

Amateur Ice Hockey Coaching and the Role of Video Feedback

Jason Procyk, Carman Neustaeder, Thecla Schiphorst*

School of Interactive Arts & Technology, Simon Fraser University

ABSTRACT

Amateur minor hockey coaches have recently begun to capture and play back video recordings to provide their teams with visual feedback of their play as a learning tool. Yet what is not clear is whether such video feedback is useful and how video feedback systems could be designed to better match the needs of amateur hockey coaches and players. As such, we wanted to understand coaches' current practices for communicating and teaching and their current use of video feedback (if at all). We observed games and practices and conducted *in situ* interviews with amateur coaches. Our results show that teaching and learning at highly competitive levels of minor hockey focuses on decision-making and comprehension of the game rather than individual physical movement. One-on-one teaching happens opportunistically and in very short time periods throughout games and practices. However, video feedback is currently used in a much different context, often away from the ice because of technological limitations. Based on these findings, we suggest video feedback systems be designed for use within the context of games and practices while balancing the individual needs of players with coaching goals.

Keywords: Hockey, video feedback, coaching.

1 INTRODUCTION

In team sports like ice hockey, coaches leverage their expertise and experience to provide analysis, feedback, and guidance for players to help them improve over time. Traditionally coaches have relied on verbal communication, physical demonstration, and simple diagrams; however, more recently, some have begun to capture and play back video recordings to provide their teams with visual feedback [16,17]. Professional clubs [1,6,7] have the resources to include video in their training and preparation routines, but many competitive amateur clubs lack the funding and resources to utilize video on a regular basis. Increasingly powerful, affordable, and portable display and camera technology (e.g. smartphones, GoPro) might help to address these problems and support new methods of teaching at all levels of hockey.

Coaching and feedback in sports in general has been studied extensively in psychology and motor learning research [5,8,26,32]. This work also includes some investigation of the efficacy and value of video feedback, but there is relatively little exploration of how coaches actually utilize video in their teaching practice [16,17] and whether or not such usage maps to the *actual* routines that coaches use to teach their players. In HCI, we have seen the use of video studied in a variety of work contexts (e.g. [15,22,29]) as well as personal situations (e.g. [3,21]). However, there has been little exploration of the design of video feedback systems for sports (notable exceptions exist [19,24]).

In our research, we wanted to understand coaches' current practices for communicating and teaching and explore their practices for using video feedback. We wanted to learn 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. To explore this problem, we conducted an observational and interview study involving highly competitive PeeWee, Bantam, and Midget minor hockey teams in first and second tier leagues. We targeted these kinds of competitive high-caliber teams because we 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.

The results of our observations and interviews reveal that teaching and learning at highly competitive levels of minor hockey focus on decision making and comprehension of the game rather than individual physical movement. This teaching often occurs one-on-one in very short, opportunistic time periods throughout games and practices. Yet those teams that used video feedback used it in a manner that was very different than their more typical coaching routines. Video feedback was used outside the context of the ice in special sessions and with the entire team present (in contrast to one-on-one coaching). This was largely because of the limitations of existing video technologies, which caused coaches to create workarounds. Based on these findings, we suggest video feedback systems for amateur hockey be designed with a different approach where they can be integrated into games and practices during short time intervals, support individual feedback in a socially-sensitive manner, and simplify video curation while still supporting the coach's unique understanding of the player's individual needs.

First, we outline the related work on communication over video, sports training systems, and the use of audio/video in physical activities. Second, we describe our study methodology. Third, we convey our results, and finally, we provide a discussion of our findings and the implications they have for the design of video feedback systems for hockey coaches and players.

2 RELATED WORK

Video has been studied extensively in HCI as a way to support collaboration in the workplace. However, there has been relatively little study 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.

2.1 Video-Mediated Communication

There is a large body of work exploring the use of video in the workplace as a way to improve productivity in collaborative work [23,29,35]. At a high level, video has been shown to support awareness amongst distributed colleagues in the workplace so they know when others are available for interaction [3,12]. At a low level, video has been used as part of collaborative workspaces where distributed colleagues work on a shared artifact (e.g., a drawing surface) [12][14][15]. Here the view of a remote

* jep4@sfu.ca; carman@sfu.ca; thecla@sfu.ca

collaborator's body and gaze becomes important for recognizing and anticipating workplace actions [13][14][15]. In other situations, video can act as data to support work activities [29]. While the above research all focuses on the use of video in distributed settings—which is unlike our 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. For example, the research highlights the importance of top-down views along with broader contextual views of a location [23][36]. Of course, competitive sport is different from office workplaces. Coaches and athletes set goals around competing, improving, and winning in a highly structured situation. We 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.

2.2 Shared Physical Activities

Researchers have studied how two or more people might use video and/or audio links to participate in physical activities such as soccer [28], jogging [30], and geocaching over distance [31]. Typically, the aim of these kinds of systems is to establish a sense of social presence between geographically-separated partners via the audio or video links. For example, in shared geocaching [31], geographically-separated partners geocached in different locations and a head-mounted video camera captured and broadcast video. 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. In contrast, in distributed soccer [28], we see the importance of seeing a third person video view of the remote player's body to anticipate and follow their play activities. In our research, we are interested in understanding how video might capture and surface valuable information for an athlete and a coach who are *collocated*. Similar to these examples, we examine the importance of viewing one's entire body *and* a first person view of what the player sees.

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 [34], golf [18], and gymnastics [4]. Both [18] and [34] found no significant difference between video feedback and traditional feedback (i.e. verbal instruction). These results might suggest that video feedback offers little advantage to athletes. In contrast, Boyer et al [4] found that video feedback did help young gymnasts improve certain techniques with a greater rate of success. Similarly, research has shown that integrating video feedback with conventional soccer coaching was valuable yet represented a complex task [16]. Groom and Cushion [17] approached this question qualitatively by conducting 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. We caution, however, that 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, our 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 HCI, there has been a limited amount of exploration of different kinds of digital feedback for athletes. Hämäläinen [18] 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) [18]. Marquardt et al. [24] 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 [24]. 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.

There are also training systems that leverage mobile devices and other kinds of feedback beyond video. The BouldAR augmented-reality system enabled rock climbers to map indoor rock-climbing routes on their smartphones [9]. It used computer vision to enable climbers to mark specific holds on a real-time display on their smartphones. Marshall [25] designed a system for swim training that leverages smartphone sensors to provide technical feedback. The author proposes that the mobility of the feedback device could present an opportunity for analysis and instruction from a remote coach. Baca and Kornfeind [2] present designs for rapid, digital feedback in rowing, table tennis, and biathlon. These designs aim to provide athletes with rapid biomechanical feedback so they can adjust their technique on the fly [2]. Fogtmann et al. [10][11] explored a more technologically specialized 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 is for self-training, and it uses LED lights to guide training exercises, and it deliberately moves away from screen-based technology in order to improve athletes' anticipation and decision making.

Each of these training systems provides athletes with a way to use feedback technology to enhance their own development. Like the video mirrors, however, they seem to operate on an individualistic model of training. In many sports, and especially in team sports, a player's training experience often involves one or more other people. As such, the goal of our work was to understand how video feedback as a training tool might fit within the interactions of hockey players and coaches.

3 STUDY METHODOLOGY

We conducted an observational and interview study to explore amateur hockey coaches' current practices for teaching, explore their current use of video (if it is used), and gather requirements for the design of video feedback systems.

3.1 Participants and Recruitment

Through snowball sampling of personal contacts, we recruited nine coaches to participate in our study. Four were head coaches, four were assistant coaches, and one was a specialized goalie coach. Three of the nine were female, and all were between the ages of 25 and 51.

All participants coached teams in minor hockey associations in a major metropolitan city in Canada. A single team typically has three or four coaches. One coach is considered the head coach and generally directs drills during practice with the assistance of multiple assistant coaches. Sometimes assistant coaches may also

present and direct drills. All coaches work one-on-one with players to discuss their learning and correct issues. During games, coaches split duties amongst the defensive and offensive players to direct smaller groups and manage shift changes.

Teams are comprised of about 20 players. The age groups of the players on these teams included PeeWee (11-12), Bantam (13-14), and Midget (15-17). The level of these teams ranged from 'AA' to 'AAA' where 'AAA' is the highest regional level out of seven 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' players are in a position to work towards that goal. Thus, we targeted serious teams who practice and compete on a regular basis.

3.2 Method

Our study method consisted of ten hours of field observations (five hours of games and five of practices) and *in situ* semi-structured interviews with all coaches.

1. Field Observations: For each participant, we first conducted approximately one hour of observations. We used this time to study the on-ice interactions of coaches and players where we focused on identifying communication and feedback patterns and the balance between performance and instruction. This stage helped to ground our follow-on interview with participants.

2. Semi-Structured Interviews: Immediately after the field observation, we conducted a semi-structured interview with the participant. This was purposeful so that coaches would likely remember specific episodes of their coaching interactions, along with their overall strategies. 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. We encouraged coaches to point or otherwise make reference to the space, and we often did the same as we recalled our observations in the interview. Each interview lasted between 30 and 40 minutes. We 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 us collect detailed descriptions of coaches' experiences and understand the interactions we observed in the field. We asked those who already used video feedback to describe their usage of it, the benefits they saw, and any challenges that they experienced.

3.3 Data Collection & Analysis

We kept handwritten notes during both the observation sessions and the interviews. All interviews were audio-recorded. We analysed our interview transcripts and notes using open, axial, and selective coding [33]. Our analysis revealed several categories of behaviours surrounding coaching practices. This included themes around the focal points of coaching, where and when teaching moments occurred, and coaching individuals vs. groups. Our analysis of video feedback usage drew out themes related to the benefits and challenges of using video feedback, along with the places where it was shown, who it was shown to (groups vs. individuals), and what video was presented (or chosen not to be presented).

Next, we outline the main findings of our study. First, we focus on the routines coaches employ as they work with their players and teams. These illustrate potential areas where video feedback

might play a role in the future given different designs. Second, we describe the *actual* ways that coaches used video feedback currently, which presents a largely contrasting view given the limitations of present-day technology.

4 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, we expected to find that coaches would spend a great deal of time communicating about technique and individual body movements. In contrast, coaches focused almost exclusively on decision-making skills and strategy when they described their current teaching practices.

4.1 Thinking the Game

We found that coaches were focused on helping players improve their ability to understand and think about the game, and they often described communication techniques that address a player's mental processes rather than their physical execution. For example, many coaches reported asking questions of players to help them understand when they had made mistakes and what they might have done differently:

"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

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.

These descriptions suggest that the development of game comprehension, thinking skills, and learning skills is much more central in the interactions between players and coaches than we initially imagined. In fact, when we observed practices, we 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 we learned that older, high-level players—even though they are considered amateurs—are expected to be able to execute most technical skills already. During our observations, many coaches' behaviours reflected this sentiment. We often witnessed a higher-level kind of 'walkthrough' demonstration on the ice in practice. Coaches would act out larger strategic concepts by stepping through the positioning of drills or re-enacting a mistake while explaining the underlying logic to their players.

At a surface level, these findings suggests that video feedback may not play a large role when it comes to understanding one's body movements (at least at the age/level we studied). Instead,

the importance of video feedback may lay in aiding cognition, decision-making, and one's overall understanding of plays.

4.2 Challenges

We found that coaches' emphasis on teaching the mental side of the game created challenges for them. Participants told us that it can be difficult to determine if a player truly lacks understanding in a given scenario. 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

Similarly, P3 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

We also learned that sometimes players will be embarrassed to admit when they do not know something. P2 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 allowing teammates to run a drill first:

"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

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.

5 COMMUNICATING IN THE RINK

We learned that coach-player interactions in hockey occur constantly 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. In practices, coaches often stand on the ice with players as they do drills. Coaches heavily relied on face-to-face, verbal communication, but they also used demonstration, drawing boards, and video recordings.

5.1 Brief Windows

In our observations, we 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 coach 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

Sometimes, the chance to give feedback is simply too short, and time becomes a barrier to communication. One coach 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

When we describe our findings around the current use of video feedback, we will detail how some coaches use video to address missed opportunities for teaching and to 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.

5.2 Group versus 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

Similarly, we often observed coaches demonstrating this social sensitivity by pulling a player off to the side before having a one-on-one conversation. However, 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.

Coaches also found it harder to gauge understanding when they were speaking to the group. As we discussed in the previous section, this is a critical point of communication, and coaches 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.

5.3 The Goalie Experience

The goaltending position in hockey 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, we 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. The location of a goalie also offers an interesting on-ice perspective that video feedback systems may want to capitalize on.

6 CURRENT USE OF VIDEO FEEDBACK

Six out of nine participants 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 irregularly or not at all: they all felt that they did not have time to include video in the team's regular schedule. 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. We asked these participants to describe their experience with video and to evaluate the benefits and drawbacks involved in using it. All of the coaches reported that preparation (i.e. capture, editing) and players' attention spans were obstacles, but they also suggested that video is a powerful teaching tool.

Our findings around the current use of video fell into four categories: replayability, objectivity, psychological and emotional utility, and the limitations of off-ice sessions. We step through each next where we 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.

6.1 Replayability

We 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. We 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

In this case, 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 not 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. P7 reported improvising this approach by using a tablet application to record video on the ice, annotate it with coloured 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.

6.2 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

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. In fact, another participant 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. We 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.

6.3 Psychological and Emotional Utility

Our inquiry focused on performance as a product of teaching and practice, but we also discovered that video is used beyond just being a resource for learning. During the interview, he used his laptop to show us 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 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, we did find a similar use of music in our observations. We regularly witnessed teams playing music before games and during stoppages in order to raise the 'energy level' in the arena.

6.4 Limitations of Off-Ice Sessions

Our study also revealed additional drawbacks with present-day video feedback systems that limited the way our 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

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

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 recordings as another major obstacle. For example, P7 talked about reviewing video recordings of his team and spending extra time analysing their performance and forming 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:

"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. We elaborate on this idea in our discussion.

7 DISCUSSION

We now summarize and discuss our findings and draw out the lessons we learned for the design of new video feedback systems for amateur hockey.

7.1 Tailoring Feedback for Team Sports

Much of the related work around video feedback for sports focuses on individual body movements (e.g. [19][24]). These systems focused on low-angle views that allowed the user to reflect on body movements. While we initially imagined that coaches and players would want to see close, detailed views of their physical actions, we found the opposite. Our results 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. We believe video feedback systems for hockey need to be designed to privilege this kind of top-down view.

However, we 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. We 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 we 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 examples would provide a contextualized glimpse of the player's perspective. We 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.

7.2 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. For example, 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.

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, we see this approach as more of a workaround than a solution for leveraging video feedback.

7.3 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.).

We are aware that computer vision is often applied to address this problem in sports, but we believe our findings suggest that there may be some benefit for the coach in manually curating content. First, we 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.

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. This 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.

7.4 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. Studies of other sports feedback systems did not report any social pitfalls of this kind, but these systems were designed for individual sports where players were self-coaching [18][24][25]. Given the more social context of team sports, we believe designers should carefully consider the privacy and visibility of feedback. For example, designers might explore individual displays for personalized feedback. This 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.

7.5 Limitations

Our research so far has focused on understanding and designing for the *coach's* experience of teaching. We recognize that the player's experience of learning might yield further constraints and design implications, and we plan to conduct a similar study of players in the future.

We also acknowledge that our participant group consisted only 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 and 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 [[20]]. Further research would be 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, we believe the competitive, adolescent age group we 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.

8 CONCLUSION

In this paper, we have contributed a qualitative study of communication, teaching, and feedback among hockey coaches and their players. Our investigation explored how coaches support player learning and how we might design future video feedback systems to assist their interactions. Our study findings show that amateur hockey coaches of competitive teams prefer to focus on one-on-one instruction during short moments of time on the ice and in the players' bench. Yet video feedback systems are currently used in much different contexts, off the ice and only after careful review and time-consuming video curation and editing. This shows that video feedback systems still have a long ways to go in order for them to be used within the context of coaches' preferred coaching strategies and routines. Overall, this presents a different design paradigm for video feedback systems for hockey, and likely fast-paced team sports more generally. Video feedback is also not just about the technical usage of such systems. Instead, it represents a complex interworking as part of the relationships between players and coaches, juxtaposed with challenging social dynamics of learning within a team setting.

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10 REFERENCES

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