more flexibility because coaches move all over the ice. A mobile device like a tablet would provide a simple portable solution. Alternatively, a more integrated solution such as projecting an image on to the ice surface or on to the glass would offer more visibility.

The alternative to this on-ice approach is video feedback *outside* of a practice or game. This approach was the norm for all participants who had experience using video, but our findings indicate that it can be extremely cumbersome and less valuable than other feedback given in context. Off-ice video feedback takes players away from the ice—the space where they can physically practice. Furthermore, unless it is presented quickly in the dressing room, it hinges on the ability of both the coaches and players to accommodate 'extracurricular' sessions. Thus, I see this approach as more of a workaround than a solution for leveraging video feedback. That said, video feedback could be used away from the ice to augment or remind players of feedback they received during a practice or a game. For example, imagine a video feedback system is present during games and practices, and it allows coaches to replay recordings in near-real time as opportunities arise. At the same time, coaches might flag important video segments that they showed to a player throughout the on-ice session. These could then be surfaced during off-ice sessions as a reminder. This approach would also help to minimize the lengthy process of reviewing and preparing video. In the next section, I discuss this problem further.

5.3 Curating Content

Beyond the problem of timing and presentation, the laborious process of content curation severely limits a coach's ability to utilize video feedback. Before video can be presented to players, it needs to be captured, coded, analysed, and edited. Each of these tasks demands a significant investment of time and effort. Organizing and analysing the video can be particularly time-consuming because it requires the coach to

mark and revisit all of the captured footage and note each different type of event (e.g. tag all breakouts, turnovers, goals, etc.).

I am aware that computer vision is often applied to address this problem in sports, but I believe my findings suggest that there may be some benefit for the coach in manually curating content. First, I learned that coaches see an overwhelming amount of activity over the course of a single practice or game. They are responsible for a team of about twenty players, and they need to attend to them as individual athletes and as a cohesive unit. Reviewing video affords coaches an opportunity to take a second (or third or fourth) look without the added pressure of trying to guide the team to victory or keep everyone active in practice. In this context, the coach has more freedom to select which details to attend to, and previously undetected patterns may emerge. This may be particularly beneficial early in the season when coaches are still getting to know members of the team. In the study, I found that understanding a player's personality and tendencies is important for providing valuable instruction. The process of reviewing video may afford coaches more time to become familiar with each player's habits, strengths, and weaknesses.

Second, we learned that coaches may use video to provide emotional and psychological stimulation for their teams. Thus, they may be able to leverage their personal relationship with the players to surface uniquely exciting or inspiring moments as they process game footage. For example, a coach might seek out an important goal by a player who does not usually score or by a player who was playing injured. It is certainly possible that an algorithm may be designed to find the same content, but we can imagine that the act of hand-picking these moments might be an important part of the relationship between a coach and his players.

Thus, designers should explore how content curation might be streamlined without minimizing the coach's control or sacrificing the coach's expertise and personal insight. While there is certainly value in maximizing efficiency, a hybrid approach that balances the coach's time with the coach's personal involvement may be valuable as well. Constant buffering techniques that allow users to selectively save pertinent video in the moment (e.g. Hayes et al., 2005) may provide an effective platform for this kind of

interaction. Looking beyond hockey, the balance between efficiency and control might shift depending on the context of use. In a slower sport like baseball, for example, efficiency might be much more valuable than control because coaches have much more time to observe and digest the events of the game. For example, a video feedback system designed for baseball might automatically cross-reference the game recording with the score sheet to generate a compilation of every error committed in a game. This compilation could be further organized by circumstance (e.g. which players were involved, what inning was it, what was the score) to help coaches identify critical clips with minimal effort. In a faster sport like hockey, control might be more valuable than efficiency because coaches are not able to attend to everything that happens on the ice. Game recordings could be organized by player so that a coach might review, in order, every shift a player took. This approach would provide some built-in structure to help coaches navigate the length of the recording, but it would leave room for slower reflection on the players' performances.

5.4 Social Sensitivity

Finally, designers should keep in mind that coaches are working with groups of adolescents in a highly competitive, highly social context. We found that coaches' teaching strategies were often influenced by social considerations. For example, coaches reported taking care not to embarrass players by giving too much individual criticism in front of other players. The benefits of video as a teaching tool need to be balanced against the social vulnerabilities of those involved. Video feedback tools need to help coaches teach their players, but they also need to allow coaches to protect players' privacy, emotions, and self-esteem.

We can imagine that a real-time video feedback system designed to review a single player's mistakes might actually create a negative experience. For example, if the video is presented plain sight of a number of the player's teammates, it might make him feel as if his mistakes are being put on display and he is being shamed. Groom et al. (2011) briefly present this kind of social pain point, but other studies of sports feedback systems did not report anything similar. In fact, many of these systems were designed either for individual sports or for more recreational use, and my findings suggest that the

there is a different social atmosphere in team sports. In recreational activities like shared walking (Consolvo et al., 2006) or shared jogging (Mueller et al., 2007), people opt-in to participate with a peer group. On a competitive sports team, there is a different dynamic. Players compete externally to win games and interally for greater responsibility on the team. When they perform poorly, they may be spoken to or even scolded, and this attention can be embarrassing., I believe designers should carefully consider the privacy and visibility of feedback. For example, they might explore individual displays for personalized feedback. Imagine displays integrated directly into each player's equipment. In hockey, players wear helmets with face-shields. If these shields incorporated small displays (similar to Google Glass or other head-mounted displays), it would provide a private, portable space coaches could use to show the player video with discretion. However, past research has shown that shared views (e.g. Gergle et al., 2004) and gestures (e.g. Tang et al., 2007) help people use video together. Small, personal displays would limit access to a shared view and make gestures awkward or ineffective. In order to discuss a video clip, both coach and player would need to know they are seeing the same video at the same time. Designers might explore how multiple personal displays might be synchronized to provide parallel yet controlled access to video feedback. They might also explore how coaches might use annotations as a substitute for gestures to communicate more clearly around video. This privacy consideration may be even more important at younger age groups where players may not have developed the social skills necessary to accept constructive criticism in a team environment. It is also likely more broadly applicable to other team sports beyond just hockey.

5.5 Summary

In this chapter, I have summarized the study findings and discussed the implications for the design of future video feedback systems for team sports. This discussion has addressed the final component of my four thesis sub-problems: we do not know how to apply this knowledge to the design of interactive systems. I have drawn out design implications around four themes: Tailoring Feedback for Team Sports, Contextualizing Feedback, Curating Content, and Social Sensitivity.

At a high level, much of the work amateur coaches need to do to utilize video feedback arises because many of the available tools for capturing, processing, and presenting video do not map well to coaches' needs and routines. First, coaches often encourage players to develop a high-level understanding of decisions and patterns in the sport, and they need to capture multiple views of the ice surface to paint an insightful picture of this mental side of the game. Currently, however, multiple views requires more camera operators (and possibly more cameras) than most teams can resource. In the future, video feedback systems should enable coaches to coordinate the capture of a selection of views *before* a practice or game begins to eliminate the need for additional help and to minimize any burden on the coach's already limited time and attention. Perhaps the only time coaches should have to worry about video during a practice or game is when they want to display it. Coaches teach opportunistically by making use of players' brief periods of downtime to provide feedback. Currently, the process of recording video on one device, transferring it to a computer, editing it, and presenting it is far too cumbersome to apply in-situ. As a result, almost all video feedback occurs in a classroom-like setting where players quickly lose interest. I have discussed previously in this chapter how this off-ice application might be improved, but I am most intrigued by the opportunity for on-ice applications of video feedback. If a video system anticipated coaches' needs and helped select and prepare video in a matter of seconds, video feedback could be aligned more closely with the context coaches work in. In looking to the future, I believe this alignment would create an opportunity to experiment with a host of new, valuable feedback interactions and to explore how they can support more effective, exciting practices for coaches and players. In the next chapter, I review the research contributions this thesis puts forward and add some final words.

6 Conclusion

This final chapter summarizes the research contributions in this thesis. To begin, I restate the research problems I outlined in Chapter 1. Next, I summarize the contributions of my research by reflecting on the extent to which I achieved each of my goals. Finally, I discuss opportunities for future study of video feedback for sports.

6.1 Research Problems and Objectives

In this thesis, I aimed to gather requirements for the design of video feedback systems for amateur hockey coaches. Currently we do not know how such systems should be best designed to support the needs of coaches and players. I addressed four sub-problems in my research:

1) **We do not know what coaches' goals and needs are in directing player learning.** Minor hockey associations typically mandate a certain level of theory from the top down (e.g. Hockey Canada recommends a set of best practices). However, we do not know how closely amateur coaches subscribe to these standards or what other goals and needs they account for in their approach to teaching the game.

2) **We do not know how coaches put their teaching strategies into practice.** Given an understanding of how amateur coaches approach teaching, we need to investigate how they execute that approach. Comparing coaches' actual behaviour to their goals can help us understand what kind of obstacles coaches encounter and what kinds of workarounds they leverage to cope.

3) **We do not know how coaches currently use video technology or what limitations they encounter in their existing practice.** This problem specifically addresses amateur coaches' experience of existing video technologies. While not all amateur coaches use video, we can investigate how those that do currently interact with video technology in order to inform the design of future video feedback systems.

4) **We do not know how to apply this knowledge to the design of interactive systems.** While the bulk of this work focuses on understanding amateur coaches' needs and behaviours around teaching and using video in hockey, the questions I ask are ultimately oriented to inform the design of new technology for these coaches. In this way, the final sub-problem is to take the insights and translate them into design recommendations.

6.2 Research Contributions

I conducted an exploratory study of the behaviours and interactions of eleven amateur hockey coaches in order to understand how we might design video feedback systems for them in the future. Based on this work, my thesis makes the following contributions:

1. An account of amateur coaches' current approach and practices around teaching hockey. The study results capture common aspects of the participants' approaches to coaching. In Chapter 4, I described how participants reported concentrating on developing players' understanding of the game. I explained how they use questions to prompt reflection. I also identified some of the obstacles coaches encounter with this kind of approach such as interpreting a player's level of comprehension or building a personal rapport with each player.

I also explained how coaches communicate with players during games and practices and identified some of the constraints they work around. Due to the fast pace of the game and the size of a team, time is a major obstacle. Coaches communicate with

players constantly but in short intervals. As a result, they have to find ways to deliver effective feedback and instruction in very short windows. Coaches also have to negotiate group dynamics: they must tailor feedback differently for addressing groups or individuals, and they need to take care to be socially sensitive.

2. An account of amateur coaches' current use of video technology. The study results also present participants' current uses of video and identify the limitations they face. In section 4.3, I reported on participants' current use of video and presented three themes that capture the strengths of video feedback. The first explained how video enables coaches to *recall teachable moments* that they missed in games practices. The second highlighted how the objective quality of video can *help bridge the gap between coaches' and players' perceptions*. The third explained how video has been used to as a *psychological and emotional tool* rather than a training tool. To conclude this section, I reported on the numerous limitations coaches encounter in their current use of video—namely players' attention spans and the time and energy required to capture, analyze, and prepare video recordings.

3. A synthesis of these accounts to produce design implications for future video feedback systems. In Chapter 5, I revisited the main study findings and used them to draw out implications for the design of future video feedback systems. This chapter addressed the fourth and final component of my research problem: applying the understanding gained from the study findings toward the design of interactive video feedback systems. I organized these implications according to four high-level themes. First, I discussed what I learned about *the constraints of a team sport* like hockey. Second, I considered how future systems might be designed to provide more *contextual feedback* than is currently available to coaches and players. Third, I addressed the challenge of *curating content* and proposed design directions that might make the process more efficient while preserving the benefits it might have for coaches. Finally, I discussed the need for *social sensitivity* and outlined ways in which video feedback systems could be designed to maintain players' privacy and support one-on-one interactions.

This knowledge contributes to a relatively new area in HCI. While there is a large body of work on video-mediated communication exploring the value and use of video in the workplace (e.g. Fish et al., 1990, Gergle et al., 2003, Tang et al., 2007) and in domestic applications (e.g. Judge et al., 2010, Yarosh et al., 2009, Ames et al., 2010), there is considerably less knowledge of how coaches and athletes might use video systems as training tools. Experimental systems like the Video Mirror (Hämäläinen 2004) and the SuperMirror (Marquardt et al., 2012) offer some insight into how an independent athlete might augment his or her own training experience. Similarly, psychology and motor learning research has attempted to measure the effect that this kind of feedback has on an athlete's performance, but it has not examined video feedback as a tool coaches can use to augment their existing practice. This thesis develops a qualitative understanding of coaches' teaching practices and provides some initial guidelines for designing video systems that might support and enhance the teaching and training interactions that already exist between coaches and players.

4. A method for studying the existing practices of coaches in amateur sports. In Chapter 3, I described a method for exploring the current goals, needs, and practices of amateur coaches. I explained the criteria and procedure for recruiting participants, and I detailed each of the study methods. These methods included field observations, in-situ semi-structured interviews, and a participatory design activity (I comment on the value of this activity in the next section of this chapter). I also described the method used to analyze the collected data. In the future, other researchers may use this knowledge to conduct new studies aimed at gathering user-centered knowledge in the domain of amateur sports.

6.3 Limitations and Future Work

First of all, I acknowledge that the participant group consisted primarily of coaches from high-level PeeWee, Bantam, and Midget teams. We recognize that coaches might have different goals and different teaching strategies for younger age groups or for more recreational teams. In fact, Hockey Canada recommends that coaches emphasize technical skills for younger players and gradually shift the emphasis to strategy and team play as they get older (Hockey Canada Long Term Player

Development Plan, 2013). Further research is needed to obtain a more comprehensive understanding of how communication and feedback between players and coaches might vary across all age groups or skill levels. However, I believe the competitive, adolescent age group I targeted is an ideal audience for video feedback tools. At these levels, the game is a serious commitment for both coaches and players, and many teams are already experimenting with video. At younger ages or in recreational leagues, more limited feedback may be sufficient.

From a methodological standpoint, researchers might also iterate on the participatory design activity. Even though I discarded it mid-way through the study, I believe it could be re-evaluated and modified to add value to a similar study in the future. Based on my experience using it, I would recommend experimenting with the number of participants involved in each session. Asking two or three coaches to collaborate in creating a modified rink might produce better results. In cases where one coach was unenthusiastic or unsure of the purpose of the activity, there would be one or more peers who could help start a dialogue. Future researchers might also reconsider the use of the model rink. Given that the interviews take place the coach's home arena, participants might be more comfortable using the real ice rink to brainstorm possible alterations. I can imagine combining props like smartphones, tablets, or generic 'magic objects' with a walk-about session around the rink to encourage creative thinking in the participants.

I should also acknowledge the possibility of some level of confirmation bias in this work. As I described in Chapter 1, the work was motivated by my own experiences with video and hockey. By time I was conducting this research, I had spent time informally experimenting with the capture and display of video in the context of the rink and with different methods for curating and analyzing recordings. It is certainly possible that these early experiments coloured my interpretation of the data collected. That said, I worked to minimize this bias by adhering to the study protocol and by carefully following the data analysis procedure I described in Chapter 3.

Lastly, my research so far has focused on understanding and designing for the *coach's* experience of teaching. I recognize that the player's experience of learning might yield further constraints and design implications, and I would recommend that

future research examines the player's experience in a similar manner. Beyond this kind of further requirements gathering, designers should first explore possibilities for providing more contextual video feedback. In order to obtain a deeper understanding of how coaches might utilize more contextual video feedback, researchers should begin to prototype and evaluate rapid feedback systems that enable them to capture and display video for near-instant replay in the middle of a practice or game. This is a crucial next step that will also provide an opportunity to examine how better video feedback might impact players' training experiences.

6.4 Final Words

Both coaches and the athletes they work with dedicate a great deal of time and effort to the sports they practice. Designing better technology to support coaches creates multiple benefits for these people. To start, it makes their lives easier. Furthermore, it creates an opportunity to improve the performance standard in their communities of practice. Ideally, better feedback supports better communication and teaching which, in turn, supports more rewarding interactions between coaches and players. This elevated standard might also help more teams be more competitive and achieve more challenging and rewarding sporting experiences.

From my perspective as a researcher, I feel that this work is positioned at an opportune time for both the technology and the domain involved. Since I began conducting this research, there has been an explosion of change and experimentation in the use of video on the commercial and entertainment side of hockey. For example, professional leagues and their affiliated broadcasters have begun to use complex cable systems to capture spectacular aerial shots during professional games. GoPro has partnered with the NHL to produce promotional materials that draw on the perspective of professional players to highlight the speed and skill of the game. In the commercial technology space, startups like HWKI are developing wearable cameras that interface with hockey equipment. I believe these developments signal a growing interest in greater integration of technology in day-to-day sports practices. At the same time, the power, affordability, and portability of cameras and displays has advanced rapidly in recent years, and it is becoming increasingly feasible to augment aspects of a sport like hockey

with mobile devices, wearables, and other exciting technology. In closing, I am optimistic that the prototyping and experimenting to further understand how coaches and players might utilize new kinds of video feedback is a next step that is not too far away.

References

ACM SIGCHI Curricula for Human-Computer Interaction. (2009). http://old.sigchi.org/cdg/cdg2.html. Retrieved February 12, 2015.

Ames, M. G., Go, J., Kaye, J. J., & Spasojevic, M. (2010). Making love in the network closet: the benefits and work of family videochat, Proc. CSCW, ACM Press.

Baca, A. and Kornfeind, P. Rapid Feedback Systems for Elite Sports Training. (2006). In *IEEE Pervasive Computing* 5(4), IEEE.

Bly, S. A., Harrison, S. R., & Irwin, S. (1993). Media spaces: bringing people together. *Comm. ACM, 36*(1), 28-46.

Boyer, E., Miltenberger, R. G., Batsche, C., & Fogel, V. (2009). Video Modeling by Experts with Video Feedback to Enhance Gymnastics Skills. J. Applied Behavior Analysis, 42(4), 855–860.

Consolvo, S., Everitt, K., Smith, I., & Landay, J.A. (2006). Design Requirements for Technologies that Encourage Physical Activity. *Proc. CHI 2006,* ACM Press.

Daiber, F., Kosmalla, F., Kruger, A. BouldAR: Using Augmented Reality to Support Collaborative Boulder Training. *Proc. CHI 2013 Extended Abstracts,* ACM Press (2013).

Fogtmann, M.H., Fritsch, J., Kortbek, K.J. Kinesthetic Interaction: Revealing the Bodily Potential in Interaction Design. *Proc. OZCHI*, ACM Press (2008).

Fogtmann M. H., Grønbæk, K., Ludvigsen, M. K., Interaction technology for collective and psychomotor training in sports. In *proc. ACE 2011*.

Fish, R. S., Kraut, R. E., & Chalfonte, B. L. The VideoWindow system in informal communication. Proc. CSCW, ACM Press (1990).

Fussell, S.R. et al. (2003). Where do Helpers Look?: Gaze Targets During Collaborative Physical Tasks. In *EA CHI 2003*, 768-769.

Fussell, S.R. et al. (2004). Gestures Over Video Streams to Support Remote Collaboration on Physical Tasks. *HCI 19(3)*, 273-309.

Gergle, D. et al. (2004). Action as Language in a Shared Visual Space. *Proc. CSCW 2004,* 487-496.

Groom, R., Cushion, C. and Nelson L. (2011). The Delivery of Video-Based Performance Analysis by England Youth Soccer Coaches:. Journal of Applied Sport Psychology 23, 1, 16-32.

Groom, R. and Cushion, C. (2004). Coaches Perceptions of the Use of Video Analysis: A Case Study. Insight 3, 7, 56-58.

Guadagnoli, M., Holcomb, W., Davis, M. (2002) The efficacy of video feedback for learning the golf swing, Journal of Sports Sciences, 20(1), 615-622.

Hämäläinen, P. (2004). Interactive Video Mirrors for Sports Training. *Proc. NordiCHI 2004*, ACM Press.

Harrison, S. (2009). Media Space: 20+ Years of Mediated Life, Springer.

Hayes, G., Truong, K.N., Abowd, G., Pering, T. Experience Buffers: A Socially Appropriate, Selective Archiving Tool for Evidence-Based Care. *Proc CHI 2005 Extended Abstracts.*

Hockey Canada Long Term Player Development Plan. (2013). http://cdn. agilitycms.com/hockey-canada/HockeyPrograms/Coaching/LTPD/ Downloads/LTPD_manual_may_2013_e.pdf. Retrieved December 3, 2014.

Jensen, M.M., Rasmussen, M.K., Grønbæk, K. (2014). Design sensitivities for interactive sport-training games. Proc DIS ’14, ACM Press.

Inkpen, K., Taylor, B., Junuzovic, S., Tang, J., and Venolia, G. (2013) Experiences2Go: Sharing Kids’ Activities Outside the Home with Remote Family Members, *Proc. CSCW ’13*, ACM Press.

Jones, B., Witcrat, A., Bateman, S., Neustaedter, C. & Tang, A. (2015). Mechanics of Camera Work in Mobile Video Collaboration, Proceedings of the Conference on Computer Human Interaction New York, NY, USA, ACM.

Judge, T.K., and Neustaedter, C. (2010). Sharing Conversations and Sharing Life: Video Conferencing in Home, Proc. of CHI, ACM Press.

Judge, T.K., Neustaedter, C., Kurtz, A. (2010). The family window: the design and evaluation of a domestic media space. *Proc. CHI 2010,* ACM Press.

Kajastila, R., and Hämäläinen, P. (2014). Augmented climbing: interacting with projected graphics on a climbing wall. *Proc CHI EA ’14,* ACM Press.

Kraut, R.E. et al. (2003). Visual Information as a Conversational Resource in Collaborative Physical Tasks. *HCI 18* (1), 13-49.

Marquardt, Z., Beira, J., Em, N., Paiva, I., Kox, S. Super Mirror: A Kinect Interface for Ballet Dancers. In *Extended Proceedings CHI 2012*, ACM Press (2012).

Marshall, J. Smartphone Sensing for Distributed Swim Stroke Coaching and Research. *Proc. UbiComp 2013 adjunct publication*, ACM Press (2013).

Mueller, F., O'Brien, S., and Thorogood, A. Jogging Over a Distance. *Proc. CHI*, ACM Press (2007).

Nardi, B. A., Schwarz, H., Kuchinsky, A., Leichner, R., Whittaker, S., and Sclabassi, R. Turning away from talking heads: the use of video-as-data in neurosurgery. *Proc. CHI 1993*, 327-334.

Procyk, J., Neustaedter, C., Pang, C., Tang, A., and Judge, T.K. Exploring Video Streaming in Public Settings: Shared Geocaching Over Distance. P*roc. CHI*, ACM Press (2014).

Schensul, S.L., Schensul, J.J., and LeCompete, M. (1999). Essential Ethnographic Methods: Observations, Interviews, and Questionnaires 2. London: AltaMira Press.

Stanley, K., Livingston, I., Bandurka, A., Kapiszka, R., Mandryk, R. (2010). PiNiZoRo: A GPS-based Exercise Game for Families. *Proc. Futureplay '10*, 276-279. ACM Press.

Strauss, A. and Corbin, J. Basics of Qualitative Research, 2nd Edition, Sage Publications (1998).

Tang, A., Neustaedter, C. & Greenberg, S. (2007). VideoArms: Embodiments for Mixed Presence Groupware, Proceedings of the 20th British HCI Group Annual Conference, Springer London, 85-102.

Van Wieringen, P.C.W., Emmen, H.H., Bootsma, R.J., Hoogesteger, M., Whiting, H.T.A. (1989). The effect of video-feedback on the learning of the tennis service by intermediate players. Journal of Sports Sciences 7(2).

Whittaker, S., Frohlich, D., and Daly-Jones, O. (1994). Informal workplace communication: What is it like and how might we support it? Proc. CHI, ACM Press, 131-137.

Yarosh, S., Inkpen, K., and Brush, A.J., Video Playdate: Toward Free Play Across Distance, *Proc. CHI*, ACM Press (2010).

Appendix A.

Recruitment Message I

Hello,

I am part of a group of design researchers at Simon Fraser University that studies computer-supported collaboration and video communication. I'm currently conducting a study to understand how hockey coaches and players can make better use of the latest video and display technologies (e.g. Google Glass, wearables, tablets, etc.) in practice or even during games.

If you are currently coaching minor hockey, you can likely provide valuable insight for some of our latest research. At a high level, we're trying to answer questions like these:

(a) How do coaches and players communicate, teach, and learn?

(b) How are coaches currently using video, and what limitations do they face?

(c) How might we design new video feedback technology to better support teaching and learning for players and coaches?

Participation involves an informal one-on-one interview about your experience and your approach to coaching. If this is something you might be interested in contributing to, please contact me to coordinate a time to meet.

Thanks for your time,

Jason Procyk

Connections Lab

School of Interactive Arts & Technology

Simon Fraser University

Appendix B.

Recruitment Message II

Hi [potential participant],

I am part of a group of design researchers at Simon Fraser University that studies computer-supported collaboration and video communication. One of my contacts, [name of referrer], recommended you as someone who might be able to provide valuable insight for some of our latest research.

I'm currently conducting a study to understand how hockey coaches and players can make better use of the latest video and display technologies (e.g. Google Glass, wearables, tablets, etc.) in practice or even during games. At a high level, we're trying to answer questions like these:

> (a) How do coaches and players on competitive teams communicate, teach, and learn?
>
> (b) How are coaches currently using video, and what limitations do they face?
>
> (c) How might we design new video feedback technology to better support teaching and learning for players and coaches?

If this is something you might be interested in contributing to, I can follow up with more detailed information about the project. Please let me know.

Thanks for your time,

Jason Procyk

Connections Lab

School of Interactive Arts & Technology

Simon Fraser University

Appendix C.

Interview Guide

Research Project Title: Player-Coach Interactions in Ice Hockey
Ethics Application Number: [2013s0878]
Current Version Date: February 4 2014

Sample Questions for Coaches

- How would you describe your role as a coach?
- How do you communicate with your players?
- How do you fail to communicate? Can you tell me about the last time you got really frustrated?
- How much do you rely on demonstration to teach?
- Can you tell me about the last time you had difficulty teaching a player? What happened?
- How do you know when a player has executed a technique or task properly? How do you know when they are improving? How do you know when they've mastered it?
- Can you walk me through the most memorable time a player mastered something they were struggling with?
- Do you use any tools to aid communication with your players? How do they help?
- How do you share information between other coaches to direct player learning?
- How does your teaching strategy with a single player differ from your strategy for a group of players?
- Have you used video as a teaching tool? How does it help? Are there any drawbacks or obstacles to using it?
- Can you tell me about a time when video feedback helped one of your players get better?

Appendix D.

Expanded Interview Guide

Research Project Title: Player-Coach Interactions in Ice Hockey
Ethics Application Number: [2013s0878]
Current Version Date: September 17 2014

General

- Can you tell me a bit about your coaching experience?

  [*How did you get into it, when did you start, where are you now*]

- How would you describe your role as a coach? Does it change at all from pre-season, to regular season, to post-season?

  [*n.b. teaching, babysitting, leading, facilitating, motivating*]

- How does teaching fit into your role? What about evaluation?

- In what ways do you communicate with your players? What kinds of tools do you use?

  [*n.b. inventory of tools, descriptions of strategies*]

- In general, what kinds of information or knowledge are you trying to communicate?

  [*n.b. technique vs. understanding; how are the two related?*]

Practices vs. Games

- How does your approach change in a game versus in practice? Are the challenges different?

  [*n.b. what are your goals? What kind of information do you focus on?*]

- How do you relate practices to games (or vice versa)?

  [*n.b. what aspects of practice do you bring into the game? what aspects of the game do you bring to practice?*]

- How do you approach special game situations (e.g. powerplay, penalty kill, final minutes)?

  [*n.b. the same as any other? different? what kind of information becomes more/less important?]*

Evaluating

- How do you evaluate players throughout a single game or practice? How do you evaluate them over longer periods of time, e.g. a whole season?

- How collaborative is the evaluation process?

  [*n.b. little ongoing conversations on the bench*]

Teaching

- To what extent do you teach around specific moments like a major error or really strong or smart play?

- To what extent do you teach around larger patterns like repeated mistakes?

- What are the biggest obstacles you encounter in teaching your players?

- How collaborative is the teaching process? Do you and the other coaches have separate responsibilities or specializations?

- How much time do you spend teaching individuals versus teaching the group? How do the two scenarios differ?

Video

- Have you used video as a coaching tool before? (Why or why not?)

- What motivated you to start using video? (Has it lived up to those expectations?)

- Can you describe exactly how you incorporate video into your coaching methods?

  [*n.b. tools used, timing around practice/game, what kind of info is important, how do other coaches get involved]*

- What is the biggest benefit you get out of video as a coach? What about the players?

- What are some of the challenges you face in using video?

- Can you tell me about a memorable time when video helped your team or one of your players?