ABSTRACT

DESIGNING COLLABORATIVE LIFELOGGING TO FACILITATE LEARNING IN COLLABORATIVE PHYSICAL-RECREATION COMMUNITIES

by
Sayed Mousa Ahmadi Olounabadi

Since the 1940s, researchers have envisioned lifelogging as the systematic capture and utilization of lived experiences for augmenting learning, performance, and community. Unfortunately, this vision was never actualized since few, if any, systems support lifelogging in the term's original sense. Technologies that emerged through the Quantified-Self (QS) movement allowed users to monitor and track almost every life aspect. However, the decontextualized self-tracking data QS systems produced are unsuitable for supporting learning and community engagement, and therefore have not made lifelogging a reality yet. Central to this dissertation is understanding how to augment learning and community through lifelogging. This is particularly a problem in learning in collaborative physical-recreation communities (CPRC) (e.g., regional volleyball communities, college campus-based dance communities) because CPRC members must work together in performance and learning.

This dissertation addresses this motivating problem by proposing Collaborative Lifelogging (CLL), a conceptual framework of lifelogging systems inspired by Collective Computing. By facilitating collaborative procedural learning in CPRC, CLL solutions could support participation in collaborative physical recreation, leading to physical and mental health benefits such as physical fitness improvements, disease prevention, and

stress relief. CLL solutions could also bring members together and improve social connectivity in the communities.

This dissertation answers the following research questions. (i) Why do individuals engage with CPRC? (ii) What types of intrinsic or extrinsic feedback do community members use for procedural learning? (iii) How do community members use current technologies to gain extrinsic feedback and support procedural learning? (iv) What community-based processes support collaborative procedural learning in CPRC? (v) What do individuals identify as teachable moments? (vi) What is the perceived utility of viewing videos of teachable moments? (vii) What are the perceived benefits of CLL solutions compared to QS systems among community members? The above research questions are addressed through a series of empirical studies of recreational volleyball and dance communities in New Jersey, USA.

Study I is a qualitative study with semi-structured interviews (n=32) and qualitative diaries (n=13) focusing on self-reported participation in community activities. The study findings show that individuals have multiple reasons for their engagement with CPRC, and they rely on various forms of intrinsic feedback for their procedural learning. However, they do not view QS systems as an effective way to support their procedural learning. While they do see value in using cameras (e.g., GoPros) for their learning, they face significant challenges in effectively using them. The study highlights the enormous potential of showing individuals' teachable moments through video snippets to support their procedural learning.

Study II is an observational study of how members collaboratively perform and learn during community activities. Findings show that community-based processes in

CPRC, such as feedback exchange among members, depend on the roles of teammates, skills levels, and personal connections in the communities. These findings inform how to incorporate these factors in the design of CLL processes for supporting feedback exchange among individuals.

Study III is a contextual inquiry of teachable moments (n=15). In the study, community members identify moments during their matches and discuss them in collaborative video viewing sessions. Findings show that individuals identify moments of their successes, unsuccessful attempts and long rallies as teachable moments. These moments are also associated with improvement areas in their individual and team performance. These insights inform how to create CLL processes for identifying, contextualizing, and categorizing video snippets of teachable moments.

Using a research-through-design approach, this dissertation translates the insights from studies I, II, and III into representations of CLL solutions by defining personas and pre-intervention scenarios, ideating post-intervention scenarios, and iterative user-interface prototyping. The final study, **Study IV**, uses a video-prototyping research method (n=11) examining the comparative utility of CLL solutions and QS systems. Findings show the perceived benefits of CLL solutions over QS systems for their support of collaborative procedural learning. The insights also highlight that integrated CLL-QS solutions are desired among high-skilled individuals. Collectively, these studies advance the understanding of the requirements for lifelogging systems supporting collaborative procedural learning in CPRC.

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To my parents,
You are the reason for who I have become today.
Thanks for your generous support and continuous care.

مادر و پدر عزیزم، همیشه قدر دان زحمات شما هستم و خواهم بود.

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CHAPTER 1

INTRODUCTION

1.1 Research Problem

Since Vannevar Bush's landmark 1945 paper, *"As We May Think"* (Bush, 1945), researchers have attempted to develop tools that augment people's ability to capture, recall, reflect on, and share information. One of the ways Bush proposed this be achieved was through the development of lifelogging (a term later coined by Gordon Bell (Bell & Gemmel, 2009, 2010)). Lifelogging aims to augment learning, performance, and community through the systematic capture and utilization of lived experiences (Gurrin et al., 2014). With the emergence of the 3rd era in computing, Ubiquitous Computing, in the 1990s (Weiser, 1991), Bell and others started to work on making the lifelogging vision a reality (Bell & Gordon, 2001; Gemmell et al., 2002; S. Hodges et al., 2006). Unfortunately, despite their attempts, it was concluded that their instantiations of lifelogging were not of significant value to individuals, as Gordon Bell himself put it, "*[lifelogging] wasn't something that was bringing a lot of value to my life."* (Elgan, 2016; Regalado, 2016).

Around 2007, a technological movement began, bringing a plethora of technologies for self-tracking to the mass market. This movement, known as the Quantified-Self (QS) movement, aimed to present ways for improving users' quality of life in terms of their health and well-being (Wolf, 2010). QS systems, which emerged through this movement, have centered on providing self-tracking-enabled measurements, such as sleep quality (Singer, 2011) or blood glucose (Sifferlin, 2017), with the aim to bring users self-knowledge on which they can act. Since QS systems have primarily centered on capturing and presenting individual-based and quantified performance metrics, they may only be useful in personal forms of physical recreation such as running (Kelly, 2016), cycling (Matassa et al., 2013), and climbing (Fritz et al., 2014). That said, decontextualized and ego-centric self-tracking-enabled measurements in QS systems have been shown to be unsuitable for supporting learning and community engagement as it was envisioned in lifelogging (Rivera-Pelayo et al., 2012).

Collaborative physical-recreation communities (CPRC) are one common instantiation of geographically-bounded communities, in which co-located members participate in collaborative physical recreation (e.g., playing pick-up beach volleyball matches) to have an enjoyable time away from everyday responsibilities. Much of participants' procedural learning in these communities is likely to be collaborative since members, to a large degree, must work together as they collectively participate in community activities (English, 2015). Lifelogging was envisioned to help learnings in such communities. However, QS systems as one of the only instantiations of lifelogging are ineffective in this area. This challenge here is that in physical recreation learning is typically collaborative and often occurs via engagement with collaborative physical-recreation communities (CPRC) (e.g., regional volleyball communities, college campus-based dance communities), and QS systems' decontextualized self-tracking-enabled measurements provide very limited support for collaborative procedural learning that occurs in CPRC.

Lack of research on these limitations and how to address them has led to a gap in our understanding of the requirements for lifelogging technologies supporting collaborative procedural learning in CPRC. These limitations are the motivating problem, which this dissertation addresses.

1.2 Objective

The goal of this dissertation is to (a) examine engagement with CPRC, perceived benefits and limitation of existing technologies, and collaborative procedural learning processes in CPRC, (b) develop Collaborative Lifelogging (CLL), a conceptual framework of lifelogging systems inspired by Collective Computing, that facilitates learning in CPRC, and to (c) evaluate the comparative utility of the proposed lifelogging solutions to existing QS systems.

1.3 Broader Impacts

By supporting learning through technological innovation, this dissertation supports participation in community activities in CPRC, promoting well-being and health among community members. Higher levels of participation in gratifying community activities may also lead to significant improvements in disease prevention, mental health, stress relief, and physical fitness and capabilities. Furthermore, supporting collaborative learning in these CPRC through technological innovation brings members together and generates interrelationships and social structures, which promote these communities.

1.4 Dissertation Organization

This dissertation first defines collaborative physical recreation (Chapter 2) and investigates CPRC as communities formed around this type of physical activity (Chapter

3). Next, it explains how motor skills acquisition occurs through learning processes (Chapter 4) and presents existing literature on how learning occurs in CPRC (Chapter 5). This dissertation then describes technologies available on the mass market for supporting learning in physical recreation (Chapter 6). After the foundational work, the dissertation presents the research questions and the research plan for this investigation of the technology requirements for supporting learning in CPRC (Chapter 7). As the first step of empirical research, the dissertation presents a qualitative study of individuals' engagement with communities, types of feedback used, and technology use for learning (Chapter 8). Based on literature review and empirical research findings, the dissertation proposes Collaborative Lifelogging (CLL) as a novel conceptual framework of lifelogging systems that effectively support learning in CPRC (Chapter 9). The dissertation refines the requirements for CLL solutions through an observational study of collaborative learning processes in CPRC (Chapter 10) and a contextual inquiry of individuals' teachable moments (Chapter 11). The dissertation uses a research-through-design approach to create representations of CLL solutions (Chapter 12) and evaluate their utility against existing QS systems (Chapter 13). Finally, the summary of the dissertation is presented (Chapter 14).

CHAPTER 2

COLLABORATIVE PHYSICAL RECREATION

This chapter examines collaborative physical recreation as a critical form of leisure activity that allows individuals to achieve health benefits, obtain a sense of well-being, and express their feelings and emotions (Hoffman, 2009). These activities also bring participants together, generate interrelationships, improve social connectedness in societies (Khasnabis et al., 2010). We start this chapter by explaining physical recreation and its different forms. We then explain collaborative physical recreation and its settings and components.

2.1 Physical Recreation

Participation in leisure activities allows individuals to spend time away from their everyday responsibilities to rest, relax, and enjoy life (Jenkins & Pigram, 2004). Such activities revolve around *experiencing leisure.* As a concept, leisure is defined as "a state of deep satisfaction and contentment, often accompanied by feelings of wonder, celebration, excitement, and creativity" (Institut Barcelona Esports, 2011). Leisure activities provide opportunities for self-reflection and allow individuals to satisfy their needs for stimulation, instant gratification, and personal rewards (Beauvais, 2001; Pacific, 1999; Tinsley & Johnson, 1984). These activities also tend to improve social connectivity and bring participants together (Khasnabis et al., 2010). As individuals collectively participate in leisure activities, they may achieve a sense of belonging and feelings of strong attachment towards other participants (Khasnabis et al., 2010; Sharpe, 2005).

While some leisure activities may not entail significant body movements (e.g., playing poker, collecting stamps), a vast portion of leisure activities center on intentional and voluntary body movements in the form of physical performances. Scholars have referred to such activities as *physical recreation or leisure-time physical activities* (Steinbach & Graf, 2008). Playing recreational sports, running, and going on a hike are a few examples of physical recreation.

Individuals may intend to achieve various goals through participation in physical recreation (see Figure 2.1). Experiencing leisure seems to be the most common intended goal in these activities. Some may also participate in physical recreation to achieve health benefits (Hoffman, 2009). These activities provide a platform for individuals to reach their social goals via interpersonal interactions with other participants. Direct and indirect competition and social comparisons can be another intended goal of physical recreation when it occurs within social contexts (Csikszentmihalyi, 1990; Laverie, 1998). Participation in physical recreation may also help with professional and educational goals. This is particularly the case for student and professional athletes who can experience leisure and improve their physical performance simultaneously in these activities.

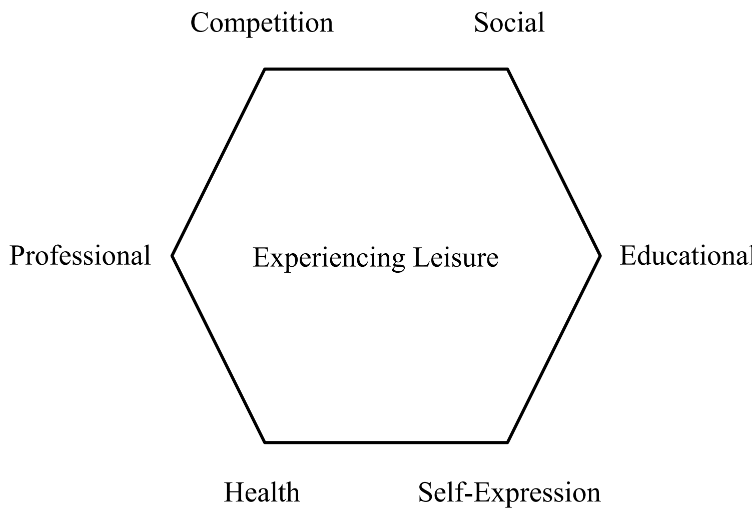

Figure 2.1 Intended goals of physical recreation.

The motivation for investigating physical recreation in this dissertation comes from the significant positive impacts of these activities on physical and mental health, social connectivity, and disease prevention and treatment (Bauman, 2004; Beauvais, 2001; Fagard & Cornelissen, 2007; Katzmarzyk et al., 2004; Khasnabis et al., 2010; Pacific, 1999; D. E. Warburton et al., 2007; D. E. R. Warburton et al., 2006). Our primary focus is on a specific form of physical recreation, known as collaborative physical recreation, because of its vast effects on social connectivity. Our review includes the primary features of these activities, settings in which they occur, and their core components.

2.2 Forms of Physical Recreation

Physical recreation may appear in a variety of different forms. Recent interdisciplinary studies on physical recreation have incorporated a social lens when examining these activities (Iso-Ahola, 1980; Nicholson & Hoye, 2008). This social perspective examines if participation in physical recreation occurs as individual or social behaviors (Benko et al., 2017). This dissertation expands this perspective and divides physical recreation into three different categories based on interdependence among participants when performing the activities. These categories are collaborative, dyadic, and personal physical recreation (see Table 2.1). A significant portion of physical recreation is collaborative, in which participants need to perform the movements of the activities collaboratively. Playing volleyball, for example, requires a team of six players to perform movements collaboratively to score against another team. Dyadic physical recreation are activities in which two participants perform movements individually against one another. For example, in a singles tennis match, two tennis players play against one another by performing a variety of movements individually. The remaining portion is personal physical recreation. In these activities, the primary form of performance requires only one participant. Running, for instance, is personal physical recreation since it can happen only with one participant, the runner.

Table 2.1 Forms of Physical Recreation

Physical Recreation	Competitive Performance	Social Practice	Private Practice
Collaborative			
Team Sports	Playing a beach volleyball match as a team against another team	Practicing spiking with a team member	Practicing volleyball serves alone at a court
Group Dancing	Performing in a dance competition with team members	Dancing with friends at a club	Practicing parts of a dance performance alone at home
Dyadic			
Dual Sports	Playing a singles tennis match	Playing tennis serves with a friend	Performing tennis ball machine drills
Personal			
Solo Dancing	Performing a solo performance in a dance challenge	Practicing dance steps with another dancer	Dancing alone in front of a mirror
Solo Exercising	Running a half marathon	Running with family members	Running alone in a park

Competition varies in each category of physical recreation (Hoffman, 2009). In collaborative physical recreation, the competition is either direct (e.g., basketball, soccer, and volleyball) or indirect (e.g., group dancing). Competitive performance in dyadic physical recreation is direct since participants compete against one another face to face. In personal physical recreation such as swimming and running, participants compete indirectly since they compete side by side without direct interactions with one another during their performances.

All forms of physical recreation also entail non-competitive performances in the format of practice. Such activities may be social or private, depending on participants practicing alone or together. In collaborative physical recreation, a participant may intend to practice segments of the collaborative performance of the activity. They may choose to do that alone or collectively with other participants who have the same goal. For instance, when a volleyball player aims to improve their spikes, they may practice the movements alone at a court or organize a group practice session with their friends. In dyadic physical recreation, a participant may practice movements alone or perform movements with another participant non-competitively with the goal of improving individual performance. Personal physical recreation is primarily through individual performance. Thus, participants of such activities may choose to practice alone or collectively with other participants to practice their individual performances (e.g., going on a hike with friends).

2.3 Settings of Collaborative Physical Recreation

Collaborative physical recreation is performed in a variety of settings. Each setting determines the underlying procedures of the activity.

2.3.1 Informal Settings

In most cases, collaborative physical recreation occurs in settings that are entirely informal. In such settings, participants collaboratively plan, organize, and perform the activities. An example is when two volleyball players join spontaneous meetups at sand volleyball courts in a park every weekend. These players find other players whom they can join and play pickup volleyball with spontaneously. Participation in collaborative physical recreation within informal settings may generate new social ties and connections. This is because participants may engage in frequent interpersonal interactions centering on the activities and become connected. For example, as the volleyball players frequently play pickup volleyball games, they may find new volleyball partners and make new friends. Collaborative physical recreation also provides opportunities for participants who are already socially connected to strengthen their interrelationships.

If interpersonal interactions among participants occur over extended periods, they may even form informal social structures that revolve around the activities (e.g., activity groups, recreational communities) (English, 2015; Wenger, 2011). In such cases, participation in collaborative physical recreation can be via engagement with these social structures. For instance, the volleyball players can engage with their regional volleyball communities as the primary way of playing volleyball. In the following chapters, we discuss these large social structures that revolve around collaborative physical recreation.

2.3.2 Semi-Formal Settings

Participants who engage in collaborative physical recreation may decide to form and join clubs that lead the planning and organization of activities (Chelladurai, 2014). Clubs create semi-formal settings that facilitate participation in the activities. By managing procedures *around* collaborative physical recreation, they allow participants to spend most of their time enjoying the activities. However, clubs do not interfere with the way participants perform the activities. A recreational volleyball club, for example, manages tournaments only to allow players to compete with one another in a systematic manner. However, they do not instruct their members on how to play volleyball.

2.3.3 Overlap with Formal Settings

Collaborative physical recreation is fundamentally different from collaborative formal activities. Such activities entail collaborative physical performances with educational and professional goals in formal settings. Two well-known groups of formal activities with collaborative physical performances are:

- *Physical education*, defined "a structured program of educational experiences in which physical activity is of paramount importance" (M. E. Carroll & Manners, 1995). Physical education is a specific curriculum to K-12 (kindergarten to 12th grade) students centering on improving their physical development and bringing them lifelong healthy lifestyles (Shape America, 2013). Conventional physical education lessons entail collaborative performances such as team sports and group dancing (Joeckel, 2012).

- *Athletics,* defined as competitive and organized activities involving a person in the guidance or leadership role with winning as the primary goal (M. E. Carroll & Manners, 1995; Stein, 1979). Athletic competition is one of the primary goals for participating in this group of activities (Griffin & Watkins, 2005). Athletes compete with one another competitions (e.g., in a sports tournament) based on their level of fitness and endurance. Athletes with educational goals participate in activities in institutional education systems to present their talents and achieve admission to higher education (e.g., receiving an athletic scholarship). Institutional education systems such as universities also employ these athletes to represent these systems in athletic conferences. Athletes with professional goals perform collaborative performances in professional sports to pursue their career goals (e.g., playing for a team in the National Hockey League). These athletes will take payments for their physical performance.

The main difference between collaborative physical recreation and collaborative formal activities is that the latter substantially relies on the roles of *instructors* (e.g., teachers, coaches) (Burton, 2018). These individuals manage the procedures *within* formal activities. They track and monitor the performances of students and athletes to identify possible areas of improvement (Drewett et al., 2006). They also provide students and athletes with feedback on their performance to help them improve and coordinate with one another in collaborative performances (Bennett, 2011; Drobny & Borchers, 2010; Sadler, 1998; Santos, 2016; Schneider et al., 2015; Tinning et al., 2001)

Having said that, participation in collaborative physical recreation and engagement in formal activities with educational or professional goals may overlap in some cases. Instructors may organize some activities specifically to allow learners to rest, relax, and enjoy life (Medrich, 1982; Sloper et al., 1990). Examples are social meetups organized for athletes to play team sports. These activities still involve instructors, which is different from primary forms of collaborative physical recreation, in which no one is formally in charge of the activities.

2.4 Components of Physical Recreation

To identify the core components of collaborative physical recreation, we must first examine these activities as a form of physical recreation. Scholars have identified exercise and motor skills as the core components of physical recreation. In the context of collaborative physical recreation, these components may be more complex. In this section, we first explain these two core components and then discuss their features in collaborative physical recreation.

2.4.1 Exercise

Exercise is defined as the application of stress to muscles (Thompson, 1994), and it centers on performing movements that result in energy expenditure above the resting level (Manley, 1996). This is through the engagement of body segments and appears in two forms:

- Rhythmic, repetitive, and structured movements of large muscles over continuous periods causing faster than normal heartbeats. These are known as *aerobic exercise* since they cause bodies to use oxygen as energy (e.g., steady-state running, cycling)(U.S. DHHS, 2008). The high levels of muscular engagement in these exercises may range from multiple limb movements to full-body movements.

- Movements that engage muscles to hold or work against an applied weight or force within intense and brief bursts. These are known as *anaerobic exercise* since

> they cause bodies to use energy stored in muscles (e.g., sprinting, weightlifting). These exercises allow individuals to increase the size of their body muscles and, in cases, enhance bone density. While individuals may use their body weight to induce muscle contraction in strength activities (e.g., push-up), they may also manipulate and interact with heavy physical objects through (e.g., lifting weights).

Performing these forms of exercise varies based on three main factors: duration, frequency, and intensity of the activities (AICR, 2005; U.S. DHHS, 2008). The *duration* of an exercise refers to the amount of time spent on the activity in a specific period (e.g., an hour spent running every week). In anaerobic exercises, duration tends to be replaced with repetitions in the activities (e.g., weekly repetitions in weightlifting). The *frequency* of an exercise indicates the number of times that the activity is performed over given periods (e.g., two instances of playing soccer in a week). The *intensity* of an exercise refers to the level of energy expenditure that the activity causes and is divided into light (e.g., walking), moderate (e.g., brisk walking), and vigorous (e.g., running).

2.4.2 Motor Skills

Motor skills are the other core component of physical recreation. Scholars have defined motor skills as "movements oriented and represented by coordination of responses to situational cues" (Gagné, 1977; Seidel et al., 2007). These skills allow physical performances in which the accuracy of timing, rhythm, forces, or direction of the movements are of importance for achieving the goal(s) of the activity (Coker, 2017; Hoffman, 2009). The use of motor skills is widespread in executing precise movements in recreational team sports (e.g., performing a forehand in tennis game) and performing arts (e.g., performing rhythmic sequences of movements in a dance performance). These skills are developed around achieving a set of outcomes and involve voluntary body movements that allow reaching the outcomes. Individuals acquire motor skills through training and practice (Coker, 2017). Interpersonal interactions may also play an significant role in facilitating the acquisition of motor skills (Nonaka & Takeuchi, 1991). For instance, serving a volleyball needs to be learned and involves body movements to reach a specific outcome, which is in this case scoring. A volleyball player acquires this skill through hours of training and practice. The player may also observe how other players use the skill to better understand and perform the movements.

2.4.3 Integration of Exercise and Motor Skills in Physical Recreation

As mentioned earlier, exercise and motor skills are the core components of physical recreation. Figure 2.2 illustrates the integration of exercise and motor skills in these activities. Participation in each form of physical recreation requires different levels and types of motor skills and forms of exercise (i.e., aerobic, anaerobic). For example, recreational team sports such as basketball and soccer entail precise performances of movements (e.g., dribbling) as well as both aerobic and anaerobic forms of exercise (e.g., running around and sprinting in a game). Activities at the lower end of the diagram require low levels of motor skills. However, participants may still need to be able to perform the basic movements of the activities. Both performing arts, as well as recreational team sports, require high levels of motor skills, while they may belong to different forms of exercise.

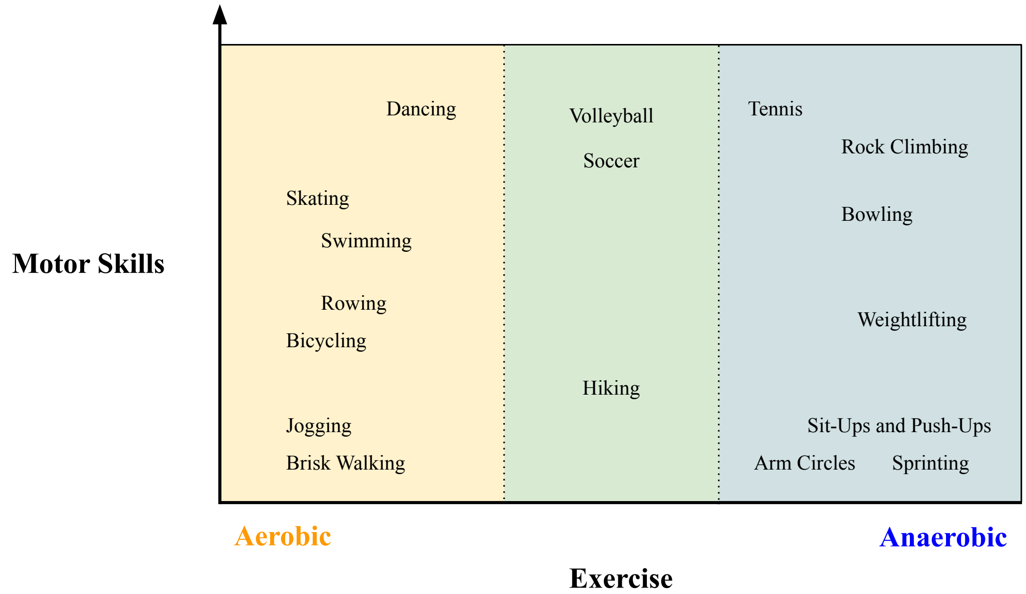

Figure 2.2 Integration of exercise and motor skills in all forms of physical recreation.

2.5 Use of Motor Skills in Physical Recreation

When physical recreation participants use a motor skill, they execute specific sequences of physical tasks. A *person* executes the physical tasks of a motor skill to achieve the *intended outcome* of the skill (see Figure 2.3). For example, the intended outcome of diving to a ball for a goalkeeper in a recreational soccer match is to stop the opposing team from scoring. These sequences of physical tasks differ in various motor skills. For instance, physical tasks and their order in performing a basic overhand serve in a volleyball game (e.g., tossing the ball, aiming for serve with the body, hitting the ball with the heel of the dominant hand) are different from physical tasks in bowling (e.g., holding the ball, approaching the foul line, aiming, and releasing the ball).

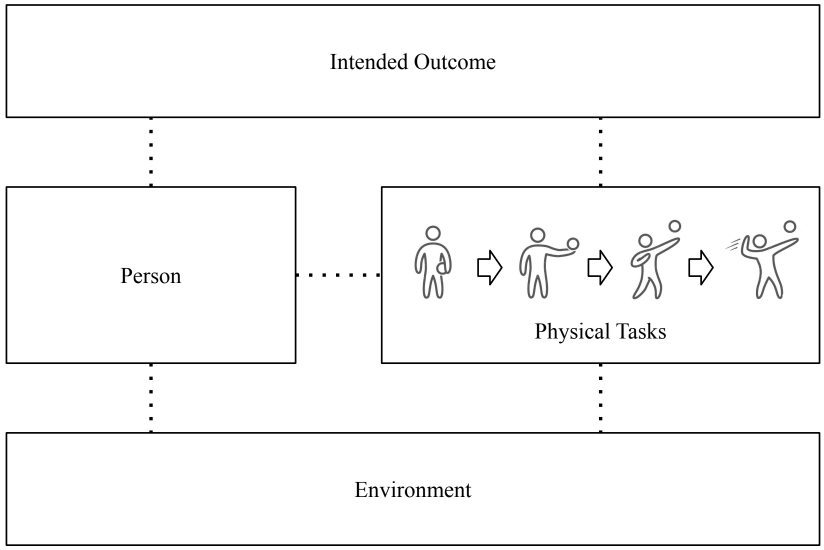

Figure 2.3 Elements of using motor skills.

Executing each physical task in a motor skill requires coordinated and controlled movements of body segments (K. M. Newell, 1985). This requires detecting situational factors in the *environment* in which motor skill are used. Depending on the situational factors, the person who uses motor skills may choose to execute the physical tasks differently, alter the order of the tasks, or focus on specific parts of the tasks. For example, when a volleyball player detects the direction and speed of the ball and the position of a player from the opposing team, they may decide to serve the ball differently. The use of a motor skills is deemed successful if the results of the movements match the intended outcome of the skill.

2.6 Types of Motor Skills in Physical Recreation

Over the years, scholars have identified various taxonomies and categorization systems for motor skills (see Figure 2.4) (Voelcker-Rehage, 2008). For example, scholars have divided motor skills into continuous, discrete, and serial categories (Schmidt, 1975).

Continuous motor skills are those that need repetition of patterns of movement, and their beginning and end either depend on situational factors or are subjective. Riding a bicycle, for instance, is a continuous motor skill since it covers repetitive movements, and its beginning and end are the beginning and the finish points of cycling paths. In discrete skills, however, the physical tasks of the skills identify their beginning and endpoints. An example is performing a spike in a recreational volleyball game, which starts from getting into position and ends with jumping and hitting the volleyball. Serial skills are combined sequences of discrete skills and require the completion of a series of movements (e.g., performing specific routines when playing recreational volleyball).

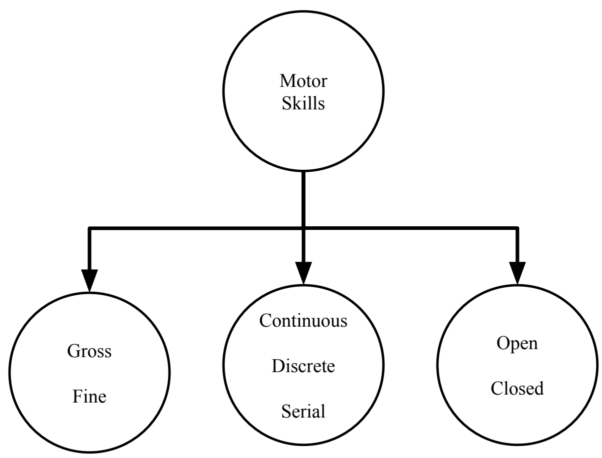

Figure 2.4 Motor skills taxonomy.

Source: (Voelcker-Rehage, 2008).

Scholars have also distinguished closed skills from open skills (Poulton, 1957). The primary variable that explains the differences between these two categories of skills is the predictability of situational factors in the surrounding environments. Closed skills are those that individuals can perform through prior planning without considering situational factors around them. In other words, situational factors either do not affect the performance of closed skills or can be anticipated and managed before and during the performance. An example of a closed skill is when a dancer performs an individual dance routine in a private session. Since the dancer is familiar with the routine and the location of the performance, she/he does not need to respond to any unexpected situational factor, and as a result, she/he is entirely in control of the performance of their skills. Open skills, in contrast, are those whose performance occurs in environments that are continually changing, and situational factors tend to unpredictable. Skills in this category tend to be more dynamic in the sense that individuals are unable to engage in prior planning and instead they need to adapt and conform to unexpected changes and dynamically decide on movements right before they are needed (Seidel et al., 2007). An example of open skills is when a volleyball player in a pick-up game needs to continuously observe and track the ball's position and their opponents and adapt their positioning and response to block the ball at the right time properly.

The final categorization of motor skills groups them into fine and gross motor skills. The main variables behind this categorization are the muscular engagement they need and how precise the corresponding movements must be. Gross motor skills are those with high levels of muscular engagement, which can range from multiple limb movements to full-body movements. Fundamental motors skills such as walking, and jogging are in this category. Fine motor skills, in contrast, require low levels of muscular engagement that allow the manipulation of physical objects (e.g., dropping a volleyball on the court).

2.7 Exercise and Motor Skills in Collaborative Physical Recreation

As explained earlier in the chapter, collaborative physical recreation requires participants to perform movements collaboratively. Participants may need to perform aerobic, anaerobic, or both forms of exercise depending on the nature of the activities. It is also crucial for participants to coordinate their duration, frequency, and intensity of exercises with other participants in their collaborative performance. Otherwise, the successful implementation of collaborative performances may not be possible.

Engaging in collaborative physical recreation also complicates all the elements of using motor skills discussed in the above: person, intended outcome, physical tasks, and environment. In these activities, multiple persons collaboratively use their motor skills. This requires these participants to coordinate their movements with one another. Physical tasks in these activities entail specific steps for each participant. Collaboratively, participants execute sequences of physical tasks to obtain their collective intended outcome. For example, two beach volleyball players in a team aim to score in a volleyball game, and they collaboratively execute the tasks to achieve their intended outcome: one player sets the ball, and the other player jumps and spikes it. To successfully perform collaboratively, each participant needs to observe others' movements. Such factors act as situational factors in their environment, which affect how they execute the physical tasks of motor skills. For instance, the way a beach volleyball player saves a ball in a game impacts their teammate's choice of the following steps: to perform a spike or dump the ball over the net.

2.8 Summary

This chapter explained collaborative physical recreation as a form of physical recreation. We explained settings for participating in such activities and examine their two core components, exercise and motor skills. Participating in these activities requires using complex motor skills. Using these skills in collaborative physical recreation requires skills to be acquired first. Thus, this dissertation specifically focuses on motor skill acquisition in the contexts of these activities. We argue that such processes occur through *procedural learning*, which stores motor skills as knowledge-of-how in human memory. While some of participants' procedural learning processes in collaborative physical recreation may occur through individual training and practices, much of them are likely to be collaborative. This is because, to a large degree, participants in these activities work together in both performance and learning.

This dissertation examines how collaborative procedural learning occurs as individuals engage with recreational communities (e.g., regional volleyball communities, college campus-based dance communities). Thus, the next chapter discusses these communities' characteristics and how members participate in joint community activities. This dissertation specifically investigates collaborative procedural learning that happens in such communities. The study of such complex processes first requires an understanding of how procedural learning happens through human memory. The following chapters explain human memory and various types of learning and then investigate the processes for acquiring motor skills. This dissertation then examines these processes in the context of recreational communities.

CHAPTER 3

COLLABORATIVE PHYSICAL-RECREATION COMMUNITIES

This chapter discusses recreational communities that center on creating informal and semi-formal settings for participation in collaborative physical recreation. These communities are known for their positive impact on individuals' physical health and mental well-being, such as physical fitness improvements, disease prevention, and stress relief (Khasnabis et al., 2010). They also have significant social impact through forming interrelationships and social structures and supporting a sense of community and togetherness among individuals (Scannell & Gifford, 2010; Wenger, 2009). The casual nature of these communities allows individuals to distance themselves from formal and professional settings and experience secure and stable environments for satisfying instant gratifications (Overs et al., 1977; Tinsley & Johnson, 1984). They are also critical for people who are disabled and want to present their skills and strengths and improve their confidence and self-respect (Khasnabis et al., 2010; Sharpe, 2005).

In investigating these communities, this chapter first explains what a community is as well as various types of communities. Then, the chapter identifies requirements for communities to be considered as recreational communities and how they support collaborative physical-recreation participation.

3.1 Community

The literature presents a wide range of different, sometimes conflicting, definitions for communities (Q. Jones, 2006). Most existing definitions aim to explain what communities are without providing sufficiently in-depth interpretations (Walmsley &

Lewis, 1993). A common theme among these definitions is referring to communities as a unique type of social system, coherent units consisting of patterned sets of social structures and interrelationships among individuals and groups (Homans, 1950; Poland & Maré, 2011; Wearing & McDonald, 2004). As social systems, communities entail frequent and continuous interpersonal interactions among interrelated groups of people who are bound by shared features (Homans, 1950; Wearing & McDonald, 2004). These interpersonal interactions occur through shared experiences, collective action, and active participation of members in community activities (Hallman, 1984; Johnson et al., 2006; Putnam, 2000).

The unique feature about communities is that their patterned sets of interrelationships and social structures support a sense of community, which emerges as the perception and feeling of belonging and willingness to maintain interdependence among members (Dingyloudi & Strijbos, 2019; Sarason, 1974). In addition to emotional bonds, a sense of community can also become visible through actions and rationalizations that show community attachment (Scannell & Gifford, 2010).

3.2 Categories of Communities

As discussed in the previous section, scholars have defined communities based on various sets of requirements. Traditionally, scholars have focused on the location of members as the shared feature in communities. This perspective regards communities as interrelated human populations within geographically delineated boundaries of neighborhoods, districts, and counties (Poland & Maré, 2011). For instance, individuals may engage with a community of people in their neighborhood who are interrelated and interact frequently.

A wide variety of communities exist within the geographically delineated boundaries of neighborhoods, districts, and counties. The type of these communities depends on features by which members are bound, in addition to their location (Rubin et al., 1992). While each of these categories of communities may exist in isolation, there are hybrid examples in which a real-world community may belong to more than one category:

a) *Circumstance communities*, in which the main feature is shared situations that members are experiencing (Marsh, 1999). An example is cancer patients who meet regularly to share their stories.

b) *Activism communities*, in which members dedicate themselves and commit to performing a specific action (Kahn, 1970). For example, students from multiple universities who assemble to pursue social change and follow a similar action are part of an activism community.

c) *Interest communities,* in which the feature is that members are bound together by common interests (Henri & Pudelko, 2003). For instance, individuals who are interested in a specific type of music and engage in online discussions about their interest are part of an interest community.

d) *Professional communities,* in which members have a shared passion or concern in a specific domain, and they frequently interact to acquire knowledge on how to perform better and more effectively in the domain (Wenger, 2011). An example of such communities is local physicians who communicate with one another and organize bi-weekly in-person meet-ups to discuss and share information about their practices.

e) *Activity Communities*, in which co-located members participate in joint activities, mostly to have an enjoyable time away from everyday responsibilities (English, 2015). An example of such communities is individuals who get together every week to play pick-up volleyball in their neighborhood volleyball court. Although this category is relatively similar to interest communities, practice in these communities implies more of an active interest leading to active engagement among the members.

While activity communities may form around various activities, the focus of this dissertation is on collaborative physical recreation. This dissertation refers to communities in which co-located members participate in collaborative physical recreation as collaborative physical-recreation communities. The next section reviews these communities.

3.3 Collaborative Physical-Recreation Communities

Collaborative physical-recreation communities (CPRC) are a common instantiation of geographically-bounded communities, in which co-located members participate in collaborative physical recreation to have an enjoyable time away from everyday responsibilities (e.g., regional volleyball communities, and college campus-based dance communities). Scholars have framed these communities as social systems that support participation in collaborative physical recreation and facilitate interpersonal interactions among participants (English, 2015). The main requirements of CPRC are (English, 2015; Wenger, 2011):

a) Community members have a shared interest in a specific domain of collaborative physical recreation (e.g., volleyball, soccer, dance). Their interest defines the identity of their community. The commitment of members to the domain distinguishes them from others who are not part of the community.

b) Community members are socially engaged with one another through discussions, information sharing, and joint community activities. Frequent and continuous interpersonal interactions distinguish CPRC from groups of individuals coincidentally coalesce.

c) Community members participate in joint community activities to engage in collaborative physical recreation. This can be in the form of competitive performances and the social practices. This participation allows members to interact with one another and form shared experiences.

3.4 Importance of Collaborative Physical-Recreation Communities

Scholars have argued that the casual and informal nature of CPRC has made these communities appealing to those who want to participate in collaborative physical-recreation (Sharpe, 2005). Engagement in these communities over time creates a sense of intimacy among members. It also offers various levels of anonymity and remoteness to members. Community members become dependent on one another through their efforts dedicated to properly performing community activities. Still, they can also withdraw from community activities or even the communities at any point.

CPRC support participation in activities through a reciprocal relationship, as illustrated in Figure 3.1 (English, 2015; Wenger, 2010). As members participate in community activities, their participation may bring them closer together, generate social structures and interrelationships among members, and strengthen these communities as a social system. In return, these social structures and interrelationships create opportunities for members to experience leisure practice their skills and interact with others. (Lave & Wenger, 1991; Wenger, 2010). This reciprocal relationship also supports a sense of community among members, which enhances their community engagement (Wenger, 2009).

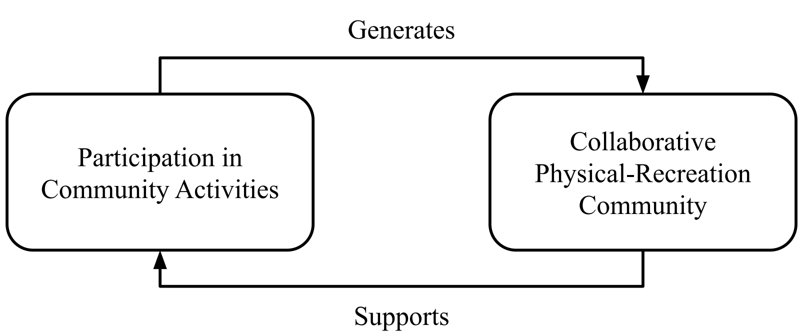

Figure 3.1 Reciprocal relationship in collaborative physical-recreation communities.

3.5 Informal and Semi-Formal Settings of Collaborative Physical Recreation Communities

Chapter 2 explained the settings for participation in collaborative physical recreation. CPRC support both informal and semi-formal settings for such activities. Community members may collaboratively plan, organize, and perform community activities within informal settings. For example, in a recreational volleyball community, a few members may spontaneously organize a volleyball practice game at their local volleyball court and invite other members to join. When they participate in this activity, other members near the venue may also decide to join the practice game and play pickup volleyball. In these activities, the volleyball players may find new partners and make new connections or strengthen their existing social ties with other players. Over time, members of CPRC may also become part of informal social structures in their communities that revolve around the activities (English, 2015; Wenger, 2011). In such cases, participation in community activities can be via engagement with these social structures. For example, a community member may become familiar with a group of local volleyball players who frequently organize and play practice games. The member may decide to join this group and participate in the group's activities.

CPRC also allows members to form and join organizations for participating in community activities in semi-formal settings (e.g., volleyball clubs, on-campus dance intramurals, and martial arts dojos). Such organizations facilitate participation in community activities by managing procedures around community activity. For instance, a volleyball club in a recreational volleyball community manages volleyball leagues to provide opportunities for members to compete with one another in a systematic manner.

Organizations in CPRC differ in how they sustain members' engagement: some may provide free access to all community members, while others may require membership fee payments for the organizations' maintenance costs.

3.6 Teams as Segments of Collaborative Physical Recreation Communities

Teams are segments of CPRC consisting of two or more members who collaboratively participate in social practice or competitive performance. The size and focus of teams differ among CPRC. Such communities may dictate a fixed number of team members (two in beach volleyball teams, six in indoor volleyball and hockey teams), while others do not have specific requirements (e.g., dance teams). Teams in a community focus on identical types of collaborative physical recreation (e.g., beach volleyball in a recreational beach volleyball community) or different variations of such activities (e.g., different dance styles in a recreational dance community).

Teams may temporarily form in community activities and disperse after the activities (e.g., an ad-hoc beach volleyball team in a pickup game) (de Laat & Simons, 2002). They may also emerge through long-term interactions among community members. For example, two beach volleyball players with frequent interpersonal interactions become a team and continuously participate in beach volleyball tournaments together.

Members of teams may select team leaders. Such roles are semi-formal and entail supporting collaborative processes for community activity procedures (e.g., a dance captain leading dance practices) (Decuyper et al., 2010; Van Der Vegt & Bunderson, 2005). Team leaders' role is different from instructors (e.g., a volleyball coach) who solely teach and manage activity procedures within formal settings (Casey & Goodyear, 2015; Dyson & Casey, 2016; Lieberman & Pointer Mace, 2008).

3.7 Summary

This chapter explained the concept of community and discussed various types of communities. We then examined CPRC as communities that center on participation in collaborative physical recreation. We also presented the requirements and characteristics of these communities. This dissertation examines CPRC and their connection to the performance and acquisition of motor skills. It follows scholars who view these communities as geographically-bounded social systems, in which the main goal and the intention of members are to coalesce and learn by assisting one another and sharing their knowledge (Wenger, 2009). The next chapter examines learning processes. Chapter 5 investigates motor skill acquisition in CPRC through collaborative procedural learning.

CHAPTER 4

MOTOR SKILL ACQUISITION

Earlier in this dissertation, we identified exercise and motor skills as the core components of collaborative physical recreation. We also explained that participating in these activities requires using complex motor skills. Since individuals need to acquire these complex motor skills first, this chapter focuses explicitly on how motor skill acquisition occurs in the context of collaborative physical recreation.

We present a theoretical background identifying motor skill acquisition processes. To achieve this goal, the chapter incorporates a perspective that views motor skill acquisition as a type of *learning*. Learning is a broad concept, and motor skill acquisition is only a specific category among all types of learning that occur during life episodes (L. W. Anderson & Sosniak, 1994; Bloom, 1956; Buescher, 1986; Dettmer, 2006; Gagné, 1977; Lafont et al., 2007). Primary forms of learning discussed in the literature refer to the learning of problem-solving skills and conceptual contents. Individuals may also learn values, feelings, and emotions (Green & Batool, 2017). In social situations, individuals may acquire social skills and learn how to interact, communicate with others, and form and maintain social relationships.

Motor skill acquisition is learning that occurs in the sensorimotor domain (Krakauer & Mazzoni, 2011; Seidel et al., 2007). This refers to learning to perform body movements guided through sensory information that is collected from the surrounding environment. Scholars refer to this form of learning as *procedural learning* (J. R. Anderson, 1992; Sternberg et al., 1996). As a process, procedural learning stores both conscious and unconscious forms of knowledge in human memory. When individuals use motor skills, they retrieve and activate these forms of knowledge to execute physical tasks.

This chapter first explains human memory and its role in supporting learning processes, including procedural learning. The chapter then expands on motor skill acquisition through procedural learning.

4.1 Human Memory

Human memory is “the means by which we retain and draw on our experiences to use that information in the present" (Tulving, 2000; Tulving & Craik, 2005). It is an essential cognitive function, which enables storing, retaining, and recalling past experiences and information. It also supports learning from past experiences and planning future actions. Human memory includes three stages of information processing, namely, encoding, storage, and retrieval, as illustrated in Figure 4.1. In the encoding stage, sensory inputs from lived experiences are transformed into storable formats. In the storage stage, the information is stored as memories, and in the retrieval stage, the information and related memories are extracted from the storage for use.

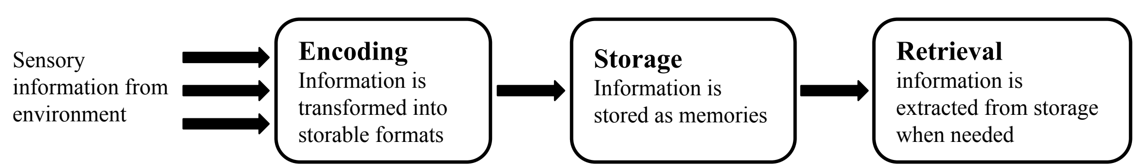

Figure 4.1 Stages of information processing in human memory.

Human memory takes several different forms, as illustrated in Figure 4.2. One significant distinction that scholars have highlighted is between short-term memory and long-term memory (R. C. Atkinson & Shiffrin, 1968). Information that is stored in short-term memory is short-lived and tends to be fragile. Since short-term memory has limited capacity, even small distractions may make individuals forget information that they have stored. In contrast, long-term memory has unlimited capacity and can keep information over extremely long periods. In long-term memory, memory traces are rarely lost, although individuals may still forget some information due to the inability to find relevant and proper memory traces. A process of rehearsal brings information from short-term memory to long-term memory. Long term memory itself consists of two fundamentally different while related types of memory: declarative memory and procedural memory (Mulligan, 2006).

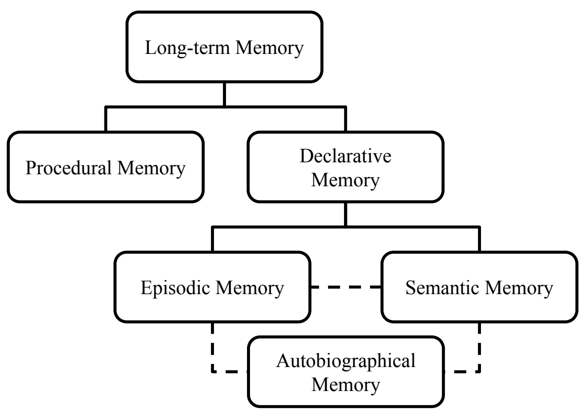

Figure 4.2 Forms of human memory.

4.1.1 Declarative Memory

Declarative memory, also known as explicit memory, contains *knowledge-of-that*: recollected knowledge in the form of facts and events. In other words, this type of memory allows individuals to access and recall their memories. Declarative memory itself is divided into episodic memory and semantic memory (Tulving, 1972). Episodic memory consists of personal experiences and specific objects, people, and events experienced at a particular time and place. Semantic memory, however, consists of facts and general knowledge about the world. Episodic memory and semantic memory tend to be interdependent and interactive (Conway, 2005).

Combinations of episodic and semantic memories create autobiographical memory forming individuals' generic, schematic, and conceptual knowledge of their lives (Conway, 1990). As a unique memory system, autobiographical memory forms overall narratives for individuals by integrating and combining their memories of past experiences (Conway & Pleydell-Pearce, 2000; Fivush, 2011) An example of autobiographical memory is when an individual recalls a day in which they went to a new restaurant and remembers the name of the restaurant (semantic) and the memorable meal they had (episodic).

4.1.2 Procedural Memory

Procedural memory, also known as implicit memory, carries *knowledge-of-how*: skill-based information covering how to follow a set of procedural steps to perform actions, make body movements, and interact with objects (Zelazo et al., 2007). On the contrary to declarative memory, individuals can neither directly recall nor easily articulate knowledge from their procedural memory. When individuals do retrieve and use knowledge from their procedural memory, they are not consciously aware of whether and how they are doing that (C. J. Berry et al., 2008; McBride, 2007). The knowledge that exists in procedural memory is sensorimotor and automatic and obtained through a process of practice and repetition. Since this type of knowledge is particularly significant and wholly embedded in body movements, scholars sometimes refer to it as muscle memory and body memory.

4.2 Learning Processes

The Merriam-Webster dictionary defines learning as “the process of gaining knowledge or skill by studying, practicing, being taught, or experiencing something” (Merriam-Webster, n.d.). In other words, learning is the acquisition of knowledge and skills, which allows learners to store and organize knowledge in their memory. As depicted in Figure 4.3, learners obtain knowledge from life episodes that they experience through two learning processes, declarative learning and procedural learning, which result in the storage of (un)conscious knowledge-of-that and (un)conscious knowledge-of-how in human memory respectively.

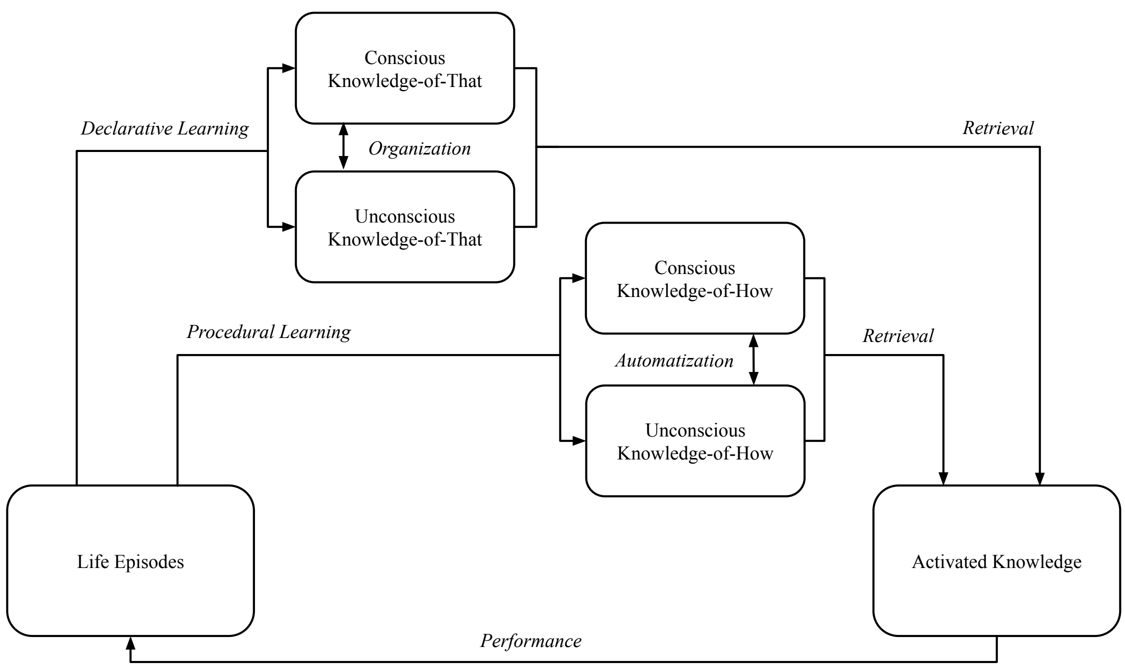

Figure 4.3 Learning processes and interactions among them.

4.2.1 Declarative Learning

Declarative learning is the process of acquiring and storing knowledge-of-that in memory as conscious semantic and episodic knowledge, which is accessible for the conscious recollection of learners. Over time and during an ongoing process of organization, conscious knowledge-of-that transforms into unconscious forms with multiple layers consisting of concepts and objects (Bruner et al., 1986; Kruschke, 2006; Love, 2003), and categories as groups of various concepts or objects with similar characteristics (Sternberg et al., 1996). Concepts, objects, and categories together create web-like forms known as semantic networks as hierarchical structures that allow learners to understand, interpret, and process any incoming sensory information (F. Bartlett, 1932; Brewer, 2001).

4.2.2 Procedural Learning

Procedural learning is the process of obtaining knowledge-of-how, initially in conscious forms as a mixture of "if-then" rules, which later transforms into unconscious knowledge-of-how as body memories. This allows learners to perform body movements in an automatic fashion without consciously thinking about them (D. Berry & Dienes, 1993; Öllinger et al., 2008) The "if" clause of the "if-then" rules in conscious forms of knowledge-of-how indicates conditions and the "then" clause explains actions that individuals perform in response to the conditions that they are facing. In other words, to implement the actions of the "then" clause, the conditions of the "if" clause need to be satisfied (G. Jones & Ritter, 2003; A. Newell & Simon, 1972). For instance, when an individual walks towards a closed-door (the "if" clause), they should slow down and attempt to open the door to avoid hitting the door (the "then" clause). It is important to note that an “if-then” rule may include several factors adding to the complexity of conditions.

Conscious forms of knowledge-of-how transform into unconscious knowledge of how through a process called automatization (Öllinger et al., 2008). In this process, learners perform and practice procedures using the explicit rules. Learners progressively get more confident and familiar with the rules leading to their automatic and autonomous utilization of the rule without being consciously aware of them.

4.2.3 Interactions of Declarative and Procedural Learning Processes

Interactions between declarative and procedural learning processes allow learners to obtain various forms of knowledge in a variety of contexts in their lifespan. When learners in a life episode obtain knowledge about specific events (episodic) and/or as general knowledge containing facts and information about the world (semantic), they experience declarative learning and store (un)conscious knowledge-of-that in their declarative memory. When learners obtain instructions and repeat relevant tasks and overtime exhibit progress in their physical performance, they experience procedural learning leading to (un)conscious knowledge-of-how in their memory (Simons, 2012).

4.3 Motor Skill Acquisition

Motor skill acquisition occurs through the procedural learning processes storing (un)conscious knowledge-of-that in human memory. This kind of learning entails three stages: cognition, automatization, and extension (see Figure 4.4) (Seidel et al., 2007). To acquire a motor skill in the cognition stage, individuals first learn the necessary procedures relevant to the successful execution of physical tasks using body movements.

For example, to perform a basic overhand serve in volleyball, individuals first need to learn how to (a) stagger their feet, (b) hold the ball in front of them, (c) ready their hitting hand, (d) toss the ball into the air, (e) aim for their serve with their body, and (f) hit the ball with the heel of their dominant hand. In the automatization stage, individuals perform and practice the procedures ((a) to (f) in this example) to generate the automated knowledge-of-how through repetition. At the beginning of this stage, individuals pay attention to all the relevant body movements and consciously follow the procedures. As individuals go through repetitions, they become more confident and familiar with the required steps of the procedures. They start to perform the procedures without being consciously aware of the steps that they take. At this point, they have developed unconscious knowledge-of-how about how to perform the procedures.

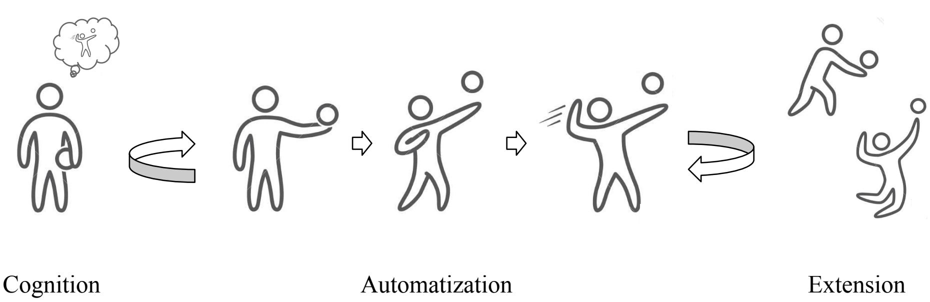

Figure 4.4 Acquisition of motor skills through procedural learning (in volleyball as an example).

After forming automated knowledge-of-how in their memory, individuals focus on strategic and tactical development regarding using their knowledge. In the extension stage, they continuously detect situational factors in their environments and learn how to apply their acquired motor skills based on such factors. Iterative strategic and tactical development in this stage generates *procedural tactical knowledge* in memory (Aquino et al., 2016; Costa et al., 2011). For instance, after knowing how to serve a volleyball, individuals plan their positioning after the serve and incorporate strategies regarding where they serve the ball. After successfully using these strategies in a match, the individuals store the strategies as procedural tactical knowledge in their memory and plan to use them in the future.

4.4 Role of Intrinsic Feedback in Motor Skill Acquisition

This dissertation refers to feedback as (sensory) information that results from a person executing specific sequences of physical tasks in physical performance (McMorris, 2014). Individuals have access to intrinsic and task-intrinsic feedback through their sensory feedback sources. In physical performance, they know this form of feedback as the "feel" of body movements that they perform (e.g., how a dancer feels about their performance). They may also obtain intrinsic feedback by engaging in reflective observation, in which they direct their attention to specific parts of their physical performance (e.g., the dancer paying attention to their turns).

Intrinsic feedback plays a central role in improving motor skill acquisition. This is through supporting active experimentation, in which learners alter the way they execute physical tasks based on intrinsic feedback for better performance (Eraut, 2000; McMorris, 2014). In this process, learners observe the outcomes of using their unconscious knowledge-of-how. Then, they transform their unconscious knowledge-of-how related to their performance to conscious knowledge-of-how. This allows them to reflect on their performance and reconstruct their knowledge-of-how if needed (Kolb, 1984). Following these steps iteratively will enable learners to continuously improve their performance and acquisition of motor skills based on their intrinsic feedback (See Figure 4.5) (Gallwey, 2000; Kuhl & Kraska, 1989).

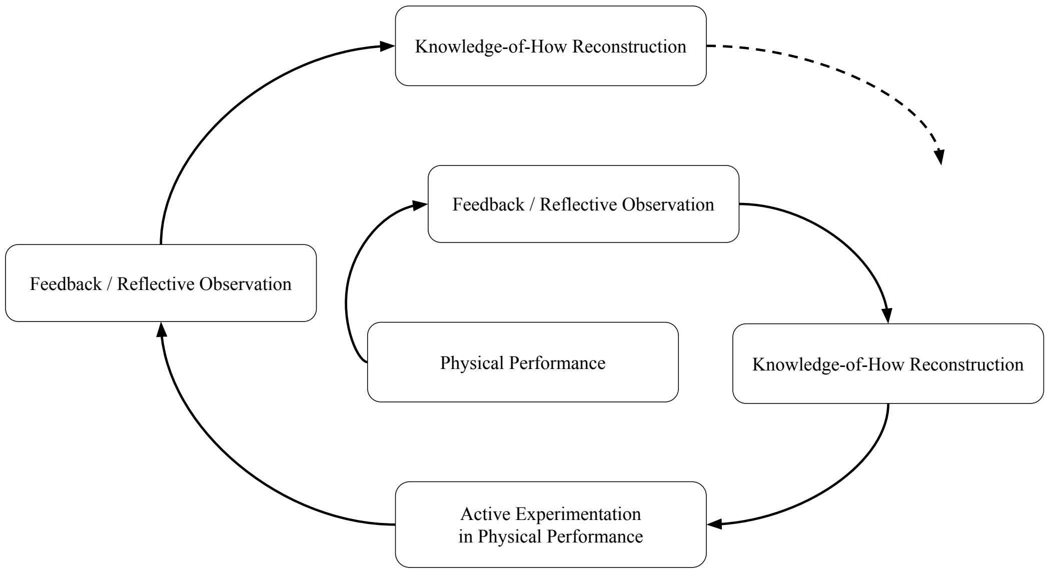

Figure 4.5 Role of feedback in motor skills acquisition.

4.5 Summary

This chapter described human memory and its role in supporting learning processes. We explained how motor skill acquisition occurs through procedural learning. We also emphasized the critical role of intrinsic feedback in motor skill acquisition. Since collaborative physical-recreation community members tend to work together to acquire their skills, the next chapter discusses how collaborative procedural learning occurs in these communities.

CHAPTER 5

MOTOR SKILL ACQUISITION THROUGH COLLABORATIVE PROCEDURAL LEARNING

We have argued in this dissertation that much of participants' procedural learning in collaborative physical-recreation communities (CPRC) does not only occur individually. Rather procedural learning in these communities is likely to be collaborative since members tend to work together in acquiring their motor skills. This chapter reviews existing knowledge in this domain to examine how motor skill acquisition occurs through collaborative procedural learning in CPRC. We define collaborative procedural learning as processes in which individuals collaborate in procedural learning by engaging in direct interpersonal interactions.

Collaborative procedural learning centers on feedback exchange among individuals. The previous chapter discussed feedback as information that results from executing specific sequences of tasks in physical performance (McMorris, 2014). We explained the significant role of intrinsic feedback, to which individuals have access through their sensory feedback sources. Another form of feedback is extrinsic feedback, which is information about physical performance from an external source (Fredenburg et al., 2001). In formal settings, external sources of feedback tend to be instructors (e.g., teachers, coaches), who manage learner's physical performance and learning (Magill, 1994). For example, a volleyball coach provides a player with extrinsic feedback when they tell the player to correct their body form when serving a ball.

Within the informal and semi-formal settings of CPRC, community members usually do not have access to instructors. Thus, they may facilitate their motor skill acquisition through collaborative procedural learning: they interact with other members and seek feedback from them (Casey & Goodyear, 2015; Dillenbourg, 1999; Dyson & Casey, 2016; N. J. Hodges & Williams, 2012; Slavin, 1980). Feedback exchange among community members is a complex process, since it entails both conscious and unconscious forms of knowledge (Nonaka & Takeuchi, 1991). It also includes community members observing each other's body movements and communicating information about the movements (McMorris, 2014). This chapter first explains the importance of feedback exchange for improving individual and team performance in CPRC. We then present a hypothetical scenario to illustrate collaborative procedural learning in a beach volleyball community setting. Lastly, we discuss the main takeaways from the hypothetical scenario regarding collaborative procedural learning processes.

5.1 Importance of Feedback Exchange for Improving Individual and Team Performance

Extrinsic feedback is critical in making individual and team performance improvements in CPRC. Individuals can use feedback from other community members to identify improvement areas in their individual motor skills and determine how to address those improvement areas (de Laat & Simons, 2002). For example, a beginner volleyball player may seek advice on how to improve their technique from an expert in their community.

Feedback exchange also benefits teams in CPRC. Teammates can frequently exchange feedback to improve each other's individual motor skills. For instance, a team of volleyball players give each other feedback after a match on how to improve their individual technique. Teammates may collaboratively identify an improvement area in their team performance. For example, two beach volleyball teammates discuss and decide how to pass the ball better. Teammates can also seek feedback from an external source on how to improve their team performance. For example, a team of volleyball players play a match in a tournament. After the game, they engage in a conversation with an expert about improving their team coordination.

The next section presents a hypothetical scenario describing how collaborative procedural learning occurs in CPRC through community members exchanging feedback.

5.2 Hypothetical Scenario of Collaborative Procedural Learning in CPRC

We illustrate what collaborative procedural learning looks like through the following scenario: Alice and Bob participate in community activities as a team (e.g., as a beach volleyball team playing at a co-ed tournament). In their first match in the tournament, Bob does a bad serve, but he scores. This is a teachable moment for Bob because he realizes that he wants to improve his serving skills. He is asking Alice for feedback on how to improve. Alice has previously observed how Bob served, and she has a “mental image” of how the body movements are supposed to look like when serving. She compares her mental image with Bob’s observed body movements. Alice then articulates and communicates her analysis with Bob as feedback. Bob listens to Alice’s feedback and decides to follow her advice.

At some later time, Alice and Bob are playing their second match. Ramy, a high-skilled beach volleyball player, also happens to be sitting by the court watching their game. During an intense point of the game, Alice makes a dive, getting the ball to Bob, which he sets for Alice up for a spike, but she does not get a kill (i.e., the opposing team returns the ball). This is a teachable moment for both Alice and Bob, as they want to improve their team coordination. They ask Ramy for feedback. Ramy experiences a sense of community and feelings of attachment to community members. Thus, he agrees to help Alice and Bob. He has observed their movements. He compares the observed movements with his mental image of the movements. He shares his analysis with them as feedback. Alice and Bob listen to Ramy's feedback and decide to follow his advice.

5.3 Collaborative Procedural Learning Processes

As illustrated in our scenario, *teachable moments* can be defined as concrete instances, in which community members want to improve their motor skills. Through examples, we highlighted that community members' personal, physical, and social contexts identify teachable moments of their physical performance. Accordingly, detecting these types of contextual information may allow identifying teachable moments and supporting collaborative procedural learning among community members.

When community members experience teachable moments and want to improve their motor skills, they may seek feedback from others in their community. While they have access to intrinsic feedback through their sensory feedback sources, extrinsic feedback from an external source allows them to complement their intrinsic feedback and better learn the movements.

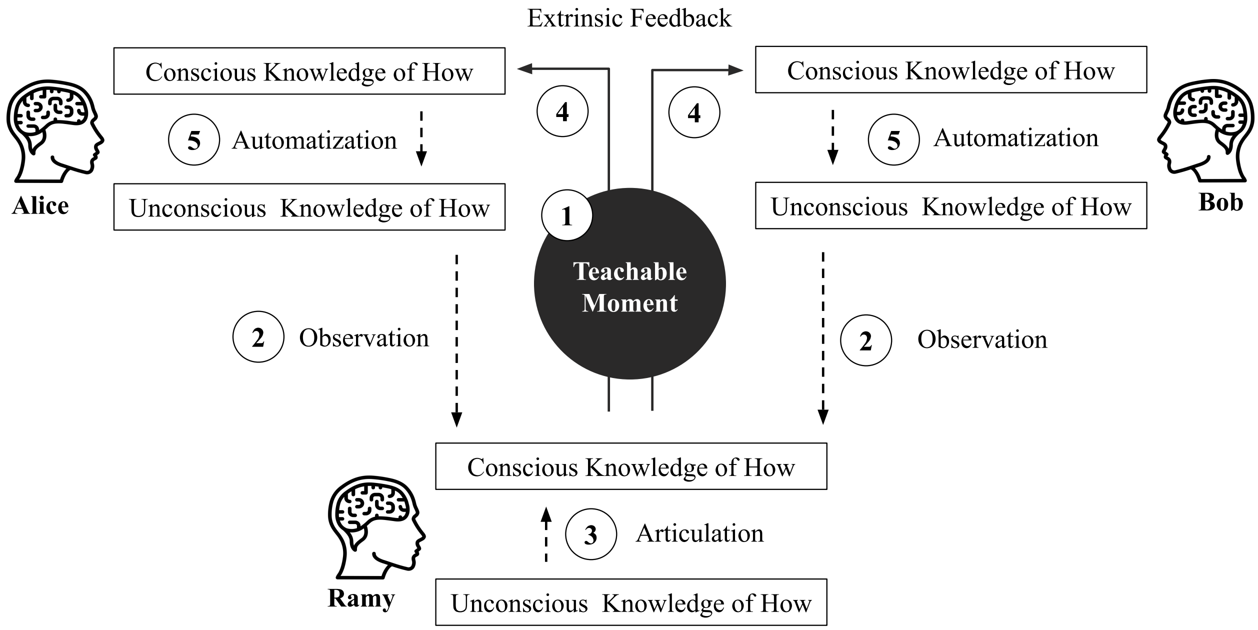

Figure 5.1 Collaborative procedural learning processes.

The scenario also illustrated feedback exchange processes in CPRC through observation and subjective analysis of movements and communication among community members about the movements (see Figure 5.1). The giver of feedback first observes others community members' movements to form conscious knowledge-of-how from their motor skills. The giver of feedback also transforms their own unconscious knowledge-of-how into the conscious form to create a mental image of how the movements are supposed to look. The giver of feedback then conducts subjective analyses of the observed movements by comparing and contrasting their observations and their mental image of the movements. They then provide feedback to the receiver(s) of feedback by sharing their analysis in the form of detailed and specific information about the movements.

The scenario of collaborative procedural learning also showed that a sense of community among members might encourage them to exchange feedback. Community engagement and activity participation create interrelationships and social structures, supporting community members' sense of community. Those who experience a sense of community may be more willing to rely on others in their community for feedback. They may also decide to show their attachment to their community and its members through actions, including providing feedback and helping other members.

5.4 Summary

This chapter explored motor skill acquisition through collaborative procedural learning in CPRC. We emphasized the importance of feedback exchange in this type of learning. Through a hypothetical scenario of collaborative procedural learning, we explained how such processes occur. The takeaways from the scenario highlight various opportunities for facilitating collaborative procedural learning, including through technological innovation. The next chapter reviews available technologies and explores their limitations. Chapter 9 outlines the requirements for technological innovation supporting collaborative procedural learning in CPRC.

CHAPTER 6

TECHNOLOGIES IN SUPPROT OF PROCEDURAL LEARNING

Our literature review of motor skill acquisition and collaborative procedural learning highlighted several opportunities for supporting learning in collaborative physical-recreation communities (CPRC) through technological innovation. To create such technologies, we first need to understand existing available technologies and explores their limitations. In this chapter, we review technologies that are designed to support procedural learning, known as feedback systems (Gao, 2017; Kos & Umek, 2018). These systems provide feedback loops, which allow users to learn how to alter their actions based on biomechanical and physiological metrics for better health and performance (AAPB, n.d.) (see Figure 6.1). Biomechanical metrics are those that characterize body movements in physical performances, such as the acceleration, velocity, orientation, and angles of body segments (R. Bartlett, 2007). Physiological metrics are those that describe the states of human body, including heart rate, blood pressure, and temperature (Giggins et al., 2013).

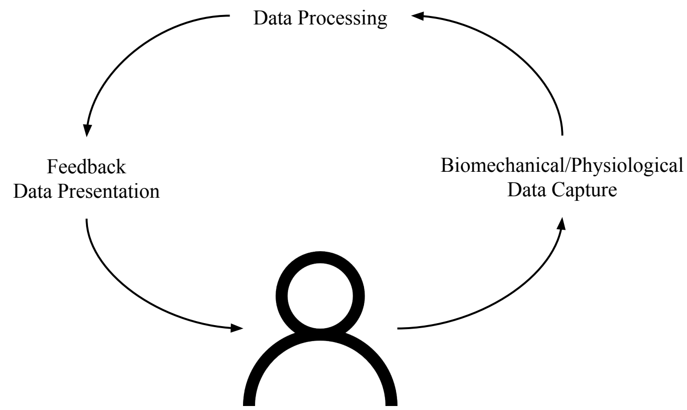

Figure 6.1 Feedback loop in feedback systems.

Feedback systems center on measuring biomechanical and physiological metrics that individuals: (a) are unable to measure through their body's sensory systems (e.g., visual, auditory, somatosensory systems), or (b) of which they are unaware (Kos et al., 2015). While individuals already have access to *intrinsic feedback* through their sensory feedback sources (e.g., how a violin player feels about their performance), feedback systems provide channels for *extrinsic feedback* (Magill & Anderson, 2012). For instance, a volleyball player may want to complement their already available sensory feedback by viewing summaries of their performance-related metrics through a feedback system.

Feedback systems have complex architectures and have significantly transformed over the years. This chapter examines feedback systems that center on providing their users with physical performance metrics. This dissertation argues that these feedback systems have incorporated features of ubiquitous computing technologies. Thus, to examine these systems, the chapter first reviews ubiquitous computing and its primary characteristics.

6.1 What is Ubiquitous Computing?

According to Weiser, Mark Weiser, a distinguished academic scholar, and former CTO at Xerox PARC, Ubiquitous Computing is the 3rd era of computing (Poslad, 2013; Weiser, 1991). He coined this term in his work, "the eras in computing," in which he described three major generations of computing technologies: (i) Mainframes, (ii) Personal Computing, and (iii) Ubiquitous Computing (Weiser, 1991). His goal was to distinguish a new type of computing technologies, i.e., ubiquitous computing technologies, that was fundamentally different from previous instantiations.

6.1.1 Background

In 1937, Alan Turing presented his vision of automated computing machines. His work led to the emergence of the first instances of computing technologies: mainframes and minicomputers. This era of computing, from the mid-1930s until the mid-1970s, is known as the *1st generation of computing*. In this era, computers were a scarce resource with a one-computer many-users model. The main applications of these computers were scientific calculation and data processing. Military and corporations adopted computers such as the Electronic Numerical Integrator and Computer (ENIAC), the Electronic Discrete Variable Automatic Computer (EDVAC), and IBM Selective Sequence Electronic Calculator (SSEC) to address their information needs (Moreau & Howlett, 1984). Educational institutions also used these computers for rapid evaluations of students' works in classrooms and providing them with programmed instruction (Dunkel, 1987; Hart, 1981; Hartley, 1974; Lockee, 2008; Skinner, 1960).

The Personal Computing (PC) era was from approximately the early 1970s until the mid-1990s. It was characterized by system designs that assumed a one-to-one ratio of computer to the user. As the 2^{nd} *generation of computing*, this era of computing was inspired by Vannevar Bush who set a fundamental goal for researchers in the field of applied computing and Human-Computer Interaction (HCI) in 1945 (Bush, 1945): to develop ways that augment people's ability to capture, recall, and reflect on information (Figure 6.2, left). He highlighted the need for proper information indexing among scientists due to their inability to track and find all the information that they needed. He hypothesized a machine that he named *Memex* as a solution to the problem that he raised (Figure 6.2, right). According to Bush, Memex allowed users to capture all forms of documents as well as lived experiences. Memex also supported the retrieval of the generated information when needed acting as a supplement to human memory. Bush pictured Memex as a machine like a desk which supported user interactions through two displays as output and levers and knobs, and a keyboard as input.

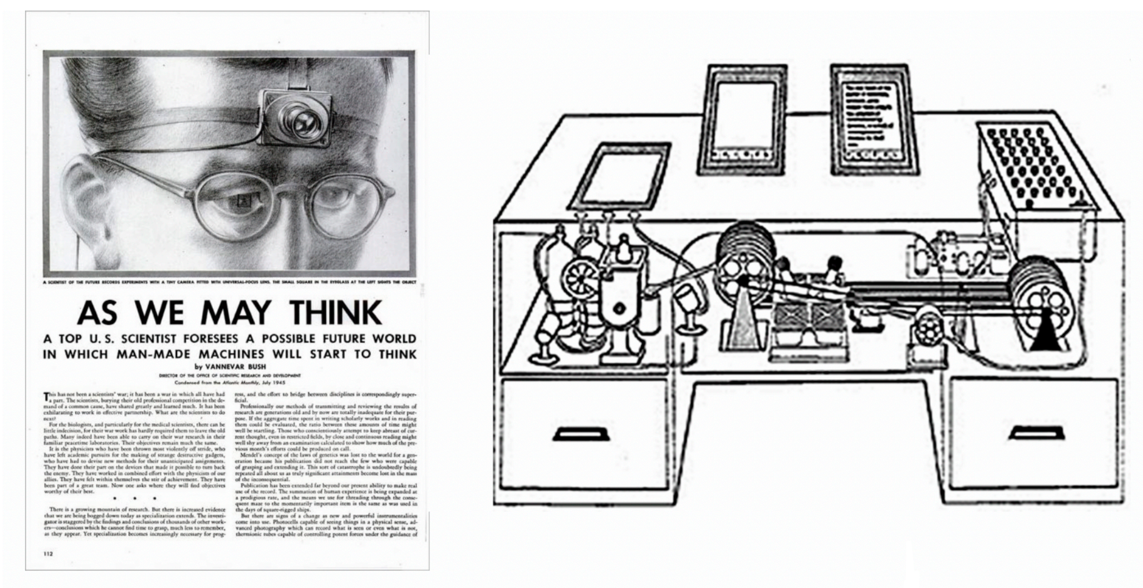

Figure 6.2 Cover of 1945 landmark paper (left) and Memex (right).

Bush's vision directly inspired the introduction of the *2nd generation of computing.* This era of computing was from the early 1970s until the mid-1990s, and it centered on Personal Computing (PC). It was characterized by system designs that assumed a one-to-one ratio of computer to the user. J.C.R. Licklider followed up on Bush's vision and published "Man-Computer Symbiosis" (Licklider, 1960). He proposed the development of computers that "enable men and computers to cooperate in making decisions and controlling complex situations without inflexible dependence on predetermined programs." It was a radical notion for 1960 that real-time interactive computing would replace mainframes. Engelbart (also inspired by Bush) wrote: "a conceptual framework" for "Augmenting Human Intellect" through computers (Englebrt, 2021).

The invention of microprocessors and the introduction of microcomputers in the 1970s boosted the implementation of Licklider's vision and led to the emergence of the first personal computer in the mass-market, Micro Instrumentation and Telemetry Systems (MITS) (Roberts & Yates, 1975). Engelbart's vision inspired the invention of bitmapped screens, the mouse, hypertext, and more. Many members of Engelbart's team eventually worked at PARC, where they continued to work on personal computers that augment their users (Kay & Goldberg, 1977). Over the years, personal computers became more personal and recognizable. In 1977, Apple II was introduced to the market. This computer was widely adopted in educational institutions (Gerald T. Gleason, 1981). Personal computers also became portable with the introduction of laptops with Toshiba T1100 (Kato & HattoriI, 1983).

In his work, Licklider also went on to propose that humans and interactive computers could be networked together to create online communities that would advance science and knowledge (Licklider & Vezza, 1978). This was instantiated as ARPANET.

In the late 1970s, ARPANET introduced TCP/IP (Transmission Control Protocol/Internet Protocol) as a set of standards for communication that occurs among networks of computers. These networks later became what we know nowadays as the Internet (Townes, 2012). In 1991, the number of computers connected to the Internet exceeded one million, and the introduction of the World Wide Web (WWW) facilitated access to information available through the Internet (Berners-Lee et al., 1992).

The 3rd era of computing, Ubiquitous Computing (Ubicomp), emerged as an entirely different class of computing technologies (Poslad, 2013; Weiser, 1991). Ubicomp was characterized by a one-to-many human to computer ratio, with user-computing services increasingly operating in the background. In the ubicomp era, the networking and miniaturization of computing devices led to a paradigmatic revolution in how people routinely interacted with computational devices. Such advancements also boosted the development of technologies that support implicit interactions. This feature of ubicomp technologies reduces information overload and distractions for users and provides them with connected, distributed, and transparently accessible resources (Poslad, 2013).

6.1.2 Relevant Features

Ubicomp technologies have specific features that differentiate them from computing technologies in the 1st and 2nd eras. This section reviews three critical features relevant to the scope of this dissertation: contextual data capture, tailored services, and adaptation.

Ubicomp technologies capture various types of contextual data, including users' biomechanical and physiological data and also data about users' environments (Poslad, 2013). Ubicomp technologies utilize this contextual data to tailor and customize their services. This allows the development of new classes of multi-platform applications based on users' data collected.

Ubicomp technologies incorporate *adaptation* to present intelligent services using user data. Adaptation is the process of personalizing and tailoring services and resources for users (J. R. Anderson et al., 1985; Brusilovsky & Millán, 2007; Specht & Oppermann, 1998). In contrast to 2nd generational instantiations of adaptation, which model users by examining the history of interactions (Brusilovsky & Millán, 2007), ubicomp technologies translate real-world data about users and their dynamic physical and social environments into models. Ubicomp technologies utilize these models to adjust, personalize, and customize their services and resources for users (J. R. Anderson et al., 1985; Brusilovsky & Millán, 2007; Specht & Oppermann, 1998). These technologies dynamically create and maintain four types of models in their adaptation processes (Bomsdorf, 2005) (see Figure 6.3):

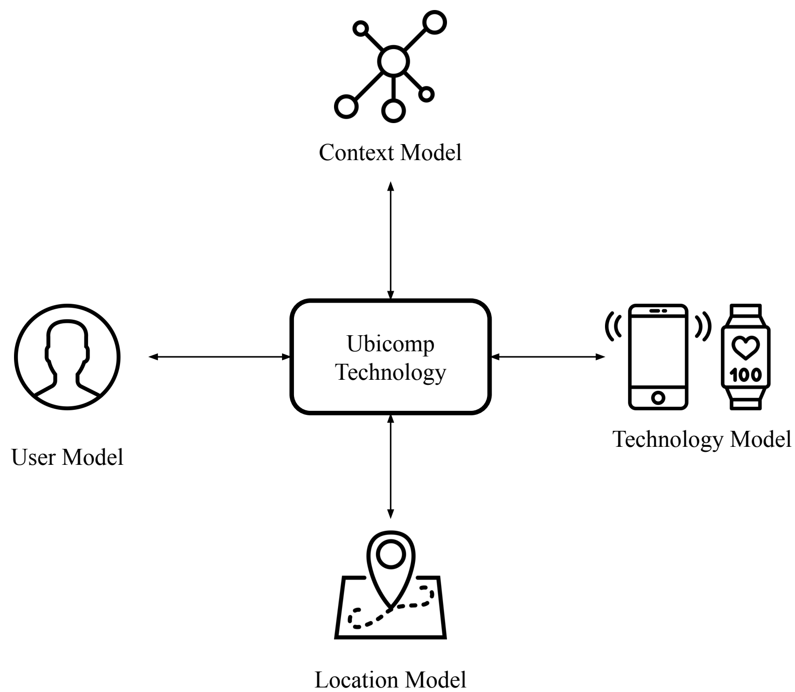

Figure 6.3 Models in ubicomp technologies.

1) The context model examines environments surrounding users, including their physical and virtual worlds as well as their goals and any available records on their previous interactions.

2) The location model incorporates data on users' location history and their current location.

3) The user model creates, maintains, and updates users' data-driven representations consisting of their performance metrics, and the levels of knowledge, abilities, and developed skills.

4) The technology model captures data on users' available technologies to tailor user experiences based on the specifications, capabilities, and supported features of their technologies.

6.1.3 In Support of Learning

These unique properties of ubicomp technologies have led to the emergence of various categories of technological innovation with the primary goal of supporting learning "anything, anytime, anywhere." This starts with mobile devices that allow individuals to take on more learning opportunities (Crompton, 2013; Njoku, 2016; O'Malley et al., 2005). Compared to personal computing technologies, mobile technologies are more tailored to their users' needs and allow users to be continuously connected. These features support the mobility of learners and facilitate their participation in learning activities at any time and in any location (Ayala et al., 2010; Kukulska-Hulme & Traxler, 2005).

Mobile devices also provided platforms for users to work together in learning and access shared computational resources regardless of their location (Rogers & Price, 2009; Sharples, 2000; Sharples et al., 2009). Scholars have highlighted the potentials of these platforms in facilitating motor skill acquisition, including in physical recreation (Milrad & Hoppe, 2012; Sharples et al., 2010). However, research in this area has been limited since the majority of studies in this area have focused on how supporting cognitive and affective domains of learning (Alavi, 1994; Daniel, 1999; Makkonen, 2000; Pate et al., 2000; Stocks & Freddolino, 2000; Webster & Hackley, 1997) and neglected the sensorimotor domain (Sharda et al., 2004).

6.2 Architecture of Feedback Systems

This section identifies the complex architecture of feedback systems and their components: biomechanical and physiological data input, processing and storage units, and feedback output (see Figure 6.4). In their architecture, feedback systems incorporate the features of ubicomp technologies to support feedback loops. This provides users with extrinsic feedback, allowing them to learn how to alter their actions based on biomechanical and physiological metrics for better health and performance (Kos & Umek, 2018).

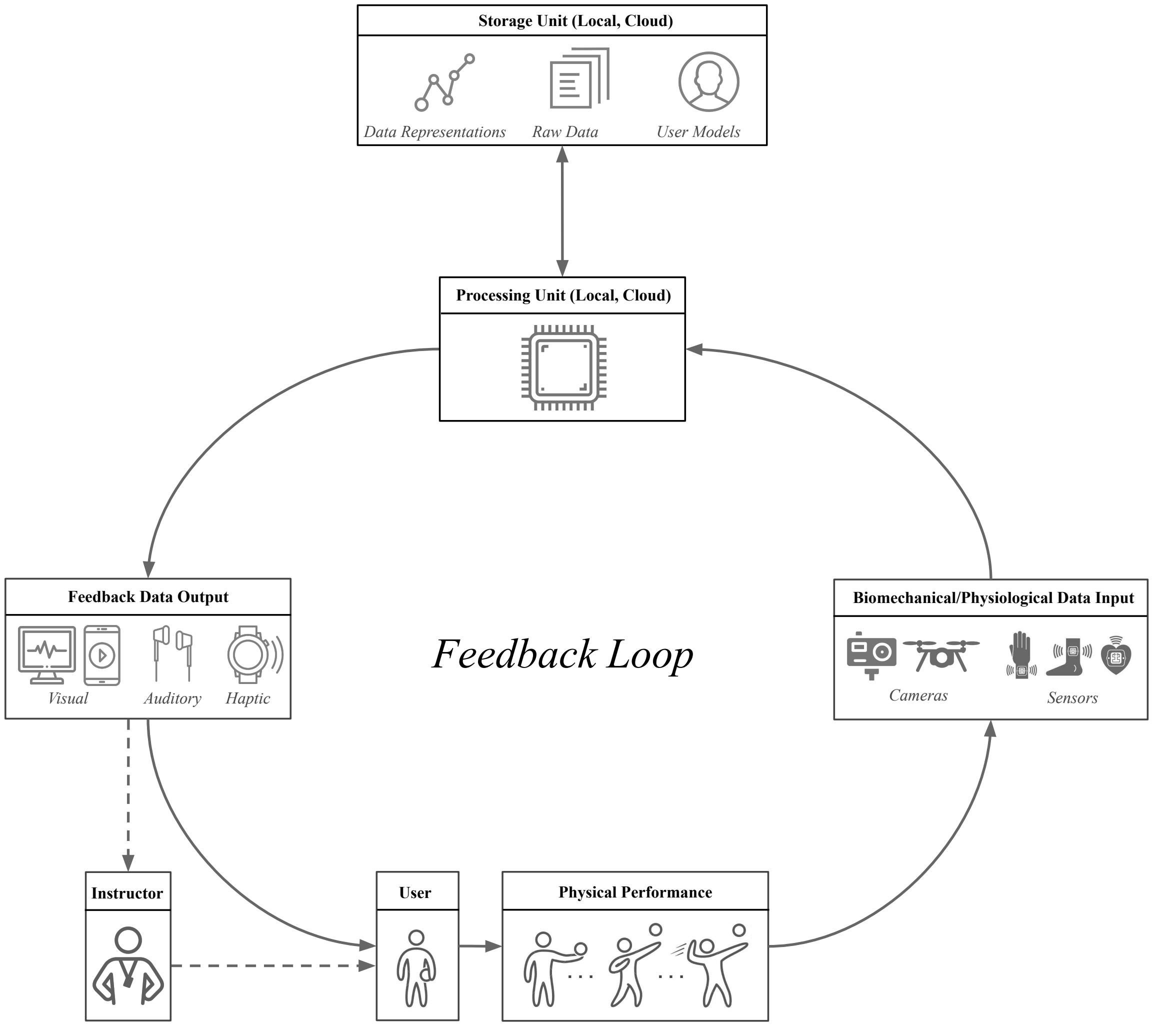

Figure 6.4 Feedback systems architecture.

6.2.1 Data Input

Feedback systems collect data from their users' life episodes. Feedback systems have incorporated cameras to capture biomechanical data in the format of video recordings (see Table 6.1) (Casey & Jones, 2011). This format of data supports detailed analyses of body movements in 3D spaces as users engage in physical performances (Kos & Umek, 2018).

Table 6.1 Use of Cameras in Feedback Systems

Cameras	Standalone Instantiation	Embedded Instantiation	Data
Active	Handheld cameras	Smartphones with built-in cameras	Third person footage
Semi-Active	Wearable and stationary cameras	Mounted smartphones with built-in cameras	First and third person footage
Passive	Wearable always-on cameras	N/A	eMemory with first person footage

Feedback systems have also incorporated a wide variety of sensors, usually as built-in features in mobile and wearable devices, to provide their services and functionalities (see Table 6.2) (Schneider et al., 2015). *Sensors* are defined as "physical or virtual objects used for tracking, recording, or measuring" (Poslad, 2013). By incorporating both biomechanical and physiological data from sensors, feedback systems provide users with extrinsic feedback and allow them to engage in sensor-based learning (Bennett, 2011; Drobny & Borchers, 2010; Sadler, 1998; Santos, 2016; Schneider et al., 2015; Specht, 2014) In most cases, sensors are embedded in wearable devices (e.g., fitness bands, smartwatches), although standalone sensors are also available on the mass-market (e.g., chest strap heart-rate monitors).

Table 6.2 Sensors in Feedback Systems

Sensor Type	Attributes Being Measured/Detected	Embedded Insanitation
Biomechanical sensors		
Accelerometer	Acceleration of body segments	Fitness bands (*FitBit*) Smart phones (iPhone) Smart watches (*Apple Watch)* Smart apparel (*OM Bra, PIVOT Yoga*) Sports equipment (*Zepp*)
Gyroscope	Angular velocity of body segments	Fitness bands (*FitBit*) Smart phones (*iPhone*) Smart watches (*Apple Watch)* Smart eyewear (*Vuzix Blade*)
Integrated (IMU)	Body orientation, position, and velocity	Wristbands (*Motus*) Footpods (*Runscribe*) Smart apparel (*Plantiga insole*, *Vert belt*)
Physiological sensors		
Heart-rate sensor	Heart-rate pulse	Fitness bands (*Fitbit*) Smart watches (*Apple Watch, Samsung Gear*) Smart apparel (*Hexoskin*)
Temperature sensor	Body temperature	Smart watches (*Acumen*) Smart wristbands (*E4/Empatica*) Smart rings (*Oura*)

6.2.2 Processing and Storage

Feedback systems have processing units at their core (Kos & Umek, 2018). These units process biomechanical and physiological data collected from cameras and sensors to generate feedback for users. Feedback systems have also incorporated storage units, allowing them to store incoming data from cameras and sensors and processing units. The stored data can range from raw user data to transformed forms of data such as user models and data-driven representations showing users' performance metrics and skill levels (Giggins et al., 2013).

Processing and storage units in feedback systems appear in various forms. They can be accessed on computers (e.g., locally set up laptops) as well as multi-purpose portable and wearable devices (e.g., smartphones, smartwatches). With the emergence of cloud computing infrastructures, cloud-based processing and storage units have also become widely available. Feedback systems that use these units have access to infinite bits and cycles (Badawi et al., 2017). This feature allows these systems to support thorough longitudinal analyses of users' biomechanical and physiological data and continuously provide users with extrinsic feedback.

6.2.3 Feedback Output

Feedback systems incorporate various forms of devices to present information as feedback to users. The most common type of feedback output devices in these systems are displays (e.g., laptops, smartphones, and smartwatches screens). These devices engage users' sense of sight and allow them to examine and interact with their data. Other forms of feedback output devices engage users' sense of touch (e.g., haptic devices) and hearing (e.g., headphones). Compared to the displays, these devices can provide users with extrinsic feedback without interrupting their engagement in activities. Feedback systems may also allow users to use more than one feedback output device if necessary.

6.3 Feedback Systems within Informal and Semi-Formal Settings

Feedback systems have allowed individuals to capture their biomechanical and physiological data and receive extrinsic feedback. Over the years, instantiations of these systems from lifelogging to QS systems have emerged in the mass market to create new opportunities for supporting learning and performance.

Lifelogging refers to the process of gathering, processing, and reflecting on life experience data (Gurrin et al., 2014; Sellen et al., 2007). The traces of lifelogging as a concept go back to 1945 when Vannevar Bush introduced Memex discussed earlier in this chapter (Bush, 1945). The initially stated goal of lifelogging was to provide a digital tool that augmenting learning, performance, and community. Bush's vision led to the development of two classes of lifelogging technologies (Sellen & Whittaker, 2010): (1) passive lifelog technologies that aim for a "complete record of everyday life, capturing as many kinds of data as possible, as continuously as possible" (e.g., SenseCam (S. Hodges et al., 2006)), and (2) active and semi-active lifelog technologies that are situation-specific and allow users to capture rich data, as entirely and automatically as possible, for specific activities in specific contexts.

While this rich original understanding of what it means to lifelog has been adopted by many (e.g., DARPA lifelog (Sniffen, 2003)), numerous other authors have used the term 'lifelogging' to refer to "self-tracking" or "self-quantification. We define self-tracking as the practice of individuals using sensor data to track and analyze information about their everyday lives.

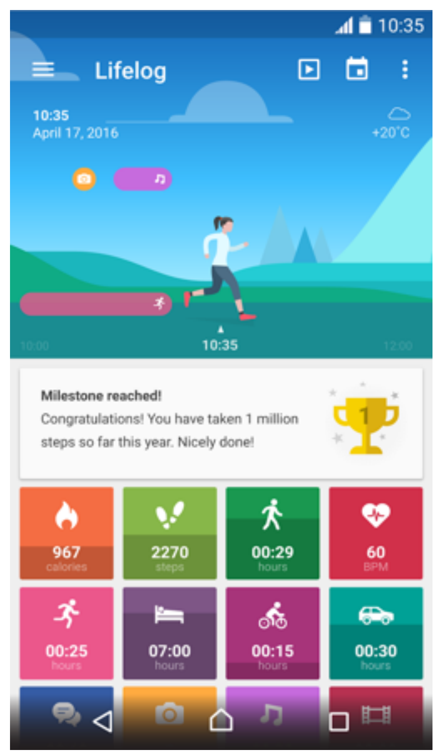

Figure 6.5 Example for self-tracking using QS systems.

A major boost in the development in this area occurred through the *Quantified-Self (QS)* movement (Wolf, 2010), which mainstreamed a plethora of self-tracking technologies (Figure 6.5 shows an example). Today, millions of individuals use wearable or regularly carried portable devices such as smartphones, to record and store information about their everyday lives automatically. The QS movement highlights that self-knowledge can be gained through self-tracking enabled measurements, and it has led to the development of a variety of QS systems.

QS systems are feedback systems that facilitate users' access to their quantified performance-related data (e.g., sleep quality (Singer, 2011), blood glucose (Sifferlin, 2017)) to bring them self-knowledge on which they can act (Kelly, 2016; Times, 2013). Today, QS systems are widespread, incorporating wearable, mobile, deployable, and embedded technologies to self-track almost every aspect of their lives. These systems provide gateways to their cloud-based accompanying services, which generate additional insights for users about their captured data (Kuniavsky, 2010; Sullivan, 2016).

Scholars have highlighted three main types of extrinsic feedback that QS systems can provide (Hattie & Timperley, 2007; Schneider et al., 2015; Specht, 2014):

a) Goals: QS systems provide users with information on whether they have achievable and reasonable goals and whether they have shown adequate levels of commitment needed to achieve the goals (Bargh et al., 2001). This information also allows users to set and adjust their goals (E. A. Carroll et al., 2013).

b) Progress: QS systems generate information on where users stand in relation to their goals and how to continue to achieve them based on the comparisons of pre-defined criteria. This information helps users to examine their progress, understand the underlying reasons behind their progress, and receive positive reinforcements when they succeed (Schneider et al., 2015).

c) Direction: QS systems provide users with information on the sequences of steps that the users have taken in their journey and also their potential courses of action (Sadler, 1998; Javier Vales-Alonso, Ĺopez-Matencio, et al., 2010).

Over the years, QS systems have also moved on to focus on performance metrics in physical recreation such as running (Kelly, 2016) cycling (Matassa et al., 2013), climbing (Fritz et al., 2014), and working out (Wang et al., 2015) (See Figure. 4.5). QS systems have also allowed their users to form online communities of self-trackers who participate in similar activities (e.g., Strava[1] for cyclists (West, 2015), MapMyRun[2] for runners). In these communities, users engage in *online communal tracking* practices, consisting of exchanging performance-related data and communicating with other members (Lupton, 2014).

To provide users with extrinsic feedback about their physical performance, QS systems may either rely on machine-generated information about the users or interpersonal interactions among users (Gedye, 2010; Schneider et al., 2015). QS system users may individually use this feedback to reflect on and improve their current physical performance level (Consolvo et al., 2008).

6.4 Feedback Systems in Formal Settings

The research community, as well as technology companies, have proposed and developed a variety of feedback systems that particularly focus on motor skill acquisition within formal settings. These technologies incorporate cameras (e.g., GoPros) as well as sensors, including accelerometers, gyroscopes, and inertial measurement unit (IMU) sensors (Bell & Gemmel, 2010; Bevilacqua et al., 2007; Mann, 2004; Van Der Linden et al., 2011). The primary goals of feedback systems within formal settings are (a) to transform how

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[1] https://www.strava.com/ (accessed Jan. 2021)
[2] *https://www.mapmyrun.com/* (accessed Jan. 2021)

learners perform and acquire motor skills, and (b) to support more effective learning strategies and potentially bring learners healthy lifestyles (Gard, 2014). This section examines feedback systems that center on physiological data (e.g., heart rate, body temperature). We then investigate systems that are specifically designed for the capture and review of biomechanical data, namely, motion capture systems, and video analysis software (Baek et al., 2018; Burton, 2018).

6.4.1 Physiological Sensors

Feedback systems allow instructors to use physiological data from sensors to analyze physical performances and provide feedback to learners (Kuklick & Harvey, 2018; Woods et al., 2008). For example, physical education teachers may use heart-rate monitors to examine their students' health when the students engage in intense exercises. Teachers can use these sensors to examine students' recovery time after specific exercises by capturing the students' heart-rate before and after the exercises. When students also have access to this data, they will be able to use it in their self-directed learning and plan and prepare for upcoming physical education classes.

6.4.2 Motion Capture Systems

Motion capture systems are a class of technologies widely used in athletics (Molías et al., 2017; Pueo & Jimenez-Olmedo, 2017) and sometimes in physical education (Molías et al., 2017; Zhier, 2016). This section examines these systems as a type of feedback systems. Motion capture systems rely on biomechanical data instead of physiological metrics. They provide feedback loops through two main processes: (1) capturing and tracking learners' total body movements in 3D spaces during physical performances, and

(2) transforming body movement data into usable information for instructors and learners. These processes particularly provide instructors with complete renderings of how learners move their body segments in physical performance. By using this information, instructors can objectively and subjectively analyze learners' physical performances and provide them with in-depth feedback on their motor skills and body movements.

Data transformations in motion capture systems do require heavy information processing. Initial instantiations of these systems did not have the necessary information processing capabilities for providing real-time feedback to instructors and learners (Kos & Umek, 2018). Thus, they aimed to provide feedback for the summative assessment of physical performances. However, with technological development in computing technologies and the emergence of cloud computing technologies, several motion capture systems nowadays can provide real-time feedback for formative assessments (Windolf et al., 2008).

Based on technologies that motion capture systems incorporate to capture data and also their data transformation methods, they emerge in three primary forms: *inertial systems, optical marker-based systems, and optical marker-less systems* (see Figure 6.6). Inertial motion capture systems use inertial sensors (i.e., accelerometers, gyroscopes, magnetometer, and IMU sensors) to capture body movements (e.g., the Xsens motion capture system) (Chambers et al., 2015). Applications of these systems are widespread and cover both open and closed spaces. They mainly quantify biomechanical data from sensors and present back to instructors and learners in a variety of formats.

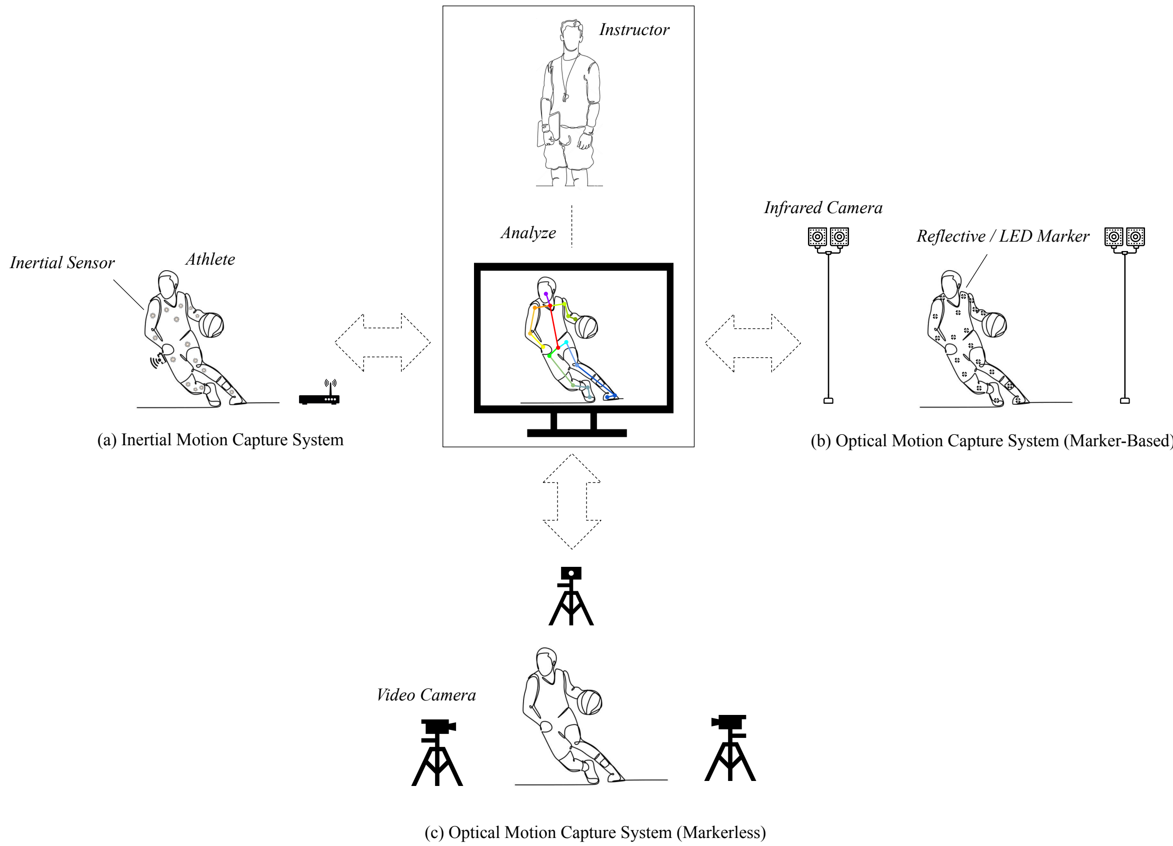

Figure 6.6 Types of motion capture systems.

Sensors that are used in inertial motion capture systems are either standalone (e.g., a chest strap IMU sensor) or embedded into wearable devices (e.g., a fitness band). For instance, Kwon and Gross (2005) presented Motion Chunk that supports taekwondo training by integrating data collected through wearable accelerometers and providing real-time motion analysis. This feature allowed instructors to help learners enhance their both dynamic and static gestures. In another example, Takahata et al. (2004) designed and developed a motion capture system for karate training and learning. Their system captures biomechanical data through wearable devices with embedded accelerometers that are put on wrists, ankles, and waists. The applications of these motion capture systems are also common in analyzing dance performances and have been extensively explored by John Crawford and colleagues in the Embodied Media Studio[1] at the University of California, Irvine (Crawford, 2005).

Optical motion capture systems, also known as camera-based motion capture systems, use cameras to record and trace body movements (Cao et al., 2018; Corazza et al., 2006). *Optical marker-based systems* incorporate multiple cameras with reflective or LED markers put on body segments (e.g., the Vicon motion capture system) (Windolf et al., 2008). In systems with reflective (or retroreflective) markers, cameras with infrared lights illuminate the markers tagged on body segments. The cameras then detect the markers' reflected light, which allows them to capture and track the position of the markers and, thus, body movements. Motion capture systems with LED markers track body movements by using cameras that measure the light that is emitted by the markers.

The primary form of output in all types of motion capture systems is visualizations of body movements and spatial positions of body segments in 3D spaces. These visualizations entail animations with skeletons and human and stick figures. Instructors can use frame-by-frame and slow-motion features to view the visualizations. These features allow the instructors to conduct the qualitative analysis of body movements, which includes systematic observations of the quality of movements performed in physical performances (R. Bartlett, 2007). Instructors may also use the visualizations to determine how to provide interventions for better learners' performance (e.g., feedback, new teaching methods).

Several motion capture systems also provide performance metrics that allow instructors to conduct quantitative and semi-quantitative analyses of physical

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[1] https://embodied.net/ (accessed Jan. 2021)

performances. For example, a coach who uses a motion capture system may examine both total body movement visualizations and metrics such as the timing of the movements and the acceleration and velocity of body segments. Instructors may also choose to conduct statistical and mathematical modeling of performance metrics that are available to them to investigate possible correlations between the metrics and learners' physical performances.

6.4.3 Video Analysis Software

A variety of software has emerged over the years to use data from cameras and support the video analysis of physical performances (Baca et al., 2009; Jensen et al., 2015; J. Vales-Alonso et al., 2012; Javier Vales-Alonso, López-Matencio, et al., 2010; Walkwitz & Cefalu-Walkwitz, 1998). This supports reviewing students' and athletes' mistakes and providing them with visual examples of correct body movements in physical performances (GilGarcia & Villegas, 2003). For instance, Wilkinson and Hillier (Wilkinson et al., 1999) proposed video analysis software for supporting learning volleyball among female high school students. Their solution included analyzing the videos of student performances from cameras to review their (un)successful moments in tournaments and calculate and compare the success rates of their forearm setting, passing, and overhead and underhand serving.

Video analysis software has also created new opportunities for physical education students and athletes to seek feedback from their peers and instructors through interpersonal interactions. These technologies allow students and athletes to capture their performances in private and/or in classrooms with the help of their instructors and later receive video feedback on various aspects of their performance. Since evaluating every student in person tended to be time-consuming and students and athletes may not be allocated enough time, these technologies provided new ways for them to receive more attention from their instructors, enhance their learning through instant, objective, and precise feedback, and improve their motivation (Heynen, 2008).

Video analysis software has also provided instructors opportunities evidence-based feedback (Baca et al., 2009; Jensen et al., 2015; J. Vales-Alonso et al., 2012; Javier Vales-Alonso, López-Matencio, et al., 2010). As an example, the study conducted by Case and Jones (Casey & Jones, 2011), illustrates various scenarios for students utilizing these technologies to improve their learning.

The mass-market has also provided several instantiations of video analysis software for both physical education and athletics. Mobile applications such as Dartfish, Hudl, and Coach's Eye, allow instructors to use videos for providing their students with feedback (Kok & van der Kamp, 2018; Tearle & Golder, 2008). For example, Dartfish provides video analysis, instant reply, and live capture features which instructors use to help learners (Harris, 2009). Coach's Eye[1], shown in Figure 6.7, allows learners to record, analyze, and exchange videos of their performance through multiple platforms. This feature allows teachers/coaches to share the videos with others (e.g., students' parents). They can also review the videos to give students feedback on various parts of their performance. This application allows instructors to annotate the videos to illustrate precisely the parts of performances to which they believe learners need to pay attention.

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[1] https://www.coachseye.com (accessed Jan. 2021)

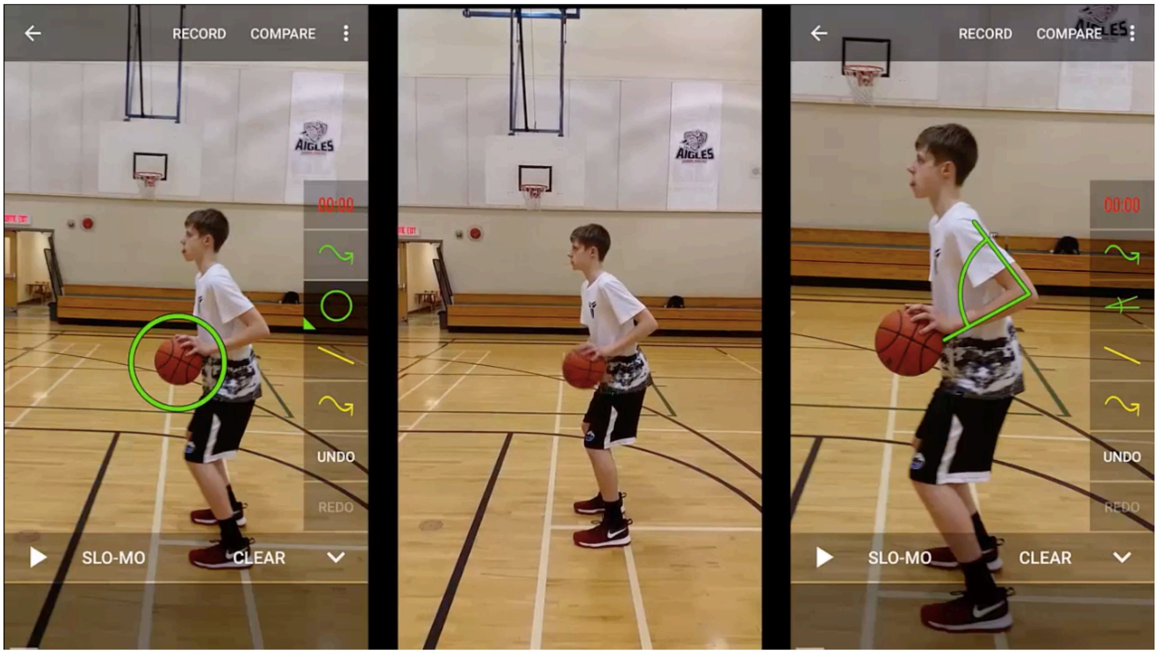

Figure 6.7 Coach's Eye application supporting video analysis in physical education.

6.5 Summary

This chapter explained feedback systems and how these technologies provide users with extrinsic feedback about their performance in the form of physiological or biomechanical data. We showed that QS systems tend to be the only available feedback systems focusing on physical recreation. Due to their ego-centric nature, these solutions provide limited support for motor skill acquisition in collaborative social contexts, including collaborative physical recreation in CPRC. Lack of research on these limitations and how to address them has led to a gap in our understanding of the requirements for technologies supporting collaborative procedural learning in CPRC. These limitations are the motivating problem which this dissertation addresses. Next, we present our research plan for addressing this gap of knowledge.

CHAPTER 7

RESEARCH PLAN

This chapter presents the research plan of this dissertation based on previous literature (Chapters 2,3,4, 5, and 6). Our literature review revealed that collaborative physical recreation communities (CPRC) support participation in collaborative physical recreation. We highlighted that community members' procedural learning tends to be collaborative since performance requires members to work together to a large degree. We also explained that available QS systems have primarily centered on capturing and presenting individuals' quantified performance metrics. These technologies represent ego-centric solutions for enhancing individual performance and learning, and thus, they provide limited support for collaborative procedural learning. This dissertation aims to investigate the requirements for systems that enhance collaborative procedural learning in CPRC. Our empirical research plan in the dissertation is designed to support this investigation.

7.1 Research Questions

This section presents the research questions in this dissertation for conducting a multi-layered inquiry revolving around collaborative procedural learning in CPRC and technological innovation supporting this type of learning. Our first group of research questions examine engagement with CRPC, members' procedural learning, and the use of existing technologies for their learning:

> *RQ1:* *Why do individuals engage with CPRC?*

RQ2: *What types of intrinsic or extrinsic feedback do community members use for procedural learning?*

RQ3: *How do community members use current technologies to gain extrinsic feedback and support procedural learning?*

In Chapter 5, we explained existing literature on collaborative procedural learning in CPRC. The second group of our research questions expand knowledge in this domain and set a direction for our technological innovation for supporting collaborative procedural learning:

RQ4: *What community-based processes support collaborative procedural learning in CPRC?*

RQ5: *What do individuals identify as teachable moments?*

RQ6: *What is the perceived utility of viewing videos of teachable moments?*

The last research question supports a comparative evaluation of proposed solutions emerging through our empirical research to QS system as existing solutions for gaining extrinsic feedback in the informal and semi-formal settings of CPRC:

RQ7: *What are the perceived benefits of our proposed solutions compared to existing QS systems among community members?*

7.2 Collaborative Physical-Recreation Communities under Study

This dissertation examines collaborative procedural learning in two main categories of collaborative physical recreation: volleyball and dance. CPRC in this investigation are local on-campus and off-campus communities that focus on these activities. This section indicates specific CPRC whose members are subjects in this inquiry.

7.2.1 Recreational Volleyball Communities in New Jersey

We engaged with two distinct recreational volleyball communities and supporting volleyball organizations in New Jersey: (1) the New Jersey Beach Volleyball Community, focusing on beach volleyball, a 2 versus 2-team sport played in local parks, backyards, and beaches, and (2) the NJIT Indoor Volleyball Community, focusing on indoor volleyball, a 6 versus 6-team sport played at gymnasiums. The engagement with (1) was via Great American Volleyball (GAV), the body that manages recreational beach volleyball tournaments and leagues on the Jersey Shore; The engagement with (2) was via the NJIT Volleyball Club, the body that manages recreational volleyball activities and hosts social meetups at the New Jersey Institute of Technology.

Community members gather to play recreational volleyball, to regularly interact, and to engage in volleyball-related and social activities. During their gatherings, they collaboratively perform and exercise volleyball skills (e.g., passing, serving, blocking, digging, and setting). These communities may also be part of broader social systems, including nationwide and international volleyball communities.

7.2.2 Recreational Dance Communities in New Jersey

We examined dance as a form of collaborative physical recreation via engagement with two communities: (1) the NJIT Dance Community, focusing on multiple styles of dance, including Jazz and Hip Hop, and (2) the New Jersey Filipino Dance Community consisting of several dance teams including (a) NJIT Purple Dancers, organized by the

NJIT Filipino Student Association with annual performances at the NJIT Rain or Shine Dance Competition, and (b) Flash DT Dance Team organized by the Filipino League at Seton Hall (FLASH) with annual performances at the Seton Hall University FLASH Dance Competition. Our engagement with (1) was via the NJIT Dance Team, the main dance team organized by the Athletic Department at the New Jersey Institute of Technology as intramurals. Community members perform during on-campus men's and women's basketball games as well as at philanthropic events and showcases throughout the academic year. Our engagement with (2) was through the captains who oversee both teams' recreational activities and training.

These communities center on various styles of dance. They consist of interrelated and co-located groups of dancers who are socially connected and interact and engage with one another. Members participate in community activities to collaboratively learn and perform dance movements. These communities may also go beyond their geographic boundaries by expanding their scope, participating in events in broader areas, and diffusing their dance culture and traditions.

7.3 Research Plan

Based on the research questions above, we present our research plan consisting of four empirical research studies (see Figure 7.1).

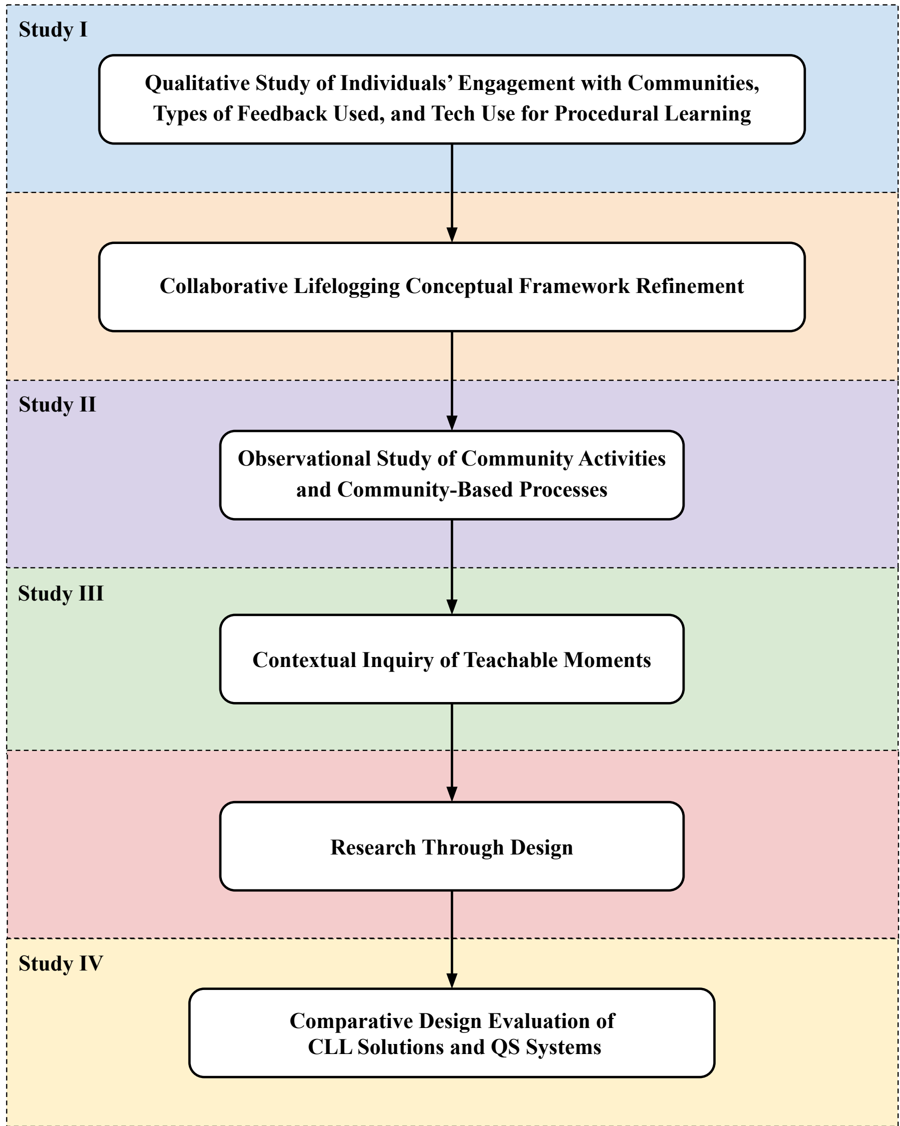

Figure 7.1 Research plan overview.

7.3.1 Study I

The first study is a qualitative study consisting of semi-structured interviews and diaries. It examines why individuals engage with their communities, the types of feedback they use, and their use of available technologies for procedural learning. We conduct semi-structured interviews with members of the recreational beach volleyball and dance communities. We also ask community members to use diary forms and provide self-reported data over two weeks. In addition, we conduct diary follow-up interviews to evaluate information logs that community members provide and co-explore the meaning, details, and unexplored aspects of the diary forms.

7.3.2 Collaborative Lifelogging Conceptual Framework Refinement

We translate the literature review insights and empirical research findings into a conceptual framework of Collaborative Lifelogging (CLL) as a class of 4^{th} generational lifelogging systems that support collaborative procedural learning in CPRC. We also identify the primary processes in CLL solutions.

7.3.3 Study II

The second study is an observational study of existing community-based processes for collaborative procedural learning. In the study, we conduct observational visits to community activity sites in the recreational volleyball and dance communities. During the visits, we use an ethnographic lens to examine interpersonal interactions among community members and how they help another with learning. We take field notes to capture a detailed view of each observational visit and navigate specific interpersonal interactions relevant to learning. We use interaction analysis methods to interpret our observations. Our approach allows us to immerse into the context of community members and helps us gradually build rapport with them for our subsequent studies. Our findings shed light on how to support community-based processes for collaborative procedural learning in CLL solutions.

7.3.4 Study III

The third study is a contextual inquiry of teachable moments. We video capture community activities in the NJ beach volleyball community and ask members to identify moments of the activities with wireless event triggers. We use data from the cameras and event triggers to create video tours, showing chronologically ordered sequences of identified moments. We conduct collaborative video viewing sessions with community members. In each session, we collaboratively explore video tours to understand what moments they identify and investigate the perceived utility of capturing and viewing those moments. The insights from this study inform how CLL solutions should capture community members' teachable moments, and how to present them back to users.

7.3.5 Research through Design

We then use a research-through-design approach to create prototypes that represent the main functionalities of CLL solutions and QS systems. We use a CLL user interface design process to translate our literature review insights and findings from Study I-III into user interfaces that supported collaborative procedural learning in the NJ beach volleyball community. The design process includes defining personas and pre-intervention scenarios, ideating post-intervention scenarios, and doing iterative user-interface prototyping. In order to be able to compare CLL solutions and QS systems, we also use our literature review insights to create prototypes that represent the functionalities of QS systems for supporting beach volleyball players' performance and learning.

7.3.6 Study IV

The final study evaluates the design of CLL solutions compared to QS systems using scenario-based video prototyping. We turn our CLL, and QS designs into scenario-based video prototypes, which simulate user interactions with CLL solutions and QS systems in real-world environments. We then conduct walkthroughs sessions with beach volleyball players. We present our scenario-based video prototypes to the players during these sessions and explain how they would interact with the technologies. We collect qualitative data and examine how players think about the comparative utility of the CLL solutions and QS systems. This study rounds up this dissertations' contributions by providing insights on each innovation's support of collaborative procedural learning in CPRC.

7.4 Impacts of the COVID-19 Pandemic on Research Plan

The COVID-19 pandemic interrupted community activities in the recreational volleyball and dance communities and, thus, impacted our research plan in the dissertation. On March 21st, 2020, NJ Governor Murphy announced a statewide stay-at-home order due to the rapid spread of COVID-19[5]. All social activities, including recreational activities, were prohibited. These restrictions affected our planning for Study III, research through design, and Study IV since all depended on individuals' participation in community activities. After the 1st and 2nd stages of reopening in New Jersey, which started on May

[5] https://www.nj.gov/governor/news/news/562020/20200321c.shtml (accessed June. 2020)

22nd and June 15th, some outdoor recreational activities were allowed[6]. The Great American Volleyball (GAV), through which we engaged with the NJ beach volleyball community, resumed its outdoor tournaments and leagues in early July. Since beach volleyball players participated in these community activities, we continued our investigation. Unfortunately, members of the NJIT indoor volleyball community, the NJIT dance community, and the NJ Filipino dance community could not continue their indoor community activities. Therefore, we could not include indoor volleyball players and dancers in Study III, research through design, and Study IV.

[6] https://covid19.nj.gov/faqs/nj-information/reopening-guidance-and-restrictions/when-is-new-jersey-lifting-restrictions (accessed June. 2020)

CHAPTER 8

STUDY I: QUALITATIVE STUDY OF INDIVIDUALS' ENGAGEMENT WITH COMMUNITIES, TYPES OF FEEDBACK USED, AND TECH USE FOR PROCEDURAL LEARNING

The first logical step in this dissertation is to study people's engagement with collaborative physical recreation communities (CPRC), the types of intrinsic and extrinsic feedback community members use, and what they perceive as the benefits and challenges of available technologies for their procedural learning.

8.1 Research Questions

This first study investigates the following research questions:

RQ1: *Why do individuals engage with CPRC?*

RQ2: *What types of intrinsic or extrinsic feedback do community members use for procedural learning?*

RQ3: *How do community members use current technologies to gain extrinsic feedback and support procedural learning?*

8.2 Method

This study follows a qualitative research method entailing semi-structured interviews and qualitative diaries (see Table 8.1). In this section, we explain each phase of our research method.

Table 8.1 Study I

Goal	Phases	Subjects	Timeline
Investigate the reasons behind community engagement, types of feedback used, and tech use for procedural learning	**(1) Semi-Structured Interviews**	N=32: Members of New Jersey Beach Volleyball Community (10 players), NJIT Dance (6 dancers), NJ Filipino Dance Community (3 dancers), Others (13 dancers).	Spring 2018
	(2) Qualitative Diaries, and Diary Follow-up Interviews	N=13: Members of New Jersey Beach Volleyball Community (8 players), Members of NJIT Dance Team (3 dancers), NJ Filipino Dance Community (1 dancers), Others (1 dancer)	Summer and Fall 2018

8.2.1 Phase 1: Semi-Structured Interviews

In the first step of the qualitative study, we conducted semi-structured interviews with members of the recreational beach volleyball and dance communities. This method entailed collecting concrete qualitative datasets in the scope of the research questions. Conducting semi-structured interviews requires following interview guides, sets of questions covering multiple aspects of the research domain. Researchers who use this methodology can go beyond questions included in the interview guide, which provides them with significant levels of flexibility and maintained focus on the research domain at the same time. We encouraged storytelling to better understand our subjects' perspectives.

To investigate the research questions that we outlined previously, our interview guide examined several aspects of subjects' engagement with their CPRC:

- Subjects' motivations for and steps required for joining the communities.
- Existing learning practices including team training sessions and individual exercises.

- Individual and collective routines in the context of recreational activity communities.
- Community-wide activities and events, and activities in which subsets of members participate.
- Interactions with other recreational and non-recreational activity communities.
- Types of intrinsic and extrinsic feedback used for supporting procedural learning.
- Subjects' use of existing technologies, QS systems in particular, for procedural learning.
- Perceived benefits of QS systems as well as their challenges for performing and learning among subjects.
- Strategies regarding tracking and evaluating subjects' performance and learning.
- Types of extrinsic feedback desired to further promote procedural learning.

8.2.1.1 Subjects. In our semi-structured interviews, we examined physical performance and procedural learning that occur via engagement with the beach volleyball and dance communities. This choice allowed us to initiate our inquiry by taking a highly focused step and laying the groundwork for the subsequent studies on both communities. We identified recreational dance and beach volleyball communities that were relevant to the scope of this dissertation. In addition to the beach volleyball communities, we communicated with a bigger pool of recreational dance communities supporting a variety of dance styles (e.g., Jazz, Hip Hop, and Ballet).

We recruited and interviewed 32 subjects. We used convenience sampling methods to recruit our subjects. The average length of our interviews was 45 minutes and 12 seconds. Nineteen subjects were members of the recreational beach volleyball and dance communities discussed earlier, NJ beach volleyball community, NJIT dance community and NJ Filipino dance community. Thirteen subjects were members of two other recreational dance communities which are of interest only in the scope of our pilot interview study:

> (1) Members of the Sacramento Ballet Community, a local dance community, which focuses on the performance of Ballet in California. We recruited these subjects through snowball sampling.
>
> (2) Members of NJIT-Rutgers South-Asian Dance Community, an on-campus dance community, which consists of student dancers from NJIT and Rutgers University-Newark. We recruited these subjects through Ehsaas, the leading South-Asian dance team.

Our sample included a diverse range of ethnicities and ages from 18 to 29 (average age 21.6). Our subjects were 44% female and mostly living in the states of New Jersey and California. After conducting our 32 interviews, we observed repetitive patterns in our interview dataset, indicating that we had reached saturation in the dataset and had conducted an adequate number of semi-structured interviews.

8.2.2 Phase 2: Qualitative Diaries and Diary Follow-up Interviews

In the second part of the qualitative study, we collected and analyzed qualitative diaries (R. P. Schuler et al., 2014). We used this method to gather in-depth qualitative data covering the subjects' long-term engagement with their communities. Our qualitative diaries method required the subjects to provide self-reported data over two weeks using diary forms.

In the diary forms, we asked our subjects to name each day's highlights related to performing and practicing collaborative physical recreation, engagement with CPRC, and participation in community activities. We then asked the subjects to describe each highlight using their episodic and semantic memories. The subjects identified and explained highlights that were of personal, emotional, or social value. We also asked the subjects to describe how such highlights impacted their individual and collaborative performance and procedural learning.

In addition to in-situ logging of information on diary forms, our qualitative diaries method also entailed diary follow-up interviews that allowed us to evaluate information logs that the subjects have provided on the diary forms and co-explore the meaning, details, and unexplored aspects of the logs.

8.2.2.1 Subjects. In this second phase, we focused on the on-campus and off-campus CPRC introduced the above. We recruited 13 subjects from the pool of subjects in phase 1, primarily from three of CPRC under study: the NJ beach volleyball community, the NJIT dance community, and the NJ Filipino dance community. We also managed to recruit a member of the Columbia dance community, as we were actively exploring the option of including this CPRC in the dissertation as well. We paid our on-campus and off-campus subjects $20 and $70 respectively as incentives for their participation. Since we anticipated challenges in sustaining the level of the subjects' engagement, we maintained close communication with each subject and motivated them to continue logging information to the diary forms. The average length of the diary follow-up interviews was 41 minutes and 18 seconds. We used diary entries to encourage storytelling in the follow-up interviews.

Our sample involved a diverse range of ethnicities and ages from 19 to 29 (average age 22.3). The subjects were 38% female. Most of the subject lived in the state of New Jersey. After collecting and analyzing data from 13 subjects, we realized that only repetitive patterns emerged in our datasets. Thus, we determined that we had reached saturation in our dataset and had an adequate number of subjects in our study.

8.2.2.2 Analysis. We recorded over 1,300 minutes of interviews. We combined this data with 1,120 diary entries collected in the study. To examine our research questions using this large volume of qualitative data, we started our analysis of the data by initially focusing on a subset of our subjects: five semi-structured interview subjects and five qualitative diaries subjects. This technique allowed us to develop a coding system, which was directed by our research questions, before expanding our analyses to our entire dataset.

We used inductive and deductive qualitative data analysis methods, particularly elements of the Grounded Theory (Glaser & Strauss, 1967), to examine our qualitative datasets. In our data analysis, we focused on finding observable patterns and insights relevant to the research questions. By using recursive analysis processes, we first identified and coded pieces of our qualitative data that we deemed relevant to the context of research questions. We then created phenomena by categorizing our coded qualitative data based on their similarities and differences, and described, interpreted, and reviewed the phenomena and identified whether they supported the investigation of our research questions. Lastly, we made conclusions and drew implications from the phenomena found through our analysis. We used NVivo as our qualitative analysis tool, which facilitated our analysis processes.

Through multiple rounds of coding and categorizing, we generated 90 codes and 22 categories through our qualitative analysis. We identified patterns, similarities, differences, and relationship that were observable in our datasets. Since our dataset was longitudinal, we also created subjects' journey maps as holistic views of the subjects' experiences throughout their engagement with their communities as well as their behaviors, actions, challenges, and existing solutions relevant to their learning.

8.3 Findings

This section presents the findings of both the semi-structured interviews and the qualitative diaries. We start by elaborating on why the subjects engaged with CPRC (RQ1). We then explain the types of intrinsic or extrinsic feedback they used for procedural learning (RQ2). Lastly, we explain how the subjects used available technologies to obtain extrinsic feedback, and how they describe extrinsic feedback types that were desired but unavailable through the technologies (RQ3).

8.3.1 Motivations for Community Engagement

When we asked our subjects why they engaged with their communities, we learned that most of them had multiple overlapping reasons. In this section, we first explain the reasons behind their community engagement.

8.3.1.1 Experiencing a Sense of Social Companionship. Several subjects said that engaging with their communities and being among other community members brings them a sense of social companionship. These subjects noted that they interacted with other community members as they routinely participated in community activities (e.g., in a beach volleyball league, in a community-wide dance event). These interactions helped the subjects connect with their community members and form social ties, leading to experiencing a sense of companionship.

Some subjects also said that having shared physical experiences with their teammates in team performances developed and strengthened their bonds. Over time, these bonds helped the subjects experience a sense of social companionship. Anna, a dancer, told us:

> "*When it comes to something physical, you have a sort of, I guess shared experience of struggle, like whether that'd be in basketball, whether it be in dance, you're all kind of breaking yourself down to build yourselves up, and when you do that together, you bond over it.*" (Anna, dancer)

We also heard from our subjects that they developed a sense of community through their long-term engagement with their communities. The subjects described their sense of community as thoughts and feelings of belonging to their communities and their willingness to maintain their social ties with community members. For example, Bob, a beach volleyball player, and member of the NJ volleyball community, described his community engagement as an emotional bond with his community. He told us:

> *"For me, volleyball is not just a sport, it's about emotional connection. It's about the community and the people around the sport."* (Bob, beach volleyball player)

Some subjects even described their communities as their second family with strong feelings of attachment. Our subjects mentioned that their sense of community had become visible through them continuously and frequently participating in community activities and maintaining their social ties in their community. Some shared that such feelings had encouraged them to take on voluntary roles in their community to plan and organize community-wide activities (e.g., dance practices, beach volleyball leagues, and open-court practices).

The subjects also shared that this sense of social companionship and community encourages them to exchange feedback with other members to help them improve their performance and overcome their learning challenges.

8.3.1.2 Passion for Dance. We heard from our subjects from the recreational dance communities that they engaged with their communities because of their passion for dance. Some of these subjects danced for years and developed a deep connection and bond to this activity. For example, Darin told us:

> *"I've always been into dance, like I'm really big into music and the dance […] I just have a very deep attachment to rhythm and music."* (Darin, dancer)

Our subjects shared that their hectic schedules (e.g., a heavy course load during a semester) sometimes stopped them from following their passion for dance, making them miss a crucial aspect of their lives. In such cases, they engaged with the recreational dance communities to continuously follow their passion. As Tamara put it:

> *"Once you start doing something and if you're really into it, like, after a few stoppings, just feel like something's missing. That's what I kept coming back and I'm still here."* (Tamara, dancer)

Some of our subjects also shared that being surrounded by other passionate dancers in their community motivated them to push themselves. They used dance practices to work with the dancers to improve their motor skills and performance.

8.3.1.3 Healthier Lifestyles. We heard from some of our subjects that they participated in community activities to get significant amounts of exercise. They shared that exercising through their community engagement had, over time, helped them create healthier lifestyles. They mentioned that their hectic daily schedules could stop them from getting enough exercise, which might negatively affect their health and wellbeing. They said that engagement with CPRC helped them avoid such situations and find opportunities to be physically active and get exercise. For example, Oliver, a member of the NJIT dance community, said:

> "*My motivation to join the team was basically to, um, take better care of myself; ever since I left college, I had been very stagnant."* (Oliver, dancer)

Our subjects also contrasted getting exercise through participating in community activities in CPRC to exercising in more formal settings (e.g., at a gym). They mentioned that community activities had created more enjoyable and convenient ways for them to be physically active and get exercise. Overall, the subjects' continuous and long-term engagement with CPRC increased their physical activity levels and brought them healthier lifestyles.

8.3.1.4 Motor Skill Improvement. We heard from our subjects that they engaged with their communities to get better at beach volleyball or dance. While our subjects viewed community activities (e.g., beach volleyball tournaments, dance practices, dance competition events) as gratifying physical recreation, they also used the activities to collaborate and compete with other community members. Such collaboration and competition opportunities helped them benchmark their motor skills. As Daniel put it:

> *"[My motivation was] to get better at volleyball together because we think we can make each other better."* (Daniel, beach volleyball player)

When volleyball players or dancers identified specific improvement areas for themselves, they used their communities to improve their motor skills and performance. Each teammates' motor skills impacted their team performance. We heard from the subjects that they also wanted to continue getting better to help their team performance as well. Janet told us:

> *"I wanted to get better so that I'm not holding anyone down because it's only the two of us. So, you know, you gotta play your part so that your partner doesn't have to do as much work."* (Janet, beach volleyball player)

8.3.1.5 Mental Health Benefits. Another motivation to engage with CPRC we heard about was to obtain mental health benefits, such as relieving stress. According to some subjects, their communities' informal nature and the sense of familiarity and habitualness with community activities created secure and stable environments for them. Sarah, a dancer, told us how participating in dance practices in her community helped her relieve stress. She said:

> *"It's like a stress reliever for me. Like if I'm mad at something. I'm just angry about a grade, or I had got into a fight with one of my friends. When I go to practice, that all goes away. So I don't think about it anymore. Cause when you do think about it, you just get sad all the time, you know. So I needed that one place where I can just think about dance and how happy that makes me. It just makes it all go away, and I can rethink all my thoughts there and have a very calm mind. And it actually helps me resolve problems and like a less feisty way*." (Sarah, dancer)

Our subjects thought the mental health benefits of their community engagement, relieving stress and experiencing a sense of calmness, had motivated them to habitually participate in community activities leading to their long-term engagement with their communities.

8.3.2 Available Types of Intrinsic Feedback

As explained in Chapter 4, individuals have access to intrinsic feedback through their sensory feedback sources. Our subjects mentioned that their intrinsic feedback played a central role in evaluating their physical performance and improving their motor skills. We asked our subjects about the types of intrinsic feedback on which they relied. They mentioned the feel of individual movements, their achieved outcome, their mental state, and their perceived team cohesion in team performance. We expand on these types of intrinsic feedback in this section.

8.3.2.1 Feel of Individual Movements. Our subjects told us about the feel of individual body movement as their primary form of intrinsic feedback. These subjects mentioned that such feedback allowed them to evaluate their individual physical performance. For example, Oliver, a dancer, described how he examined his dance through this type of intrinsic feedback:

> "*I can feel in myself kinesthetically, like first, you know, when you mess up, and you're offbeat."* (Oliver, Dancer)

Our subjects also shared that using this type of intrinsic feedback was the primary way to identify possible improvement areas. The subjects who aimed to improve their individual physical performance used the feel of their movements to engage in reflective observation and correct their movements. They also continuously monitored this type of intrinsic feedback to ensure that they were making progress.

8.3.2.2 Achieved Outcomes of Movements. We heard from our subjects that they examined the achieved outcomes of their movements as a type of intrinsic feedback. The subjects considered movements successful when the achieved outcome matched the intended outcome of the movements. Our NJ beach volleyball community subjects also relied on the beach volleyball scoring system to evaluate their skills. During their matches, if they scored points repeatedly, they indicated that they had successfully used their motor skills. As Jennifer put it:

> *"I think the cool thing about beach volleyball is that you can kinda evaluate your performance by the score. It's not the kind of game where you can ... I mean you can play really well and still lose, but you kinda just know how you're gonna do based on the score. There's not many situations where you're playing well, and you still lose, or you're playing bad, and you still win."* (Jennifer, beach volleyball player)

When the subjects did not achieve their intended outcome, they identified their movements as improvement areas and engaged in active experimentation to improve the related motor skills.

8.3.2.3 Mental State during Performance. Several subjects from the NJ beach volleyball community shared that they examined their mental state during their physical performance as intrinsic feedback. These subjects mentioned that changes in their mental state were a strong indicator of their physical performance (e.g., becoming nervous during a volleyball rally). Bob, a beach volleyball player, mentioned his nervousness during games as his intrinsic feedback. He said:

> "*I've been playing long enough to know that if I'm playing well or I'm not playing well. It's a mental thing. If I can feel myself playing nervous, and I'm making mistakes then, obviously I'm not playing as well."* (Bob, beach volleyball player)

Our subjects said that they used this type of intrinsic feedback reciprocally. They monitored their mental state during physical performance to engage in reflective observation to identify possible improvement areas. At the same time, we heard from the subjects that they aimed to improve their mental strength and preparedness. They believed such factors could significantly impact their physical performance (e.g., being more confident could help them play or dance better). David, a beach volleyball player, told us that he monitored his mental state during his games, which helped him realize that he needed to improve his spiking. Over time, he also noticed that he tended to put too much pressure on himself, which lowered his mental strength and negatively affected his performance during the games. He said that he decided to work on his mental strength gradually and improve his physical performance overall.

8.3.2.4 Perceived Team Cohesion. Several subjects said that they relied on their perceived team cohesion when evaluating their team performance. This type of intrinsic feedback refers to the degree to which team members perceived all members to be engaged in the activity and committed to achieving their team's shared outcomes. Our subjects considered their perceived team cohesion crucial since they saw a connection between this type of intrinsic feedback and their team performance: the higher they viewed their team cohesion, the higher their coordination with other members, and the better they performed as a team. Dustin, a beach volleyball player, told us about using this type of intrinsic feedback:

> *"There's not really much that we can use to evaluate other than how you feel as far as how you and your partner connect as a team […] That's just the feel of the game. If you're running at a good pace and everything feels right, you know you have a good connection. If it feels like you're just lost on the court all the time, then you and your partner aren't connected."* (Dustin, beach volleyball player)

Our subjects from the dance communities described that each member portrayed a certain energy level in dance. They viewed their team cohesion as the extent to which all dancers' energy levels matched in a group dance. Sarah told us about this type of intrinsic feedback in dance practice:

> *"You can just tell from the energy that you're dancing. When you are dancing in a big group, you have to feed off people's energy. If one person is doing it very slowly, then the whole dance looks boring, then the person next to them starts to get boring. If everyone is doing it fully, like the energy and how the crowd*

reaction is just very powering [...] the team as a whole is happening." (Sarah, dancer)

Overall, our subjects told us that perceived team cohesion tended to be a valuable type of intrinsic feedback, allowing them to evaluate their team performance and learn how to better coordinate and perform with their teammate(s).

8.3.3 Extrinsic Feedback within Formal Settings outside Communities

In Chapter 4, we explained that besides intrinsic feedback available through sensory feedback sources, individuals may seek extrinsic and augmented feedback. This type of feedback consists of information about physical performance from an external source provided to the performing person. We also discussed that having access to extrinsic feedback allows individuals to complement their intrinsic feedback and achieve higher physical performance levels and better procedural learning.

Some subjects said they had access to formal settings outside their community for participating in activities (e.g., volleyball lessons, dance classes) in addition to community activities. In the formal settings, they worked with instructors, such as teachers or coaches, who continuously observed their movements and gave them feedback. As Adam, who is a dancer, explained receiving feedback in his dance class:

"Usually after a performance, the way that I evaluate personally is one of my teachers will give me feedback." (Adam, dancer)

Those who had access to the formal settings used feedback from the instructors to improve their motor skills repeatedly. The instructors' support of their learning also allowed them to enhance their competitive performance during community activities such as beach volleyball tournaments or dance competitions. However, this form of extrinsic feedback was not available to all the subjects. Many sought extrinsic feedback from others in their community or learned primarily through trial and error. As Nate, one of the dancers, told us about how he learned dance:

> *"It's a lot of trial and error. Uh, you know, not everything's gonna be perfect […] trial and error, um, continuing through knowing that eventually, it's going to get done, you know."* (Nate, Dancer)

8.3.4 Extrinsic Feedback from Technology for Individual Use

Our subjects described several extrinsic feedback types they obtained through existing technologies, and specifically the following two categories of individual feedback systems: Quantified-Self (QS) systems allowed them to track and monitor their basic quantified movement metrics (e.g., speed, number of steps) and physiological metrics (e.g., heart rate, body temperature). Cameras (e.g., GoPros., smartphones with built-in cameras) supported their capture of video recordings showing the quality of their body movements. Our subjects also told us about their challenges for using QS systems and their perceived challenges and benefits of cameras for obtaining extrinsic feedback, which are further outlined below.

8.3.4.1 Basic Physiological Metrics. Some subjects mentioned cases in which they used QS systems in their volleyball games or dance practices to obtain basic quantified physiological metrics from their physical performance. These subjects told us that they used the metrics (e.g., heart rate and body temperature changes) to understand better how their body status changed during their physical performances. Some subjects also shared that they used QS systems that specifically allowed them to analyze their recovery after their physical performance and adjust their resting and sleeping time to recover faster (e.g., WHOOP Strap[7]).

Having said that, most subjects, including the QS systems users, mentioned various challenges of using such quantified metrics. They viewed QS systems as ego-centric solutions and emphasized that these technologies only supported their individual use rather than their collective use with their teammate(s). Some subjects also shared that they did not consider quantified physiological metrics provided through QS systems as meaningful extrinsic feedback for their procedural learning. Tom, a dancer, shared that he was skeptical of QS systems since the quantified metrics they provided did not cover the extrinsic feedback he desired. He said:

> "*I guess I would say I'm very skeptical of them. They don't seem very helpful in my eyes [...] it just doesn't offer anything that I would be willing to use.*" (Tom, dancer)

In conclusion, although some subjects saw value in using quantified physiological metrics through QS systems in their activities, most subjects either did not fully incorporate the metrics or avoided them altogether because of their limitations.

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[7] https://www.whoop.com/ (accessed Aug. 2020)

8.3.4.2 Basic Movement Metrics. We further learned about the subjects' use of basic quantified movement metrics (e.g., speed, number of steps) generated by QS systems. Most subjects mentioned that they found these metrics informative but not useful as extrinsic feedback. For instance, we heard from our dance community subjects about their use of activity trackers. These devices allowed the dancers to record and analyze their number of steps during a dance practice. However, they mentioned that such data provided minimum value for their physical performance and learning. Sarah, one of our subjects, told us how these challenges stopped her from using these devices:

> *"It didn't really make much sense to me. Cause 'oh, I did 10,000 steps today'. Yay! 'Oh, 5,000'. Well, I don't care [laughs]. I wasn't really making sure I hit a certain number every day, so it wasn't really beneficial. It was just cool to have, you know."* (Sarah, dancer)

Our subjects viewed QS systems on the mass market as generic solutions. They said these technologies generated movement metrics for personal physical recreation (e.g., speed in cycling or running), which were different from advanced movement metrics they needed for collaborative physical recreation (e.g., jump height in beach volleyball).

8.3.4.3 Quality of Movements through Videos. Our subjects told us that they examined videos showing the quality of their movements as extrinsic feedback. They video captured their activities through different cameras (e.g., GoPros, smartphones with built-in cameras) and used the videos as an alternative perspective over their motor skills. Yanni, a dancer, told us:

> "*I have recorded myself practicing a lift with my partner, and it's kind of a hard lift, and I'm performing it. So, I want to practice that. Um, [The video] helps to see what it looks like. It puts a different perspective to see what it looks like and what could be done better."* (Yanni, dancer)

The use of cameras varied in the communities under study. We only heard from the beach volleyball players with high skill levels, such as Open and AA players, that they routinely relied on these technologies. However, using cameras was widespread in the recreational dance communities, and community members from all skill levels mentioned that they relied on these technologies for extrinsic feedback.

Several beach volleyball players and dancers told us that they faced challenges in effectively using cameras to gain extrinsic feedback and support their procedural learning. While the subjects liked the idea of incorporating videos for their learning, they shared that, in many cases, they did not have enough time during their activities to set up cameras for video capturing. Mary, a dancer, told us about her team's challenges in using cameras during dance practices and performances:

> *"Time during practice will limit how much we can record because it does take time to set everything up to record it and all of that [...] it would be nice if we would have someone that would just come to all of our performances always record it, but we don't have someone like that." (Mary, dancer).*

We also heard from a few subjects that cameras generated many lengthy videos, and they faced challenges storing the videos since they took significant amounts of storage. Bob, one of the beach volleyball players, shared: "*These games are pretty long. [The videos] take up a lot of space."*

Some of the subjects shared that while cameras provided them with videos showing the quality of their movements, these devices did not point them to specific possible improvement areas. In order to retrieve specific parts of the video to examine critical aspects of their performance, they had to manually edit or navigate through their videos, which was described as cumbersome and time-intensive. As Bob put it: "*Few people really have the video editing skills to look through all of [the videos]."*

Seeing irrelevant video recordings that were not of interest also made them nitpick about their performance and, thus, negatively affected their motivation to improve and learn. As Adam, one of the dancers, put it:

> *"I feel like if I started going down that path, I could nitpick a lot of things […] You don't want to know everything all at once, you know?"* (Adam, dancer)

All these challenges had become obstacles for the subjects to incorporate cameras for gaining extrinsic feedback.

8.3.5 Extrinsic Feedback from Technology for Collective Use

We learned from the dancers that they had collaborative processes for video capturing their activities and using the footage together. Figure 8.1 shows that these processes of (1) collaborative video capturing, and (2) collaborative video use, when combined, created feedback loops for the dancers allowing them to analyze their team performance and exchange feedback. This section presents collaborative processes specific to the dance communities.

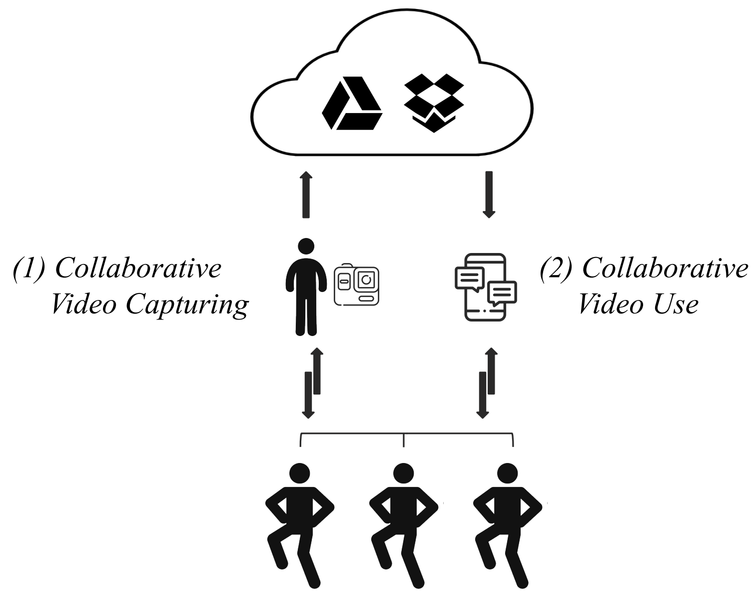

Figure 8.1 Collaborative processes supporting team performance analysis and feedback exchange in the dance communities.

8.3.5.1 Collaborative Video Capturing. Our subjects described their processes for video capturing the quality of their movements through cameras. These processes emerged in two different forms. Some subjects told us that they spontaneously collaborated to capture their practices. For example, we heard from some of the dancers that they sometimes collaboratively used their phones to record their dances during dance practices. Other subjects shared about instances in which the dance captains were primarily in charge of recording the practices. Members who recorded community activities uploaded all the videos to cloud storage services such as Google Drive and Dropbox. They shared that such collaborative processes resolved their video storage issue discussed earlier and allowed all involved members to access the videos.

8.3.5.2 Collaborative Video Use. When we asked our subjects about how they used their available videos, they shared about their collaborative processes. They used group chat applications, namely, Slack[8] and Band[9], to import the videos from the cloud. They used the messaging features in these applications to give one another feedback. As an example, Nate, who is a dancer, told us about how his dance group has incorporated collaborative processes for exchanging feedback. He said:

> *"We recorded every practice when we would do a dance. We will look at it and give critiques to each other when we come back [...] There are times where there are certain people that need more practice, like even just outside of the normal practice."* (Nate, dancer)

We also heard from the dancers that they used collaborative processes for analyzing their team performance and identifying possible improvement areas. For instance, Mary told us how her dance team collaboratively analyzed the quality of their movements using the videos through Google Drive and Slack. She said:

> "*We use the recordings to watch our spacing because formations are a huge part of competitive dance [...] so we use the videos to watch and see what we can improve upon.*" (Mary, dancer)

Our subjects shared that the collaborative processes explained above created new opportunities for supporting distant procedural learning. They told us that since these processes created a repository for videos covering dance practices, absent community members could use these videos to continue their learning and catch up with the rest of the members. Ron told us:

> "*So if someone misses practice and they don't know the choreography, we take a video of it, and we have a private YouTube page. So, you can go on the page and watch what you missed and learn it.*" (Ron, dancer)

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[8] https://slack.com/ (accessed Aug. 2020)
[9] https://band.us/ (accessed Aug. 2020)

We also heard that the absent community members used their personal cameras to record their individual performance and share the videos with other members to show their progress and commitment to improving team performance.

Having said that, our subjects from the dance communities mentioned the challenges of using videos through cloud storage services. They encountered massive volumes of videos generated through the collaborative processes without pointing them to possible improvement areas. They also said that they had to edit and shorten these large videos to analyze the quality of their movements. They saw these challenges as an obstacle for exchanging feedback and evaluating their individual and team performance.

8.3.6 Desired but Unavailable Types of Extrinsic Feedback

As previously mentioned, our subjects shared that they used full videos of their performance through cameras to evaluate the quality of their movements. However, such videos did not point them to specific improvement areas and provided limited value to their understanding of their movements. When we asked our subjects about their desired but unavailable types of extrinsic feedback, several of them told us that instead of full videos, they desired video snippets as short video clips showing specific moments of their performance. They shared that capturing and reviewing moment-specific video snippets would allow them to examine their motor skills thoroughly and closely. For example, Daniel, a beach volleyball player, told us that he experienced a challenging moment during a tournament match. He desired a video snippet of that moment to analyze the quality of each movement. He said:

> *"It'd be useful to, you know, have a visual [of the challenging moment]. If I had a camera to record me and look at that play again, I can look at my body movements and learn from them. I can break it down based on the hierarchy of*

> *movements. Biggest problems that can be fixed to the smallest ones that may need to be tweaked."* (Daniel, beach volleyball player)

We heard from the subjects about a variety of moments of which they desired video snippets. Some of the subjects wanted video snippets that would cover their individual performance weaknesses. Tom, for example, shared with us about a moment of his performance with which he repeatedly struggled. He said:

> *"We basically have used our phones, and we shoot our phones towards the mirror, and we do it for every performance when it comes to in the studio [...] There was one moment that was really important where there was this one move that I always got wrong, and no matter how many times I did it, I was always getting it wrong. So when it came to performance or when it came to doing it, that one moment to me was the most important [...] I would say that's always the biggest challenge for me when it comes to performing."* (Tom, dancer)

Other subjects mentioned that they desired video snippets of moments that would highlight weaknesses in their team performance. Such moments pointed to improvement areas in each teammate's quality of movements or coordination of movements among teammates. Our subjects shared that video snippets of such moments would help them to exchange feedback with their teammates and improve their team performance. Mary, who is a dancer, shared with us:

> *"Our dances are a minute long. During practices, it'd be good to have a recording of a certain part that somebody's struggling with, um, just so that we can have that, and they can refer to it. So if I don't notice that somebody might be struggling with a certain part, we might not have footage of that specifically. I think that's just what people need overall."* (Mary, dancer)

Our subjects said that continuous access to video snippets for extended periods would help them develop an in-depth understanding of their movements. They shared that they would use such knowledge to iteratively evaluate the quality of their movements, identify improvement areas, and troubleshoot their individual and team performance.

8.4 Discussion

This section discusses the semi-structured interview and qualitative diary findings regarding (1) engagement with CPRC, (2) types of intrinsic and extrinsic feedback used, and (3) the perceived benefits and challenges of using existing technologies to gain extrinsic feedback.

8.4.1 Broader Impact of CPRC Engagement

The findings of this study showed that participation in collaborative physical recreation through engagement with CPRC creates social, physical, and mental broader impact.

The study insights indicate that developing senses of social companionship are specific social impacts of interrelationships in CPRC. Consistent with the previous studies of community-based physical recreation (Khasnabis et al., 2010; Sharpe, 2005), our research emphasizes processes in which members use community activities to develop new connections and strengthen their existing social ties. Our findings suggest that since community members collectively engage in experiences of physical activity, they may become deeply connected and form strong feelings of companionship. A sense of community emerges as members engage with their communities in the long term. Such feelings act as a social glue in CPRC, helping members maintain their social ties with one another and encouraging continuous and frequent community activity participation.

The study insights contribute to knowledge about the social aspects of community engagement and participation in community activities. This contribution comes at a critical time since the U.S. holds a particularly dire need to repair social and community bonds among its citizens. A 2019 Pew Research poll found 46% of all young American adults are "low trusters," with 71% of the group agreeing with the statement, "most people would try to take advantage of you if they got the chance." (Gramlich, 2019). Rapid urbanization, new technologies, and mobility might have exacerbated such trends since they have undermined traditional communities, which have been sources of social capital (e.g., information or social support) among individuals (Levy, 1989; Lin, 2002; Putnam, 2000; Ricken et al., 2014). However, studies have also shown that interpersonal interactions and community-based collaborations can alter such trends and foster interpersonal trust in the U.S. (Gramlich, 2019). Our research emphasizes that CPRC can effectively help facilitate such interactions and collaboration and even act as alternatives to traditional communities. Technological innovation in this regard plays a highly crucial role as it can facilitate interactions and collaborations among members of society and provide them with the essential social capital resources they need.

This study further found getting exercise and creating healthy lifestyles to be significant reasons for engaging with CPRC. This finding is of particular importance since, in today's society, barriers such as lack of time, social support, energy, or motivation have significantly decreased physical activity levels (Centers for Disease Control and Prevention, 2020). Since 1975, obesity rates have tripled worldwide. Nearly 2 billion of the world's adults, approximately 40% of the over-18 population, are overweight or obese. A further 340 million children aged 5 to 19 exceed healthy weight standards (H. Ritchie & Roser, 2017). Such trends highlight the need for developing solutions that can effectively improve physical activity levels. The insights in this study suggest that CPRC supports enjoyable and gratifying methods of getting exercise. In the long-term, such methods can improve physical activity levels in society, help members tackle and prevent health issues such as obesity or life-threatening diseases, and overall mitigate public health challenges (Bauman, 2004; Fagard & Cornelissen, 2007; Katzmarzyk et al., 2004; Khasnabis et al., 2010; D. E. Warburton et al., 2007; D. E. R. Warburton et al., 2006).

This study also found stress relief as a reason for engagement with CPRC. This finding is aligned with previous studies of exercise and its mental health benefits (Bauman, 2004; Fagard & Cornelissen, 2007; Katzmarzyk et al., 2004; Khasnabis et al., 2010; D. E. Warburton et al., 2007; D. E. R. Warburton et al., 2006). The positive mental health benefits of CPRC are significant today. The COVID-19 pandemic has disrupted life throughout the world, including in the United States. The mental disorder symptoms of the pandemic, such as feelings of stress, anxiety, and depression, have already emerged on a population level (Passavanti et al., 2021; Vahratian et al., 2021). Through engagement with CPRC in safe settings, society members can regain self-reflection opportunities, satisfy their needs for stimulation, achieve instant gratification and personal rewards, and experience a sense of self-importance. Thus, CPRC can play a critical role in mitigating the mental disorder symptoms and improving overall mental health and well-being in society.

The significant benefits of CPRC on both physical and mental health reiterates the need for technological innovation that facilitate community engagement and bring users these benefits. This dissertation has taken on this unique opportunity to create technologies that have the potential to support the generation of these benefits and to boost the communities' positive role in increasing and maintaining overall health and well-being in society.

8.4.2 Supporting Procedural Learning through Community Engagement

In addition to the perceived physical, mental, and social benefits of engagement with CPRC, the findings showed the significant role of these communities in supporting procedural learning. Members gained competition and collaboration opportunities as they participated in community activities, which they can use to continuously examine their individual and team performance and identify improvement areas. Such processes support their procedural learning as they focused on improving their motor skills through training.

Technological innovation can play an important role in helping community members to learn effectively. As indicated earlier in this chapter, the primary technologies for such purposes are feedback systems, allowing users to capture and view their individual and team performances and obtain extrinsic feedback. Creating such systems requires an understanding of the existing uses of intrinsic feedback.

This study's findings indicate specific forms of intrinsic feedback which community members rely on in procedural learning processes. The findings confirmed our previous claims in this dissertation that the feel of movements and the achieved outcome of movements are important forms of intrinsic feedback for procedural learning in collaborative physical recreation. The findings further showed that community members also used two other types of intrinsic feedback to evaluate their performance and support their learning: mental state during performance and perceived team cohesion.

Technology designers can apply this knowledge to propose technological innovation generating extrinsic feedback that complements community members' intrinsic feedback. For example, feedback systems may capture and show teammates' commitment to their teams' success through training and practice. Such extrinsic feedback through feedback systems may positively affect teammates' perceived team cohesion and improve their performance and learning.

Another method of supporting procedural learning through technological innovation is to store users' self-reported intrinsic feedback (e.g., their mental state during performances) and represent this data back to them as extrinsic feedback. Such features in a feedback system may allow community members to monitor their intrinsic feedback persistently and examine how situational factors, such as game occurrences, affect their intrinsic feedback (e.g., getting nervous in long rallies). Technology designers may also provide users with tailored training guidelines based on users' self-reported data to help them enhance their mental game and decision-making during competitive performances.

8.4.3 Limitations of Existing Technologies in Supporting Procedural Learning in Collaborative Physical Recreation Communities

The findings of this study highlight that community members may obtain extrinsic feedback using two categories of technologies. Quantified-Self (QS) systems support the individual capture and use of basic quantified movement metrics and physiological metrics in communities. Our insights suggest that the community members do not view such metrics as meaningful data for procedural learning. As discussed earlier in Chapter 6, this limitation might be due to the ego-centric nature of these technologies.

The study's insights shine light on collaborative processes of using cameras for procedural learning in the recreational dance communities. We learned that processes centered on capturing dance practices, storing video recordings from cameras to cloud storage services, and sharing the video recordings through group chat applications. These collaborative processes form a feedback loop, supporting both individual and collaborative procedural learning. The findings further highlight the challenges of these collaborative processes due to the limitations of the existing technologies, specifically that videos generated through these processes do not point to possible improvement areas and using them for learning requires cumbersome and time intensive editing and shortening. Based on these insights, we propose new classes of technologies that simultaneously incorporate the collaborative processes and address their limitations. We argue, in this dissertation, that such technologies must provide users with videos that specifically point to their improvement areas to support their procedural learning.

8.5 Study Limitations

This section explains the limitations of the study in the subject recruitment and research methods. We followed a top-down model for approaching the recreational volleyball and dance communities (e.g., via collaborations with the volleyball club, engagement with the dance captains). This model allowed us to communicate our research objectives with interrelated community members who were highly engaged with their communities. Our convenience sampling methods centered on recruiting subjects from this sample of individuals, which might have skewed our findings. For instance, while our subjects discussed procedural learning as a reason for community engagement, less integrated community members may have had different opinions on such topics.

We used qualitative research methodologies, semi-structured interviews and qualitative diaries, to examine individuals' engagement with their communities, types of feedback used, and technologies used for procedural learning. The first limitation of these methods is that they covered the depth but not the breadth of the existing behaviors and patterns in the communities.

Secondly, while the qualitative methods allowed us to explore how community members participated in community activities, we could not investigate their behaviors through an ethnographic lens. As a result, we have likely missed nuances of community activity participation (e.g., the order of events during the activities) in our qualitative dataset. We address this limitation by conducting an observational study of community activities presented below.

Lastly, in the qualitative diary method, the subjects used diary forms to name and describe their participation in collaborative physical recreation, including via engagement with their communities. We asked the subjects to enter such information on the diary forms persistently. However, this research method was highly dependent on the subjects' memory recall. Possible memory recall issues might have negatively affected their information input (e.g., completing the forms without providing a detailed description of a community activity), which could limit our understanding of the topics under study.

8.6 Summary

This chapter presented a qualitative study consisting of semi-structured interviews and qualitative diaries. We examined reasons behind engagement with CPRC, types of intrinsic and extrinsic feedback community members used, and what they perceived as the benefits and challenges of available technologies for their procedural learning. Our findings showed that individuals engage with the communities for multiple reasons, including supporting their learning, creating healthy lifestyles, getting mental health benefits. Our results showed forms of intrinsic and extrinsic feedback that community members use in their procedural learning. Our insights also highlighted that QS systems provide minimal support for collaborative physical recreation via engagement with the communities. Most importantly, while community members use cameras to video capture their performances, they face challenges in effectively using the video recordings for their learning. Instead, they desire video snippets of their teachable moments as extrinsic feedback. In the next chapter, we discuss the design implication of this study and outline technological innovation for procedural learning in the communities.

CHAPTER 9

A CONCEPTUAL FRAMEWORK OF TECHNOLOGICAL INNOVATION FOR COLLABORATIVE PROCEDURAL LEARNING

This chapter discusses the design implications of Study I. It translates the literature review insights and empirical research findings into a conceptual framework of technological innovation supporting collaborative procedural learning in collaborative physical-recreation communities (CPRC). We argue in this chapter that holistic support of collaborative procedural learning requires novel and transformative feedback systems inspired by the 4th generation of computing technologies, known as Collective Computing (CC) (Abowd, 2016). We start with summaries of our literature review and empirical research findings. The chapter then introduces Collective Computing and presents our conceptual framework. We end with proposing the primary processes of the framework.

9.1 Summary of Literature Review

Based on our literature review on motor skill acquisition and collaborative procedural learning, we developed a conceptual framework of collaborative procedural learning in CPRC (see Chapter 5). This framework shows processes for community members exchanging feedback to help each other with learning and described community members' teachable moments as concrete instances, in which they want to improve their motor skills. Literature review also showed that, as community members experience teachable moments and want to improve their motor skills, they may seek feedback from others in their community. Feedback exchange, in such cases, occurs through observation and subjective analysis of movements and communication among community members about them. Based on the insights, we conclude that technological innovation for collaborative procedural learning in CPRC must enable community members to identify teachable moments in situ. Such technologies must also allow community members to seek feedback specific to their teachable moments and have other community members observe their movements and give them feedback.

9.2 Summary of Empirical Research

Study I examined why members engage with their communities, their use of available technologies for procedural learning, and the types of feedback they use and desire. We found that Quantified-Self (QS systems) provided beach volleyball players and dancers opportunities for monitoring and tracking their basic movement metrics (e.g., speed, number of steps) and physiological metrics (e.g., heart rate, body temperature). However, they consider these metrics of minimum value and not meant for supporting their performance and learning. Instead of QS systems, beach volleyball players and dancers often rely on cameras (e.g., GoPros., smartphones with built-in cameras) to capture their performance and view their video recordings to analyze the quality of their movements. That said, beach volleyball players and dancers also face challenges in effectively using cameras to support their procedural learning. Video recordings from these devices do not point to specific possible improvement areas. Beach volleyball players and dancers have to manually edit and navigate through their video recordings to retrieve specific parts showing their movements. Otherwise, they miss their chances of examining critical aspects of their performance. Seeing irrelevant video recordings that are not of interest also makes them nitpick about their performance and, thus, negatively affects their motivation to improve and learn. We found that dancers use a combination of cloud storage services (e.g., Google Drive, Dropbox) and group chat applications (e.g., Slack, Band) to collaboratively capture and view video recordings of their practices. While such approaches created opportunities for dancers' collaborative procedural learning, they still relied on cameras with limited support for procedural learning. They also do not present cohesive and systematic solutions, which highlights a venue for technological innovation.

Most importantly, we found that beach volleyball players and dancers desire a form of extrinsic feedback, which is not fully available through existing technologies. Instead of generic and lengthy videos of their performances, they want video snippets that show their movements in their teachable moments. They think capturing and viewing video snippets would allow them to examine their movements closely, identify improvement areas, troubleshoot their individual and team performance, and even exchange feedback with others, including their teammates.

Based on the Study I findings, we conclude that technological innovation for procedural learning in CPRC must support collaborative processes for video capture of community activities and allow community members to view video snippets of moments of the activities that they identify as teachable.

9.3 Requirements for Technological Innovation Supporting Collaborative Procedural Learning in CPRC

Based on our literature review and empirical research insights, we gather the requirements for feedback systems that support collaborative procedural learning in CPRC as follows:

(A) Incorporate cameras for video capture of community activities.

(B) Support collaborative processes for video capture of community activities.

(C) Provide in-situ interactions for users to identify teachable moments.

(D) Retrieve video snippets of teachable moments and present the video snippets to users.

(E) Allow users to exchange feedback using video snippets of teachable moments.

We argue in this dissertation that addressing these requirements requires creating entirely new classes of feedback systems inspired by the 4th generational Collective Computing technologies (Abowd, 2016), a concept further explained in the next section.

9.4 The Emergence of the 4th Generation of Computing

Building on Mark Weiser's "eras of computing" discussed in Chapter 6, Gregory Abowd (Abowd, 2016), a well-known computer scientist, outlined how the 4th generation of computing has emerged since the mid-2000s. Referred to as "Collective Computing" (CC), this new generation of computing is enabled by the convergence of three main components, as illustrated in Figure 9.1: the 'cloud,' 'crowd,' and what Abowd calls the 'shroud' (i.e., lifelog and sensing technologies capturing biomechanical and physiological data). The cloud services provide infinite bits and cycles. The crowd allows for human collectives to learn, and problem solve through interpersonal interactions. It also supports human-computation where work not easily performed by computers is outsourced to humans (e.g., tagging and labeling pictures) (von Ahn, 2011). The shroud provides a layer between potentially every physical object (including humans) and the digital world.

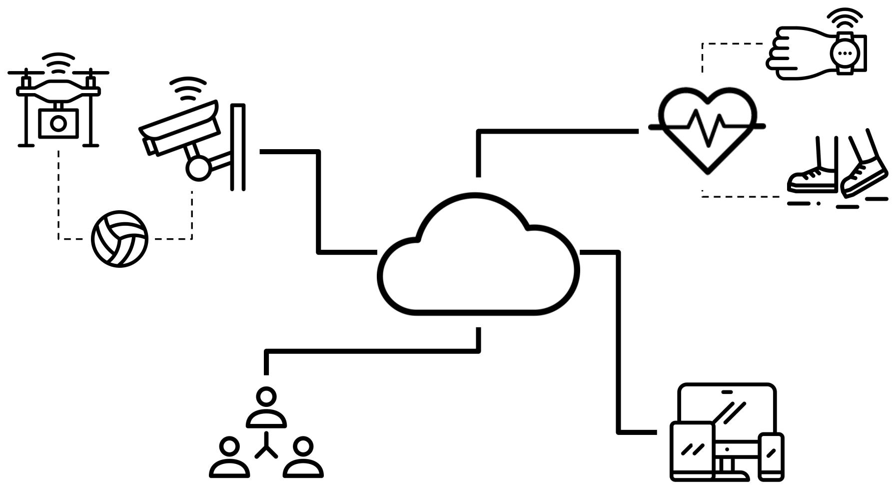

Figure 9.1 Collective Computing architecture.

CC is still in its infancy, and most of the applications that characterize this era are yet to be developed and deployed. This dissertation focuses on the capacities and potentials of CC in offering a fundamentally different approach to how humans experience and interact with computers. One well-known prototypical CC application is Waze[1], the world's largest community-based traffic and navigation app. Waze allows drivers to share real-time traffic and road information and help each other reduce commute times and expenses through users' collective efforts. Waze's services are provided by the cloud, the crowd (commuting users), human computation with drivers sharing information about traffic and policing, and sensing devices primarily embedded in mobile phones. CC blurs the distinction (in the eyes of the user) between what is derived from the user community and what is computational.

Successful instantiations of 4th generational computing technologies such as Waze have provided opportunities for new intelligent systems that support learning. Abowd

[1] https://www.waze.com/ (accessed Jan. 2017)

(Abowd, 2016) suggests that the integration of wearable devices with the existing learning platforms would allow the identification and classification of teachable moments. This integration may also help promote collaborative learning among those within physical or virtual proximities. Abowd also argues that 4^{th} generational computing technologies can facilitate in-situ learning by providing context-aware and proportionate informational recommendations.

We argue in this dissertation that integrating cloud computing infrastructures and cameras with crowd computing paradigms in feedback systems could provide unique opportunities for addressing the requirements for supporting collaborative procedural learning in CPRC. The next section presents Collaborative Lifelogging (CLL) as a conceptual framework for 4^{th} generational lifelogging systems that holistically support collaborative procedural learning in CPRC.

9.5 Collaborative Lifelogging Supporting Collaborative Procedural Learning

This dissertation proposes Collaborative Lifelogging (CLL) as a CC-inspired transformative type of lifelogging systems. CLL transitions lifelogging from a 3^{rd} to 4^{th} generational class of technologies. It integrates cloud and crowd computing with cameras and integrates human and machine computation to support collaborative procedural learning in CPRC holistically. CLL solutions entail three primary processes as described in Table 9.1.

Table 9.1 Processes in Collaborative Lifelogging Solutions

CLL Processes	Description	Process Output (Input for Next Process)	Requirements Addressed
(1) Collaborative Video Capture *(Shroud, Crowd, Cloud)*	Allowing community members to collaboratively video capture their community activities using cameras and in-situ interaction devices	• Full videos • Teachable moments timestamps • Participants IDs/names	(A) Cameras for video capture (B) Collaborative capturing (C) In-situ interactions
(2) Identification and Contextualization of Video Snippets *(Cloud, Crowd)*	Identifying and retrieving video snippets through machine computation Contextualizing and categorizing video snippets through integrating human and machine computation	• Contextualized and categorized video snippets of teachable moments stored in cloud-based storage entities and presented on user interfaces	(D) Retrieving and presenting video snippets of teachable moments
(3) Feedback Exchange Using Video Snippets *(Cloud, Crowd)*	Supporting feedback exchange using contextualized and categorized video snippets	• Communication among community members based on their video snippets presented on user interfaces	(E) Feedback exchange using video snippets of teachable moments

9.5.1 Collaborative Video Capture of Community Activities

CLL solutions incorporate cameras (e.g., head-mounted GoPros, smartphones with built-in cameras on tripods) to capture rich data as entirely and automatically as possible during activities. They also support in situ interactions to allow users to identify teachable moments (See Figure 9.2). Such interactions can be through technologies that do not interrupt users' participation in activities (e.g., through wireless event triggers). As a user identifies a teachable moment, CLL solutions flag the recorded video and store the teachable moment's timestamp and information of the person experiencing the moment (e.g., facial features, device ID).

CLL solutions also enable users to collaborate in video capturing activities. They form ad-hoc groups of participants of each activity based on users' proximity. For each group, CLL solutions incorporate available cameras and in-situ interaction devices to allow the users to collaboratively video capture their activities. CLL solutions use these processes to video capture community activities persistently. Also, the processes support the capture of teachable moments from multiple perspectives, which may help users better understand and analyze the quality of their movements.

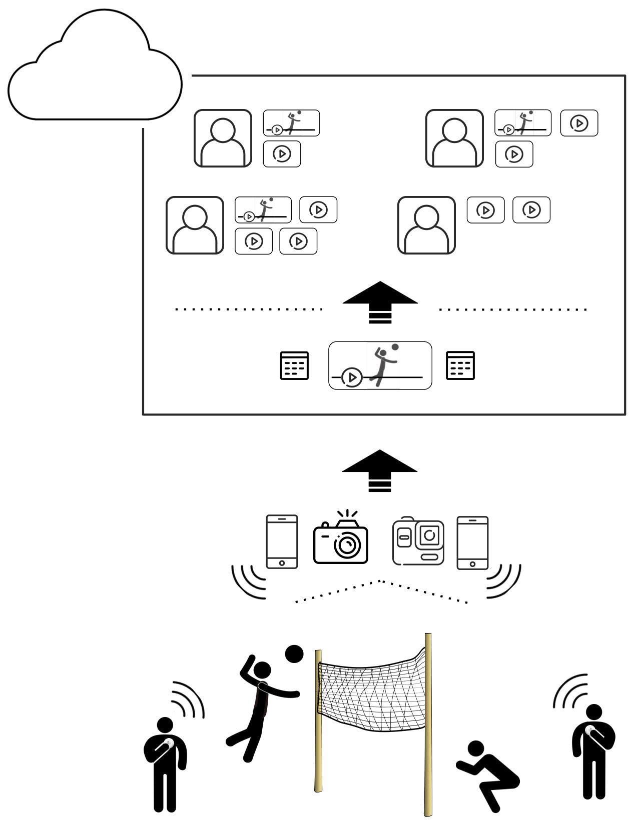

Figure 9.2 Collaborative video capture of community activities and storing video snippets in cloud-based storage entities

9.5.2 Identification and Contextualization of Video Snippets of Teachable Moments

CLL solutions identify, retrieve, contextualize, and categorize video snippets of teachable moments and present them back to users. The first step is through machine computation:

CLL solutions utilize available cloud-based processing units to retrieve video snippets of teachable moments using the captured videos, teachable moments' timestamps, and participants' information. They then store video-snippets in Avatars, cloud-based storage entities (Borcea et al., 2015). Each user will have access to their secure Avatar containing all their available video snippets from their activities (see Figure 9.2). They also can apply their privacy preferences to their Avatars, giving them complete control over their video snippets. In the beginning, an Avatar will be far from a good representation of a person. As they continuously participate in community activities, the Avatars will 'grow' over time as it collects more and more video snippets.

Next, CLL solutions follow the crowd computing paradigm in CC systems to contextualize and categorize video snippets available in the cloud-based Avatars (see Figure 9.3). Video-snippets are presented to users through user interfaces. They navigate through video snippets and tag them based on the teachable moments' perceived social contexts. Such an approach utilizes user collectives to work together and help contextualize data through an integration of human and machine computation. By putting users in the information loop and contextualizing their data, CLL solutions prepare contextualized and categorized video snippets necessary for presentation to users and supporting their procedural learning.

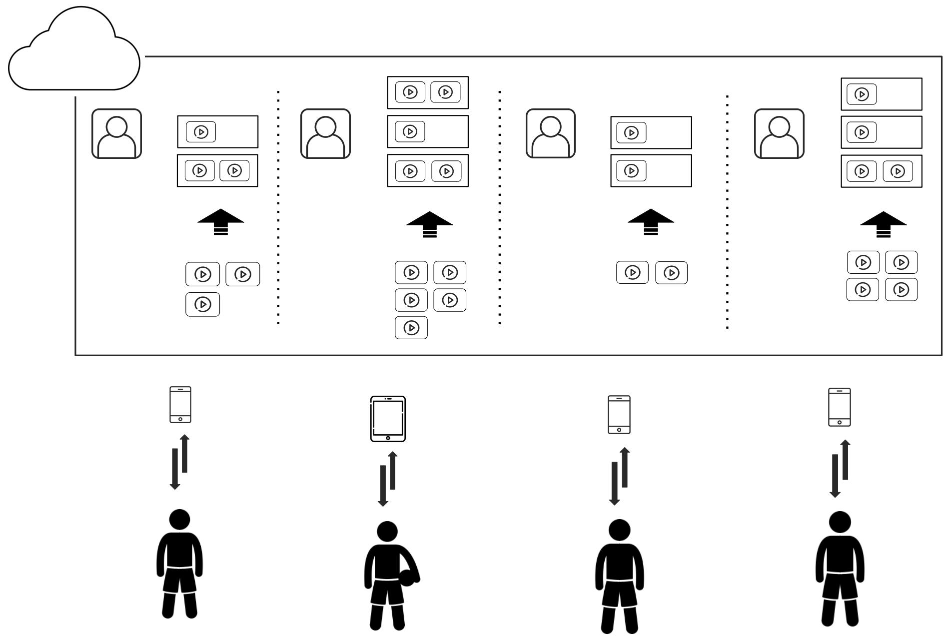

Figure 9.3 Contextualization and categorization of video snippets using an integration of human and machine computation.

Over time, as users repeatedly tag their video snippets, CLL solutions utilize their cloud-based processing units to examine emerging patterns among users' teachable moments. CLL solutions incorporate deep-learning-based scene analysis to train their video-contextualization and classification models (L. Wang & Sng, 2015). They use these models to evaluate and analyze new incoming videos to find moments suspected as teachable based on their similarity to previously seen teachable moments. When CLL solutions recognize a teachable moment, they automatically retrieve video snippets of the moment and present them to users. Such processes also allow users to have access to video snippets of their teachable moments persistently and gradually rely less on in-situ interactions.

9.5.3 Feedback Exchange Using Video-Snippets of Teachable Moments

CLL solutions store contextualized and categorized video snippets in Avatars, allowing users to navigate through their teachable moments. Such access generates an entirely new way for users to share their data and help each other with learning (see Figure 9.4). CLL user interfaces connect users and allow them to share video snippets and exchange feedback based on their observations. They collaboratively examine each other's movements and communicate their understanding using messaging and annotation functionalities available on CLL user interfaces. Such processes facilitate feedback exchange among users and support their collaborative procedural learning.

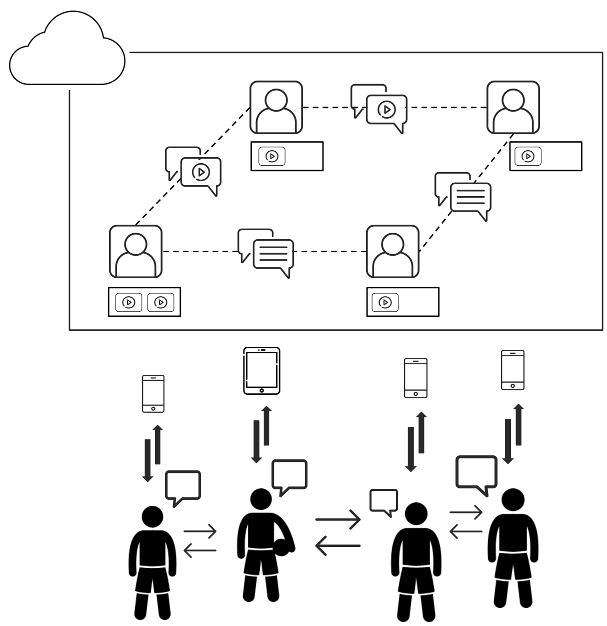

Figure 9.4 CLL solutions supporting feedback exchange

9.6 Summary

This chapter discussed the requirements gathered through our literature review and empirical research insights for technological innovation that holistically supports collaborative procedural learning in CPRC. We argued that such innovation requires novel and transformative types of lifelogging systems. We presented Collaborative Lifelogging (CLL) as a conceptual framework for lifelogging systems inspired by Collective Computing (CC). CLL integrates cloud computing infrastructures and cameras with crowd computing paradigms. We explained how CLL addresses the requirements for technological innovation for collaborative procedural learning in CPRC and presented three primary processes in CLL: collaborative video capture of community activities, identifying and contextualizing video snippets of teachable moments, and feedback exchange among users with the video snippets. Now that we have defined these primary CLL processes, the next studies aim to generate an in-depth understanding of community-based processes before technological intervention. We use this knowledge to refine the determined requirements and inform the CLL processes.

CHAPTER 10

STUDY II: OBSERVATIONAL STUDY OF COMMUNITY ACTIVITIES AND COMMUNITY-BASED PROCESSES

The second study in this dissertation explores participation in community activities and examines existing community-based processes for collaborative procedural learning in collaborative physical-recreation communities (CPRC). Our conceptual framework of collaborative procedural learning explained in Chapter 5 indicated that this type of learning occurs through interpersonal interactions during community activities. This study investigates such interactions through an ethnographic and observational perspective.

10.1 Research Question

In this study, we investigate the following research question:

> RQ1: *What community-based processes support collaborative procedural learning in CPRC?*

10.2 Method

In this observational study, interaction analysis was used to examine community-based processes for collaborative procedural learning (see Table 10.1). This section first explains the background of interaction analysis and then describes each stage of this research method.

Table 10.1 Study II

	Goal	Subjects
Observational Study	Examine engagement in community activities and collaborative procedural learning processes	Members of NJIT Indoor Volleyball Community Club, NJIT Dance Team, NJ Filipino Dance Community

10.2.1 Method Background

Interaction analysis is an ethnographic research methodology centering on the empirical investigation of verbal interactions (i.e., conversations) and non-verbal interactions (gestures, body movements, gaze, and manipulating objects). This research method is widespread in the studies of learning processes in social systems (Jordan & Henderson, 1995).

Ethnographic research methods have originated from cultural and social anthropology and focus on understanding and describing people and their ways of living in their natural settings (P. Atkinson & Hammersley, 1994; Malinowski, 1989). Over the years, these methods have become popular in areas other than social sciences, including in HCI and CSCW. Scholars in these domains have used ethnographic research methods for (1) understanding potential users and their constraints and problems regarding the use of existing technologies, and (2) incorporating findings to inform design decisions in user-centered design processes (Faulkner, 2007; Hughes et al., 1994; Mackay et al., 2000; Salvador et al., 2010; Tatar, 1989; Tognazzini, 1996; Vertelney, 1989).

Interaction analysis scholars use an ethnographic lens to examine interpersonal interactions that occur in social systems. These scholars argue that knowledge about people and their actions and behaviors is situated within these interactions (Frohlich, 1993; Jordan & Henderson, 1995). Human-computer interaction (HCI) scholars have also used interaction analysis to (a) gain knowledge about how individuals interact and identify opportunities for technological intervention, and (b) investigate interactions between individuals with artifacts, including their proposed technological interventions (Augstein et al., 2017; Nawahdah & Inoue, 2013; Rojano-Cáceres et al., 2017).

10.2.2 Study Design

In our observational study, our first goal was to identify sites in which collaborative community-based procedural learning occurs. Interaction analysis scholars refer to such sites as *interactional hotspots* (Jordan & Henderson, 1995). In CPRC, interactional hotspots are community activity sites in which members coalesce to perform and learn collaboratively. Therefore, we considered training sites in the recreational dance communities and training and tournament sites in the recreational volleyball communities as interactional hotspots in this study. Our approach included immersion into the context of community members and allowed us to build rapport with them gradually for our subsequent studies.

We conducted observational visits to the interactional hotspots of four different CPRC: the NJIT Beach Volleyball Community, the NJIT Indoor Volleyball Community, the NJIT Dance Community, and the NJ Filipino Dance Community (see Figure 10.1). We visited each community's interactional hotspot at least three times. This method allowed us to collect and synthesize ethnographic data on an iterative and reciprocal basis.

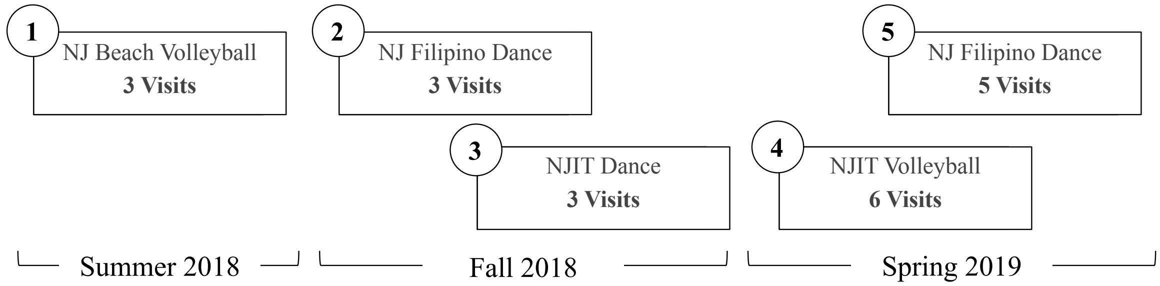

Figure 10.1 Timeline for visits to community sites.

10.2.3 Community Engagement

This section describes the steps for engaging with the recreational communities under study before starting our observational visits. We used our Study I findings and publicly available information about these communities to identify their interactional hotspots. Since our goal was to observe community activities in the interactional hotspots, we sought access to the venue and reached out to community members to get their cooperation. We particularly focused on building relationships with the gatekeepers of these activities. Ethnographic scholars have referred to gatekeepers as individuals in organizations, institutions, and communities who "have the power to grant or withhold access to people or situations for the purposes of research" (Burgess, 2002).

Our research findings indicated that the Great American Volleyball (GAV) and NJIT Volleyball Club members were the gatekeepers of community activities in the recreational volleyball communities. We also found that dance captains in the NJIT Dance Team, NJIT Purple Dancers, and the Flash DT Dance Team were the gatekeepers to the recreational dance communities' community activities.

After receiving our Notice of Approval from the NJIT Institutional Review Board (IRB), we conducted in-person meetings with the gatekeepers or communicated through email when an in-person meeting was not feasible. In our communications, we shared our research objectives and data collection methods for the observational study. We also informed the gatekeepers that the IRB approved all the related procedures in our research. These efforts led to our success in building rapport with the gatekeepers, gaining their trust, and receiving their permission to access the community activities.

In addition to the gatekeepers, we also took steps to build rapport with other community members gradually. Before starting our observational visits, we attended the community activities to introduce ourselves, explain our research to community members, and connect with them. Over time, we assured the community members that we did not intend to intrude on their activities. Our approach made the community members feel comfortable with our presence during the community activities and supported our immersion into their contexts.

10.2.4 Context

As mentioned above, we considered training sites in the recreational dance communities and training and tournament sites in the recreational volleyball communities as interactional hotspots in this study. We observed differences among these contexts: each interactional hotspot varied in facilitating collaborative physical recreation and collaborative procedural learning. This section describes each context in our observational study. Knowledge of the contexts is critical in understanding and interpreting the insights of our observational study on how collaborative procedural learning occurs in the interactional hotspots.

10.2.4.1 Recreational Beach Volleyball Tournaments. We observed Great American Volleyball (GAV)[1] weekly tournaments. This organization manages 25 beach and grass recreational volleyball tournaments between April and October in Point Pleasant, Bradley Beach, Atlantic City, Wildwood, and other Jersey Shore venues. We picked tournaments held in Point Pleasant in the summer of 2018 (Figure 10.2 depicts the venue).

Figure 10.2 Recreational beach volleyball tournament in Point Pleasant.

GAV organized the tournaments on weekends (See Table 10.2). Saturdays were Men`s and Women`s 2s (two players in each team) Open (highest level), AA, A, and B (lowest level) tournaments. Sundays were Coed (men and women play together on the same court) 2s AA, A, BB, and B tournaments. Players between 10 and 18 years old also played in Junior Boys & Girls tournaments on Sundays.

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[1] http://greatamericanvolleyball.com/ (accessed Aug. 2020)

Table 10.2 Number of Teams Participated in the GAV Tournaments

Visit	Men's A	Women's A	Men's AA	Women's AA	Men's Open	Women's Open	Coed 2's A	Coed 2's AA
1	25	18	26	18	23	16	—	—
2	33	18	25	17	20	11	—	—
3	—	—	—	—	—	—	16	8

The tournaments' layout consisted of round-robin pool play (all teams in a pool played each other) followed by single or double elimination brackets, dependent on the number of teams available. In each tournament match, two teams competed on a sand court. Matches consisted of sets, and sets entailed multiple rallies. Each team's goal in each rally was to send the ball over the net to ground it in their opponent's court. At the same time, each team tried to block the same effort by their opponent. Each team had three hits, including the block touch, to return the ball. A team would win a rally if their opposing team failed to return the ball, failed in its service, or committed other faults (e.g., the ball going out). The team that won a rally had the right to serve next. In each set, teams that scored 21 points with a minimum lead of two points won the set (if each team scored 20 points in a set, they continued to play until one of the teams reached a two-point lead). In each match, teams that won two sets won the match. If each team won a set, the 3rd set would be the deciding set and was played to 15 points with a minimum lead of 2 points. Teams that won their pool advanced to single or double elimination brackets, and teams that won the last match of their brackets were announced the winners of the tournaments.

10.2.4.2 Indoor Recreational Volleyball Open-Court Practices. We also observed weekly open-court practices held at the NJIT Wellness and Events Center (WEC) in Newark, New Jersey. NJIT Volleyball Club manages these games to promote intramural volleyball at the NJIT campus. The Club focused on indoor recreational volleyball; a six versus six-team sport played at gymnasiums. We joined open-court practices in the spring of 2019 (Figure 10.3 shows the venue).

Figure 10.3 Weekly open-court practices at NJIT.

The venue consisted of two full-length practice courts in the WEC shared between both basketball and volleyball players. Around 45 volleyball players participated in each open-court practice. The participants were around 20% female. The NJIT Volleyball Club leaders formed 8 teams of five to six players in each event. The matches followed a round-robin pool play format with two pools, each including four teams. Each pool was assigned to a court. For each match, two teams from the same pool competed, and the other two teams in the pool observed their match.

Significant differences between recreational indoor and beach volleyball matches existed. While players could freely move on the court in beach volleyball matches, each indoor volleyball player had a specialized position and mostly remained in their position throughout their match. Another difference was their scoring systems. Indoor volleyball teams that scored 25 points with a minimum lead of two points won the set. Teams that won two sets would win the match. If each team won two sets, the 5th set would be the deciding set and was played to 15 points with a minimum lead of 2 points.

In each open-court practice, each team played up to six matches. Then, the winners of each pool competed, and the teams that won the match became the winner of the event.

10.2.4.3 Dance Practices and Showcases. We observed dance practices and showcases in the recreational dance communities (see Table 10.3)**.** In this section, we describe these two contexts of our observational study. The NJIT Dance Team managed and held the NJIT Dance Community's practices at the NJIT WEC. In the New Jersey Filipino Dance Community, the NJIT Purple Dancers held the practices at the NJIT WEC, and the Flash DT Dance Team used multiple locations across the Seton Hall campus in South Orange, New Jersey (Figure 10.4 depicts the dance practice venues).

Table 10.3 Number and Demographics of Dancers Participated in Practices in the Study

Team	**Number of Members**	**Gender Breakdown**
NJIT Dance Team	14	78% Female
NJIT Purple Dancers	18	27% Female
Flash DT Dance Team	10	50% Female

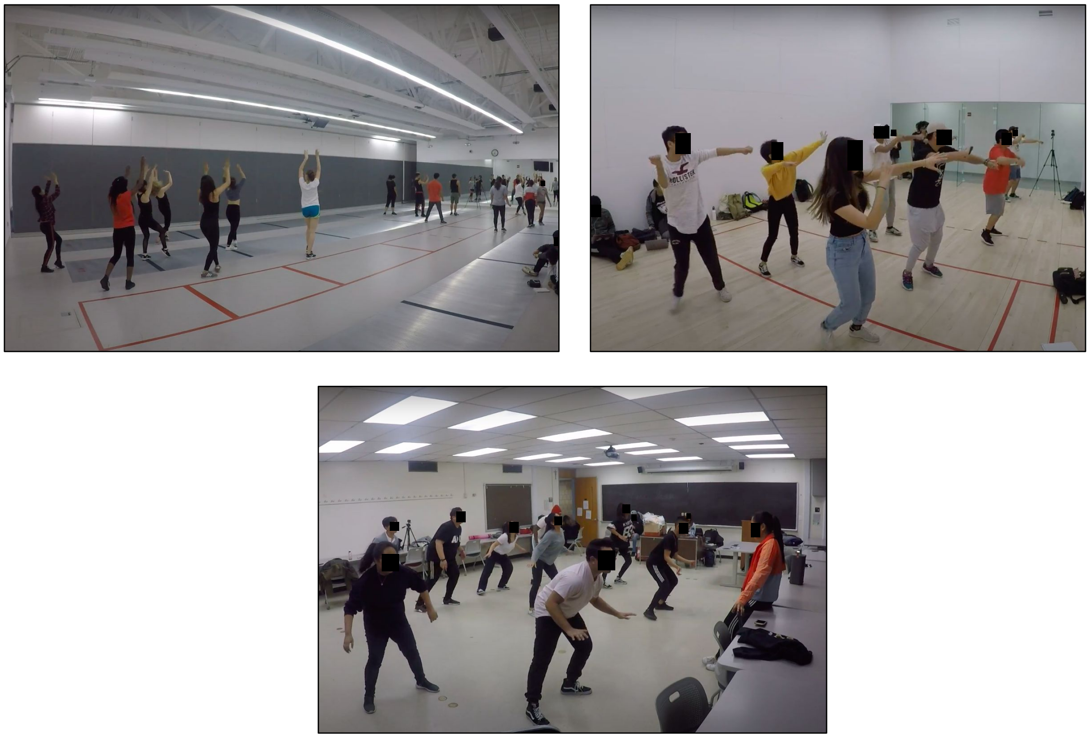

Figure 10.4 Dance practices by the NJIT Dance Team (top left), the NJIT Purple Dancers (top right), and the Flash DT Dance Team (bottom).

In each practice, the dancers followed specific style(s) of dance (e.g., Jazz, Hip Hop). Practices centered on learning new routines and performing previously learned routines. Procedures in each practice were dependent on the number of dancers available. When less than ten dancers attended a practice, the dancers formed one group. In larger groups, dancers were grouped into two subgroups to practice different parts of their routines.

In small practices, the dance captain(s) performed the routines step by step and the dancers followed them. For each step, the captain(s) showed all the movements. The dancers observed all the movements and practiced with the captain(s) to acquire the new motor skills. In case the dancers needed clarification about the movements, they communicated that with the captain(s). After going through the entire routine, the dancers practiced the routine with music. At multiple points, the captain(s) paused the music to help the dancers and ensure they understood the movements. The dance team repeated these procedures until the captain(s) acknowledged that all the dancers had learned the entire routine.

As mentioned above, dancers were grouped into two subgroups in large practices. Each subgroup took a corner of the room and practiced a section of the routines. A dance captain led the procedures in each subgroup: they showed all the movements in front of their subgroup. The dancers in each subgroup first practiced without music going through each step. Then, they put the music on and practiced their section of the routines. Through repetition and practice, each subgroup refined and perfected their performance. Then, the two subgroups merged, and the entire group practiced their full routines multiple times.

The dance showcases in our observational study occurred in the NJ Filipino Dance Community: Annual NJIT Rain or Shine Dance Competition and the Annual Filipino League at Seton Hall (FLASH) Dance Competition at Seton Hall University campus (See pictures in Figure 10.5). Compared to dance practices that centered on performing and learning dance routines, the showcases also allowed community members to showcase and compete, and judges in showcases often evaluated each dance team's performance.

After each dance team arrived at the venue, they warmed up. Before the audience and judges arrived, some of the dance teams briefly took the stage and practiced. When the event officially started, dance teams waited for their turn to perform in front of the audience. As each dance team performed, judges observed their performance. At the end of the event, they announced the winners. They also privately delivered their critique (e.g., improvement areas, performance strengths) to the dance teams either verbally or through handwritten notes.

Figure 10.5 Dance showcases at Seton Hall (left) and NJIT (right).

10.2.5 Data Collection

Our goal in our data collection method was to incorporate multiple perspectives for documenting interpersonal interactions in the community activities. Such a method would support a collaborative and reliable approach for in-depth and thorough analyses of the interactions. To achieve this goal, we recruited four undergraduate students with HCI background as research assistants.

While these students were skilled in conducting qualitative research, their familiarity with ethnographic research methods was limited. Therefore, before the study started, we conducted several workshops for the research assistants to teach them concepts of ethnography and instruct them on how to conduct observations, conduct ethnographic interviews, write field notes, and conduct qualitative analysis using ethnographic data. After completing the workshops, we asked the research assistants to conduct a pilot observational study. After reviewing their work and confirming their knowledge of ethnographic research methods, we moved on to the next step.

We defined our researcher roles in the observational visits as *the observer as participant*. We did not become part of the communities nor interfered in community activities. Instead, we participated in the activities merely as a means for conducting observations. This approach allowed us to follow a *legitimate peripheral participation* process (Adler & Adler, 1994; Chaiklin & Lave, 1996; Lave, 1988; Lave & Wenger, 1991; Wenger et al., 2002). We became observers with legitimate participation status to observe interpersonal interactions unnoticeably. We informed our subjects about our roles in advance.

We took field notes during each observational visit and created content logs to document community activities and collaborative procedural learning instances (Figure 10.6 shows examples of our field notes from an observational visit). The use of field notes, which are common among interaction analysis scholars (Minneman, 1991), allowed us to capture a detailed view of each observational visit and navigate specific interpersonal interactions that were of interest in this investigation. We also aimed to collect video recordings of the activities to create supplementary datasets supporting in-depth and iterative analyses of our field notes.

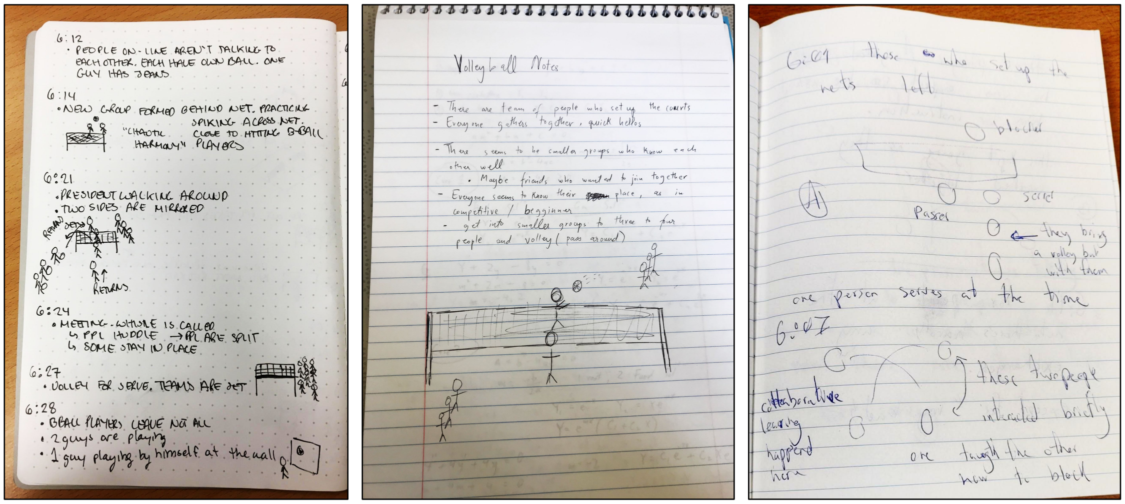

Figure 10.6 Observational study field notes.

Unfortunately, we were unable to conduct video recordings of activities in the recreational volleyball communities, since our observational visits to the recreational beach volleyball tournaments occurred early in the study, and we did not have the proper equipment to record these activities. After noticing the importance of ethnographic videos to our study, we took steps to prepare the equipment for future visits. For the indoor recreational volleyball open-court practices, we reached out to the gatekeepers and inquired about collecting video recordings of the activities. However, they informed us that they deemed video recordings of their activities to be inappropriate due to privacy concerns.

In the recreational dance communities, the research assistants collected video recordings of the community activities. Before our observational visits, we sought and obtained the gatekeepers' permission to collect video recordings of their activities. After receiving their approval and before starting our observational visits, we also did pilot visits to ensure that our use of lifelog devices (e.g., stationary GoPros around a dance court) would not interfere with the activities.

We specifically recorded videos of entire dance practices and showcases rather than detached video snippets of the activities. Our rationale for avoiding video snippets was that they might decrease our chances of capturing significant interpersonal interactions supporting collaborative procedural learning. Throughout our observational visits, we generated more than 16 hours of video recordings, which included 5 hours and 15 minutes of the NJIT Dance Team practices, 5 hours and 30 minutes of the NJIT Purple Dancers practices and showcases, and 6 hours of the Flash DT Dance Team practices and showcases.

We also engaged in informal conversations with the subjects about our observations. Most of these conversations occurred during breaks in the dance practices. In our conversations, we inquired about social connections among the subjects. At multiple points, we also asked the subjects about specific interpersonal interactions that targeted their learning and performance. We entered responses from the subjects into our field notes and used them to complement our ethnographic dataset.

After each observational visit, the author and the research assistants met to compile all the field notes and ethnographic videos and store them using cloud-based data repositories.

10.2.6 Data Analysis

Our observational study followed the qualitative analysis method of Framework Analysis, consisting of five primary steps: familiarization, identifying a coding framework, indexing, charting, and mapping/interpretation (J. Ritchie & Spencer, 1994;

Urquhart et al., 2018). During the observational visits, we avoided making interpretations. Instead, after each visit, we organized and conducted analysis sessions to get *familiarized* with our observational data of field notes and captured videos. We also collaboratively examined emerging preliminary themes in our dataset.

In our analysis sessions, the author and the research assistants shared and discussed themes that they independently found in the dataset. These discussions allow us to collaboratively *identify a coding framework* for further in-depth analyses.

In the *indexing* step, the author used the previously negotiated coding framework to analyze the subjects' participation in community activities and community-based processes for collaborative procedural learning (Table 10.4 presents the high-level codes used). The author first coded the fieldnotes focusing on the structures of participation through which the subjects mutually engaged in and disengaged from activities with others. Next, the author coded interpersonal interactions based on their relative meaning, associated context, and connection to existing structures. The author used the fieldnotes to compare the interactions with primary forms of interactions indicated through our conceptual framework for collaborative procedural learning. This step allowed the author to use the framework as a roadmap in the interaction analysis.

Table 10.4 Observational Study Coding Framework

Code	Code Name	Code Definition
1	Participating member	A community member who participates in a community activity
2	Type of performance	If a community member participates in private practice, social practice, or competitive performance
3	Physical task executed	A physical task that a community member executes during a community activity, especially those that initiate feedback exchange
4	Form of interaction	How interpersonal interactions among two or more community members occur
5	Exchange of feedback	Instances of two or more community members exchanging feedback
6	Giver of Feedback	The community member who provides feedback in a feedback exchange
7	Receiver of Feedback	The community member who obtains feedback in a feedback exchange
8	Use of Feedback	How a community member applies the obtained feedback
9	Mode of Communication	If feedback exchange occurs through verbal, non-verbal, or written communication
10	Situational Factor	Situation factors in the environment that affect feedback exchange
11	Lack of Feedback	Instances of extrinsic feedback desired but unavailable
12	Use of Observation	A community member learns through observing other members

The author studied feedback exchange by closely examining structures of exchange through which subjects take turns in performing movements and conversations with others. If available, the ethnographic videos were also used to navigate to specific interpersonal interactions of interest in this investigation. The author focused on observable behavioral elements regarding such interactions, including verbal exchanges, body movements, alignments of bodies, mutual gaze, or patterned eye contact. Examining these elements covered both verbal and non-verbal interactions in our analysis.

After indexing our observational data, in the *charting* step, we used recursive analysis processes and also elements of Grounded Theory (Corbin & Strauss, 1990; Glaser & Strauss, 1967) to refine our codes and coding framework and create phenomena by categorizing the coded pieces based on their similarities and differences.

Lastly, we described, interpreted, and reviewed the phenomena and identified whether they supported the investigation of our research questions. We also made conclusions and drew implications from the phenomena found through our analyses.

The author and the research assistants met weekly over the period of the study to collaboratively evaluate the development of the coding framework and review the study insights. We used NVivo as our qualitative analysis tool, which facilitated our data analysis processes.

10.3 Findings

This section presents the findings of our observational study. We explain community-based processes for collaborative procedural learning during our observational visits to the communities' interactional hotspots (RQ1). We outline processes centered on teammates’ roles, skill levels, and personal connections in the recreational volleyball and dance communities. We provide several excerpts, including fieldnote entries and video screenshots, to depict our findings.

10.3.1 The Role of Teammates

We found that teammates in the beach and indoor volleyball and dance teams frequently observed each other's movements and exchanged feedback to improve their team coordination and overall team performance. The beach and indoor volleyball players exchanged feedback in a spontaneous manner, while the dancers tended to follow systematic methods for exchanging feedback. The following sections describe community-based processes that centered on the role of teammates.

10.3.1.1 Beach and Indoor Volleyball Teammates Exchanging Feedback. As the players competed in beach volleyball tournaments and indoor volleyball open-court practices, we often observed them exchange feedback with their teammates. We noticed that playing together gave them opportunities to observe their teammates' movements and share their feedback. Instances of feedback exchange ranged from brief comments (e.g., a player telling their teammate to set the ball higher for them) to extended conversations between teammates about their teamwork during their breaks. Often feedback exchanges between teammates helped them coordinate their movements and perform better as a team. Here we present an excerpt from our field notes illustrating feedback exchange between two teammates during a GAV coed tournament. We observed Jennifer, who was playing in a coed 2's AA tournament with her teammate, Martin. Throughout the matches, she carefully observed Martin's movements and gave him feedback. During one of her breaks, we asked her about her feedback exchange with Martin. She said: *"As people have acquired new skills or get more consistent, you notice* *that. You can be like 'oh, you've gotten a lot better', you notice it [...] when you're playing with them you realize that they can do something new."* Jennifer and Martin continued to exchange feedback throughout their matches. (Excerpt from field notes 6/17/18)

10.3.1.2 Dance Teammates Exchanging Feedback. We also observed teammates in the dance teams collaboratively exchanging feedback. During their practices, they often took turns forming subgroups. Each subgroup performed in front of the rest of the team, which allowed the teammates to observe each other's movements and exchange feedback. We noticed that this collaborative process engaged all the teammates to help one another and improve their coordination. The dance captains helped facilitate these processes, but the dancers mainly relied on collaborations with their teammates. Here we present an excerpt describing teammates in the NJIT Dance Team collaboratively exchanging feedback. We noticed that toward the end of a dance practice, the dance captains randomly selected three dancers and asked them to perform a specific routine in front of the group (see Figure 10.8 [1]). The three dancers performed the routine, and all the other dancers observed their performance [2]. After they completed the routine, the three dancers received feedback from all the other teammates on their individual skills and coordination [3]. Then, the dance captains selected three other dancers to perform in front of the team. This process continued until all the dancers received feedback. (Excerpt from field notes and video recordings 12/5/18). In addition to facilitating the dancers' learning, this process also helped them become more comfortable in their performance. One of the dance captains explained to us: "*Some people aren't good at … they'll either* *get nervous in front of crowds or they're not good at making facial expressions. So, having people to dance for will make it easier."*

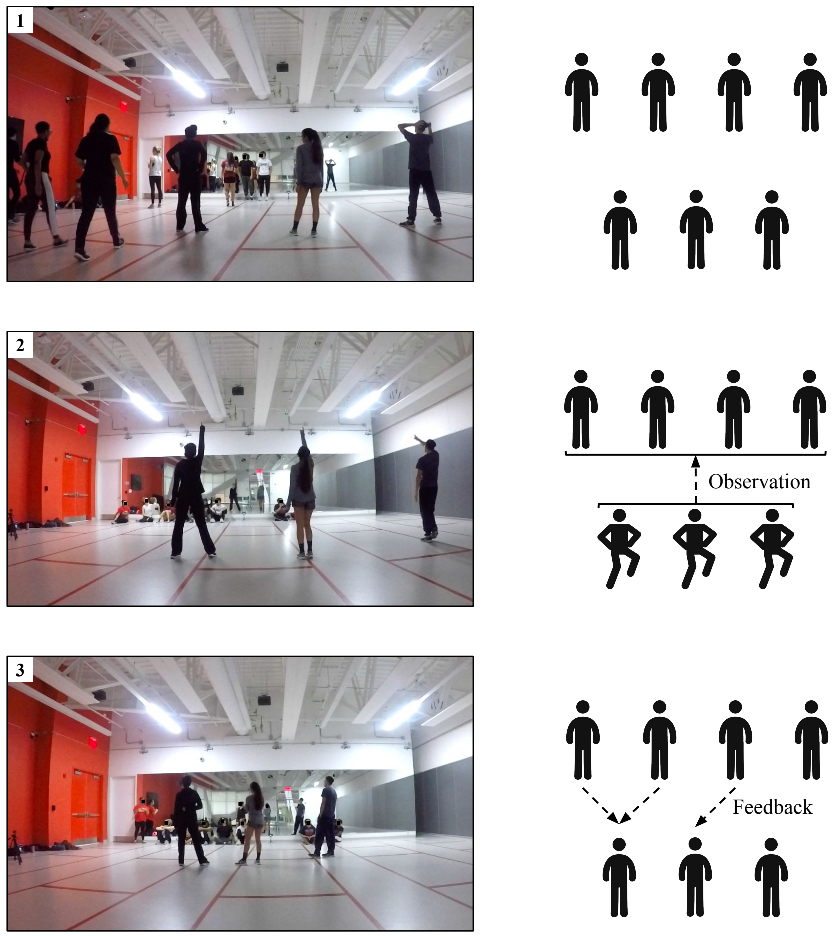

Figure 10.7 Field visit notes and video recording screenshots showing feedback exchange between dance teammates.

10.3.2 The Role of Skill Level

We found a set of processes that centered on differences in skill levels among community members. When individuals struggled with movements, they looked for high-skilled community members, who could help them with learning. Observing high-skilled community members and getting their feedback played a critical role in the individuals' procedural learning.

10.3.2.1 Beach and Indoor Volleyball Players Observing High-Skilled Opponents. We found the beach and indoor volleyball players observed their opponents to learn from them. As mentioned earlier in the chapter, the beach volleyball players played in parallel tournaments based on their skill levels: Open (highest level), AA, A, and B (lowest level) tournaments. Since the beach volleyball tournaments coincided, we noticed the players from low skill levels watched high-skilled players' matches to observe their movements and learn from them. Teammates used their observations of their opponents to discuss their team performance. They often compared and contrasted their performance with their opponents and collaboratively identified improvement areas. Some also planned concrete steps to address the improvement areas before their upcoming matches. The following excerpt in Figure 10.8 presents an example of two beach volleyball players we observed following such a process: Bob and his teammate finished their matches in the tournament. As they were taking a break, they started to watch an open-level match. Bob observed how the players performed and formed a mental image of their movements. As the match ended, Bob turned to his teammate and discussed the passing skills he observed. Bob and his teammate then talked about improving their skills to prepare for future tournaments. (Excerpt from field notes 6/9/2018)

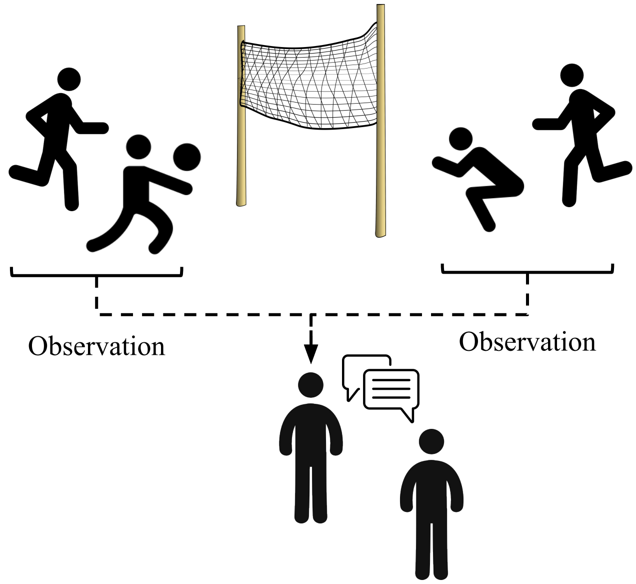

Figure 10.8 Field visit note showing observation of opponents' matches.

We also learned that sometimes, outside tournaments, the players had rare opportunities to play against high-skilled players. Players from low skill levels explained to us how they used these opportunities to observe the higher-skilled opponents' movements and improve their competitive performance. For example, Justin and Alex, two level-A beach volleyball players recalled playing a pickup match with two open-level players. Justin said: *"[The open players] were like 'hey, do you mind if we play with you?' and I was like, 'of course! Do you mind if we play with you?' [...] I got lit up and stuff, but like I also learned more in those two hours than ever."* Alex told us that he had hesitation about playing with open-level players. He said: *"[The open players] were very competitive, and I didn't want them playing with me to hinder their training or anything. So it was kind of the moment where I realized, you know, I'm helping them get better."* (Excerpt from field notes 6/17/18)

While playing with high-skilled opponents was rare, such opportunities allowed the players from low skills levels to identify improvement areas that they had missed. By addressing these improvement areas, the players were able to improve their performance for their future matches.

Furthermore, we observed similar situations in the indoor volleyball open-court practices, where volleyball players from all skill levels were randomly assigned to teams. During those matches, where players had the opportunity to play with high-skilled opponents, we noticed that they often used these opportunities to observe their opponents' movements and learn from their skills. In addition to observations during the matches, the players also spent their idle time between their matches to watch their opponents' matches and discussed their observations with their teammates. For example, during one of our field visits we observed two volleyball teams, who finished their match and let two other teams take the court. The players who were on a break decided to sit by the court and watch the upcoming match. They carefully observed the match and exchanged comments on the opponents' performances. At a point, a volleyball player perfectly spiked the ball and scored. One of the idle volleyball players who observed the spike turned to another player to his side and said: "*You need to do that. That is how you do it*." Then, these two players discussed how they could collaboratively perform the spiking skill in their next match. (Excerpt from field notes 4/4/19). This highlights how volleyball players may use their observations of other teams to identify an improvement area.

10.3.2.2 Dancers Getting Feedback from High-Skilled Teammates. We further learned that dancers often sought and received feedback from their high-skilled teammates. Since the dance captains tended to have the highest skill levels in each dance team, they often guided the dancers in the practices and provided feedback repeatedly. We observed how dancers in each team heavily relied on their dance captain's feedback to support their learning. For example, during one of our field visits, we observed how during the FLASH DT Dance Team practice, the dancers worked on a new routine. The captain walked the dancers through all the movements step by step. At various points, the dancers asked clarifying questions. The dance captain patiently answered the questions and moved to the next part of the routine. At a part of the routine, the dancers had to pair up and move together. The movement included each pair turning until the dancers faced each other. Some of the dancers did not perform the part of the routine correctly. The captain quickly observed their movements and gave them feedback about how they needed to turn. The dancers listened to the feedback and corrected their movements. After the team successfully performed this part of the routine, the dancers moved on to the next part (Excerpt from field notes and video recordings 4/11/19). Figure 10.9 shows a video recording screenshot from our ethnographic observation of this dance practice.

Figure 10.9 Field visit video recording screenshot showing dance captain providing feedback.

In addition to the dance captains, each dance team had other high-skilled dancers, who were often old-timers and very familiar with their team's dance routines. As the dancers were learning new dance routines, some were not yet familiar with the movements. We noticed how the high skilled dancers voluntarily helped the struggling dancers and gave them feedback to help them learn the dance routines. For example, during a dance practice we observed, the NJIT Purple Dancers worked together to learn a new routine. First, they loosely performed the entire routine from start to end. Then they started to clean their performance (i.e., make incremental improvements). During the cleaning phase, the dancers sought feedback from high-skilled dancers who were familiar with the movements. When we asked Laura, the dance captain, about this process, she said: *"The people who already know the choreography would be helping out others who don't understand the movements. Or the people who are more comfortable with the specific movements would just teach them, teach one another."* Early in the cleaning phase, two of the dancers failed to keep up with the team and thus approached a high-skilled dancer. They shared that they struggled with proper spacing with one another. Since the high-skilled dancer was familiar with the routine, he provided them with specific feedback about their spacing. The dancers iteratively practiced with the high-skilled dancer till they successfully performed the entire routine (Excerpt from field notes and video recordings 11/2/18). Figure 10.10 presents a screenshot from our field video recordings created during an observational visit to an NJIT Purple Dancers' practice.

Figure 10.10 Field visit recording screenshots illustrating feedback from high-skilled dancers to other dancers.

In addition to feedback exchange, we also learned about how the dancers used the dance practices to observe the high-skilled dancers and learn from them unnoticeably. We saw dancers closely observing the high-skilled dancers' movements to learn how to improve their dance skills. For example, as we observed a group of dancers in the NJIT Dance Team practicing a new dance routine, the dance captain performed the routine step-by-step in front of the dancers. Two high-skilled dancers were in front of the group and behind the dance captain. They quickly picked up significant portions of the new routine and started to perform it with the dance captain. Other dancers were still unfamiliar with the movements. These dancers carefully observed, either directly or through mirror reflection, how the dance captain and the other high-skilled dancers performed the routine. Each dancer used the observations to learn the movements. After steadily completing the movements, they became familiar with their routine. After multiple iterations, most dancers learned the routine and started to perform it with the group. (Excerpt from field notes 12/4/18). Figure 10.11 shows field visit note and videos recording screenshot highlighting observations of high-skilled dancers during practices.

Figure 10.11 Field note and video recording screenshot showing dancers (in the back) observing high-skilled dancers (in the front).

10.3.3 The Role of Personal Connections

We found that personal connections among community members also played an important role in community-based processes for procedural learning. Individuals felt more comfortable observing and exchanging feedback with others with whom they had a personal connection. This section described such processes in the dance practices, beach volleyball tournaments, and indoor volleyball open court practices.

10.3.3.1 Connected Beach and Indoor Volleyball Players Exchanging Feedback. We observed that teammates who had high familiarity with each other were often more comfortable exchanging feedback. The subjects also told us that since they were familiar with their connections' backgrounds and skill levels, they relied on the connections for feedback. These teammates had played together over extended periods and gained knowledge of each other's skills. They used such knowledge to exchange tailored feedback, which had made them receptive to each other's feedback. For example, we observed this type of feedback exchange between two familiar beach volleyball teammates in a GAV tournament: We met Alex and Justin, who had played beach volleyball together since high school. They told us they practiced together multiple times during the week and played in the tournaments every weekend. As they were taking a break between their first and second matches in the tournament, we noticed them exchanging feedback several times. When asked about how they communicated, Justin said: "*He is not afraid of telling me that I suck. So a couple of days ago, I was playing awful, and he freaked out. It's just that way that we are not afraid to tell each other the* *truth. Throughout the game, I tell him just swing away, make something better.*" (Excerpt from field notes 6/9/18)

In teams with low familiarity levels (e.g., a recently started beach volleyball team, six volleyball players who form a team during an open-court practice), we also saw players exchanging feedback. However, these players were more cautious about sharing feedback, as they wanted to ensure that their feedback was received well. We noticed that as the teammates continued playing together, some became more familiar with each other's performance and managed to exchange tailored feedback. For example, during a coed 2's AA tournament, we met Daniel and Kat, who were teammates. During a match, Kat set the ball for Daniel, but the ball was too far from him, and he could not kill it. Daniel wanted to give Kat feedback. He first started with positive feedback: "*Hey, it's good"*. Then, he moved on to provide Kat with specific feedback about how she set the ball. He said: "*Hey, just bring in a little bit more to the middle of the court".* He also briefly explained how her skill affected him in the game. Kat listened to Daniel's feedback and responded, *"Okay, I'll work on it".* Daniel also acknowledged that Kat was doing her best and gave her more positive feedback. We asked Daniel about how he exchanged feedback with his teammates in the GAV tournaments. He shared: *"It depends. Like my teammate from yesterday, because I played with them all the time, I'll tell them, you know, right away. Saying 'hey, you're setting too low' or 'you're overrunning the bone' things like that. If I haven't played with them ever, I try to feel them out, see how they react to criticism. [...] You have to be careful in making sure that you stay positive. Always positive criticisms. Do you have anything negative to say? Try to spin it into a positive. Try to leave it after the game. So maybe when we're sitting* *around about to start up another day, be like, 'Hey, remember last time you did this? Just try to avoid that.'"* (Excerpt from field notes 6/17/18). This highlights how feedback exchange between teammates with low familiarity levels differs from feedback exchange between teammate who have strong personal connections.

10.3.3.2 Connected Dancers Exchanging Feedback. When the dancers struggled in the dance practices, we learned that they sometimes preferred to seek feedback from familiar teammates rather than from the dance captains or other high-skilled dancers. As the dancers continuously interacted during community activities, they formed social ties and became acquainted with each other's skill levels and dance backgrounds. We observed how these socially connected teammates tended to frequently help one another and exchange feedback during the dance practices.

Over time, newly formed social ties and connections in the dance teams had created new opportunities for the members to seek guidance and extrinsic feedback during their learning experiences. Figure 10.12 illustrates a feedback exchange between two connected teammates in the NJIT Dance Team. In a dance practice during one of our field visits, we noticed Sarah struggled with some of the movements. She stood next to Oliver, and Sarah knew Oliver and tended to ask him for feedback. She had mentioned to us earlier, *"[Oliver] is the kind of guy that answers everything, and he's very good with counts […] he's had a lot of dance experience. He's a freestyler, so he can pick it up very quickly, luckily too. So yeah, he's the main person."* At that point of the practice, we observed how she reached out to Oliver (see Figure 10.12 [1]). She performed the movements with Oliver and requested feedback [2]. Oliver observed Sarah's movements and then explained to Sarah how the movements were supposed to look [3]. Sarah listened to Oliver's feedback and tried to perform the movements again. Since Oliver wanted to help Sarah even further, he performed the movements with her [4]. Sarah quickly picked up the movements and was able to move on in the dance practice. (Excerpt from field notes and video recordings 12/5/18)

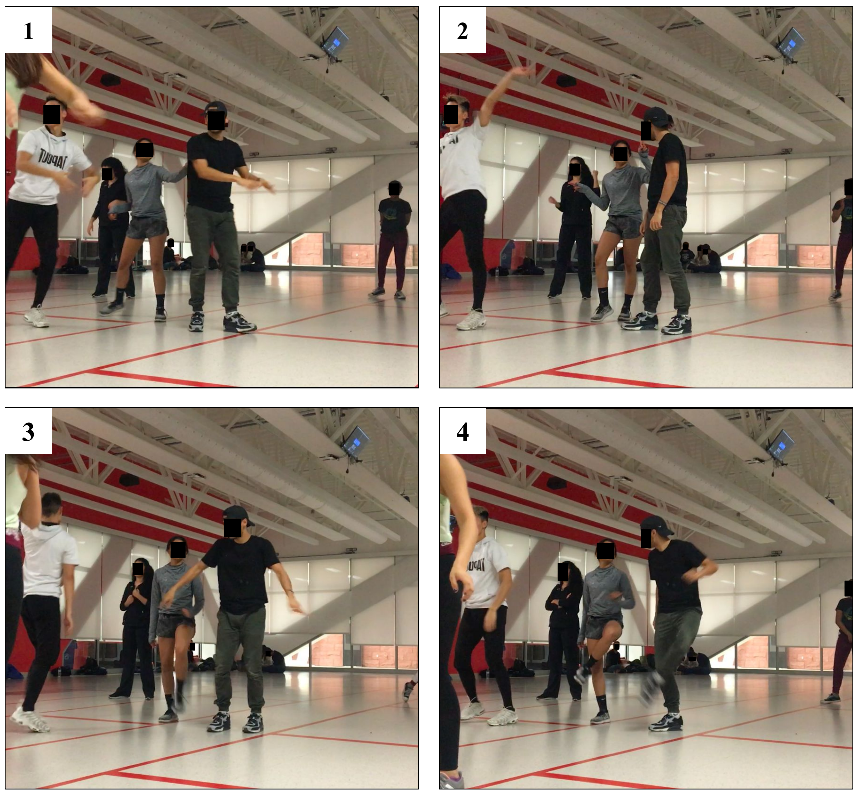

Figure 10.12 Field visit video recording screenshots illustrating feedback exchange between connected dance teammates.

10.4 Discussion

This section presents a discussion of our observational study findings regarding the existing community-based process for collaborative procedural learning in the recreational dance and volleyball communities. We found community-based processes centering on the roles of teammates, skill levels, and personal connections among individuals. Our themes outline possible directions for supporting collaborative procedural learning in CPRC.

Our first theme of findings showed that volleyball and dance teammates exchanged feedback to help each other with learning. This finding is aligned with our review of the literature and our arguments in Chapter 2. Teammates in collaborative physical recreation, including volleyball and dance, need to perform their movements collaboratively. Therefore, it was expected to observe that teammates repeatedly exchange feedback to coordinate their movements. This finding suggests that facilitating iterative feedback exchange among volleyball and dance teammates could positively impact their learning and enhance their motor skills. Supporting feedback exchange between them can further help them find improvement in their team performance areas and address them together.

This finding also informs solutions, including technological innovation, for supporting collaborative procedural learning. We argue that allowing teammates to exchange feedback on their teachable moments can help the teammates frequently discuss their performance and determine how they can improve as a team. Having said that, we argue that solutions that support feedback exchange among teammates must acknowledge certain constraints. First of all, such solutions may create situations in which teammates exchange feedback excessively. Research on feedback theories has shown that additional feedback is not always helpful and may even hinder performance and learning instead of improving them (Chu, 2017; Magill, 1994; Wulf & H. Shea, 2004). Feedback can effectively support teammates' learning only if it is presented to them with proper timing and frequency. Also, feedback-seeking preferences may vary among individuals. Some teammates may desire frequent and thorough feedback from their teammates. Others may rely more on their intrinsic feedback and view extrinsic feedback from teammates as inhibiting their performance and learning. Further research is needed to inform solutions for collaborative procedural learning about proper timing and frequency of feedback among teammates and their preferences.

Secondly, situations can frequently occur in teams, especially beach volleyball teams, when all teammates have similar skill levels. In such cases, feedback exchange among teammates can only benefit their learning to some limited extent. Instead of their teammate's feedback, they may desire a knowledgeable external source to observe their movements and give them feedback. Without external feedback, teammates may also face difficulty analyzing their team performance. Solutions for collaborative procedural learning must avoid relying only on feedback exchange among teammates because such solutions may create bubbles for teams. Solutions instead should allow teammates to seek constructive feedback from other community members, such as high-skilled players or dancers in their community. This would enable the teammates to collaboratively seek and use feedback and identify improvement areas in their team performance.

Our findings shed light on the community-based processes centering on the role of skill levels, i.e., how individuals observed high-skilled players and dancers in their community and sought and used their feedback. As we showed in Study I, trial and error, although limited, is a significant way for community members to acquire motor skills. At multiple points during matches and practices, high-skilled players and dancers helped others with lower skill levels with their learning. Such feedback can be extremely valuable to recently-joined community members who may not be familiar with movements.

That said, we learn from our findings that access to high-skilled individuals varies between the recreational volleyball and dance communities, and thus, supporting community members' learning may require different solutions. High-skilled dance captains actively observed others and gave them feedback. Sometimes, the dance captains could not provide thorough feedback to each dancer since multiple dancers participate in each dance practice. In such cases, other high-skilled dancers voluntarily helped dancers who struggled with learning the movements. We learned from these findings that solutions for supporting collaborative procedural learning must first establish the dance captains' roles and connect them with other dancers. Solutions also need to incorporate high-skill dancer roles from whom dancers can seek complementary feedback.

In the recreational volleyball communities, competition with high-skilled players and observing their movements was one of few opportunities for observing them and receiving their feedback. This finding suggests that solutions that allow players to compare and contrast their motor skills against high-skilled players can positively impact the players' learning. Solutions in this domain can connect players throughout communities to encourage competition among them. Based on players' locations and skill levels, solutions can also match nearby players and create in-person competition opportunities that boost the players' learning (See (Mayer et al., 2015, 2016) for a similar work in this domain).

One constraint to keep in mind for supporting collaborative procedural learning in all the communities is that high-skilled individuals may not be willing to provide feedback to everyone around them. Providing feedback to multiple community members may be overwhelming for high-skilled individuals. Before connecting high-skilled dancers and others, solutions must examine the high-skilled individuals' availability and willingness to provide feedback.

We learn from our findings that interrelated individuals are more willing to exchange feedback and help each other with learning. Such insights have a significant impact on collaborative procedural learning and solutions supporting the processes. While players and dancers may have access to high-skilled players around them, they prefer to seek feedback from those with whom they are personally connected. Without such connections, attempts for supporting feedback exchange among individuals may be limited. Solutions must maintain existing ties and also create new meaningful connections among individuals to support collaborative procedural learning.

We also learn from our findings that the intersections of personal connections with teammates and their skill levels affect collaborative procedural learning in teams. Individuals may engage with their teammates in matches, performances, and practices. However, if they do not feel comfortable with one another, feedback exchange among them can be limited. Solutions for supporting collaborative procedural learning must consider teammates' familiarity levels to facilitate their feedback exchange. Teammates who have played together over extended periods may be comfortable with exchanging detailed feedback on each movement. Recently-connected teammates, however, may prefer to receive generic feedback from one another until they become familiar with each other's styles. As they reach such levels, they may become comfortable receiving direct and detailed feedback from each other.

In summary, we discussed the roles of teammates, skill levels, and personal connections in the community-based processes. We also emphasized the importance of these roles when considering technological innovation for supporting collaborative procedural learning in the recreational volleyball and dance communities.

10.5 Limitations

This section presents the limitations of our observational study. First, in the NJ beach volleyball community, we only visited the beach volleyball tournaments. While our visits shed light on community-based processes for collaborative procedural learning, we could not attend practices that occur outside the tournaments. Therefore, we might have missed processes that the beach volleyball players followed in their practices. Also, as mentioned earlier, we could not conduct video recordings of activities in the recreational volleyball communities. While we continuously took field notes during our observational visits, we might have missed certain interactions among the players. The lack of video recordings of such interactions might have affected the comprehensiveness of our observational data.

While we observed how individuals helped each other with learning, we were unable to objectively measure the levels of learning that occurred. Thus, we could not compare the effectiveness of each community-based collaborative procedural learning process. It is likely that some of these processes were far more effective than others and, therefore, more important in this investigation. Further research examining the effectiveness of the processes is needed.

Lastly, our focus in this study was on instances of direct observations and feedback exchange supporting individuals' learning. However, we anticipate that indirect feedback exchange also positively impacted teammates' learning. For example, when two dancers exchanged feedback, it is likely that the bystander dancers indirectly learned by observing the two dancers' feedback exchange. Further research in the domain is needed to shed light on such important processes for supporting collaborative procedural learning.

10.6 Design Implications

As discussed earlier, CLL solutions provide users with video snippets of their teachable moments and create an entirely new way of sharing data and exchanging feedback. This study expanded knowledge of the existing community-based collaborative procedural learning process in CPRC. Thus, it outlines the design of CLL solutions, specifically the process for feedback exchange using video snippets. This section presents the design implications of the study findings for this CLL process.

10.6.1 Supporting Feedback Exchange among Teammates

Since our findings highlighted the role of teammates in beach and indoor volleyball and dance teams, we determine that CLL solutions must center on supporting feedback exchange among teammates. We suggest creating such support of feedback exchange in teams by (a) forming collective Avatars and (b) incorporating communication functionalities for teammates' collaborative use of video snippets. During each community activity (e.g., beach volleyball tournament, dance practice), CLL solutions must create collective Avatars for each team, which are retrieving and storing video snippets from all the teammates. By giving all teammates in each team complete control over their collective Avatars, CLL solutions would allow them to view and examine each other's video snippets. CLL solutions must maintain and update their teams' collective Avatars continuously for teammates who play together over extended periods. As teammates gain more video snippets by participating in community activities together, their collective Avatars would collect more video snippets and grow.

The CLL solution must also incorporate functionalities for teammates to fetch video snippets from their collective Avatars and collaboratively examine them to identify improvement areas in their individual and team performance. Such functionalities would allow them to share their understanding of the video snippets and exchange feedback. For example, teammates could analyze each other's video snippets over time and determine if they have made enough progress.

The CLL process for feedback exchange using video snippets must acknowledge differences in teammates' collaborative procedural learning processes between beach/indoor volleyball teams and dance teams. Such differences would require adjusting functionalities for using video snippets in these teams. Since beach and indoor volleyball players exchange feedback more spontaneously and primarily in pairs, the CLL process must use the communication functionalities to connect teammate pairs for sharing video snippets and exchanging feedback. Since dancers exchange feedback with all teammates, the CLL process could effectively support collaborative procedural learning by allowing team-wide communication and video snippets sharing.

10.6.2 Supporting Feedback Exchange among Connected Individuals based on Skill Level

Since our findings illustrated feedback exchange through personal connections, we suggest that CLL solutions consider connections among individuals. These solutions must incorporate functionalities that allow individuals to connect with their existing ties in their community. The CLL solutions must also create ad-hoc collective Avatars for connected individuals to share data, examine each other's video snippets, and exchange feedback when needed.

In addition to supporting existing ties, CLL solutions could also create opportunities for forming new personal connections in CPRC. Such processes can be through incorporating user profiles in CLL solutions. A user profile is the surface of an Avatar presenting an overall view of the users' stored data. Since users have complete control over their Avatars, they could select which of their video snippets to share on their profiles. When using CLL solutions, individuals could examine each other's user profiles based on skill levels, personality traits, or other factors. Access to such information might encourage them to form new relationships with others. CLL solutions could support feedback exchange among newly connected individuals by allowing them to share and discuss their data through ad-hoc collective Avatars.

User profiles in CLL solutions create a unique opportunity for building social networks tied to individuals' skill levels. As mentioned above, such profiles would allow individuals to share their videos snippets. A significant factor in the profiles would be individuals' skill levels. Since insights highlighted the critical role of skill level in the collaborative procedural learning processes, we suggest CLL solutions customize and maintain social networks of individuals based on their skill levels. The CLL process for feedback exchange using video snippets must incorporate functionalities for determining each user's skill levels through machine computation, human computation, or an integration of both. After determining individuals' skill levels, the CLL solutions could add skill level information to the user profiles. Individuals could use such information to determine high-skilled individuals in their social network effectively. By forming connections with high-skilled individuals, users in CLL solutions could seek their feedback when needed.

CLL solutions must consider significant constraints of adding skill level information to user profiles and creating social networks based on this information. The first constraint is that individuals may be unevenly skilled in all of their movements. Thus, in addition to showing overall skill level information on user profiles, CLL solutions must also present a breakdown of individuals' motor skills to determine how skilled they are in each type of movement. The second constraint is differences between volleyball and dance in evaluating skill levels. Beach and indoor volleyball have pre-defined skill level systems related to their competition levels. For example, open beach volleyball players are considered high-level players throughout their communities. Players may use this information instead of video snippets on user profiles to identify high-skilled players in their communities. Since dance teams in this study do not have such skill-level systems, we anticipate that dancers become dependent on analyzing video snippets on user profiles to identify high-skilled individuals around them.

10.6.1 Creating Community-Wide Repositories of Video Snippets

Since we found that observations of high-skilled players have an essential role in supporting individuals' procedural learning, we suggest that CLL solutions create community-wide repositories for sharing video snippets. CLL solutions must respect individuals' privacy preferences and maintain their complete control over their data in Avatars. At the same time, CLL solutions could encourage high-skilled individuals to share some of their video snippets with their entire community to help their fellow community members with learning. By incorporating these video snippets in the community-wide repository, individuals with lower skill levels could access this data and learn from observing the high-skilled players' or dancers' movements in the video snippets. While they may have access to tutorials on video-based platforms (e.g., YouTube), they could use their community-wide repositories more effectively to learn from other community members. CLL solutions could also incorporate user interfaces such as community feeds to facilitate access to community-wide repositories.

10.7 Summary

This chapter presented an observational study of community-based processes for collaborative procedural learning in CPRC. The findings showed processes centering on the roles of teammates, skills levels, and personal connections in the recreational volleyball and dance communities. The chapter also discussed the importance of these roles when considering technological innovation for supporting collaborative procedural learning in CPRC. We explained how the findings informed the CLL process for feedback exchange using video snippets. Next, we present Study III, which aims to generate an in-depth understanding of teachable moments in CPRC to inform the CLL process for identifying and contextualizing video snippets.

CHAPTER 11

STUDY III: CONTEXTUAL INQUIRY OF TEACHABLE MOMENTS

This chapter presents the third study in this dissertation, a contextual inquiry of teachable moments. As explained in Chapter 9, one of the critical processes in Collaborative Lifelogging (CLL) is identifying and contextualizing video snippets of teachable moments. Chapter 5 described teachable moments as concrete instances, in which individuals want to improve their motor skills. In addition, our literature review highlighted the importance of teachable moments in supporting collaborative procedural learning. This study aims to expand our understanding of what individuals identify as teachable moments in the NJ beach volleyball communities. By providing beach volleyball players with video snippets of their teachable moments, we also examine the perceived utility of viewing this data type for supporting procedural learning. Finally, we present a discussion of the study insights and explain how they inform the CLL process for identifying and contextualizing video snippets.

11.1 Research Questions

In this study, we investigate the following research questions:

> RQ1: *What do individuals identify as teachable moments?*
>
> RQ2: *What is the perceived utility of viewing videos of teachable moments?*

11.2 Method

We used video-based contextual inquiry as the research method of our study. Our goal was to closely investigate beach volleyball players' perspective of their teachable moments in community activities. Inspired by the CLL process for collaborative video capture, we video captured community activities in the NJ beach volleyball community and asked members to identify important moments during the activities with wireless event triggers. We used data from the cameras and event triggers to create video tours showing chronologically ordered sequences of identified moments. Afterwards, we conducted collaborative video viewing sessions with beach volleyball players. Collaboratively with the players, we explored video tours to understand their identified moments. We also used the video tours to investigate the perceived utility of capturing and viewing those moments. We first introduce this research methodology and then describe the steps we took in this method.

11.2.1 Method Background

Contextual inquiry is an empirical application of ethnographic research methodologies focusing on understanding individuals in their contexts (S Pink et al., 2016; Smith & Otto, 2016). Among ethnographic methods, contextual inquiry is well-suited for research domains in which resources and time are limited (Beyer & Holtzblatt, 1998; D. Schuler & Namioka, 1993). Scholars in the field of Human-Computer Interaction (HCI) and Computer-Supported Cooperative Work (CSCW) have commonly used contextual inquiry to understand potential users of technological solutions.

Context, *partnership*, *interpretation*, and *focus* are the four principles of conducting a contextual inquiry (Hammersley & Atkinson, 2007; Whiteside et al., 1988)

The *context* principle highlights the importance of understanding subjects in their real-world environment. Contextual inquiry follows this principle through a master-apprentice model. In this model, subjects are *master craftspersons* performing specific tasks, and researchers observe and interview the subjects to learn about how they perform the tasks (Beyer & Holtzblatt, 1998). This principle also indicates that apprenticeship may revolve around how subjects engage in interpersonal interactions and also interactions with certain artifacts under study.

The *partnership* principle emphasizes the importance of engagement and collaborations and partnerships between researchers and subjects in exploring research domains. The main channel of partnership is through researchers interacting with subjects in the format of observations and interviews.

As an ethnographic research methodology, contextual inquiry also relies heavily on the *interpretation* principle. This principle focuses on assigning meaning to the collected datasets about the behaviors and actions of subjects through interpretation. By acknowledging and documenting their assumptions before starting the interpretation phase and continuously examine the assumptions, researchers can provide valid and reliable interpretations of data using contextual inquiry.

Lastly, the *focus* principle indicates that it is crucial for contextual inquiry researchers to constantly direct their method of collecting data, including observations and interviews, to provide an in-depth exploration and examination of specific aspects of the research domain.

While contextual inquiry through observing and interviewing subjects in their real-world environment could be effective in numerous contexts, it may interrupt subjects' participation in certain activities, such as collaborative physical recreation. To address this limitation, scholars have incorporated video-based contextual inquiry (Sarah Pink et al., 2017). Such methods use cameras to capture subjects performing tasks or participating in activities and use the video recordings to interview the subjects and learn about their perspective. The use of video-based contextual inquiry is common in the fields of HCI and CSCW to understand potential users of technological innovation (Buur et al., 2000; Faulkner, 2007; Hughes et al., 1994; Tatar, 1989). Specifically, scholars have used this method to examine technological innovation supporting photo and video capturing, editing and sharing in physical recreation communities, such as winter swimming, parkour, snowboarding, and skateboarding communities (Rajanti et al., 2005; Tikkanen & Cabrera, 2008).

In investigating teachable moments in the NJ beach volleyball community, this dissertation uses a video-based contextual inquiry. Next, we describe our steps in this applying research method.

11.2.2 Study Design

For our video-based contextual inquiry, we focused on the Bradley Beach 2s League[1], organized by the Great American Volleyball (GAV) as one of the main community activities in the NJ beach volleyball community. This activity is a 9-week competitive event for beach volleyball players happening over summers. During leagues, teams play against each other, with 8 teams making it to the playoffs. Beach volleyball matches are held from 6:15 pm to 7:45 pm on Tuesdays for men's and women's 2s and Thursdays for

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[1] https://greatamericanvolleyball.com/pages/bradley-beach-league (accessed Aug. 2020)

coed 2s. To conduct our video-based contextual inquiry during the league, we attended this event eight times between August 6th and September 3rd, 2020. We utilized elements of the CLL process for collaborative video capture of community activities throughout these steps to facilitate this investigation.

11.2.2.1 Step 1: Multi-Perspective Video Capture of Community Activities. We video-captured beach volleyball players' matches using multiple stationary cameras, which generated 3rd person videos (See Figure 11.1). During the league, we approached several courts and explained the objectives of our study to the players and inquired whether they were willing to participate in our contextual inquiry. We informed the players about our intention to record their matches and asked them to sign our consent form for being recorded. Most of them shared that they did not mind us video capturing them with our setup and signed the form. That said, we did hear from one of the players that they did not want to be recorded. They said: "*Playing a match is stressful enough. I don't want [being recorded] to be on top of that.*" We respected their decision and actively avoided recording their matches.

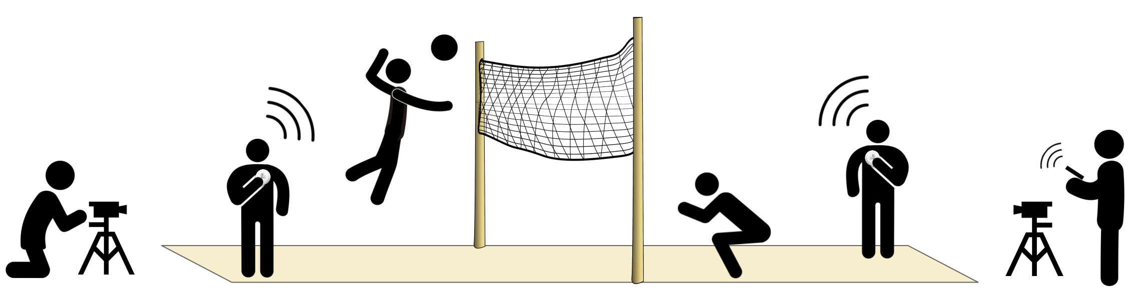

Figure 11.1 Multi-perspective capture of community activities and identification of moments using event triggers.

Overall, we video captured 11 hours and 40 minutes of the beach volleyball matches, 1 hour 27 minutes on average for each day of our contextual inquiry. Our setup with multi-perspective cameras generated more than 35 hours of video recordings, 4 hours and 24 minutes on average per day.

11.2.2.2 Step 2: Support In-Situ Interactions for Identifying Moments. In our video-based contextual inquiry, we incorporated in-situ interactions from CLL solutions to allow beach volleyball players to identify any moment of their matches. We provided beach volleyball players with wireless event triggers[1] (see Figure 11.1). We communicated with the players about the study's objective and demonstrated how to use the wireless event triggers. We asked them to press the button on the event triggers to identify any important moment of their matches. We stored the players' input in our databases for our next steps. During breaks, we reminded the players to use their event triggers to ensure they efficiently identified all of their moments of interest. We minimized our interruptions and dedicated our efforts to recording videos from the cameras and storing data from the event triggers.

Twenty-eight beach volleyball players participated in our video-based contextual inquiry and used the event triggers to identify moments of their matches. They pressed the button on their event triggers more than 760 times, each player 27 times on average.

11.2.2.3 Step 3: Retrieve Video Snippets and Generate Video Tours. After collecting data through our previously described setup, we used videos from the cameras and timestamps from the wireless event triggers to retrieve video snippets of the players' identified moments. We manually retrieved 294 video snippets through a time-intensive

[1] https://flic.io/ (accessed Aug. 2020)

process, 10.5 video snippets per player on average. Each video snippet showed a player's identified moment through multiple perspectives. We also used the video snippets to create video tours showing chronologically ordered sequences of identified moments. Our method generated 28 video tours for our next step.

11.2.2.4 Step 4: Conduct Collaborative Video Viewing Session with Players. As a final step, we organized and conducted collaborative video viewing sessions with the beach volleyball players, who had identified moments of their matches. We conducted nine sessions with 15 beach volleyball players. For six of the sessions, we managed to recruit players who were teammates during the league. Other sessions were with individual players. Due to the COVID-19 pandemic, we could not conduct the collaborative video viewing sessions in-person and instead used video conferencing tools (e.g., WebEx, Zoom). We asked the subjects to sign consent forms before participating in our sessions. In the first part of each session, we co-explored video snippets of their identified moments with the subjects. They viewed on average 12 video snippets per session. In addition to our subjects explaining each identified moment, we asked our subjects in-depth follow-up questions about each moment:

- *Why did you identify this moment?*
- *What aspects of it were important to you?*
- *What aspects of it stood out to you?*
- *How did viewing the video snippet of the moment affect your perception of it?*
- *What aspects of their performance did you observe using the video snippet?*
- *What did you learn from viewing the video snippet*?

In the second part of the sessions, we provided the subjects with additional video snippets showing moments that they did not identify. We examined their perceptions of such moments to compare and contrast the moments we identified with their identified moments.

In the third part of the sessions, we asked the subjects to categorize their identified moments. During this procedure, they carefully examined their identified moments and grouped them based on their similarities and differences.

In the last part of the session, we shared the full videos of their matches with the subjects in each session and we overserved how the subjects explored their full videos. When they paused the videos to review a specific part of the video, we asked them to share their motivation for doing so and any additional thoughts they had about the moment.

The average length of our collaborative video viewing sessions was 51 minutes. We recorded the audio and video of our interactions with the subjects, including their interactions with their data and our discussions with them.

11.2.3 Data Analysis

We analyzed our contextual inquiry datasets, including videos and qualitative data, using elements of Grounded Theory (Corbin & Strauss, 1990; Glaser & Strauss, 1967). This included obtaining insights directed by our research questions through open coding. Our analysis method consisted of several steps:

- Identifying and coding pieces of our qualitative data covering critical points of the data.
- Generating concepts and phenomena by categorizing and grouping our codes based on their content and similarities and differences among them.

- Describing, interpreting, and reviewing the phenomena guided by our research questions.
- Recursively engaging in multiple cycles of coding and categorizing to improve and refine our understanding of the data.
- Making conclusions and drawing implications from the phenomena found through our analyses.
- Providing theories that allow us to interpret similarities, differences, or sequences in our datasets whenever possible.

We developed 67 codes and 21 categories through multiple rounds of coding and categorizing. We identified patterns, similarities, differences, and relationships that were observable in our datasets. When we observed repetitive patterns in our analysis, we acknowledged that we had reached saturation in our dataset. We used NVivo as our qualitative analysis tool to compile our video tours and qualitative data and facilitate our analysis processes.

11.3 Findings

This section presents our contextual inquiry findings centering on teachable moments. We first describe our subjects' getting used to our CLL practices. We then explain what parts of their activity the subjects identified as teachable moments (RQ1) and the perceived utility of viewing videos of their teachable moments (RQ2).

11.3.1 Getting Used to Collaborative Lifelogging Practices

Our subjects initially faced challenges using their event triggers during their matches. However, they became more comfortable with using the devices over time. At multiple points between the matches, we asked our subjects about their experiences with the event triggers. We heard that since they had only used the event triggers for a short time, they had to remind themselves to actively use these devices during their matches. For instance, in one of our collaborative video viewing sessions, two of our subjects shared:

> *"[Using the event triggers] was definitely awkward. You had to think about it. You had to get used to it. If we'd done it maybe for multiple games or throughout several weeks, it probably would have come more naturally. It was definitely the beginning. I was like 'Oh, wait, yeah, I can click.'"* (Kate)

> *"I think we just forgot it was there sometimes, you know, I really forgot about it. And second, it didn't come to me naturally to just click it right away."* (Brandon)

However, subjects who consistently participated in our CLL practices shared that they became more comfortable with the devices over time and had enjoyable experiences with them. Some subjects even encouraged one another to use the clickers to highlight multiple moments of their matches. "*Click that!"* they said numerous times.

In our collaborative video viewing sessions, our subjects shared their excitement about viewing their identified moments. They carefully examined their videos, including highlight reels of their video snippets and full videos of their matches, and shared their thoughts. Teammates also often discussed and communicated their understanding of their moments with each other.

11.3.2 Identifying Unsuccessful Attempts as Teachable Moments

In our collaborative video viewing sessions, we learned that our subjects identified moments of their matches when they could not win a rally (i.e., they could not return the ball). In such moments, they suspected that specific improvement areas in their performance stopped them from succeeding. We heard from our subjects about various improvement areas, each corresponding to a category of teachable moments, such as individual motor skills mistakes, teammates' motor skill mistakes, and teamwork mistakes.

11.3.2.1 Individual Motor-Skill Mistakes. Our subjects selected moments in which they failed to correctly use specific individual motor skills, bringing disappointment and frustration feelings. They shared that they identified such moments with the event triggers to obtain videos of the moments and analyze them. As stated by Maya, one of our subjects about her identified moments: *"I wanted to see where I was and why I hit the ball so terribly [...] I clicked that for that error."* When we provided the subjects with video snippets of their identified moments, they carefully reviewed their movements to determine and address the underlying reasons behind their failed attempts. They found this information beneficial in troubleshooting their performance. For example, Max identified a moment in which he could not dig the ball during a rally. In the collaborative video viewing session, he analyzed the video snippets of his failed attempt and learned that he incorrectly did his footwork, which negatively affected his performance. He said: "*I took way too many steps, like a lot of tiny steps. I shouldn't really do that. It should be more big explosive steps*."

The subjects also used videos of these moments for tactical and strategic development. Our subjects thought that viewing the video snippets of moments covering tactical issues helped them re-examine their choice and implementation of tactics and strategies. They perceived video snippets helpful in determining how to improve their strategic planning and avoid future problems in that area. Sonia shared with us how watching a video snippet of a mistake during her match made her rethink her positioning in her match:

> *"When I was defense waiting for the other team to hit the ball, sometimes I have a tendency of cheating inside the court, instead of protecting my line or giving myself, you know, the room where I can still reach a ball that's hit directly on it. So I learned that from watching that play."*

11.3.2.2 Teammate's Motor Skill Mistakes. In addition to their own motor skill mistakes, our subjects also identified moments when they noticed their teammate's motor skill mistakes. Such mistakes had negatively affected their team performance and caused unsuccessful attempts in their matches. During a collaborative video viewing session with both teammates, Scarlett shared that she had identified moments of her teammates' mistakes:

> Scarlett: *"Jared tends to do a lot of funny hits, and it pisses me off."*
>
> Jared: *"[Laughs] rude! [...] Scarlett clicked every time she was mad at me."*

Teammates who had played together over extended periods were familiar with each other's common mistakes. We learned that they had identified moments of their teammate's frequent mistakes. For example, Richard identified a moment when his teammate Ted did not have the proper form and could not save the ball properly. Richard said that he identified the moment since Ted had repeatedly struggled with his form. He also told us that such common mistakes negatively impacted their team performance. He said: "*It was simple things like that that really bothered me when we mess up on such easy things."*

When the subjects viewed video snippets of these moments, they analyzed their teammate's motor skill mistakes. Some used the video snippets to ensure that their teammates' mistakes were the reason behind their unsuccessful team attempts. In such cases, they used the video snippets as a reference point for their team. In the collaborative video viewing sessions with only one of the teammates, the subjects saw value in gaining insights about how to help their teammates to correct their mistakes in the future. When both teammates were present in the collaborative video viewing sessions, they used the video snippets to analyze one another's motor skills, communicate their insights, and determine improvement areas. In their collaborative video viewing session, Brandon and Kate examine a moment that Brandon had identified. The video snippet showed that Kate could not correctly hit the ball.

> Brandon: *"Kate's initial hit … I had a great set. And then Kate headed into the net and then we lost."*
>
> Kate: *"Shut up [laugh] [...] I think, obviously, I just need to work on my spiking skills.*

11.3.2.3 Teamwork Mistakes. Several subjects identified moments when they made unsuccessful attempts because of teamwork mistakes. These subjects shared that teamwork was a critical part of their team performance. To succeed, teammates had to show effective teamwork, through which they collaboratively performed and positioned their movements in relation to one another. The subjects identified moments when they failed to coordinate their movements, causing ineffective teamwork and, therefore, their unsuccessful attempts. Kate, for example, identified a moment when she noticed an issue with her and Brandon's positioning in relation to one another:

> *"Our positioning wasn't great. When they hit it back, we were just parallel to each other [...] we were in a straight line and somebody should have been up closer to the net and somebody should have been further back. We have to be close. Somebody should be more back. Something's wrong."*

The subjects shared about their identified moments focusing on their own role in their teamwork mistakes. They assumed that their movements had negatively impacted their teammate in such moments, causing their teamwork mistakes. In their collaborative video viewing session, Jorge and Susan examined a moment that Jorge had identified. Jorge discussed how his bad positioning affected Susan and led to a teamwork mistake:

> *"I was trying to get a perspective of where Susan was on the court because I basically cut her off. And if I let her go, she probably would have made a better pass."*

In multiple instances, our subjects identified moments of communication issues with their teammates. They shared that proper communication (e.g., saying "line" or "cross-court," indicating where to hit the ball on their opponent's court) was crucial for their teamwork in their matches. They discussed their communication issues in their identified moments and that such issues had negatively affected their teamwork and, thus, caused their unsuccessful attempts. Evan told us about one of his identified moments covering a communication issue with his teammate:

> *"One of the big things about balls straight down the middle between us is communication […] I didn't call it quick enough. I gotta say, me or you as the ball's getting hit, and I'm gonna grab it or not."*

Viewing videos snippets of moments covering their teamwork mistakes gave them an opportunity to examine their teamwork thoroughly. We observed during the collaborative video viewing sessions with both teammates that they used the video snippets to collaboratively identify improvement areas in their teamwork and plan for team performance improvements. In Jorge and Susan's collaborative video viewing session, Susan told us how analyzing their video snippets together helped them gain a better understanding of their relative positioning during their matches. She said:

> *"[With the video snippets] we see how we play together, and we are able to see how we stand, and we feel, and how much space we left sometimes. We think that we cover everything, but sometimes we're giving too much space, thinking that another player or another team is not going to play that far. So yeah, it's good to see that part."*

When communication issues were the underlying reason behind their teamwork issues, the subjects used the video snippets to determine how they could alter their communication with their teammates to avoid similar future issues, and collaboratively planned to enhance their team communication for better outcomes.

11.3.3 Identifying Success Moments as Teachable Moments

When we showed the subjects their video snippets, we found that they had often identified success moments as teachable moments. For example, several subjects had identified moments of their team winning rallies (i.e., they played in way that their opponents could not return the ball). The focus of some of the subjects was on their individual role and how they helped their team create an advantage over their opponents and win the rally. For instance, we asked Max about one of his identified moments when his team scored. He said: "*I pressed the button because I thought I did a good cut shot.*" Other subjects focused on how their effective teamwork with their teammate caused their team's success. For example, Evan had identified a moment of his match in which he and his teammate showed effective teamwork and scored against their opponents. When we asked why he identified the moment, he said:

> *"It's a good rally with solid passing from both of us. We kept the ball in front of us. We didn't make any stupid mistakes when we got that the point on a little tip over."*

Even though the subjects had won their rallies in these moments, they used video snippets of the moments to gain an in-depth understanding of their performance and identify improvements to get their performance to the next level. Evan told us how watching the video snippet of his team winning helped him re-examine his positioning. He said:

"I definitely should've been a little more behind the ball. I wasn't in my feet enough. So I kept getting caught under the ball instead of behind it when attacking."

Some of the subjects also shared that they had specific learning goals for improving their motor skill (e.g., how to spike the ball better). They had set such goals to prepare for future matches with more competitive players. They used video snippets of their team's winning moments to analyze their motor skills and determine how to reach their learning goals. Richard shared as he viewed a video snippet of his team scoring:

"I wanna learn how to hit properly, hit better. I only set the ball in high school. I was never a hitter. I want to learn how to do that better [...] I just felt like when I hit the ball over, I just hit it softly. If it was like one of the younger guys that we played against, they probably would have gotten it [...] So I have to improve my hitting."

While the subjects had initially identified these moments because of winning their rallies, they examined the moments to further improve their motor skills. Therefore, the subjects viewed the moments as teachable moments. The collaborative video viewing sessions also highlighted the value of video snippets since they helped the subjects determine their previously missed improvement areas and support their procedural learning.

11.3.4 Identifying Long Rallies of Matches

In some cases, we found that the subjects had used their event triggers to identify long rallies of their matches. These subjects focused on the entire rallies rather than specific moments of the matches. Both teams showed highly competitive performance during the long rallies and continuously saved and returned the ball over extended periods. Scarlett, for example, shared with us about why she identified a long rally of her match:

> "*Well, this was a long rally. I tend to like the rallies that are a lot of … when they go back and forth a lot, despite how each makes me so tired.*"

Viewing video snippets of long rallies allowed the subjects to analyze their motor skills and teamwork regardless of the outcomes of the rallies. Since such video snippets showed the subjects' performance for their entire rallies, the subjects could analyze how their motor skills changed over time. We observed subjects specifically examining how the pressure of long rallies affected their motor skills. Some mentioned that the video snippets helped them realize that their motor skills performance had diminished over time. Max said about viewing a video snippet of his long rally:

> "*I feel like I've noticed that as the rally gets longer and longer, my approach or some things I get messed up and, I'm not sticking to my fundamentals.*"

Video snippets of long rallies also helped the subjects examine their choice and implementation of tactics and strategies extensively. By analyzing their team performance over extended periods, the subjects analyzed multiple tactics and strategies at once and determined which ones were ineffective. They used this knowledge for their tactical and strategic development and to improve their competitive performance against their opponents. Scarlett shared with us how she used a video snippet of a long rally to re-examine her team's hitting strategy:

> *"Um, I saw that we tended to put the ball over right away when they were out of position, when they were sort of scrambling […] We need to put it to the left, but even more specific than that, like more towards the line or shorter. So that's something to help in future play."*

11.3.5 Identifying Additional Teachable Moments using Captured Videos

In addition to the moments identified during matches, the subjects also identified and discussed a new set of teachable moments using the captured videos of their matches. As they navigated through the full videos, they continuously compared their performance shown on the videos against what they remembered about their intrinsic feedback from the matches. They identified teachable moments when they detected discrepancies between these two forms of feedback. For example, some of the newly identified teachable moments were instances in which the subjects' observed fitness levels were different from what they previously perceived. Maya, one of our subjects, carefully examined videos of her matches and then identified a teachable moment pointing to her fitness level in a rally. When we asked why, she shared that her fitness level in that moment was different from what she thought. She said: "*I don't look as athletic as I felt.*"

We also observed our subjects identifying teachable moments when they noticed discrepancies between their perceived motor skills and how the videos portrayed their movements. In many instances, the subjects assumed they correctly performed their motor skills, but when they received extrinsic video-based feedback and examined each movement, they noted some of the tendencies they missed before. Such opportunities allowed them to identify improvement areas for their individual and team performance. For instance, in a collaborative video viewing session, Jared watched a video of his match. He paused the video to inspect a part of the match when he successfully performed a volleyball dump (i.e., he performed a surprise attack as a setter catching the defense off guard). Based on the feel of his movements and the achieved outcome, he had assumed that he correctly performed the movements. However, after watching the video, he realized that his movements were very uncoordinated. Access to his videos allowed him to identify a teachable moment and determine an improvement area.

Identifying and examining teachable moments using captured videos of their matches brought the subjects a high-level understanding of their performance. The subjects felt that reviewing these teachable moments brought their attention to possible gaps between extrinsic video-based feedback and intrinsic feedback, which supported their learning.

11.4 Discussion

This section presents a discussion of our contextual inquiry findings. We explain how the insights contribute to the knowledge of performance improvement areas associated with teachable moments. We also determine how to support individual and collective uses of video snippets to provide value to beach volleyball players. At the end of this section, we use the study insights to speculate individuals' teachable moments in activities other than beach volleyball.

11.4.1 Performance Improvement Areas Associated with Teachable Moments

Our findings showed that the beach volleyball players' teachable moments were associated with improvement areas in individual or team performance. We specifically found that the moments pointed to individuals' fitness and motor skills, their teammates' motor skills, and tactics and teamwork in their team. These findings are aligned with existing literature on how participants in team sports assess their individual and team performance (Gréhaigne & Godbout, 1995). In this section, we describe these improvement areas and discuss opportunities for technological innovation.

11.4.1.1 Examining Fitness. The beach volleyball players identified additional teachable moments by examining discrepancies between their perceived and observed fitness levels. We determine that fitness levels are a significant improvement area for beach volleyball players that influence their individual and team performance. The beach volleyball sport is played with only two players in each team on unstable sand surfaces. Therefore, it can more demanding and require higher fitness levels than other recreational activities such as indoor volleyball (Wisewell, 2013). The insights in this study make a case for technological innovation that allows beach volleyball players to track and monitor their fitness levels (e.g., their strength or endurance levels) during their matches. Quantified-Self (QS) systems may play a positive, although limited, role in providing the players with quantified fitness-related metrics. Teammates may be interested in collectively using their quantified metrics, which is unavailable in existing QS systems. The next study examines the potential benefits and challenges of QS systems in this domain.

11.4.1.2 Examining Motor Skills. As we explained in Chapter 2, motor skills are a core component of physical recreation. Participation in collaborative physical recreation heavily relies on successfully using motor skills. This study showed that beach volleyball players pay close attention to their individual motor skills. This finding is aligned with our previous arguments in this dissertation about the importance of motor skills. It also reiterates our Study I insight around players leaning towards using cameras (e.g., GoPros) for capturing and analyzing their individual motor skills.

Our contextual inquiry also revealed that beach volleyball teammates want to examine improvement areas in each other’s motor skills. Existing technological solutions are ego-centric and only allow individuals to examine their individual motor skills. These solutions provide limited value to teammates whose primary goal is to improve their team performance. In this dissertation, we put forward that novel solutions must incorporate user interactions that enable teammates to collaboratively examine and review each other's motor skills to enhance their team performance.

11.4.1.3 Examining Tactics and Teamwork. We explained in Chapter 4 that after acquiring motor skills, individuals might extend their skills through tactical and strategic development. We also explained that in collaborative physical recreation, teammates need to show effective teamwork, i.e., coordinate their movements to achieve their intended outcome. Our contextual inquiry of teachable moments showed that beach volleyball players identify moments associated to improvement areas in their tactics and teamwork**.** Thus, we believe that technological solutions that enable individuals to continuously analyze their tactics and teamwork could benefit their learning and team performance. The solutions must also incorporate processes for engaging both teammates to study their tactics and teamwork to yield better team improvement results.

11.4.2 Individual Use of Video Snippet of Teachable Moments

Insights from the collaborative video viewing sessions in our study suggest various scenarios in which individuals could benefit from having access to video snippets of their teachable moments. First of all, individual use of video snippets allows individuals to troubleshoot their motor skills. This finding is compatible with our Study I result that individuals desired video snippets of their teachable moments to improve motor skills. Feedback systems incorporating such data and presenting it to users could provide benefits beyond existing technologies and provide meaningful input to individuals' procedural learning.

Other potential opportunities for technological innovation are regarding beach volleyball players' learning goals. The players' interactions with their data during the collaborative video viewing sessions showed that they used their video snippets in relation to their learning goals. They closely examined their motor skills and identified improvement areas to determine how to reach their goals. We explained in Chapter 6 the importance of users' goals in feedback systems, such as QS systems. These technologies allow users to set their goals, create plans for reaching the goals, and examine their progress over time (Hattie & Timperley, 2007; Schneider et al., 2015; Specht, 2014). Continuous access to video snippets would open doors to numerous new opportunities for users to set goals regarding their motor skills acquisition, plan further improvements, and navigate their progress. We argue that technological innovation in this domain could generate enormous positive impact in these areas since it would persistently allow players to identify improvement areas related to their learning goals.

11.4.3 Collective Uses of Video Snippets of Teachable Moments

Our findings from the collaborative video viewing sessions illustrated the collective use of video snippets among teammates and showed opportunities for technological innovation. Beach volleyball players could benefit from the collective use of video snippets since it would allow them to examine their team performance from an outside perspective. Collective use of video snippets also supports collaborative procedural learning and feedback exchange in teams. In Chapter 5, we explained the importance of feedback exchange in teams. We also showed in Study II that beach volleyball teammates exchanged feedback to improve their team coordination and overall team performance.

Technological innovation that supports collective use of video snippets of teachable moments in teams is critical in facilitating collaborative procedural learning. These solutions could act as a platform for communication and feedback exchange between teammates. Individuals could also seize these opportunities to collaboratively examine and review their team data, plan for team performance improvements, and evaluate their team progress over time.

11.4.1 Perception of Teachable Moments Based on Activity Type

Our findings of teachable moments among beach volleyball players, i.e., moments of unsuccessful attempts, successes, and long rallies, suggest that the perception of teachable moments in collaborative physical recreation depends on the characterization and structure of the activities. Beach volleyball players relied on established scoring systems as objective means for examining their individual and team performance. Our insights from our previous studies about the recreational dance communities showed that dancers do not rely on objective scoring systems for performance evaluation. Instead, they in most cases examine their performance subjectively (e.g., evaluating a dance performance based on its cleanliness).

The fact that beach volleyball players identified long rallies of their matches further highlights the connections between teachable moments and the categorization and structure of activities. Long rallies are specific to beach and indoor volleyball and tend to show high competition among two teams and thus were of interest to the players in our study. High competition moments may appear differently in other forms of collaborative physical recreation. For example, dancers may experience high competition moments as they perform in competitive events and indirectly compete with others. Therefore, determining teachable moments, such as high competition moments, in each form of collaborative physical recreation requires an understanding of the structure of the activities.

Differences in perceptions of teachable moments throughout collaborative physical recreation may suggest that one-fits-all solutions are unsuitable for supporting performance and learning in these activities. Designing technological innovation for supporting collaborative procedural learning in CPRC requires a thorough understanding of the activities' characterization and structure. Especially, knowledge of what individuals determine as success and what competition in each activity looks like can inform technologies for identifying teachable moments of the activity.

11.5 Limitations

This section presents the limitation of the study in the research method and the scope of this investigation. We experienced challenges in our research method which might have affected the insights of this study. In steps 1 and 2 of our research method, we video captured the community activities and enabled the players to identify moments. Our initial plan was to start conducting the collaborative video viewing sessions soon after finishing the activities. However, we gained massive volumes of data, which consisted of videos from the cameras and timestamps from the wireless event triggers. In step 3, we manually retrieved video snippets of the players' video snippets. We had to create video tours by matching and combining video snippets captured through multiple cameras. We also experienced difficulty storing these large volumes of data and sharing it with the research team. Together, all these constraints led to a 2-month delay between video capturing the activities and conducting the collaborative video viewing sessions. While we only encountered few cases in which the subjects did not recall their identified moments, their possible memory recall issues might have affected their perception and discussion of the moments. This limitation might have impacted the insights about the subjects' teachable moments.

Another limitation is in the scope of this investigation. Our contextual inquiry examined teachable moments among beach volleyball players. As a 2 versus 2 player sport, beach volleyball is less complex in terms of tactics and teamwork than many other forms of collaborative physical recreation. Team sports such as indoor volleyball, soccer, hockey, or basketball tend to entail sophisticated tactical and teamwork components requiring multiple teammates to work together and coordinate their movements. Components like team play and composition systems describe complex patterns of play through which players integrate their movements in a coordinated manner to achieve their defensive or offense objectives (Kumar, 1999; Mutebi, 2015).

We anticipate that individuals in complex forms of collaborative physical recreation may identify moments associated with tactical or teamwork not covered in this study. We also expect that in some activities such as dance, individuals focus more on motor skills and less on tactics and teamwork. Further research, such as a contextual inquiry of teachable moments centering on different activities, could address this limitation of our study and show individuals' teachable moments in various forms of collaborative physical recreation.

11.6 Design Implications

We explained in Chapter 9 that CLL solutions need to identify, retrieve, contextualize, and categorize video snippets of teachable moments and present them back to users. Based on our empirical research findings in this study about individuals' teachable moments the perceived value of viewing video snippets of these moments, we propose a set of requirements for the CLL solutions, especially the process for identifying and contextualizing video snippets.

11.6.1 Retrieving Video Snippets of Teachable Moments

Our findings regarding the beach volleyball players identifying moments of their successes, unsuccessful attempts, and long rallies suggest an overview of how CLL solutions must retrieve video snippets from the full videos of the players' matches. We have already discussed that these solutions must bring video snippets of players' identified moments for their review. In addition to these steps, we suggest, based on this study's insights, that the CLL process for identifying and contextualizing video snippets must also (a) automatically detect rallies in beach volleyball matches, (b) identify players' long rallies and successes and unsuccessful attempts, and (c) store video snippets of these moments in the players' Avatars and bring the data to their attention.

Achieving this goal requires CLL solutions to adopt certain functionalities from other available technologies and existing academic research in the domain of computer vision and image processing (He et al., 2020; Xie et al., 2002). By analyzing match videos and identifying the players' play and idle times, CLL solutions could detect rallies, including long rallies. CLL solutions could also adopt elements of computer vision processes systems with ball-tracking technology (e.g., Hawk-Eye[1]) from professional sports to identify successes and unsuccessful attempts in the detected rallies. These steps would allow CLL solutions to provide players with video snippets of their teachable moments.

Automatic retrieval of video snippets is critical for individuals in the early stages of adopting CLL solutions. Our study insights showed that these individuals might initially feel hesitant to interact with CLL solutions during their match. A reason behind this might be that these individuals have not yet any value in using the solutions. Automatic detection of teachable moments and retrieving and presenting video snippets may show players the value of CLL solution for their performance and learning and encourage them to use in-situ interactions to get data that better match their learning needs.

11.6.2 Contextualizing and Categorizing Video Snippets through User Interactions

We discussed in Chapter 9 that CLL solutions must follow the crowd computing paradigm in CC systems to contextualize and categorize video snippets. We explained that CLL solutions need to present video snippets to individuals through user interfaces for tagging the video snippets based on the teachable moments' perceived social contexts. Our insights in this study highlighted that teachable moments are associated with improvement areas in beach volleyball players' individual and team performance. The insights suggest specific categories of improvement areas that the user interfaces must incorporate to facilitate how individuals tag their video snippets:

1. How players see their individual fitness levels and use of motor skills.

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[1] https://www.hawkeyeinnovations.com/ (accessed May. 2021)

2. How players see their teammate's fitness levels and use of motor skills.

3. How players see their team tactics during rallies.

4. How players see their teamwork through which they coordinate their movements with their teammate.

As individuals use these categories to contextualize video snippets of their teachable moments, CLL solutions use their input to categorize video snippets based on the associated improvement areas. CLL User interfaces must also present filtering functionalities based on the categories of improvement areas and individuals' selected tags on the video snippets to allow users to survey their data. We anticipate that such functionalities will allow beach volleyball players to systematically use video snippets of their teachable moments to support their procedural learning.

11.6.3 Automatic Contextualization and Categorization of Video Snippets

CLL solutions could learn from users' tagging interactions to create processes for the automatic contextualization and categorization of video snippets. Over time, as users repeatedly tag their video snippets, CLL solutions could utilize their cloud-based processing units to examine emerging patterns among the visual elements of video snippets and their associated improvement areas. CLL solutions could incorporate deep-learning-based scene analysis to train their video-contextualization and classification models (L. Wang & Sng, 2015). They could use these models to evaluate and analyze newly-retrieved video snippets to find possible improvement areas. This process will allow CLL solutions to automatically contextualize and categorize video snippets and present them to individuals.

The video-contextualization and classification models could also allow CLL solutions to improve their processes for retrieving video snippets from match videos. By analyzing possible improvement areas in the videos (Zhong & Chang, 2001), they could automatically retrieve video snippets associated with improvement areas that are of interest to users.

11.6.4 Improve Utility of Video Snippets for Procedural Learning

The study findings showed that one of the critical uses of video snippets was for closely analyzing motor skills. Therefore, we suggest that CLL solutions could further support beach volleyball players' examination of motor skills by visualizing body forms, movements, poses, and gestures. Visualizing these elements for all players in each match may allow individuals to thoroughly analyze their individual and teammate's motor skills. CLL solutions could use real-time multi-person detection systems such as OpenPose (Cao et al., 2018, 2017; Simon et al., 2017; Wei et al., 2016) to add visualizations to video snippets. We anticipate that these steps, on top of access to contextualized and categorized video snippets, will generate meaningful data for examining and improving individual and team performance.

11.7 Summary

This chapter presented our contextual inquiry of teachable moments. First, we provided beach volleyball players with in-situ interactions, allowing them to identify moments of their matches. Then, we co-explored the players' identified moments in collaborative video viewing sessions. Our findings showed that the players identified moments of their successes, unsuccessful attempts, and long rallies as teachable moments. The players' teachable moments were also associated with improvement areas in their individual and teammates' motor skills, teamwork, and tactics. The players used video snippets of their teachable moments to troubleshoot their individual and team performance. Teammates also used their video snippets to exchange feedback to improve their team coordination and overall team performance. The players also identified additional teachable moments by reviewing their matches' videos. They used the videos of these moments to examine how their motor skills and fitness level changed over extended periods. Finally, we discussed these findings and explained how they informed CLL solutions, especially the CLL processes for identifying and categorizing teachable moments.

CHAPTER 12

RESEARCH THROGH DESIGN: USER INTERFACE DESIGN PROCESS

As mentioned earlier in this dissertation, we followed a research-through-design approach to evaluate the utility of Collaborative Lifelogging (CLL) solutions to Quantified-Self (QS) systems. Research through design is a well-known research methodology in Human-Computer Interaction (HCI), through which researchers "generate new knowledge by understanding the current state and then suggesting an improved future state in the form of a design" (Zimmerman & Forlizzi, 2014). Scholars have differentiated research through design from *research for design* and *research about design*. The research-through-design approach centers on creating prototypes that support expanding knowledge rather than generating commercially viable products (Frayling, 1993; Zimmerman et al., 2007). It is an effective means for examining the perceived benefits of proposed technological innovation and exploring any unexpected impacts on individuals' lives.

This chapter presents the first part of our research-through-design approach, in which we created prototypes that represent the main functionalities of CLL solutions and QS systems. We used a CLL user interface design process to translate our literature review insights and empirical research findings into user interfaces that supported collaborative procedural learning in the New Jersey Beach Volleyball Community. We also used our literature review insights to create prototypes that represented the underlying functionalities of QS systems. The resulted QS prototypes centered on similar motivating problems as our CLL prototypes, i.e., supporting beach volleyball players' performance and learning.

We describe our steps in our CLL and QS user interface design process, review the resulted user interfaces, and present a deployment scenario for each set of user interfaces. The outcomes of this chapter support the next step of our research-through-design approach, which is the comparative design evaluation of CLL solutions and QS systems and will be presented in the next chapter.

12.1 Collaborative Lifelogging User Interface Design Process

This section describes our design process for generating CLL user interfaces. Our process entailed three steps: (1) defining personas and pre-intervention scenarios, (2) ideating post-intervention scenarios, and (3) iterative user-interface prototyping. We explain how we dedicated our efforts to each step of our process.

12.1.1 Defining Personas and Pre-Intervention Scenarios

Our first goal in the CLL user interface design process was to define personas and pre-intervention scenarios. These two elements are critical to the process and required for its subsequent steps. We extracted these elements from our empirical research findings from Studies I, II, and III and iteratively refined them. This section introduces personas and pre-intervention scenarios and explains how we generated them.

Personas are composite archetypes that present fictional yet realistic descriptions of target users of products, including new technologies (Cooper, Reimann, Cronin, & Noessel, 2014; Harley, 2015). As powerful tools for both designers and researchers, user personas facilitate decision-making processes by utilizing research insights about potential or existing users, including their goals, needs, frustrations, and behaviors. In this dissertation, we translated our empirical research findings into user personas representing several subsections of the CPRC in our study population.

We initially created seven personas in our CLL user interface design process. Four of these personas emerged through our analysis of the recreational volleyball communities, and we generated the other three based on members of the recreational dance communities. Since we decided to focus solely on the New Jersey beach volleyball community in this dissertation, we built on the first group of personas. At the end of this step, we finalized three beach volleyball player personas. Figure 12.1 shows one of the personas in our design process. We employed our three personas in the subsequent steps of the process.

Figure 12.1 Beach volleyball player persona.

We then worked on pre-intervention scenarios. Scenarios are concise narratives that describe a "day in the life" of personas. They are central to the scenario-based design methodology allowing technology designers to manage the direction of their design efforts (J. M. Carroll, 2000; Fowler et al., 2007; Rosson & M. Carroll, 2009). In this methodology, scenarios appear in two forms. Pre-intervention scenarios are narratives of current practices, behaviors, themes, and relationships. Such scenarios are powerful tools in understanding potential users' needs, goals, and existing pain points. Post-Intervention scenarios are narratives describing how technological innovation helps the personas reach their goals and fits into their context. These scenarios are incredibly beneficial in designing and evaluating user interactions and investigating the impacts of technological interventions on personas' lives.

Creating pre-intervention scenarios is a complex task requiring thorough qualitative analyses and interpretation of insights. Instead of directly translating our empirical research findings into narratives, we followed a bottom-up approach. We first used *empathy maps* to extract blocks of our narrative descriptions. We then used *journey maps* to carefully synthesize the blocks and formed our scenarios. We explain these two powerful tools and how we incorporated them into our CLL user interface design process.

Empathy maps are specific forms of visualization describing individuals' thoughts, feelings, and behaviors in various situations (Gibbons, 2018; Hodges-Schell & O'Brien, 2015). We created eighty-four empathy maps by identifying and extracting situations and relevant contextual information that were aligned with the research questions in this dissertation (Figure 12.2 illustrates examples of the extracted empathy maps). The empathy maps showed our subjects' thoughts, feelings, and behaviors as they engaged with their communities and participated in community activities.

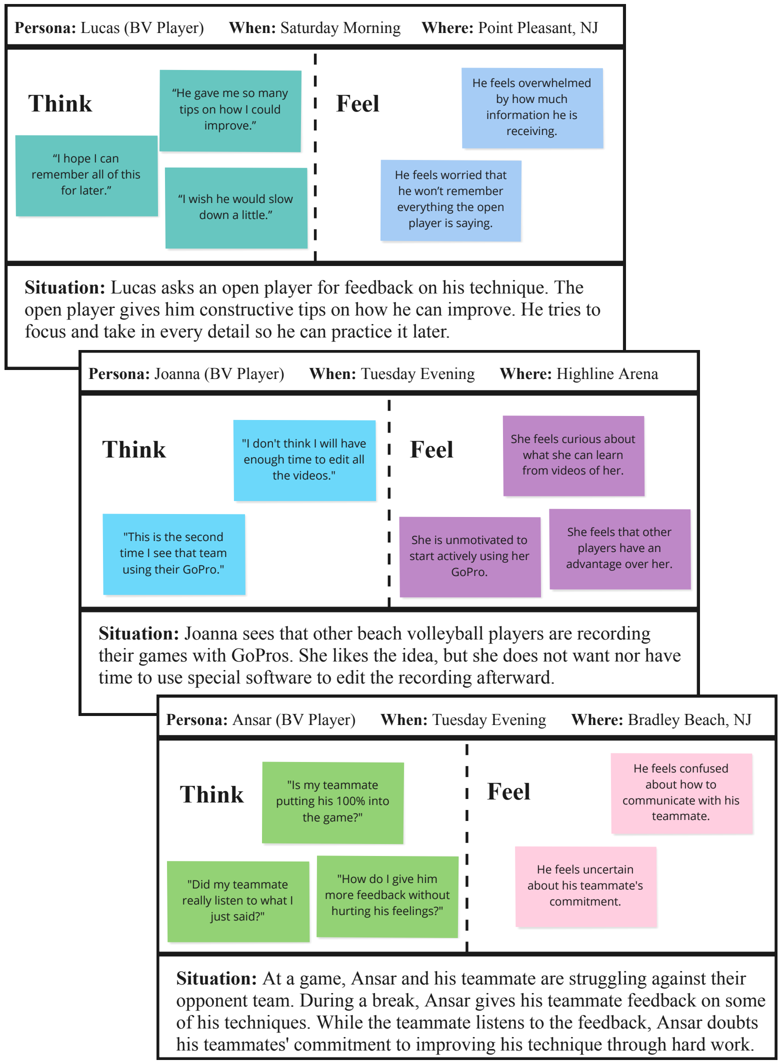

Figure 12.2 Examples of empathy maps for beach volleyball players.

Journey maps are another form of visualizations that depict individuals' experiences towards achieving their goal(s) (Hodges-Schell & O'Brien, 2015). The primary use of journey maps is to identify existing practices and pain points. We initially created twelve journey maps. After iterative refinement of the journey maps, we finalized six maps that visualized how the subjects engage with their communities and participate in community activities (Figure 12.3 illustrates one of the finalized journey maps). Our journey maps also highlighted specific experiences in which community members faced collaborative procedural learning challenges.

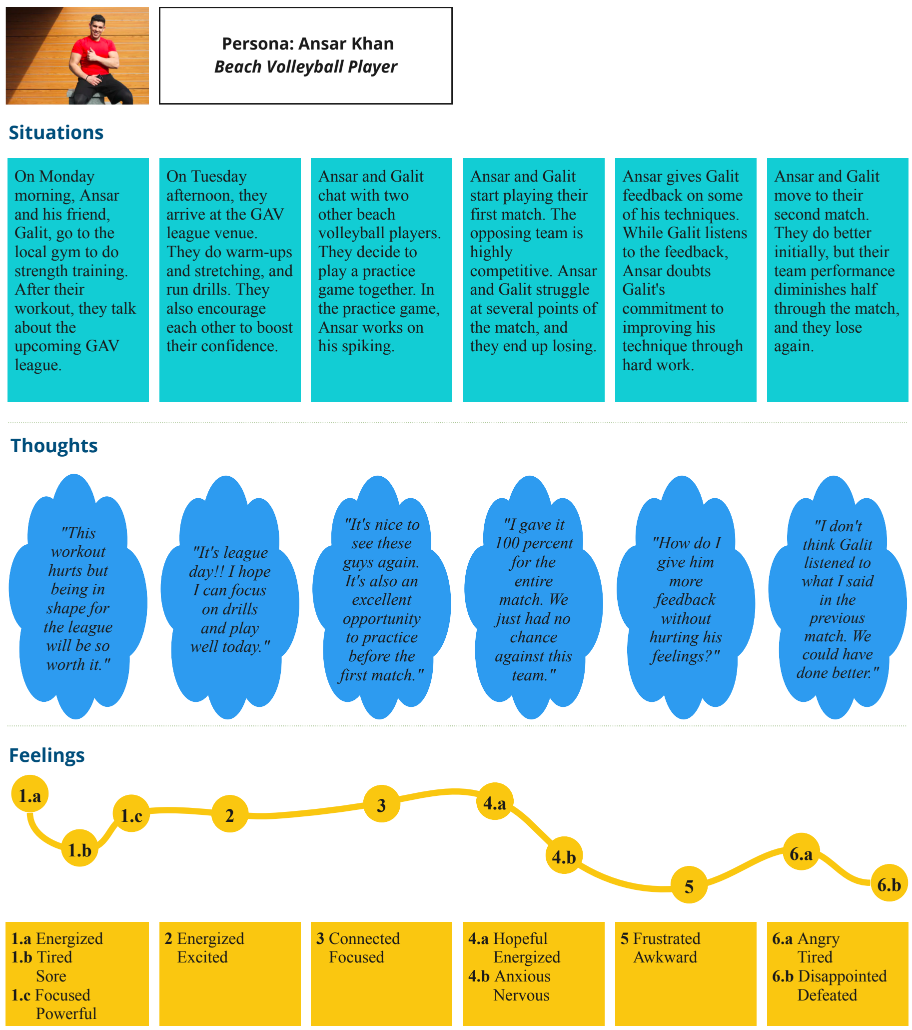

Figure 12.3 An example of journey maps for beach volleyball players.

We utilized our empathy maps and journey maps as building blocks for the narrative in our pre-intervention scenarios. We created six scenarios: three beach volleyball players and three dancer scenarios. These scenarios allowed us to examine the subjects' contexts before designing CLL user interfaces. To improve the communication of pre-intervention scenarios, we also used storyboarding techniques visualizing our personas' current practices, behaviors, and relationships (See Figure 12.4 as an example).

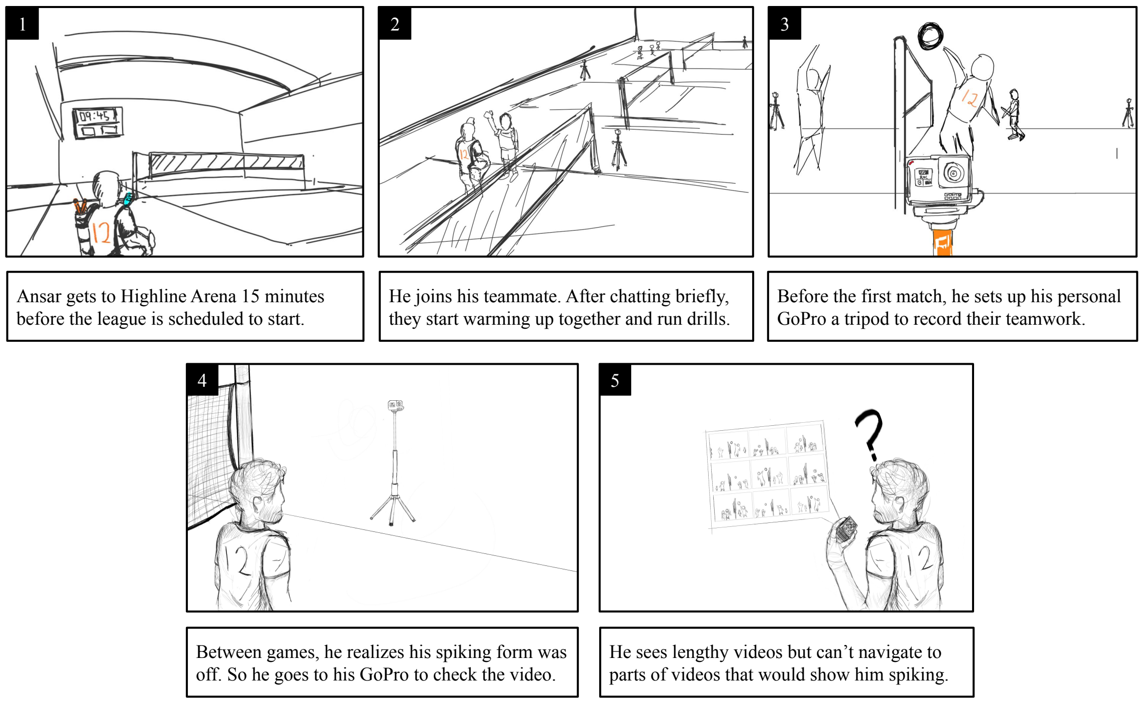

Figure 12.4 An example of pre-intervention scenario storyboards.

12.1.2 Ideating Post-Intervention Scenarios

Our second goal in the CLL user interface design process was to develop post-intervention scenarios that described how CLL solutions would fit into the subjects' contexts and help them reach their goals. Our post-intervention scenarios also helped us as designers to create and evaluate user interactions and investigate our innovation's impacts on the subjects' lives heuristically.

We conducted twelve *ideation* sessions to utilize our personas and pre-intervention scenarios and generate post-intervention scenarios. These sessions allowed us to set the theme for designing our CLL user interfaces. In each ideation session, we:

1. Examined the pre-intervention scenarios to determine situations in which there were opportunities for technological intervention.

2. Identified categories of interventions that could have positive impacts in these situations.

3. Brainstormed how CLL solutions could support our intended interventions specifically.

4. Developed and created post-intervention scenarios that illustrated possible interactions between the CLL solutions and potential users in their context.

We documented every step of our ideation sessions and used these documents to engage in heuristic evaluations of our solutions' effectiveness (see Figure 12.5 which shows outcomes of an ideation session as an example). These evaluations allowed us to iteratively improve our CLL solutions' concepts and their behaviors towards users.

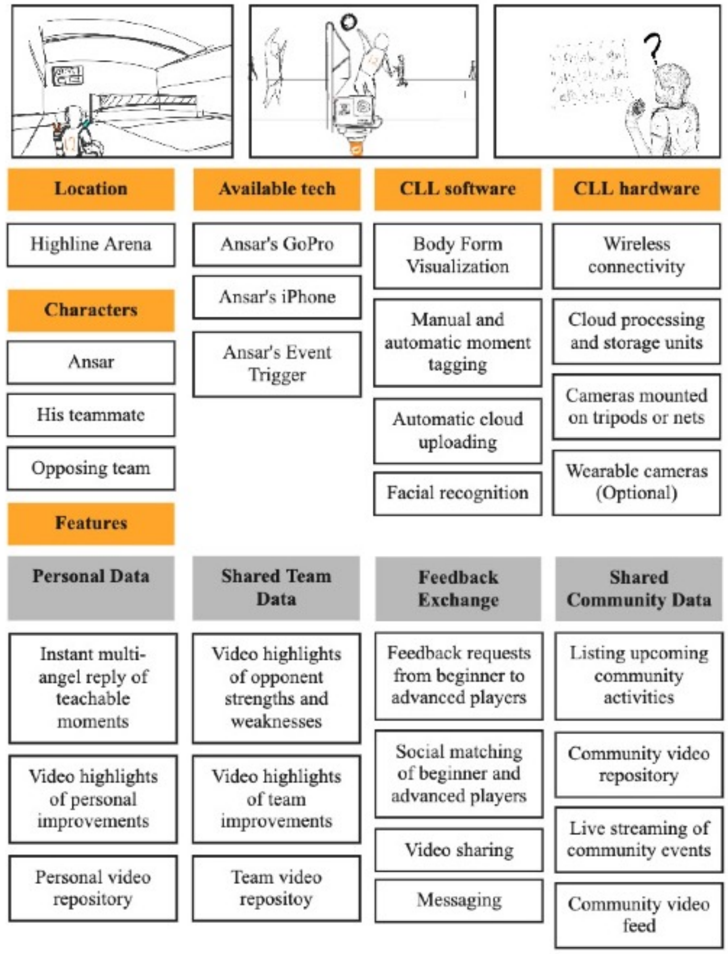

Figure 12.5 Outcomes of an ideation session focusing on post-intervention scenarios of CLL solutions.

We initially created four post-intervention scenarios through our ideation sessions: two for the dancer personas and two for the beach volleyball personas. Since we decided to focus on the New Jersey beach volleyball community, we continued our design process with the post-intervention scenarios for the beach volleyball personas. The scenarios showed how our beach volleyball personas used CLL solutions as they participated in community activities. We used the scenarios to facilitate our discussions about the design requirements posed by our empirical research findings.

12.1.3 Iterative User Interface Prototyping

The last goal of our CLL user interface design process was to create user-interfaces for our technological innovation. We built prototypes based on the representations of our solutions that emerged in our ideation sessions. Our prototypes provided methods of depicting our CLL solutions' main functionalities. To create these representations, we:

1. Thoroughly navigated through our post-intervention scenarios.
2. Identified every interaction between CLL solutions and users.
3. Designed user interfaces that accommodate all the interactions.
4. Refined the user interfaces based on our design requirements.
5. Accumulated these interfaces and established user flows among them.

Our prototyping methods differed based on our progress in the design process. We initially created our CLL user-interfaces using low-fidelity prototyping methods, mainly paper prototyping (Rettig, 1994) (Figure 12.6, left, shows an example). In the later stages of our process, we moved on to high-fidelity prototyping tools, namely, Axure[1] and Figma[2]. Throughout our design process, we iteratively refined our user-interfaces based on empirical research findings (see Figure 12.6).

[1] https://www.axure.com/ (accessed May. 2021)
[2] http://figma.com/ (accessed May. 2021)

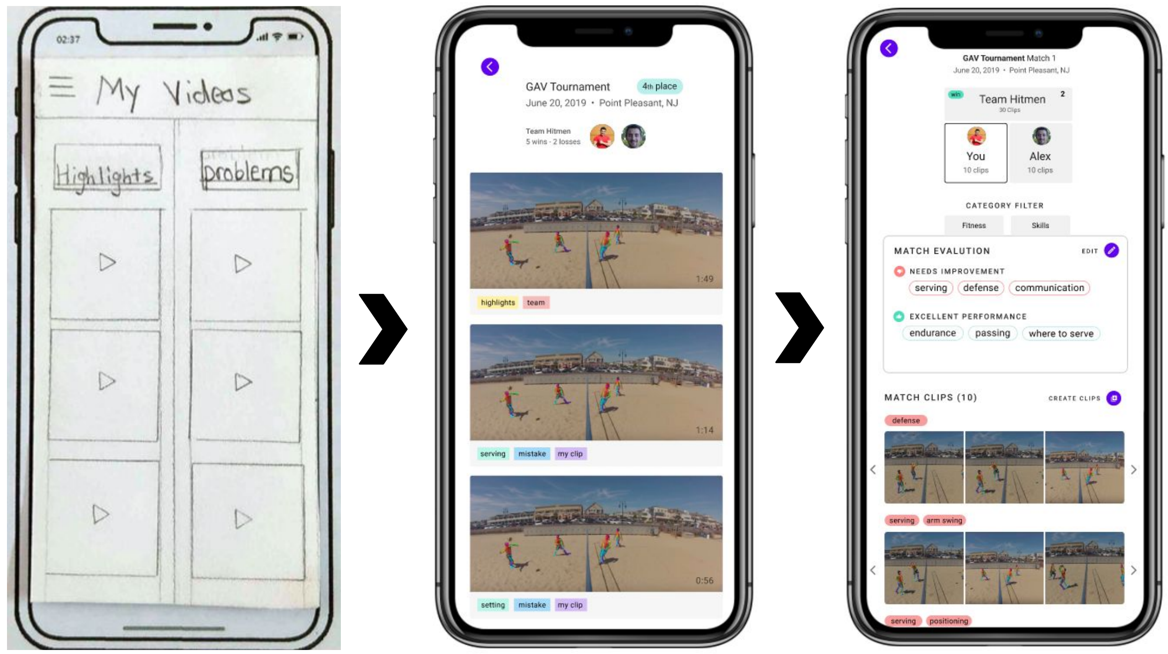

Figure 12.6 Stages of CLL user interface prototyping.

In the next section, we present user interfaces designed through our prototyping. Later in the chapter, we also present a hypothetical CLL deployment scenario illustrating interactions between users and our user interfaces.

12.2 Outcomes of CLL User Interface Design Process

This section presents user interfaces generated through our CLL user interface design process as part of our research-through-design approach. We explain how these interfaces support the primary processes in CLL solutions.

12.2.1 CLL User Interfaces for Collaborative Video Capture

Based on Study I insights and our conceptual framework of CLL, we created user interfaces that aim to support the collaborative video capture of community activities. As discussed in Study I, individuals may not have readily accessible cameras in their community activity sites. Rather, they need to bring their personal devices (e.g., GoPros with tripods, smartphones with built-in cameras) to the sites to video capture their activities. To support the video capture of community activities, we designed user interfaces that allow community members to coordinate for bringing their personal devices to each community activity (see Figure 12.7). Based on the number of participants and publicly available information about community sites (e.g., the number of courts shown on a venue website), the user interfaces suggest a camera quota for the multi-perspective video capture of each activity. The interfaces suggest that all activity participants contribute to this CLL process by bringing along their personal devices. As this camera quota is reached, the interfaces inform the participants that the multi-perspective video capture of the activity is now possible.

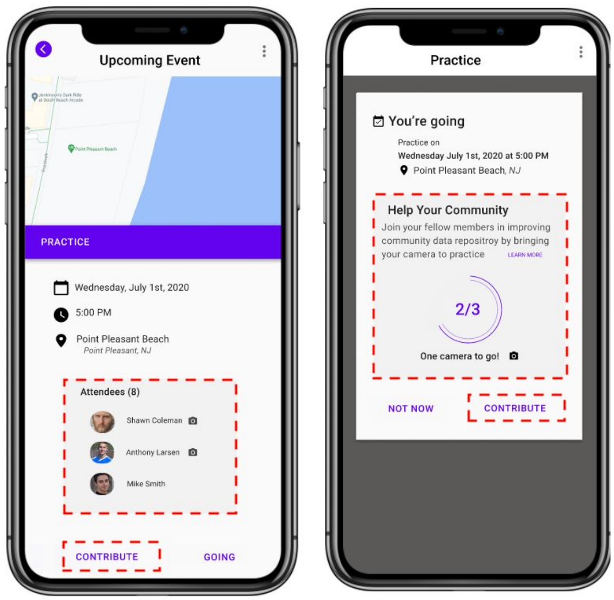

Figure 12.7 CLL user interfaces supporting coordination among individuals for collaborative video capture of activities.

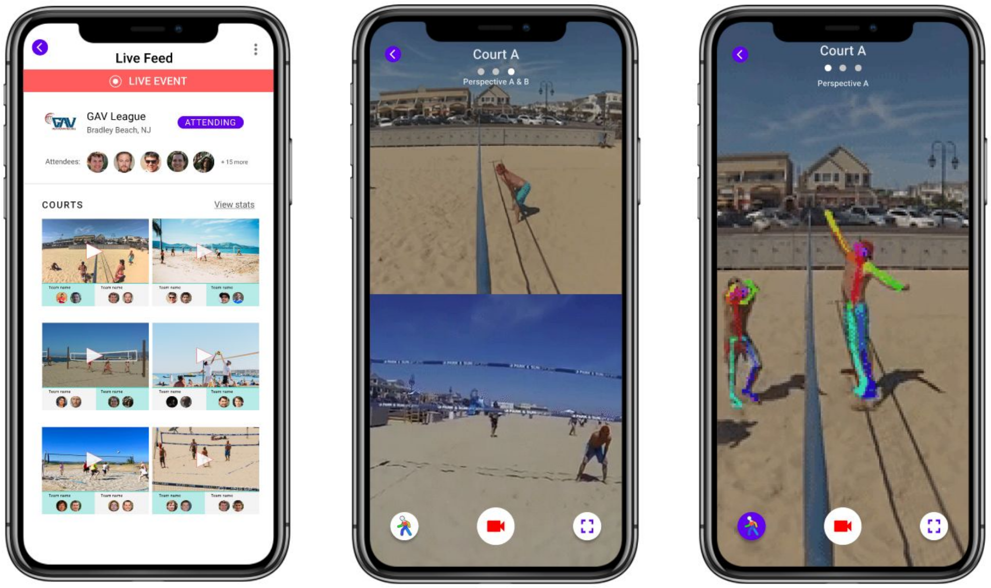

Figure 12.8 CLL user interfaces showing collaborative video capture of community activities through multiple perspective.

As participants attend community activities, CLL solutions automatically detect and incorporate their available cameras for the collaborative video capture of the activities. CLL solutions also use facial recognition modules to detect beach volleyball players and identify teams in each match. CLL solutions capture each match separately and store the players' video snippets in their Avatars. Figure 12.8, left, shows a live-feed user interface illustrating the outcomes of these steps in CLL solutions.

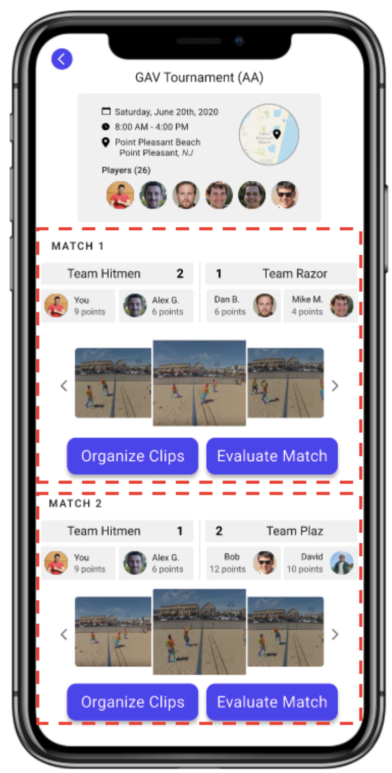

Figure 12.9 CLL user interfaces for exploring data after matches.

CLL solutions automatically combine multi-perspective video snippets of players' teachable for their use. Figure 12.8, center, presents our user interface showing how players view their multi-perspective video snippets. In addition, CLL solutions visualize the players' body forms, movements, poses, and gestures and add the visualizations to their video snippets. Figure 12.8, right, illustrates the resulted CLL user interface. We also created user interfaces through which beach volleyball players can navigate their data from their Avatars after their matches. In addition to their video snippets, the players can view video snippets showing their teammate's performance and their overall team performances. Figure 12.9 illustrates CLL interfaces presenting players with data from their matches after a beach volleyball tournament as an example.

12.2.2 CLL Interfaces for Identifying and Contextualizing Video Snippets

Based on our conceptual framework of CLL and Study III insights, we created user interfaces for identifying and contextualizing video snippets of teachable moments. Our user interfaces present beach volleyball players with video snippets of their identified moments and the automatically retrieved video snippets of their successes, unsuccessful attempts, and long rallies. The user interfaces allow players to evaluate their video snippets using red (negative) and green (positive) tags. Players can create new tags, re-use tags from the past, or use automatically-generated tags (through the CLL video-contextualization and classification models). Players specifically tag their individual and team performance based on specific categories of improvement areas (see Figure 12.10, left): (a) how they see their individual fitness levels and use of motor skills, (b) how they see their teammate's fitness levels and use of motor skills, (c) how they see their team tactics, and (d) how they see their teamwork.

To facilitate players' access to their data, we also created user interfaces that allow players to evaluate their matches using a similar tagging feature (Figure 12.10, center). Players use this tagging feature to determine how they view their overall individual and team performance in relation to the improvement areas explained above.

Lastly, we created user interfaces that show players their video snippets categorized based on their input (see Figure 12,10, right). The players can use a filtering feature to explore their individual video snippets as well as video snippets from their teammate and their team. The filtering feature allows players to find specific video snippets based on improvement areas they want to examine.

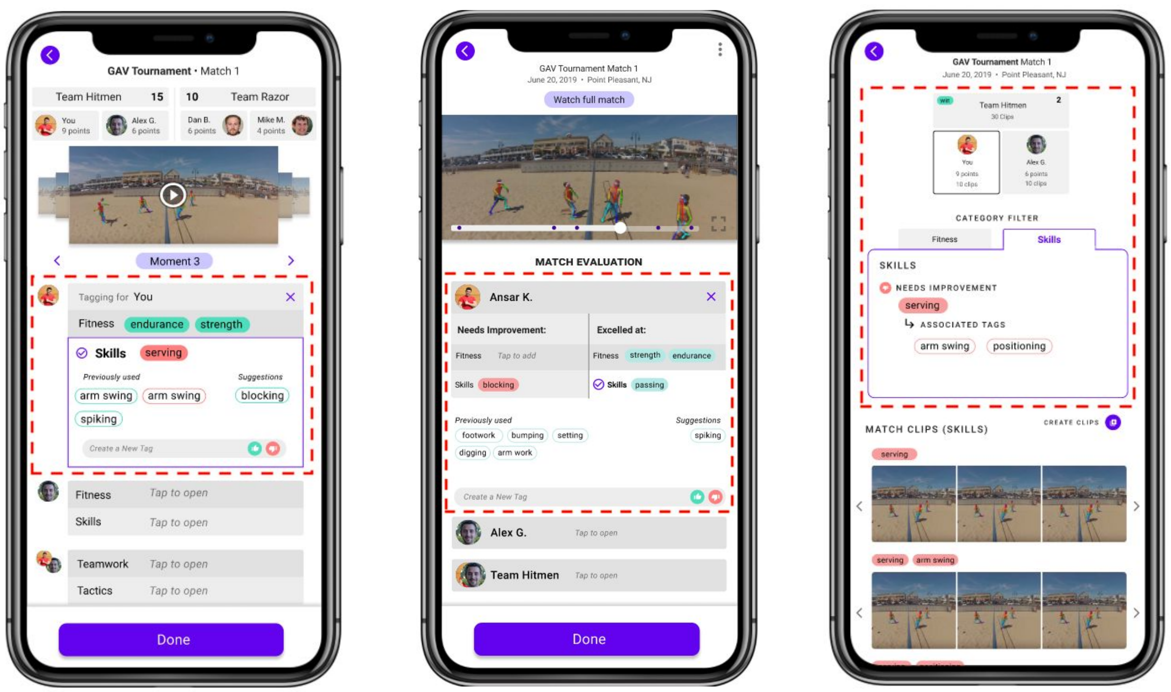

Figure 12.8 CLL user interfaces for identifying and contextualizing video snippets of teachable moments.

12.2.3 CLL User Interface for Feedback Exchange Using Video Snippets

Based on our conceptual framework of CLL and Study II insights, we created user interfaces for supporting feedback exchanging using video snippets of teachable moments. After viewing their video snippets categorized based on their improvement areas, beach volleyball players can select specific video snippets and request feedback on them. The user interfaces allow players to send feedback requests to their high-skilled fellow community members and personal connections (see Figure 12.11, left). CLL solutions form a collective Avatar for each feedback request, allowing players to view each other's multi-perspective and visualized video snippets. Using text communication functionalities, the players can discuss their understanding of one another's performance.

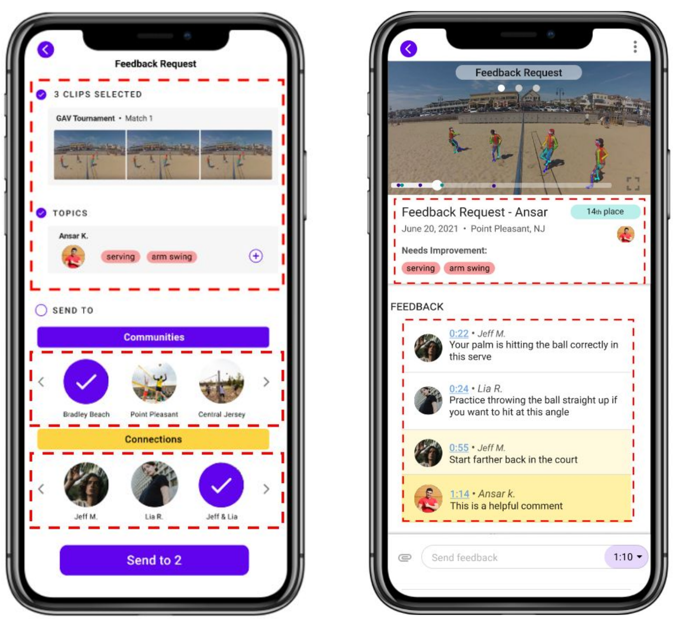

Figure 12.9 CLL user interfaces for feedback exchange using video snippets.

based on their video snippets' assigned tags (see Figure 12.11, right). Through such communication, players determine how to address the improvement areas mentioned in the feedback request.

We also created user interfaces for community feeds which allow players to access their community's video repository of shared video snippets (see Figure 12.12). By navigating these feeds, players can observe high-skilled players' movements and learn from them.

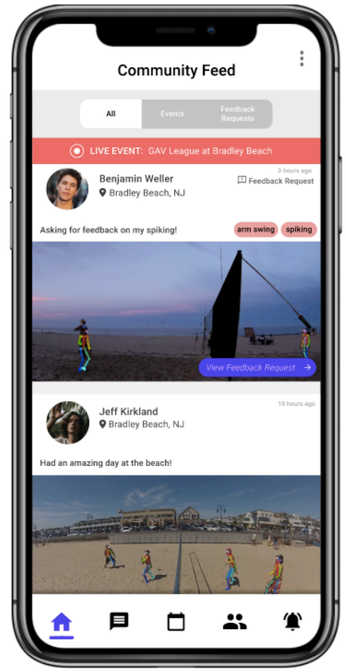

Figure 12.10 CLL community feed user interfaces.

The next section presents a hypothetical scenario to illustrate how a recreational beach volleyball player persona, Ansar, uses the CLL application, i.e., the user interfaces mentioned above, to support his performance and learning.

12.3 Hypothetical CLL Deployment Scenario

On Friday, Ansar opens the CLL application to review some of the video snippets covering his serving skills, especially his swing. He uses the filtering feature on the app to navigate to the video snippets (see Figure 12.13).

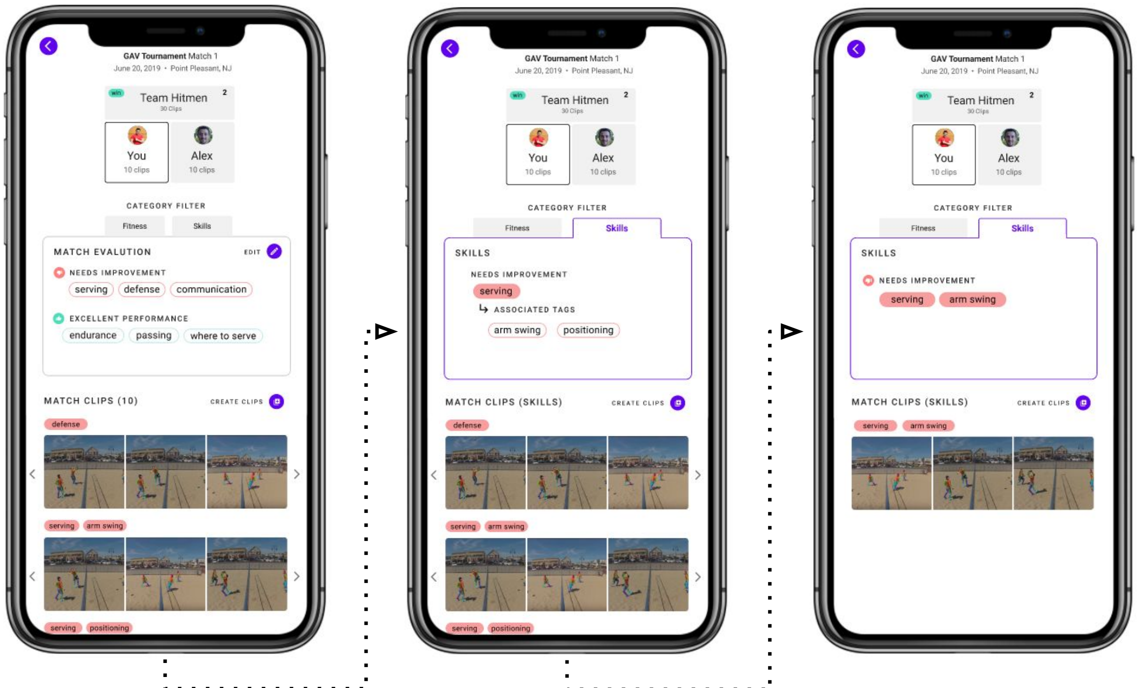

Figure 12.11 Persona exploring their contextualized and categorized video snippets.

When he plays a video snippet, the CLL application shows visualizations of his movements on top of the videos (see Figure 12.14). Ansar uses these visualizations to closely analyze his arm swing when he served.

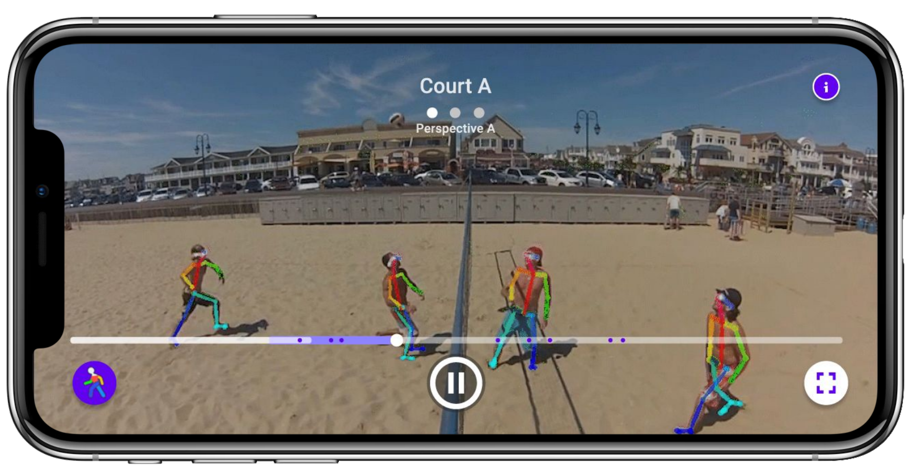

Figure 12.12 Persona viewing visualized video snippet of their teachable moment.

On Saturday morning, Ansar heads to local sand courts at Point Pleasant. There are 6 volleyball nets set up, and 24 individuals are participating in a beach volleyball tournament. When he arrives at the courts, he recognizes his friend, Alex. After greeting each other, they do a quick warm-up. Alex has already set up his GoPro on a tripod. Ansar also sets up his two GoPros on the volleyball net (see Figure 12.15). Ansar and Alex both wear their event taggers on their hips and connect them to their smartphones in their backpacks.

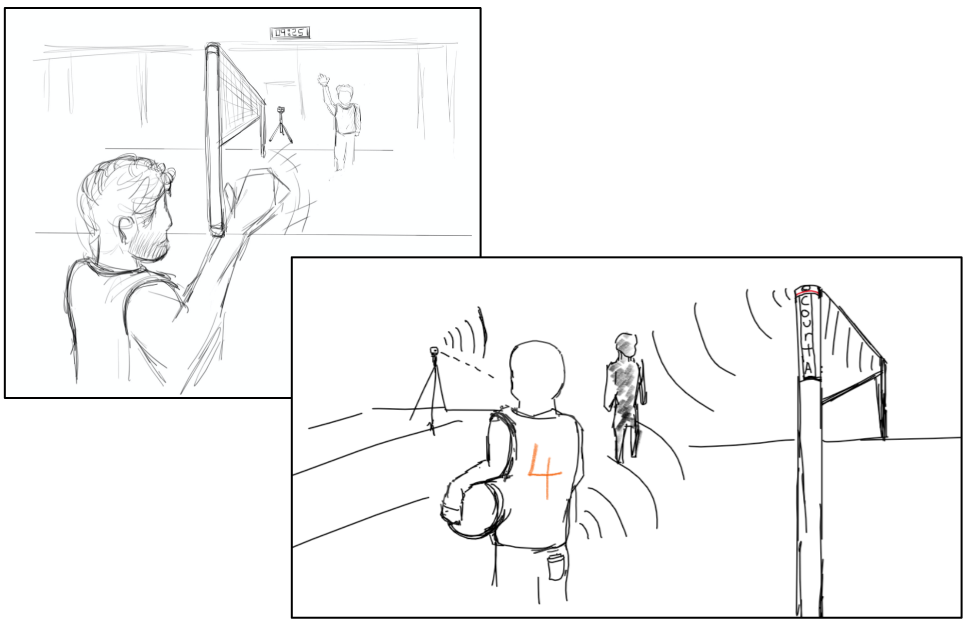

Figure 12.13 CLL automatically detecting and incorporating cameras and event triggers in a community activity.

The CLL application detects all devices to be part of "court A" and then begins collecting their data from the GoPros and the event triggers. Ansar and Alex start their first match in the tournament with two other beach volleyball players. The CLL application forms an ad-hoc group consisting of all the players on the court and provides them with cloud and crowd computing platforms to work together to video capture their match and identify their teachable moments (see Figure 12.16).

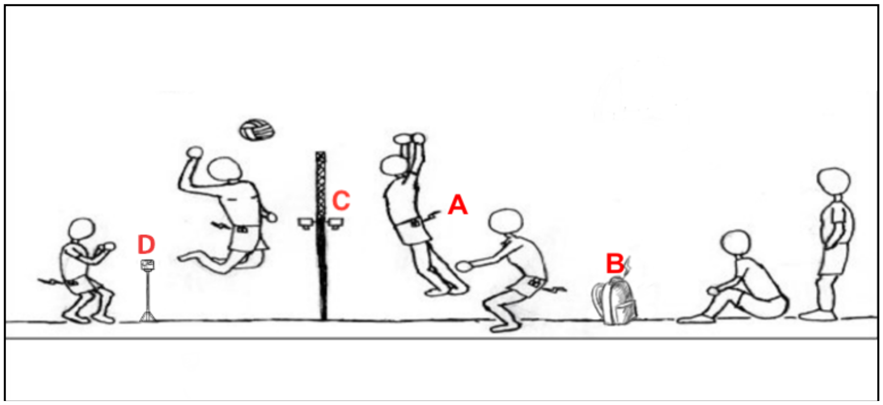

Figure 12.14 Collaborative Lifelogging at the Jersey Shore incorporating (A) event triggers, (B) smartphones, (C) GoPros on volleyball net, (D) GoPros on tripod.

After 20 minutes, Ansar and Alex both use their event triggers to identify a moment of their match as a teachable moment. During a break, they use the CLL application to watch a video replay of that moment (see Figure 12.17).

Figure 12.15 Teammates collectively using CLL to analyze video snippet of their teachable moment.

The CLL application creates and presents a multi-perspective video snippet showing Ansar's and Alex's movements to help them view how they passed the ball. They use the video snippet to discuss how they could improve their coordination based on the opposing team's style (see Figure 12.18).

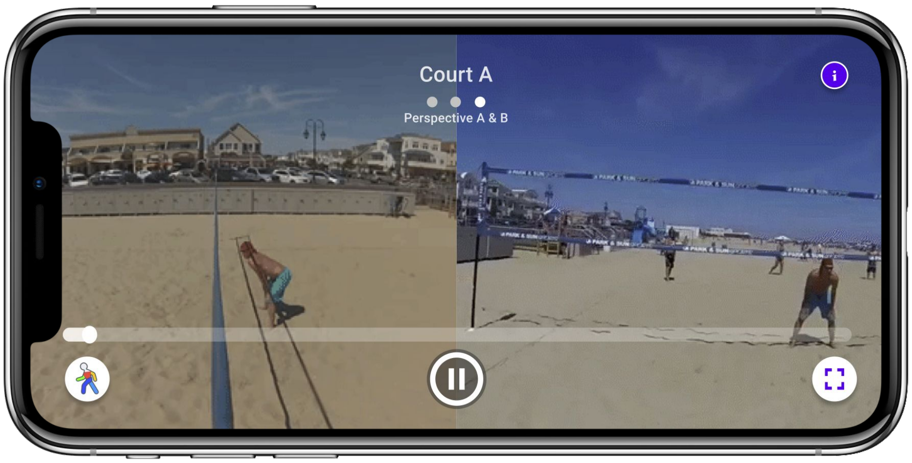

Figure 12.16 Teammates viewing multi-perspective video snippet of their teachable moment.

During a point of their match, Ansar serves the ball. He puts a good amount of power into it, but he serves it right to the opposing team’s stronger player. The opponents quickly save and spike the ball. Ansar and Alex are not well-positioned, so they cannot save the ball and they lose the point. Ansar uses his event trigger to identify this moment as a teachable moment (see Figure 12.19).

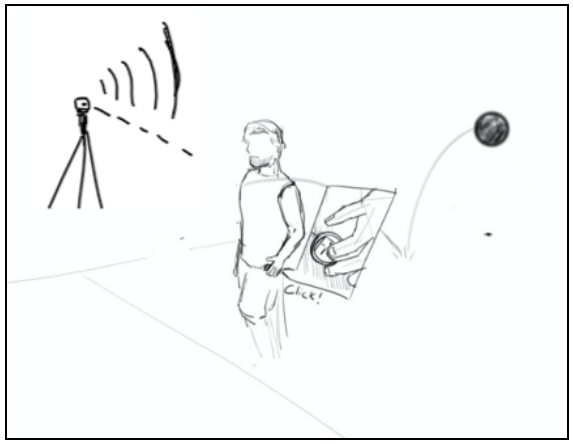

Figure 12.17 Persona using their event trigger to identify a teachable moment.

As the tournament ends, Ansar receives a notification from the CLL application asking him to review his teachable moments. Ansar uses tags available on the user interface to let the CLL application know why he identified the moments (see Figure 12.20). The CLL application uses Ansar's input to contextualize and categorize the video snippets from his matches. The CLL application also uses this information to train its Artificial Intelligence (AI) engine and recognize similar moments in the future.

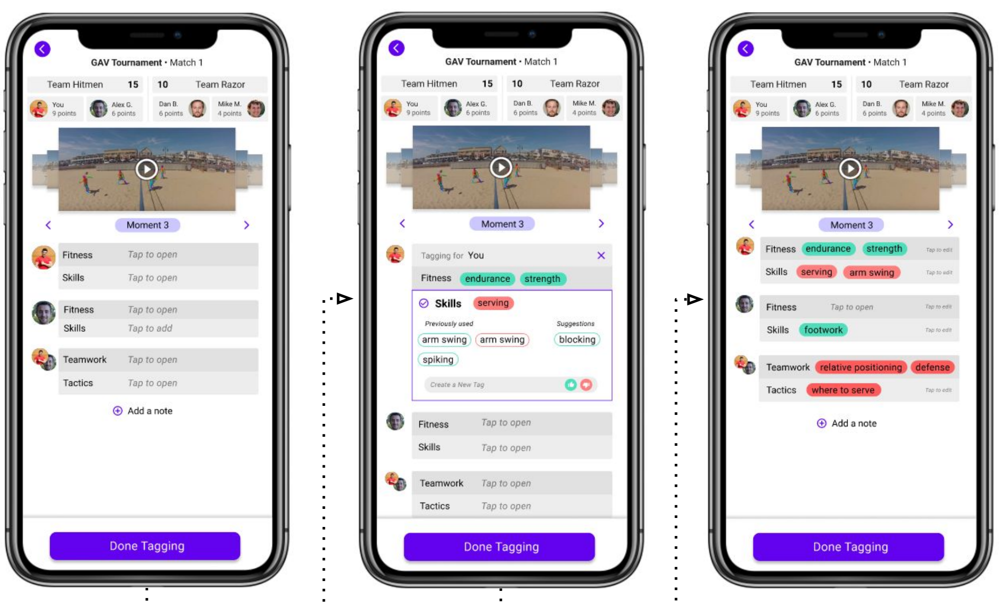

Figure 12.18 Persona using CLL user interfaces to tag video snippets based on their associated improvement areas.

To facilitate Ansar's access to all video snippets of his teachable moments, the CLL application also asks him to use tags on the user-interface to evaluate his matches from the entire tournament (see Figure 12.21).

Later in the day, as Ansar gets back home, he wonders if he incorrectly served the ball during the first match. Using the filtering feature on the CLL application, he finds video snippets that show his serving skills. To seek feedback on his skills, he sends the video snippets to (a) his beach volleyball community members, and (b) two of his high-skilled connections, Jeff and Lia (see 12.22).

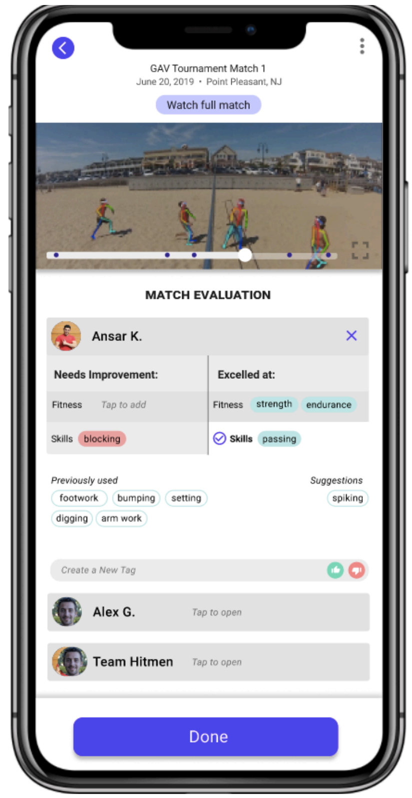

Figure 12.19 Persona using tags to evaluate their matches using CLL user interfaces.

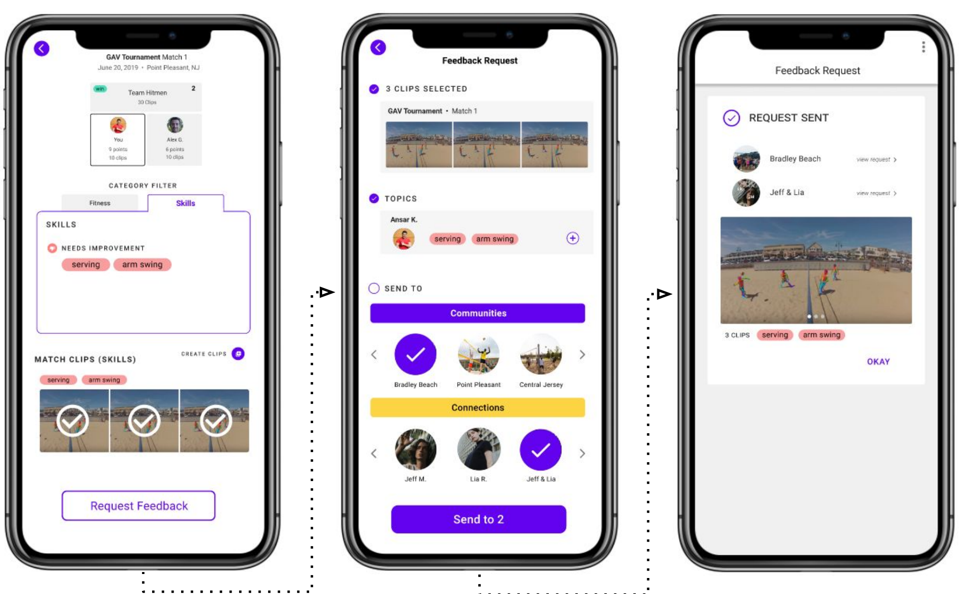

Figure 12.20 Persona using CLL user interfaces to request feedback.

A few minutes later, he receives a notification saying he has received feedback from Jeff and Lia. When Ansar taps on the notification, he views detailed comments from Jeff and Lia explaining how Ansar could improve his body form. Ansar finds their comments helpful and understands the improvements he needs to make with his posture (see Figure 12.23).

Figure 12.21 Persona using feedback received from high-skilled personal connection.

An hour later, Ansar gets a notification from the CLL application that his friend, Sarah, has sent her a feedback request regarding her relative positioning. Ansar taps on the notification and views Sarah's video snippet. Ansar thinks that he has video snippets that could help Sarah learn how to improve her positioning. He navigates through his data and shares two of his video snippets with her. He also leaves comments on several aspects of the shared video snippets to which Sarah needs to pay attention (see Figure 12.24).

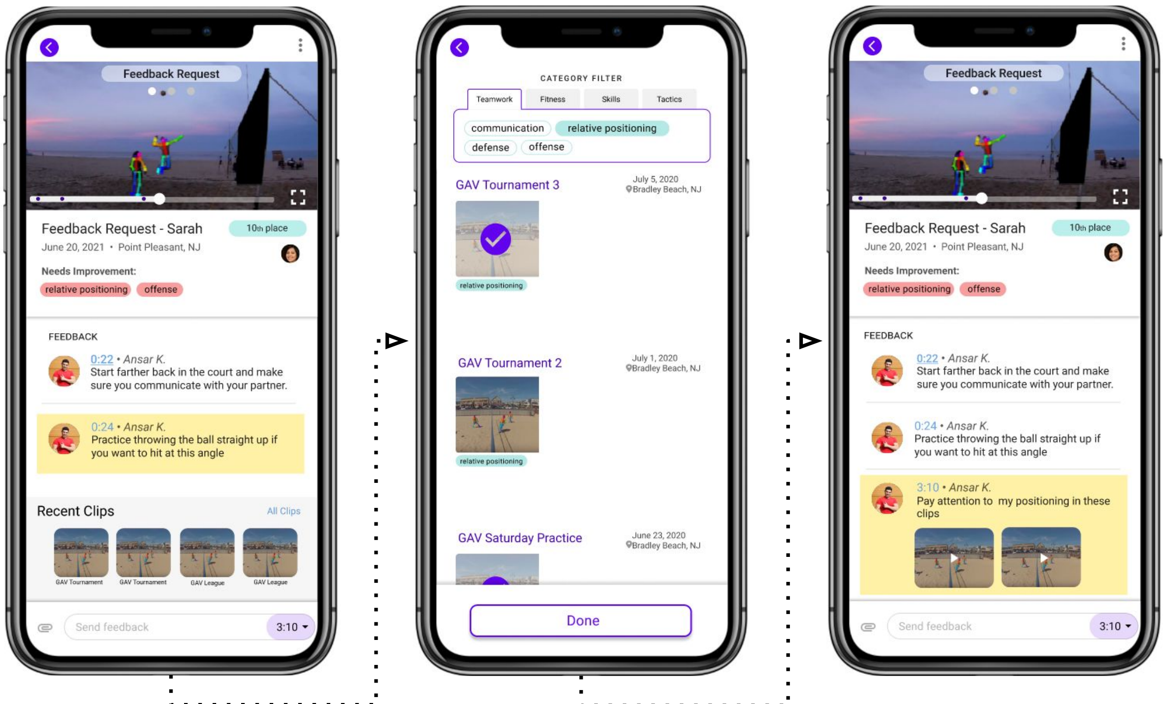

Figure 12.22 Persona sharing their video snippets with personal connection to facilitate feedback exchange.

On Wednesday, Ansar receives a notification reminding him of the upcoming Great American Volleyball (GAV) league on Saturday. Ansar taps on the notification and views the details of the event. To support the collaborative video capture of the activity, the CLL application suggests that community members bring their GoPros to the event and set them up at different locations throughout the venue. Since Ansar wants to capture his teachable moments during league, he lets the CLL application know that he will bring along his personal GoPro (see Figure 12.25).

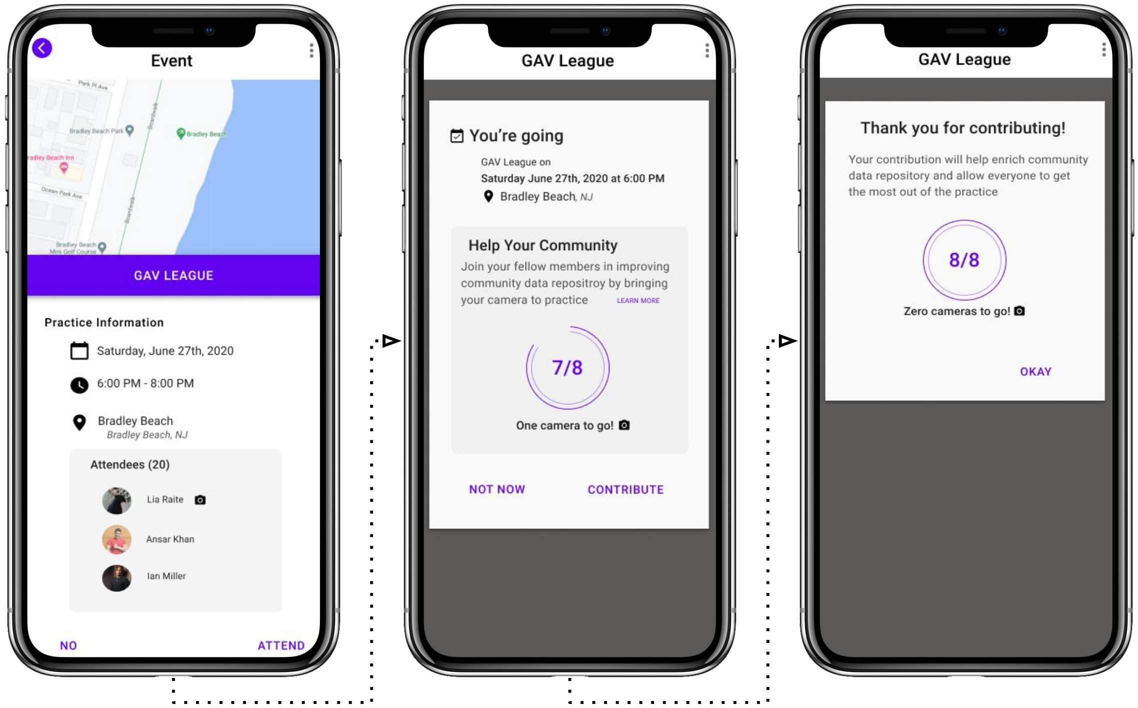

Figure 12.23 Collaborative video capture support on CLL interfaces.

Ansar also views the community feed on the CLL application to explore video snippets shared by his fellow community members. As he navigates through the videos, he catches up with others. He also observes Open players' movements in the video snippets and learns from them.

12.4 Quantified-Self User Interface Design Process

This section describes how we incorporated the literature review and empirical research insights in our research-through-design approach to create prototypes representing the underlying functionalities of QS systems.

We discussed in our literature review that QS systems create feedback loops for users and give them access to their biomechanical and physiological metrics. We explained that biomechanical metrics are those that characterize body movements in physical performances. Physiological metrics are those that describe the states of the human body. We learned in Study I that members of CPRC only received basic quantified movement metrics (e.g., speed, number of steps) and physiological metrics (e.g., heart rate, body temperature). They did not see much value in using these metrics for supporting their procedural learning.

To compare and contrast CLL solutions and QS systems, we aimed to create QS prototypes that, like our CLL prototypes, support beach volleyball players' performance and learning. We explored literature on existing QS systems that provided quantified metrics tailored to beach and indoor volleyball players (Borges et al., 2017; Charlton et al., 2017; Damji et al., 2021). Our research found solutions, such as VERT[1] that centered on advanced learning-focused biomechanical metrics for the players. These metrics are (1) jump metrics showing the players' vertical displacement such as number and height of jumps, (2) landing impact metrics showing instantaneous acceleration (G-Force) caused by players' landings, (3) kinetics energy metrics showing the amount of energy that players' bodies possess during their movements, and (4) stress metrics showing the amount stress that the players put on their joints, tendons, and muscles.

We created QS prototypes with user interfaces that would allow users to continuously track and monitor these metrics (see Figure 12.26). Our designs incorporated the existing methods for presenting the metrics for effective performance and learning support. Players can immediately view and examine their metrics with our

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[1] https://www.myvert.com/gvert (accessed May. 2021)

user interfaces. We also provided functionalities that give players access to their longitudinal data (e.g., jump metrics over the period of eight weeks).

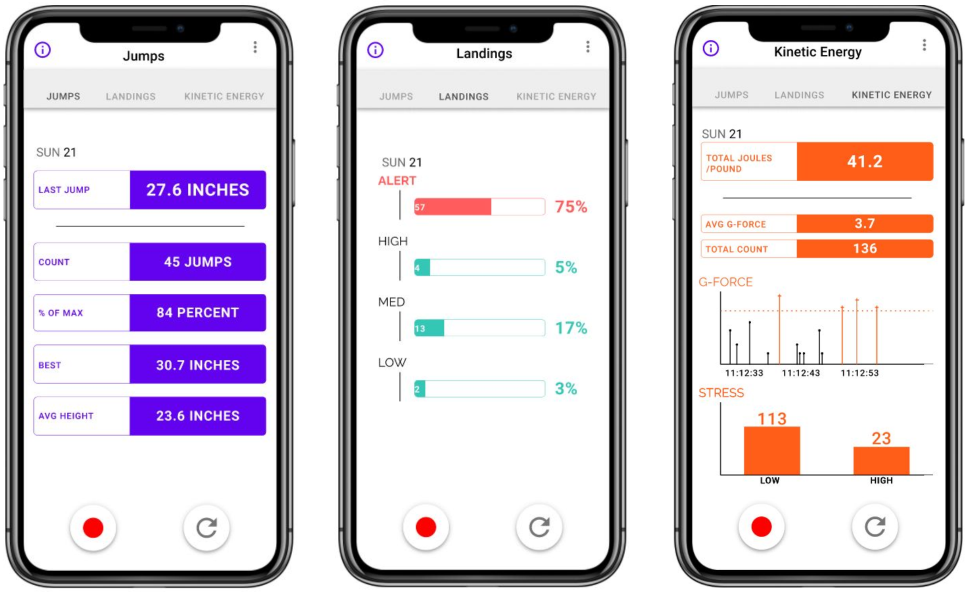

Figure 12.24 QS prototype user interfaces showing players' jump, landing impact, kinetic energy, and stress metrics.

In addition to the user interfaces for the individual use of the metrics, we created user interfaces for community feeds that allow players to participate in online communal tracking (see Figure 12.27). Players can use the community feeds to explore quantified metrics shared by others in their community and exchange metrics with fellow members. The user interfaces also provide functionalities such as liking and commenting for players to communicate with other members based

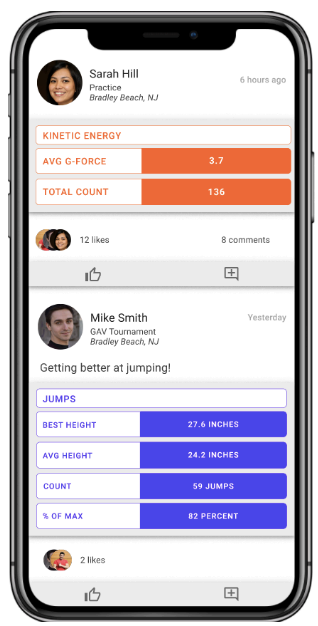

Figure 12.25 User interface representing community feeds in QS systems.

on the shared quantified metrics.

Next, we present a hypothetical scenario, describing how our recreational beach volleyball player persona uses our QS prototype (QS application) as he participates in a beach volleyball tournament.

12.5 Hypothetical QS Deployment Scenario

On Saturday morning, Ansar heads to local sand courts at Point Pleasant. There are 6 volleyball nets set up, and 24 individuals are participating in a beach volleyball tournament. When he arrives at the courts, he recognizes his friend, Alex. After greeting each other, they do a quick warm-up. Alex wears his tracking device (an inertial-measurement-unit sensor) on his hips and connects it to his smartphone in his backpack (see Figure 12.28).

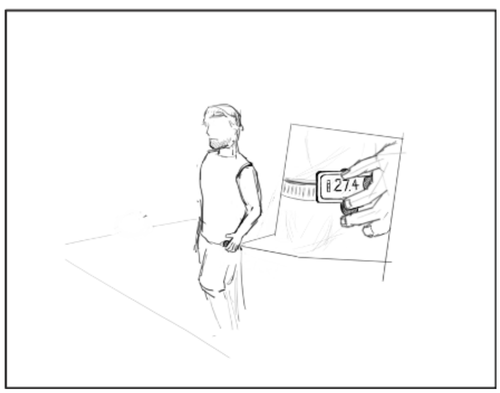

Figure 12.26 Use of QS tracking device.

During his first match, he manages to successfully block the ball multiple times. After the match, he is wondering how high he jumped throughout the rallies. He opens the QS application on his phone, checks his quantified jump metrics, and realizes that he has set a new personal record. Cheerful of his success, he heads to the second match.

During his second match, Ansar repeatedly struggles with spiking the ball. In one of his breaks, he opens the QS application to review his data. Based on his jump and kinetic energy metrics, he realizes that before spiking the ball, he approached it without the kinetic energy needed for a high jump. He identifies this as an improvement area and plans to address it in the upcoming matches.

As the tournament ends, Ansar grabs his backpack and unhooks his tracking device. He feels an ache in his leg joints and muscles. To understand the cause of his pain, Ansar opens the app to check his jump, stress, and landing impact metrics. He notices he had been tired during his last match, since his jumps were not as high as the previous matches. He also realizes that he put more stress on his joints, and his landing impact was in the alert zone as he got tired. He decides to avoid similar situations in the future by spending more time on strength and conditioning training.

12.6 Summary

This chapter presented the first step of the research-through-design approach in this dissertation. We created prototypes that represent the main functionalities of CLL solutions and QS systems. We used a CLL user interface design process to translate our literature review insights and empirical research findings into user interfaces supporting collaborative procedural learning in CPRC. To be able to compare CLL solutions and QS systems, we also used our literature review insights to create prototypes that represent the functionalities of QS systems for supporting beach volleyball players' performance and learning. The next chapter presents how we conducted a comparative design evaluation of CLL solutions and QS systems by employing the outcomes of this chapter and using a scenario-based video prototyping method.

CHAPTER 13

COMPARATIVE DESIGN EVALUATION OF COLLABORATIVE LIFELOGGING SOLUTIONS AND QUANTIFIED-SELF SYSTEMS

The second step of our research-through-design approach was to evaluate the designs of user interfaces created through our CLL and QS design processes. Our objective was to examine the comparative utility of our CC-inspired feedback system, CLL, to existing QS systems. This study rounds up this dissertation's contributions by providing insights into each innovation's support of collaborative procedural learning in CPRC.

13.1 Research Question

This study addresses the following research question:

> *RQ1:* *What are the perceived benefits of CLL solutions compared to existing QS systems among community members?*

13.2 Method

This study used a scenario-based video prototyping method (see Table 13.1). We turned our CLL, and QS designs from the previous chapter into scenario-based video prototypes, which simulated user interactions with CLL solutions and QS systems in real-world environments. We then conducted walkthroughs sessions with beach volleyball players. We presented our scenario-based video prototypes to the players during these sessions and explained how they would interact with the technologies. We collected qualitative data and examined how players perceived the utility of the CLL solutions compared to the QS solution. Our research method supported the examination of the comparative utility of both technologies (Zwinderman, 2013).

Table 13.1 Study IV

	Goal	Subjects
Comparative Design Evaluation	Assessing the comparative utility of CLL to existing QS systems	Members of NJIT Indoor Volleyball Community Club, NJIT Dance Team, NJ Filipino Dance Community

13.2.1 Method Background

Scenario-based video prototyping is a research method commonly used for examining the context of use and expected use of emerging technologies, especially among CSCW and ubiquitous computing scholars (Zwinderman et al., 2013). In this method, researchers first create video recordings of hypothetical personas using prototypes in scenarios that represent realistic use contexts. Researchers then play the video recordings to subjects and capture qualitative data covering their thoughts on technological innovation under study.

Several features of scenario-based video prototyping have made them useful for technological innovation evaluation. This method introduces individuals to technologies without exposing them to overwhelming technical aspects. This feature allows individuals to direct their attention to high-level functionalities that prototypes represent and helps them feel comfortable sharing their thoughts about if and how certain technologies would benefit them (Mackay, 1988). Also, in contrast to storyboards or text-based scenarios covering discrete representations of design ideas, scenario-based video prototypes present a continuous medium for showing detailed interactions (Bardram et al., 2002). This feature allows researchers to visualize and examine technology user interactions in a wide range of situations and contexts. Overall, scenario-based video prototyping is highly effective in examining design ideas in the early stages since it tends to provide insights close to resulting product evaluation studies (Zwinderman et al., 2013).

13.2.2 Data Collection

In our comparative design evaluation study, we turned our mockups from Chapter 12 into scenario-based video prototypes. We pre-recorded scenarios that demonstrate sequences of events and hypothetical users' interaction with the CLL and QS designs (Figure 13.1 shows an example). We generated these stories based on the insights obtained through the previous studies. Each scenario highlights the deployment of CLL solutions or QS systems in a specific situation covering their real-world use among members of CPRC.

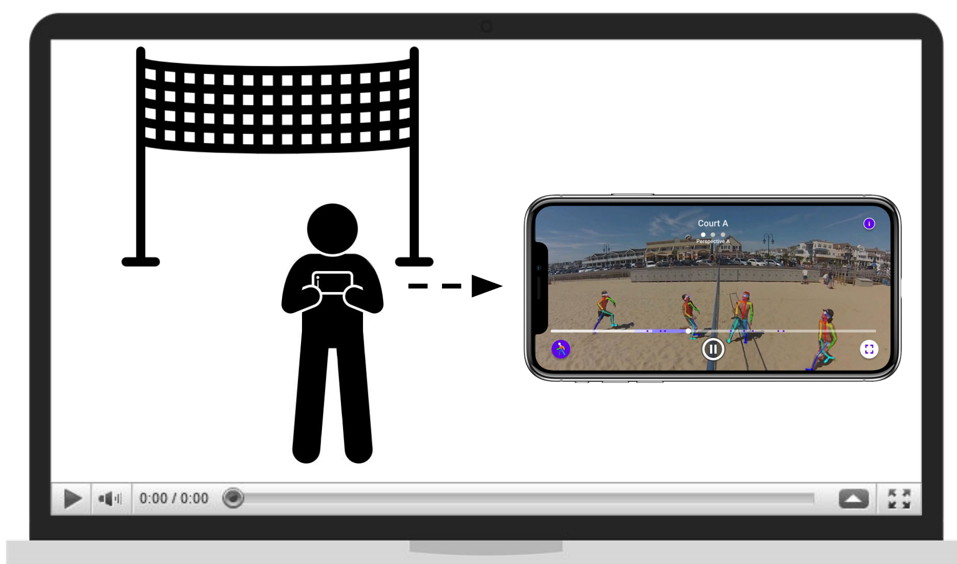

Figure 13.1 Scenario-based video prototype example.

After we created our scenario-based video porotypes, we conducted walkthrough sessions with members of CPRC and asked them to participate in the comparative evaluation of the CLL and QS designs by sharing their perceived utility of both solutions. In our session, we considered members' skill levels as we anticipated that this was a factor that might affect their understanding of each solution. During each session, we first introduced the CLL, and QS designs to subjects. We then explained to subjects hypothetical user interactions with each set of designs. For each user interaction, we explained to subjects the specific user interfaces components that were used and the any additional contextual information about the use of the designs. We included situations in which user interactions occur during community activities and interactions outside the activities, such as in private training.

Throughout our walkthrough sessions we collected qualitative data to compare and contrast the comparative utility of CLL solutions and QS systems. We used this lens to study how the subjects perceive each design and how they would incorporate them into their existing practices. We also investigated whether these solutions could interrupt the subjects' current practices or form new processes. Our qualitative data sets allowed us to investigate how each design affects CPRC in several areas: collaborative community-based procedural learning, members' community engagement, and social connectedness among community members. We also used our qualitative data to further explore new requirements for designing technological innovation for supporting performance and learning in CPRC.

13.2.3 Subjects

We recruited 11 beach volleyball players through snowball sampling. Our sample involved a diverse range of ethnicities and ages from 19 to 32 (*average age* 23.6). The subjects were 27% female. Seven of the subjects played at Open level tournaments, which indicates that they have high to very high skill levels. We refer to these subjects as *the advanced-competitive players*. Other subjects play at the A and AA level tournaments, showing their medium to high skill level. We refer to these subjects as the *competitive players*.

We paid each subject $20 as incentive for their participation. After collecting and analyzing data from 11 subjects, we noticed repetitive patterns emerging in our datasets, and thus determined that we had reached saturation in our dataset and had an adequate number of subjects in our study. The average length of our sessions was around 50 minutes, generating over 540 minutes of audio and video recordings.

13.2.4 Data Analysis

We used our qualitative data set to identify and analyze similarities and differences in how our subjects evaluated the CLL and QS designs. We used deductive coding processes, which started with closed-coding of a portion of our qualitative data set, and then expanded our analysis to the entire dataset. We formed categories by grouping our codes based on their observed similarities and differences. Through following these steps repeatedly and recursively, we developed 59 codes and 18 categories. We described, interpreted, and reviewed patterns emerging through our coding and categorizing process. We then made conclusions and drew implications based on our analyses.

13.3 Findings

Overall, we learned that most of the subjects preferred the CLL solutions over the QS systems between the two technologies. In this section we review why the subjects thought the CLL application (i.e., the CLL prototype) would support their individual learning and learning with their teammates better, why the subjects only saw value in the QS application (i.e., the QS prototype) as individual-based solutions for evaluating their fitness in their matches, and how they compared the social impacts of each application.

13.3.1 Perceived Benefits of CLL Application

We learned about the perceived benefits of the CLL application among our subjects. They shared that these benefits significantly influenced their preference for the CLL application over the QS application.

13.3.1.1 Supporting Individual Learning. The subjects discussed how the CLL applications would effectively support their individual procedural learning. They saw value in the processes for identifying and analyzing their teachable moments. While they were already aware of potential cameras for supporting their procedural learning, they brought up those challenges of using these technologies had stopped them from fully benefitting from their tech use. They explained that the processes for identifying and examining teachable moments in the CLL application would effectively address their tech use challenges and provide robust ways for enhancing their learning. Jennifer, an advanced-competitive player, shared her thoughts about the CLL application:

> *"It's so difficult to ... it's really tedious to go through like film and try to pick out like moments where you've improved or like highlights because there's always so*

much downtime. So like having the ability to pinpoint it is really cool [...], I could easily look back on how I did a certain thing. If I got like a really good hit, I could be like, 'okay, let me look at what my body looked like at that moment.'" (Jennifer, advanced-competitive player)

Furthermore, the subjects shared that video snippets of teachable moments available in the CLL application would allow them to examine and monitor their motor skills and determine improvement areas. Milo, a competitive player, told us about his perceived benefits of video snippets in the CLL application:

"Being able to tell what your body's doing at a specific moment [...] seeing what form where my body's position, how I'm positioned [...]being able to hit the clicker, and then going back to see what I did, exactly, and how I positioned everything." (Milo, competitive player)

The subjects also evaluated the benefits of the feedback exchange processes in the CLL application. They agreed that community members would value such processes to exchange feedback and help each other iteratively. Particularly, they told us that players with lower skills could use the processes extensively to seek feedback from high-skilled players and boost their learning. John, a competitive player, shared about the benefits of the feedback exchange processes:

"I think for like lower levels, like maybe be a double A, they can find the high-level feedback very valuable for them, because maybe they want to eventually get to open levels." (John, competitive player)

When comparing the CLL application to the QS application, they criticized that quantified metrics in the QS application would simply be ineffective in facilitating their learning, and therefore, they preferred the CLL application over the QS application. As Roger, an advanced-competitive player, put it:

"I think the [the CLL app] is a better process because, at least for me, I'm a visual learner, and I can actually see what I'm doing wrong [...] being able to see the whole game and run through that exact moment with a video would be more beneficial than just the raw numbers." (Roger, advanced-competitive player)

13.3.1.2 Supporting Learning among Teammates. The subjects mentioned that in addition to the support of their individual procedural learning, the CLL application could help teammates to learn together. They shared that teammates would use the CLL processes for tagging and examining their teachable moments to iteratively navigate and address their improvement areas. They would collaboratively incorporate video snippets in their practices to improve as a team. As Roger put it:

> *"If we're working on passing one week, then we can just watch our pass videos, see what we need to work on, and then go into practice from there. And be able to match our focus on those things that we see in the videos […] [the CLL app] helps us grow. And I mean, volleyball is a very mental game, in my opinion. So being able to conquer that with your teammates would definitely help."* (Roger, advanced-competitive player)

Subjects also discussed how teammates could use the CLL application to analyze their team performance from another perspective. Video snippets could allow them to specifically focus on their tactical and strategic development and teamwork improvements. Louis, an advanced-competitive player, told us:

> *"[We can use the CLL app] to analyze how we can better pass the ball in certain situations [...] We improve the communication, and we analyze the way the other team is serving […] we can make changes to adapt to [the opponent]'s strategy."* (Louis, advanced-competitive player)

The subjects also mentioned that the feedback exchange processes in the CLL application would allow them to request feedback from their teammates and ask for help with movements with which they struggle. Teammates could use these processes to repeatedly work together to address improvement areas in their team performance. Milo told us about how he pictured using the feedback exchange processes with his teammates:

> *"Being able to sit down after a game, especially if it's someone who I played with regularly, a partner, being able to see what exactly we did wrong, especially if we're going to play again [...] I can literally just be like 'this is what we struggled*

> *with last week against this team' [...] [the CLL app] would give that feedback to my team".* (Milo, competitive player)

Overall, the subjects emphasized the potential value of the CLL application in supporting learning with their teammates and enhancing their team performance. Since the subjects did not see such benefits using quantified metrics in the QS application, most of them shared that they preferred the CLL application over the QS application. As Louis told us:

> *"In terms of studying the volleyball that my partner and I play, understand the overall picture of volleyball, I think the [CLL app] would be more beneficial."* (Louis, advanced-competitive player)

13.3.2 Perceived Benefits of QS Application

As mentioned above, most subjects said that they preferred the CLL application over the QS application. We did hear from some subjects, who were advanced-competitive players, about a few instances, in which they saw value in the QS application. Most of our subjects agreed that, unlike the CLL application supporting players from all skill levels, the QS application was more tailored to advanced competitive players. They thought, since players from low skill levels are at the early stages of their learning journey, they could not effectively use quantified metrics in the QS application. As Liam put it:

> *"If I'm playing the AA, or A even, I'm not gonna care about how high I'm jumping, I'm still trying to figure out the volleyball side of it [...] you'd have to be playing a pretty high level for [the QS app] to make sense."* (Liam, advanced-competitive player)

However, the advanced-competitive players shared that using quantified metrics in the QS application would help them better understand their fitness levels, such as their strength and endurance. They told us that continuously accessing and monitoring the metrics would allow them to push their fitness to their optimal levels. Since they saw fitness and performance to be connected, they believed that fitness improvements would enhance their performance. Louis told us about how he perceived the benefits of the QS application:

> *"The overall picture of [the QS app], in my opinion is to optimize your performance [...] it helps you have a big picture of how well your body is doing, and how tired your body is, so you can measure when you can go a little harder."* (Louis, advanced-competitive player)

Unlike the CLL application that would allow them to use their data from matches collectively, subjects said that the QS application would only support individual use of their quantified metrics. They shared that such data would only help them improve their personal fitness and performance levels rather than their team performance. Jack told us his thoughts about using the QS application:

> *"[The QS app] is a more personal application [...] it majorly benefits the person himself using the application, it's more about improving yourself."* (Jack, competitive player)

The advanced competitive players also mentioned that the QS application would allow them to examine their strength and endurance levels in their matches longitudinally. Such analysis would help them monitor their body status throughout the matches and identify improvement areas in their personal fitness. They thought that addressing such improvement areas could lead to them performing better during their matches.

> *"[The QS app] is more of [...] how strong you push, and how at the beginning of the game versus at the end of the game, if you still have that stamina, you still have that strength."* (Jennifer, advanced-competitive player)

Moreover, several subjects said the QS application would allow players with high-skill levels to evaluate and improve their personal fitness and performance. Because of the perceived benefits of the QS application among the advanced-competitive players, they preferred to have quantified metrics in addition to video snippets of their teachable moments and the feedback exchange processes. They valued integrations of the CLL and QS applications' features for examining multiple aspects of their performances at once, including their fitness levels and motor skills. Louis shared why he preferred an integration of both apps for evaluating his jumps during his matches:

> *"[The QS and CLL apps] complete each other […] I think they are a combo. In the [QS app] you have the number of jumps, best jump, the average height of the jumps, and on the [CLL app] you are able to understand ... you are able to visualize when you had your best jump or when you didn't jump the way you should have."* (Louis, advanced-competitive player)

13.3.3 Perceived Social Impacts of CLL Application

In addition to the perceived benefits of the CLL application for their learning, the subjects shared potential types of social impact of this solution. This section reviews the perceived social impact of the CLL application.

13.3.3.1 Enhancing Social Connectivity in Community. We heard from the subjects that the CLL application, mainly the feedback exchange processes and community video repositories, could have significant positive social impact in the context of their community. They shared that the CLL application would affect their connections with others in their community. By continuously exchanging feedback and interacting with one another using the CLL application, they expected they would form new connections and strengthen their existing ties. Jennifer shared how she saw the CLL application strengthening her social bonds:

> *"[With the CLL app] you just continue to develop a relationship with someone the more you're in contact with them […] I think it would just continue to, you know, this person shared feedback with me, therefore, we have a better relationship [...]*

At the end of the day, it's not about winning and losing and that kind of thing. It's about the relationships that you build within the sport and the exercise of it, so I feel like [the CLL app] would just help to continue to build those relationships." (Jennifer, advanced-competitive player)

Subjects also talked about how the use of the CLL application for collaborative procedural learning could develop a sense of social companionship and community among members. Players, who help each other and learn together, could become closer. When such collaborations become widespread across a community, they could build strong community bonds and create well-connected communities. Milo saw exchanging feedback with others improving his community:

"Seeing that type of feedback, that type of coaching, and that camaraderie that we have with each other, I think would just make us stronger as you could have a more tight-knit community. I think that really would be the main beneficiary. I think for sure [the CLL app] would help just strengthen those bonds of that community." (Milo, competitive player)

Overall, the subjects saw positive impact in using the CLL application, including improved connections with other members, strengthened community bonds, and higher connectivity levels in community. Such perceived social impacts were also motivating subjects to use the CLL application when available.

13.3.3.2 Supporting Social Tie Formation Based on Skill Level. Our subjects described how the CLL application could support creating new social ties among players based on their skill levels. They told us they often faced challenges finding activity partners with specific skill levels (e.g., same-level or higher-level players) in their proximity. The CLL application could address their challenges by giving them concrete data to study and select potential activity partners based on their skill level. They would use video snippets in community video repositories to analyze other players' motor skills and then seek out players who fit their skill level requirements. Seth, for example, is an advanced competitive player and shared his challenges of finding activity partners. Using the CLL application, he said, could address the challenges he faced:

> *"Nobody wants some guy to walk up and say 'hey, can I play?' And you guys just start playing [...] He's learning and he's wanting to grow, which is amazing. And that's what we love. But we don't want the frustration that he can't pass [...] I see [the CLL app] as me meeting or connecting with one or two professionals that really like my back and we have a great relationship."* (Seth, advanced-competitive player)

Even after players formed new social ties with their activity partners and participated in activities together, they could continue to use the CLL application to evaluate each activity partner based on their team performance on an ongoing basis to determine partners with whom they perform best. Jasmine told us about viewing video snippets of her match to examine her activity partners:

> *"[With the CLL app] you can see how you're playing as like a team. Everyone plays differently with each other. So it'd be easier to see if 'oh, this like is really working for me playing with this partner, but not this one.'"* (Jasmine, competitive player)

The subjects thought that access to video snippets in the community video repositories would allow them to become familiar with other players' skill levels. They found the CLL application valuable for finding activity partners with specific skill levels and forming ties with them.

13.3.4 Perceived Social Impact of QS Application

We also discussed the potential social impact of the QS application with subjects. Unlike the CLL application, which could support social connectivity and tie formation among members, the subjects viewed the QS application as less effective in that domain. They shared that since the QS application represented individual-based solutions for examining their fitness, it would have little impact on social connections in their community. While the subjects acknowledged that QS application users could interact with one another, they thought that the ego-centric nature of the application was an obstacle in creating real-world positive impact on their community. As Liam told us:

> *"It's pretty limited as to the interactions that are going on … I don't see [the QS app] being very …. I don't see that forming a community. I don't see people really gravitating towards that. Because it's basically just numbers on a page."* (Liam, advanced-competitive player)

We also heard from our subjects that instead of supporting collaborations, the QS application would cause social comparisons in their community. Quantified metrics in the application would highlight players' fitness levels. A player's higher metrics would suggest that they had achieved higher fitness levels and had a higher place in their community. The subjects thought that the metrics and their presentation on the QS application would indirectly encourage them to compete with others to show off and claim a higher place in the community. Roger said:

> *"[I would use the QS app] definitely to push myself […] me and most of my friends are pretty competitive. So if we were all posting our jumps, then we would try to be increasing our vertical consistently."* (Roger, advanced-competitive player)

The subjects even saw the QS application causing social comparisons among teammates. They told us when one teammate achieves higher metrics, the other teammate may feel pressured to also show their fitness improvements. Jennifer, for example, told us how quantified metrics in the QS application would affect her and her teammate:

> *"I think if I was in a team setting, I think that being able to compare statistics [using the QS app] with teammates and other things, it would just continue to motivate everyone to work harder."* (Jennifer, advanced-competitive player)

While the QS application would support online communal tracking, i.e., exchanging quantified metrics and communicating with other members, we learned that it might have unintended consequences on community members' understanding of one another and their interpersonal interactions. Instead of supporting collaborations among players, the QS applications would cause social comparisons among them and create peer pressure situations among teammates to contrast their fitness levels constantly. Such social comparisons and competitions using quantified metrics could encourage players to improve their personal fitness.

13.3.5 Feedback Exchange Processes in CLL Application

This section presents our findings regarding the perceived uses of the feedback exchange processes in the CLL application, which were unavailable in the QS application. When we asked our subjects how they would use the processes for exchanging feedback with others, most of our subjects told us, since same level players may not be able to effectively help them with learning, they would only seek feedback from higher-skilled players. For example, when asked about requesting feedback, David said:

> *"Not all feedback will be good. You know, it's tough, because when you're looking at players at your own skill level, they may not necessarily know what the right way of performing a skill is."* (Daniel, advanced-competitive player)

Among higher-skilled players who could provide the subjects with feedback, they were more inclined to request feedback from players with whom they had a personal connection. As Liam put it: *"[For feedback] I would probably reach out to my immediate friends, the people I practice with.*" The subjects said that since their connections were familiar with their skills, they could give them tailored feedback and effectively help them learn. We even heard from our subjects about their preferences to provide feedback to players with whom they were connected. Since they had repeatedly interacted and communicated with these connections, they knew that their feedback could be helpful to their learning. Jennifer shared with us about her giving feedback to her connections:

> *"[I will exchange feedback through the CLL app] with my friends [...] I just have a personal relationship with them [...]. With a stranger, I know that I could use a certain terminology and they either don't know that or there would just be greater miscommunication."* (Jennifer, advanced-competitive player)

We also asked our subjects about providing feedback to players with whom they were not connected. We heard from the advanced competitive players that they could see players at their level voluntarily giving other players feedback because they want to help their community members. However, these subjects also mentioned that players at their level might need incentives for giving feedback to people other than their connections since they might need to put significant effort into examining video snippets and sharing their detailed analysis of movements. As Liam shared:

> *"Some people might [give feedback] because they're just nice people. But I think that ultimately for an open player to be acting as a coach for another player, they probably want some kind of monetary incentive [...] For me to help a stranger, I'd probably need to be motivated in some capacity."* (Liam, advanced-competitive player)

In summary, our subjects were excited about the potential use of the CLL application for exchanging feedback with specific players. They highlighted the interactions of skill levels and personal connections affecting how they would use the feedback exchange processes. However, lack of personal connections with individuals could particularly impact the advanced competitive players' inclination to provide feedback. In such cases, other measures such as giving incentives could be effective.

13.4 Discussion

The section presents a discussion of the study's findings regarding the value beach volleyball players see in CLL solutions, and the reasons why they prefer them over QS systems. We explained in this dissertation that QS systems have incorporated elements of ubiquitous computing (ubicomp) as the 3rd generation of computing. We argued that supporting procedural learning in CPRC requires transitioning feedback systems from 3rd generational technologies to 4th generational technologies, known as Collective Computing (CC). The main reason for this transition is that a significant portion of learning processes in these communities are likely to be collaborative, and existing 3rd generational technologies are incapable of supporting such collaborative processes. While CC is in its infancy and only very few applications of this generation of computing are available (e.g., Waze[1]), this dissertation takes practical steps towards bringing another real-world application of CC to life. Our findings of research-through-design approach showed that beach volleyball players prefer such 4th generational CLL solutions to QS systems because our CLL solutions would provide them with effective data to facilitate collaborative procedural learning processes in their community. We discuss what we learned from our research-through-design approach examining the comparative utility of these technologies in multiple domains. We also discuss the perceived benefits of CLL solutions over QS systems, and end by proposing an integrated CLL and QS approach as 4th generational technological innovation for procedural learning in CPRC.

[1] https://www.waze.com/ (accessed Aug. 2020)

13.4.1 Collaborative Procedural Learning Support over Basic Data Sharing

Perhaps the main perceived difference between CLL solutions and QS systems is the nature of interactions that they support. The primary form of interactions in QS systems is through online communal tracking practices, which is exchanging performance-related metrics and communicating with other members (Lupton, 2014). Although a social practice entailing performance data, online communal tracking does not inherently lead to collaborative procedural learning opportunities and may only create incidental opportunities for feedback exchange. On the contrary, as we showed in this dissertation, supporting collaborative procedural learning must be deliberatively researched and designed.

CLL solutions have processes specifically for facilitating collaborations between teammates and among community members. By creating collective Avatars, CLL solutions support sharing and discussing video snippets, which could boost opportunities for feedback exchange, and thus, collaborative procedural learning. CLL user interfaces could also be effective in allowing individuals to exchange feedback with their teammates and seek feedback from their high-skilled connections. Overall, CLL solutions could facilitate collaborative procedural learning, which is not currently possible using QS systems.

While QS systems only allow tracking, analyzing, and optimizing individual fitness levels, we argue that they could incorporate collective Avatars from CLL solutions to allow teammates to examine each other's quantified metrics and exchange feedback. These collective uses of quantified metrics would help teammates to improve their team's overall fitness levels.

13.4.2 Video Snippets over Quantified Metrics

By conducting empirical research, this dissertation determined the challenges of using videos from generic technologies (e.g., GoPros) for procedural learning. We identified that individuals desire video snippets of teachable moments for supporting their learning. Through our research-through-design approach, we created prototypes of CLL solutions with processes that would specifically provide beach volleyball players with video snippets of teachable moments. This study showed that our proposed CLL solutions and the related processes would effectively address beach volleyball players' challenges of incorporating videos for learning. Aligned with our previous arguments in this dissertation, the study's findings suggest that the perceived incremental impact of video snippets on learning and their advantage over quantified metrics may encourage players to choose CLL solutions over QS systems.

13.4.3 Data Contextualization over Data Abstraction

In addition to the data format (i.e. video snippets), this study also demonstrated the perceived value of data contextualization on procedural learning opportunities in CPRC. CLL solutions contextualize and categorize video snippets based on teachable moments' social context to make this data suitable for procedural learning. QS systems, however, tend to measure and present quantified metrics islolated from factors that could affect their metrics, including social context (Rivera-Pelayo et al., 2012). This feature of QS systems is among reasons for their limited support of procedural learning. The study's findings suggest that QS systems could incorporate additional processes for contextualizing quantified metrics based on social factors, and further integrating and presenting this data for supporting procedural learning opportunities. For instance, QS systems could identify individuals who are teammates to allow them to collaboratively navigate through their data and exchange feedback on their fitness levels (Müller et al., 2011; Rivera-Pelayo et al., 2012).

13.4.4 Social Connectivity over Social Comparisons

When comparing CLL and QS, we learned that a difference in the two types of data outputs is their social impact on CPRC. Video snippets are not directly comparable and thus may be less often used for social comparisons. They may encourage learning through observations and help individuals develop a sense of connectivity and community. Quantified metrics, in contrast, are presented as numbers, which can be directly compared. Thus, these metrics inherently cause social comparisons and competition between teammates and among community members. Studies have shown both positive and negative aspects of social comparison. Some have viewed them as effective means for promoting physical activity. Other studies highlighted that individuals might feel pressure to outperform others (Zuckerman & Gal-Oz, 2014), and that quantified metrics can push individuals away from each other (Laverie, 1998). This is a drawback of QS systems that CLL can alleviate by supporting social connectivity over social comparison.

13.4.5 Limits of Quantified-Self in CPRC

QS systems aim to allow individuals to gain "self-knowledge through numbers" (Wolf, 2010). These systems are widespread and commonly used in various settings, including in physical recreation. They allow individuals to track, analyze, optimize their performance in the activities (Ruckenstein & Pantzar, 2017). Over the years, QS systems have become the mainstream technologies available for physical recreation. We have argued throughout this dissertation that although these systems support many forms of physical recreation, they are ineffective in supporting procedural learning in CPRC.

This study showed that QS systems have applications in evaluating individuals' fitness levels, in particular among high-skilled players. They center on the exercise component of the activities and, therefore, have very limited impact on the support of procedural learning for motor skill acquisition. Since quantified metrics only cover a small portion of what individuals who are still in the process of acquiring new motor skills or improving their existing skills need, QS systems may have little to offer. They provide no meaningful value to their motor skills acquisition or understanding of tactics or teams in their matches. However, these systems do have some applications for high-skilled players, who have mastered their motor skills and now want to optimize their performance. This finding is compatible with studies showing that use of QS systems for optimizing performance is common among individuals with high motor skill levels (Ng & Ryba, 2018; Ruckenstein & Pantzar, 2017).

Limitations of QS systems in supporting collaborative procedural learning is due to insufficient academic research on the requirement of technological innovation for collaborative physical recreation (Lupton, 2014). Furthermore, the existing trajectory of technology development on mass market has centered either on developing QS systems for personal physical recreation (e.g., Strava[1] for cycling, MapMyRun[2] for running) or

[1] https://www.strava.com/ (accessed May. 2021)
[2] https://www.mapmyrun.com/ (accessed May. 2021)

creating technologies for athletes and supporting their motor skill acquisition (e.g., Hudl[1]) (Lowe, 2015). Hence, the available QS systems are developed without real support of collaborative physical recreation.

13.4.6 4th Generational Integrations of CLL Solutions and QS Systems

We examined CLL solutions and QS systems as separate technological innovation classes and showed that beach volleyball players may prefer CLL solutions over QS systems mainly to support procedural learning. However, our findings suggest that integrating these two technologies could be effective for further support of collaborative procedural learning among high-skilled players. We argue that 4th generational integrations of CLL systems and QS systems may be desired in CPRC for their simultaneous support of procedural learning and fitness tracking.

Integrated CLL solutions could provide individuals with both video snippets and quantified metrics. They could extract quantified metrics from video snippets and present the metrics on top of the video snippets. For example, they could use video snippets of beach volleyball matches to calculate the players' jump height and show data types at once.

Alternatively, new technologies could emerge that incorporate video snippets and feedback exchange processes from CLL systems and quantified metrics from QS systems. Such integrations are feasible in the Collective Computing (CC) era of computing since its main data capture component, 'shroud,' combines cameras and sensors collectively capturing biomechanical and physiological data.

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[1] https://www.hudl.com/ (accessed May. 2021)

These new 4th generational CLL-QS integrations would support collaborative procedural learning by incorporating CLL processes studied in this dissertation: collaborative video capture, identifying and contextualizing video snippets, and feedback exchange using video snippets. In addition, such 4th generational CLL-QS integrations need to utilize the processes for contextualizing and integrating quantified metrics presented in literature and discussed above (Müller et al., 2011; Rivera-Pelayo et al., 2012) to allow teammates and community members to collaboratively navigate through their data and exchange feedback on their fitness levels. Collectively, all these processes could create truly collaborative technological innovations capable of supporting CPRC. While this provides an overall direction for this new integrative class of technological innovation, we acknowledge the need for more in-depth studies of the requirements of CLL-QS integrations, including their processes for capturing, retrieving, contextualizing, and merging data.

13.5 Limitations

This section describes the limitations of this study due to the choice of research methodology. Our initial plan was to provide CLL and QS design to beach volleyball players during community activities. We also planned to give the players video snippets of their teachable moments and quantified metrics of their performance to explore how they make sense of each data type during the activities. However, frequent restrictions because of the COVID-19 pandemic made our initial plans impossible to implement. Thus, we relied on scenario-based video prototyping for the comparative design evaluation of CLL solutions and QS systems. As a result, while we learned about the solutions' perceived comparative utility, we could not investigate them in real-world environments, which might have limited the study's insight. Future studies could address this limitation by implementing and deploying CLL and QS prototypes to study their benefits. Future studies could also use concrete learning measurement (such as in (Casey & Jones, 2011)) to expand knowledge about the extent to which CLL solutions support individual and collaborative procedural learning in real-world settings.

13.6 Summary

This study examined the comparative utility of CLL and QS designs that emerged through our research-through-design approach. Using a scenario-based video prototyping approach, we asked beach volleyball players to compare and contrast the solutions in simulated real-world environments. The study showed that the players preferred the CLL solutions over QS systems due to their support of individual and collaborative procedural learning. They shared that QS systems could be effective for tracking, analyzing, and optimizing fitness levels. The insights also showed the perceived social impact of each solution. CLL solutions could encourage collaborations among community members and bring them closer together, while QS systems may cause social comparisons among individuals, creating peer-pressure situations and pushing them to improve their fitness levels. We discussed the study's findings, including how they set a new direction for creating 4th generational integrated CLL-QS solution as truly collaborative technological innovation for supporting performance and learning in CPRC.

CHAPTER 14

SUMMARY AND EXPECTED CONTRIBUTIONS

As we conclude this dissertation, we highlight once again our key learnings and contributions and their broader impact on supporting collaboration procedural learning in collaborative physical-recreation communities (CPRC). We also present the expected contributions of this dissertation.

14.1 Summary

Lifelogging was originally envisioned to augment learning, performance, and community, but this vision never became a reality. Technological development and the emergence of the Quantifies-Self (QS) movement led to a plethora of self-tracking technologies. Over the years, several QS systems have been introduced aiming to bring users better health and performance. QS systems provide self-tracking-enabled metrics, allowing users to track, analyze, and monitor their performance. However, they have primarily centered on capturing and presenting individual-based and decontextualized metrics unsuitable for supporting learning and community. This is particularly a problem in learning in CPRC because members have to work together in performance and learning.

We began this investigation into CPRC by presenting the communities' characteristics and how members participate in joint community activities. We also explored the communities' positive impact on social connectivity and individuals' physical health and mental well-being.

To examine how members help each other in learning in CPRC, we first explained human memory and various types of learning, and then described the processes for acquiring motor skills. In Chapter 5, we explored motor skill acquisition through collaborative procedural learning in CPRC through community members observing each other's movements and exchanging feedback. The takeaways from collaborative procedural learning processes in CPRC highlighted various opportunities for facilitating this type of learning, including through technological innovation.

We reviewed existing technologies and argued that QS systems tend to be the only available technologies for physical recreation. However, due to their ego-centric nature and decontextualized metrics, we highlighted that these solutions provide limited support for collaborative procedural learning in CPRC.

In our first study, in Chapter 8, we conducted semi-structured interviews and qualitative diaries to examine reasons behind engagement with CPRC, types of intrinsic and extrinsic feedback community members used, and what they perceived as the benefits and challenges of available technologies. Our findings showed that individuals engaged with the communities for multiple reasons, including supporting their learning, creating healthy lifestyles, getting mental health benefits. This study further showed forms of intrinsic and extrinsic feedback that community members used. Our insights also highlighted that QS systems provided minimal support for individuals' learning. Most importantly, while community members used cameras to video capture their performances, they faced challenges in effectively using the data for their learning. Instead, they desired video snippets of their teachable moments as extrinsic feedback.

Based on the literature review and empirical research insights, we identified a set of requirements for technological innovation that support collaborative procedural learning in CPRC. Since such innovation requires novel and transformative types of technologies, we proposed Collaborative Lifelogging (CLL) as a conceptual framework for 4th generational lifelogging systems. We explained how CLL solutions could address our identified requirements through three primary processes: (1) collaborative video capture of community activities, (2) identifying and contextualizing video snippets of teachable moments, and (3) feedback exchange among users with the video snippets.

Through two empirical research studies, we then examined and refined these CLL processes. Through an observational study, we examined community-based processes for collaborative procedural learning in CPRC. Our findings showed that these processes consisted of observations and feedback exchange among community members, which depended on the roles of teammates, skill levels, and personal connections. We used the findings to inform the CLL process for feedback exchange using video snippets. Through a contextual inquiry of teachable moments, we further examined individuals' teachable moments. We found that players identified moments of successes, unsuccessful attempts, and long rallies as teachable moments. Their teachable moments were also associated with improvement areas in their individual and teammates' motor skills, teamwork, and tactics. We also examined the perceived value of viewing video snippets of teachable moments. We found that players used the video snippets to troubleshoot their individual and team performance and exchange feedback with teammates. We used these insights to inform the CLL process for identifying and categorizing video snippets of teachable moments.

We used a research-through-design approach to conduct a comparative design evaluation of CLL solutions and QS systems among beach volleyball players. We first translated our literature review insights and empirical research findings into CLL user interfaces. We also used our literature review insights to create prototypes that represented the functionalities of QS systems for supporting beach volleyball players' performance and learning.

Using scenario-based video prototyping, we asked beach volleyball players to compare and contrast the solutions. We found that most of them preferred CLL solutions over QS systems due to the support of individual and collaborative procedural learning. They shared that the solutions could encourage collaborations among community members and bring them closer together. QS systems were thought to be effective for tracking, analyzing, and optimizing fitness levels. They said that these technologies might cause social comparisons among individuals, create peer-pressure situations, and push them to improve their fitness levels. Finally, we set a new direction for creating 4^{th} generational integrated CLL-QS solution to further support performance and learning in CPRC.

Collectively, this dissertation expanded knowledge of the requirements for systems supporting collaborative procedural learning in CPRC. Furthermore, through supporting participation in collaborative physical recreation, the outcomes of this dissertation could lead to significant positive benefits for individuals' social connectivity and physical and mental health.

14.2 Expected Contributions

The findings of this dissertation contribute meaningfully to the broader body of research on computer-supported collaborative learning (CSCL) and human-computer-interaction (HCI). In order to share these learnings with the academic community, the author intends to publish findings through various scholarly venues. Currently, a portion of the conceptual framework of CLL solutions has been published (Ahmadi et al., 2019). The complete CLL framework and empirical research findings will be shared at social and technology conferences within the next year to disseminate this research. The collaborative procedural learning literature review and Study II insights will be submitted to the Conference on Human Factors in Computing Systems (CHI). Results from our contextual inquiry of teachable moments, Study III, and the identified requirements of CLL solutions will be submitted to the Conference on Intelligent User Interfaces (IUI). The author will submit Study I findings and the conceptual framework of CLL solutions to the Conference on Computer-Supported Cooperative Work and Social Computing (CSCW). Finally, our research-through-design, consisting of our CLL and QS prototyping and Study IV insights, will be submitted to the Joint Conference on Pervasive and Ubiquitous Computing (UbiComp).

APPENDIX A

IRB APPROVALS AND CONSENT FORMS

In this appendix you will find the:

(1) IRB Form for Study I (May 2018)

(2) Consent Form for Study I (May 2018)

(3) IRB Form for Study II (October 2019)

(4) IRB Form (Recovery Review) for Study III - IV (July 2020)

(5) Consent Form for Study III (July 2020)

(6) Consent Form for Study IV (July 2020)

(1) IRB Form for Study I (May 2018)

NJIT
New Jersey Institute of Technology

Institutional Review Board: HHS FWA 00003246
Notice of Approval
IRB Protocol Number: F378-18

Principal Investigators: Quentin Jones, PhD (Information Systems)

Title: Collaborative Lifelogging for Recreational Sports Communities

Type of Review: FULL [X] EXPEDITED [ ]

Type of Approval: NEW [X] RENEWAL [ ] REVISION [ ]

Approval Date: May 8, 2018 Expiration Date: May 7, 2019

1. **ADVERSE EVENTS:** Any adverse event(s) or unexpected event(s) that occur in conjunction with this study must be reported to the IRB Office immediately (973) 596-6053.

2. **RENEWAL:** Approval is valid until the expiration date on the protocol. You are required to apply to the IRB for a renewal prior to your expiration date for as long as the study is active. It is your responsibility to ensure that you submit the renewal in a timely manner.

3. **CONSENT:** All subjects must receive a copy of the consent form as submitted. Copies of signed consent forms must be kept on file with the principal investigator.

4. **SUBJECTS:** Number of subjects approved: 100

5. The investigator(s) did not participate in the review, discussion, or vote of this protocol.

6. **APPROVAL IS FOR PILOT STUDY OF THIS RESEARCH. APPROVAL IS GRANTED ON THE CONDITION THAT ANY DEVIATION FROM THE PROTOCOL WILL BE SUBMITTED, IN WRITING, TO THE IRB FOR SEPARATE REVIEW AND APPROVAL.**

Norma Rubio, IRB Co -Chair,

(2) Consent Form for Study I (May 2018)

NEW JERSEY INSTITUTE OF TECHNOLOGY
323 MARTIN LUTHER KING BLVD.
NEWARK, NJ 07102

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

TITLE OF STUDY:

I, ____, have been asked to participate in a research study under the direction of Dr. Quentin Jones. Other professional persons who work with them as study staff may assist to act for them.

PURPOSE:

To explore the instantiation of Collaborative Lifelogging, a 4th generation computing system that supports users collaborating on sensor data capture through the formation of on-the-fly self-tracking groups, providing for the capture of multiple perspectives on an individual's activities.

DURATION:
My participation in this study will last for around two weeks.

PROCEDURES:
I have been told that, during the course of this study, the following will occur: First, I will be interviewed about what types of lifelogging or self-quantification technologies I currently use and what information I currently share with members of my community. Then I will be filling out diary forms with information about significant activity moments that I would find worthy of recording. Lastly, I will be interviewed about the information entered into the diary forms.

PARTICIPANTS:
I will be one of about ~50 participants in this study.

EXCLUSIONS:
I will inform the researcher if any of the following apply to me:

Under 18 years old

RISKS/DISCOMFORTS:
I have been told that the study described above may involve the following risks and/or discomforts:

When discussing and examining lifelogging technologies, community-related moments of my life might be captured.

There also may be risks and discomforts that are not yet known.

I fully recognize that there are risks that I may be exposed to by volunteering in this study which are inherent in participating in any study; I understand that I am not covered by NJIT's insurance policy for any injury or loss I might sustain in the course of participating in the study.

CONFIDENTIALITY:
I understand confidential is not the same as anonymous. Confidential means that my name will not be disclosed if there exists a documented linkage between my identity and my responses as recorded in the research records. Every effort will be made to maintain the confidentiality of my study records. If the findings from the study are published, I will not be identified by name. My identity will remain confidential unless disclosure is required by law.

AUDIOTAPING:
I understand that I will be audio taped during the course of this study. Audio tapes will be stored for 5 years after the end of this project (4/25/2019). After that time, the recordings will be erased. Recordings will be stored digitally on university-owned computers located in a secure lab in the New Jersey Institute of Technology and will not be made available to anyone except investigators who are involved in this research.

PAYMENT FOR PARTICIPATION:
I have been told that I will receive $50 compensation for my participation in this study.

RIGHT TO REFUSE OR WITHDRAW:
I understand that my participation is voluntary and I may refuse to participate, or may discontinue my participation at any time with no adverse consequence. I also understand that the investigator has the right to withdraw me from the study at any time.

INDIVIDUAL TO CONTACT:
If I have any questions about my treatment or research procedures,
I understand that I should contact the principal investigator at:

Quentin Jones, Principal Investigator
Department of Informatics
New Jersey Institute of Technology
323 Martin Luther King Boulevard
Newark, NJ 07102
(973) 596-5290
quentin.jones@njit.edu

If I have any addition questions about my rights as a research subject, I may contact:

Farzan Nadim, IRB Chair
New Jersey Institute of Technology
323 Martin Luther King Boulevard
Newark, NJ 07102
(973) 596-5825
irb@njit.edu / farzan@njit.edu

SIGNATURE OF PARTICIPANT

I have read this entire form, or it has been read to me, and I understand it completely. All of my questions regarding this form or this study have been answered to my complete satisfaction. I agree to participate in this research study.

Participant Name ____________________

Signature ____________________

Date ____________________

SIGNATURE OF READER/TRANSLATOR IF THE PARTICIPANT DOES NOT READ ENGLISH WELL (Only needed if English fluency is not an exclusion criteria)

: person who has signed above, ______________________________, does not read English well. I understand English and am fluent in (name of the language) ______________________________, a language the subject understands well. I have translated for the subject the entire content of this form. To the best of my knowledge, the participant understands the content of this form and has had an opportunity to ask questions regarding the consent form and the study, and these questions have been answered to the complete satisfaction of the participant (or his/her parent/legal guardian).

Reader/Translator Name ____________________

Signature ____________________

Date ____________________

(3) IRB Form for Study II (October 2019)

NJIT New Jersey Institute of Technology

Institutional Review Board: HHS FWA 00003246
Notice of Approval
IRB Protocol Number: F378-18

Principal Investigators: Quentin Jones, PhD (Information Systems)

Title: Collaborative Lifelogging for Recreational Sports Communities

Type of Review: FULL [X] EXPEDITED [ ]

Type of Approval: NEW [ ] RENEWAL [X] REVISION [ ]

Approval Date: May 8, 2018, October 24, 2019 Expiration Date: October 23, 2020

1. **ADVERSE EVENTS:** Any adverse event(s) or unexpected event(s) that occur in conjunction with this study must be reported to the IRB Office immediately (973) 596-6053.

2. **RENEWAL:** Approval is valid until the expiration date on the protocol. You are required to apply to the IRB for a renewal prior to your expiration date for as long as the study is active. It is your responsibility to ensure that you submit the renewal in a timely manner.

3. **CONSENT:** All subjects must receive a copy of the consent form as submitted. Copies of signed consent forms must be kept on file with the principal investigator.

4. **SUBJECTS:** Number of subjects approved: 100

5. The investigator(s) did not participate in the review, discussion, or vote of this protocol.

6. **APPROVAL IS GRANTED ON THE CONDITION THAT ANY DEVIATION FROM THE PROTOCOL WILL BE SUBMITTED, IN WRITING, TO THE IRB FOR SEPARATE REVIEW AND APPROVAL.**

Eric Hetherington, PhD, IRB Co-Chair

(4) IRB Form (Recovery Review) for Study III - IV (July 2020)

NJIT
New Jersey Institute of Technology

Date:	7/30/2020
Principal Investigator:	Dr. Quentin Jones
Action:	Recovery Review- Approval
Action Date:	7/30/2020
Protocol Number:	F378-18
Protocol Title:	Collaborative Lifelogging for Recreational Sports Communities

The NJIT Institutional Review Board has reviewed your recovery plan and approved your protocol to restart in-person interactions. These interactions must abide by the plan you outlined in addition to all institutional policies and public health practices. Any on-campus interactions must at all times conform with NJIT's Pandemic Recovery Plan guidance, which can be found at https://www.njit.edu/pandemicrecovery/. In cases where this guidance may limit the number of people on campus, you may need to coordinate with other labs and/or your department chair to ensure these expectations can be met.

*Any modifications to the recruitment materials resulting from changes in precautionary measures must be approved by the IRB.

If you have any questions, please contact the NJIT IRB Committee at irb@njit.edu. Please include your IRB # in all future correspondence. Best of luck with your research!

Sincerely,

James Britt Holbrook
Co-Chair, NJIT Institutional Review Board

New Jersey Institute of Technology:FWA00003246

(5) Consent Form for Study III (July 2020)

NEW JERSEY INSTITUTE OF TECHNOLOGY
323 MARTIN LUTHER KING BLVD.
NEWARK, NJ 07102

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

TITLE OF STUDY: Collaborative Lifelogging for Recreational Sports Communities

I, ____, have been asked to participate in a research study under the direction of Dr. Quentin Jones. Other professional persons who work with them as study staff may assist to act for them.

PURPOSE:

To explore the instantiation of Collaborative Lifelogging, a 4th generation computing system that supports users collaborating on sensor data capture through the formation of on-the-fly self-tracking groups, providing for the capture of multiple perspectives on an individual's activities.

DURATION:
My participation in this study will take two hours.

I have been told that my participation in this research study is important for the success of the research and that the results of this research study are expected to produce the following benefits to society and for me as a subject.

BENEFITS FOR SOCIETY AND THE SUBJECT:
I have been told that the benefits are:

The emergence of a new class of technologies that promote recreational activities communities, potentially bringing positive social, psychological, and health-related impacts to the society.

PROCEDURES:
I have been told that, during the course of this study, the following will occur:

First, I will be video-taped as I engage in recreational activities with other community members in public sites. Then, I will be interviewed about various points of the videotapes covering my engagement in the activities.

PARTICIPANTS:

I will be one of about 100 participants in this study.

EXCLUSIONS:
I will inform the researcher if any of the following apply to me:

Under 18 years old

RISKS/DISCOMFORTS:
I have been told that the study described above may involve the following risks and/or discomforts:

During interviewing practices, community-related moments of my life might be captured.

There also may be risks and discomforts that are not yet known.

I fully recognize that there are risks that I may be exposed to by volunteering in this study which are inherent in participating in any study; I understand that I am not covered by NJIT's insurance policy for any injury or loss I might sustain in the course of participating in the study.

CONFIDENTIALITY:
I understand confidential is not the same as anonymous. Confidential means that my name will not be disclosed if there exists a documented linkage between my identity and my responses as recorded in the research records. Every effort will be made to maintain the confidentiality of my study records. If the findings from the study are published, I will not be identified by name. My identity will remain confidential unless disclosure is required by law.

AUDIOTAPING:
I understand that I will be video and audio taped during the course of this study. Video and audio tapes will be stored for 5 years after the end of this project (10/25/2020). After that time, the recordings will be erased. Recordings will be stored digitally on university-owned computers located in a secure lab in the New Jersey Institute of Technology and will not be made available to anyone except investigators who are involved in this research.

PAYMENT FOR PARTICIPATION:
I have been told that I will receive $20 compensation for my participation in this study.

RIGHT TO REFUSE OR WITHDRAW:
I understand that my participation is voluntary and I may refuse to participate, or may discontinue my participation at any time with no adverse consequence. I also understand that the investigator has the right to withdraw me from the study at any time.

INDIVIDUAL TO CONTACT:

If I have any questions about my treatment or research procedures,
I understand that I should contact the principal investigator at:

Quentin Jones, Principal Investigator
Department of Informatics
New Jersey Institute of Technology
323 Martin Luther King Boulevard
Newark, NJ 07102
(973) 596-5290
quentin.jones@njit.edu

If I have any addition questions about my rights as a research subject, I may contact:

Farzan Nadim, IRB Chair
New Jersey Institute of Technology
323 Martin Luther King Boulevard
Newark, NJ 07102
(973) 596-5825
irb@njit.edu / farzan@njit.edu

SIGNATURE OF PARTICIPANT

I have read this entire form, or it has been read to me, and I understand it completely. All of my questions regarding this form or this study have been answered to my complete satisfaction. I agree to participate in this research study.

Participant Name:

Signature:

Date:

(6) Consent Form for Study IV (July 2020)

Consent to Participate in a Research Study

NEW JERSEY INSTITUTE OF TECHNOLOGY
323 MARTIN LUTHER KING BLVD.
NEWARK, NJ 07102

1. Please enter your full name here:

____

Title of Study: Collaborative Lifelogging for Recreational Sports Communities

I have been asked to participate in a research study under the direction of Dr. Quentin Jones. Other professional persons who work with them as study staff may assist to act for them.

Purpose

To explore the instantiation of Collaborative Lifelogging, a 4th generation computing system that supports users collaborating on sensor data capture through the formation of on-the-fly self-tracking groups, providing for the capture of multiple perspectives on an individual's activities.

Duration

My participation in this study will last for an hour.

I have been told that my participation in this research study is important for the success of the research and that the results of this research study are expected to produce the following benefits to society and for me as a subject.

Benefits for Society and the Subject

I have been told that the benefits are:

The emergence of a new class of technologies that promote recreational activities communities, potentially bringing positive social, psychological, and health-related impacts to the society.

Procedures

I have been told that, during the course of this study, the following will occur:

First, I will be viewing the design mockups of new and existing technologies. Then, I will be interviewed about my thoughts on the mockups.

Participants
I will be one of about 100 participants in this study

Exclusions
I will inform the researcher if any of the following apply to me:

Under 18 years old

Risks/Discomforts
I have been told that the study described above may involve the following risks and/or discomforts:

There also may be risks and discomforts that are not yet known.

I fully recognize that there are risks that I may be exposed to by volunteering in this study which are inherent in participating in any study; I understand that I am not covered by NJIT's insurance policy for any injury or loss I might sustain in the course of participating in the study.

Confidentiality
I understand confidential is not the same as anonymous. Confidential means that my name will not be disclosed if there exists a documented linkage between my identity and my responses as recorded in the research records. Every effort will be made to maintain the confidentiality of my study records. If the findings from the study are published, I will not be identified by name. My identity will remain confidential unless disclosure is required by law.

Videotaping/Audiotaping
I understand that I will be video and audio taped during the course of this study. Video and audio tapes will be stored for 5 years after the end of this project (5/31/2021). After that time, the recordings will be erased. Recordings will be stored digitally on university-owned computers located in a secure lab in the New Jersey Institute of Technology and will not be made available to anyone except investigators who are involved in this research.

Payment for Participation
I have been told that I will receive $20 compensation for my participation in this study.

Right to Refuse or Withdraw
I understand that my participation is voluntary and I may refuse to participate, or may discontinue my participation at any time with no adverse consequence. I also understand that the investigator has the right to withdraw me from the study at any time.

Individual to Contact

Quentin Jones, Principal Investigator
Department of Informatics
New Jersey Institute of Technology
323 Martin Luther King Boulevard
Newark, NJ 07102
(973) 596-5290
quentin.jones@njit.edu

If I have any additional questions about my rights as a research subject, I may contact:

Horacio G. Rotstein, PhD
IRB Chair
New Jersey Institute of Technology
323 Martin Luther King Boulevard
Newark, NJ 07102
(973) 596-8460
irb@njit.edu /horacio@njit.edu (email is preferred)

Signature of Participant

I have read this entire form, or it has been read to me, and I understand it completely. All of my questions regarding this form or this study have been answered to my complete satisfaction. I agree to participate in this research study.

2. Please sign by typing your full name below:

____

3. Date

____

APPENDIX B

SEMI-STRUCTURED INTERVIEW GUIDE

This is the semi-structured interview guide used in Study I, the Qualitative Study of Individuals' Engagement with Communities, Types of Feedback Desired, and Tech use for Procedural Learning.

Subject's Name: _______________ Interviewer: _____________________ Date: ___________

Semi-Structure Interview Guide

Step 1: Get to know a little bit about your subject.

1. Demographics:
   - Age ___________ Gender Male / Female / Non-Binary
   - Level of education ____
   - Occupation/degree ____
   - Location ____
2. What does your typical weekday look like? How about weekends?
3. When do you first use the Internet on a typical day?
4. What are some of the apps and websites you use the most?
5. How often do you capture moments of your daily life?
6. What technologies do you use to capture these moments?

Step 2: Engagement in Community Activities

1. When was the last time you participated in a dance activity?
   1.1. What was the activity?
2. Was there anything that you needed to prepare before the activity? Please give examples.
3. Was there anything that you needed to do after the activity? Please give examples.
4. How did the performance/practice go?
5. What were the most significant parts of the activity?
6. How did you and your team decide on choreography (positions and techniques)?
   6.1. What information did you need to decide on positions and techniques?

Step 3: Perceived Benefits of Community Engagement

<u>Conjecture:</u> *Members engage with their communities to improve their physical fitness, psychological well-being, and competitive performance.*

1. How did you find out about the community?
2. What was your motivation to join the community?
3. Who are the members of the community?
4. How long have you been part of this community?

5. How do you interact with other members of the community?
   5.1. What memories do you have with them? Please provide a few examples.
6. How do you interact with your opponents?
7. How do you interact with your teammates?

Step 4: Intrinsic Feedback

Conjecture: Members rely on their intrinsic feedback, including their feel of the movements, perceived team cohesion, mental perception of performance, for procedural learning.

1. How did you evaluate the performance? What factors did you look at?
2. How did you track the progress of your teammates? (before/after)
   2.1. What information did you need to track their progress?

Step 5: Extrinsic Feedback

Conjecture: Members seek extrinsic feedback from other members to support their procedural learning.

1. In which situations do you receive feedback?
   1.1. From who do you receive feedback?
   1.2. What types of information do you receive from them?
2. In which situations do you give feedback?
   2.1. To whom do you give feedback?
   2.2. What types of information do you share with them?

Step 6: Use of Technologies

Conjecture: Members attempt to obtain extrinsic feedback through use of existing sensing and lifelog technologies. In some communities, members have developed specific processes around the use of these technologies.

Conjecture: Members attempt to obtain extrinsic feedback through use of existing sensing and lifelog technologies.

Conjecture: Existing sensing and lifelog technologies provide basic physiological and movement metrics, which do not fully support procedural learning.

Conjecture: Community members desire quantified activity-specific metrics and video-snippets of their teachable moments as extrinsic feedback for procedural learning.

1. Did you use any technologies during this activity?

1.1. What did you use?

1.2. What challenges did you face when using these technologies?

2. Did other members use any technologies during the activity? What did they use?
3. How do you individually record your performances and trainings?
4. Do you use any self-tracking technologies? If yes, what are those?
5. Do you use any lifelogging technologies? If yes, what are those? How do you use them?
6. How does your team record community activities?
7. Do members use self-tracking technologies? If yes, what are those?
8. Do members use any lifelogging technologies? If yes, what are those? How do they use them?
9. What tools and technologies do you use for exchanging feedback?

Summary

Reconfirm Perceived Benefits of Community Engagement:

- How has your participation in community activities impacted your life?

Reconfirm Challenges for Tech Use:

- What challenges have you faced in using existing technologies for learning?

Subject's Name: _______________ Interviewer: _____________________ Date: ___________

APPENDIX C

QUALITATIVE DIARIES INTERVIEW GUIDE

This is the interview guide used for the qualitative diaries in Study I, the Qualitative Study of Individuals' Engagement with Communities, Types of Feedback Desired, and Tech use for Procedural Learning.

Subject's Name: _______ Interviewer: ________ Interview Date: _______ Diary Dates: _______

Qualitative Diaries Interview Guide

Step 1: Brief summary of participation in the study.

1. Can you please give me a summary of the two weeks that you participated in our study?
2. What community activities did you participate in during these two weeks?
   2.1. Did you do any performances/tournaments during this period? How did they go?
   2.2. Did you do any practices/trainings during this period? How did you do that?
   2.3. Did you attend social gatherings with other members during this period? With whom? How did they go?
3. How was your experience with filling out our diary forms over the two weeks?

Step 2: Loop through diary entries.

Conjecture: *Participation in community activities creates opportunities for interpersonal interactions and forming social ties among community members.*

Conjecture: *Members engage with their communities for social benefits, including obtaining senses of companionship and community.*

1. Please describe this activity that you have written down on the diary form.
2. How did you feel when you participated in this activity?
3. How often do you participate in such an activity?
4. Who were the people involved in the activity?
   4.1. How is your relationship with them?
   4.2. How long have you known them?
   4.3. How do you interact with them? How often?
   4.4. Do you have any goals in common with them?
   4.5. How do you feel about them?
   4.6. How experienced are they? Is everyone equally experienced?
   4.7. Did this activity impact your perception of them? If yes, how?
   4.8. Did this activity bring you closer with them? If yes, how?
5. You have mentioned on the form that you found this (part of) activity significant. Can you please explain why?
   5.1. How was the intensity of that performance / match / practice / training?
   5.2. Was (this part of) the activity challenging to you? Why?

6. You have mentioned on the form that you would like feedback on (his part of) the activity. Can you please explain why?
   6.1. What information exactly would you like to receive as feedback?
   6.2. From whom would you like to receive feedback?
   6.3. How would you use such feedback? Please give examples from the past.
7. You have listed this moment as a moment that you found **important to your community.** Can you please explain why?

Summary

Reconfirm Perceived Benefits of Community Engagement:

- How has your participation in community activities impacted your life?

APPENDIX D

COLLABORATIVE VIDEO VIEWING SESSION GUIDE

This is the guide used for the collaborative video viewing sessions in Study III, the Contextual Inquiry of Teachable Moments.

Collaborative Video Review Session Guide

Step 1: Get to know a little bit about your subject.

1. Demographics:
   - Age __________ Gender Male / Female / Non-Binary
   - Level of education
     ____
   - Occupation/degree
     ____
   - Years playing beach volleyball
     ____
   - Beach volleyball activities
     ____
2. How did your beach volleyball journey start?
3. How often did you play beach volleyball before the pandemic? How often do you play now?
4. How has your participation in beach volleyball activities with others impacted your life?
5. With whom do you play beach volleyball?
   5.1. How often do you play with them?
   5.2. What activities do you do with them?
   5.3. What is your connection with them?
6. Are there skills that you would like to learn/improve individually?
   6.1. What are those?
   6.2. How would/have you do/done that?
7. Are there skills that you would like to learn/improve with each other / your teammate?
   7.1. What are those?
   7.2. How would/have you do/done that?

Step 2: Moments recall.

1. Do you remember the dates on which you participated in our video recording activity? How long ago was it?

2. We have recorded videos from (both of) you on: (MM/DD/YYYY). What do you remember from your matches on those days?
3. What moments do you think you identified with the clickers on those days?
4. Do you remember moments that you wanted to identify with clickers but did not manage to do so? What were those moments? What happened?
5. How were your interactions with the clickers throughout the activity? What did you like or dislike about them?

Step 3: Loop through moments in the highlight reel.

Conjecture: *Key moments are when BV players: (a) collaboratively reach their desired game outcomes with their teammate, (b) show exceptional physical or psychological preparedness, or (c) experience disagreements with their teammate or opponents.*

Conjecture: *Key-to-learning moments are when BV players: (a) reach their motor skill acquisition or tactical development goals, or (b) they collaboratively reach their desired tactical outcomes with their teammate through effective planning, teamwork, and interpersonal coordination.*

Conjecture: *Teachable moments are when BV players: (a) incorrectly use their motor skills, (b) ineffectively choose or implement tactics, (c) observe that their teammate incorrectly uses their motor skills, (d) experience communication issues with their teammate.*

1. Why did you identify this moment using the clickers?
    - 1.1. What did you think/feel about it when it happened?
    - 1.2. What aspects of it were important to you?
    - 1.3. How often does such a moment happen?
2. Did a disagreement occur in this moment?
    - 2.1. What was it about?
    - 2.2. Who was involved?
    - 2.3. Did the people involved discuss it? How did they do it?
    - 2.4. Was it resolved? How?
3. What outcome(s) did you desire in this moment? What outcome(s) did you achieve?
    - 3.1. How did you achieve this outcome?
    - 3.2. How did you work with each other/your teammate to achieve this outcome?
    - 3.3. How did you feel when you achieved this outcome? What aspects of your individual / team / teammate performance work?
    - 3.4. What stopped you from achieving the outcome you desired? What aspects of your individual / team / teammate performance did not work?

4. What aspects of each individual / team / teammate performance stood out to you? What aspects needed improvement?
    4.1. How about physical/psychological preparedness?
    4.2. How about skills?
    4.3. How about tactics?
    4.4. How about communication with each other / your teammate?
5. How was your individual performance compared to:
    5.1. Each other/your teammate?
    5.2. Your opponents?
6. How was your team performance compared to your opponents?
7. How did your individual / team performance impact your competition with the opponents?
8. Now that a video replay of this moment is provided to you:
    8.1. How did viewing this video clip affect your perception of this moment?
    8.2. What are you learning from the video clip of this moment?
    8.3. What aspects of your individual / team / teammate performance are you observing?
    8.4. What aspects of the match are you observing? How did they impact your individual / team / teammate performance?
    8.5. Does viewing the video clip help you improve the individual / team performance? If yes, how does it help?
    8.6. Would you use this video clip with each other / your teammate for feedback exchange? If yes, how would you do that?
    8.7. What do you think of the direction of your individual / team / teammate performance after watching the video clip? What do you plan to do next?

Step 4: Loop through moments highlighted by the moderator.

1. What happened in this moment that we have identified?
2. Are there aspects of this moment that were important to you? If yes, what are they?
3. What did you think/feel about this moment when it happened?
4. Why didn’t you identify this moment with the clickers?
5. What outcome(s) did you desire in this moment? What outcome(s) did you achieve?
    5.1. How did you achieve this outcome?
    5.2. How did you work with each other/your teammate to achieve this outcome?

5.3. How did you feel when you achieved this outcome? What aspects of your individual / team / teammate performance work?

5.4. What stopped you from achieving the outcome you desired? What aspects of your individual / team / teammate performance did not work?

6. What aspects of each individual / team / teammate performance stood out to you? What aspects needed improvement?

   6.1. How about physical/psychological preparedness?

   6.2. How about skills?

   6.3. How about tactics?

   6.4. How about communication with each other / your teammate?

7. How was your individual performance compared to:

   7.1. Each other/your teammate?

   7.2. Your opponents?

8. How was your team performance compared to your opponents?

9. How did your individual / team performance impact your competition with the opponents?

10. Now that a video replay of this moment is provided to you:

    10.1. How did viewing this video clip affect your perception of this moment?

    10.2. What are you learning from the video clip of this moment?

    10.3. What aspects of your individual / team / teammate performance are you observing?

    10.4. What aspects of the match are you observing? How did they impact your individual / team / teammate performance?

    10.5. Does viewing the video clip help you improve the individual / team performance? If yes, how does it help?

    10.6. Would you use this video clip with each other / your teammate for feedback exchange? If yes, how would you do that?

    10.7. What do you think of the direction of your individual / team / teammate performance after watching the video clip? What do you plan to do next?

Step 5: Moment categorization.

1. Among all the video clips that you viewed, which one helped you most with learning? Why?

2. What similarities or differences did you see between the moments that you viewed?

3. Which moments would you group together? Please think aloud as you do that.

4. Which group of moments are of the highest importance to you? Why?

Step 6: Video capturing and viewing preferences (informing CLL user interface design).

Conjecture: *When viewing teachable moments, BV players prefer: (a) videos augmented with visualization for analyzing motor skills, (b) videos augmented with telestration for analyzing tactics, (c) video perspectives directed at their skills and tactics of interest, and (d) videos in slow-motion for analyzing complex movements.*

1. Please describe how these visualizations affect your perception of your individual / team / teammate performance in the moments discussed earlier.
   1.1. What aspects of the visualizations are you observing?
2. What additional types of visualizations would you desire to observe your individual / team / teammate performance in these moments?
3. Between viewing video clips of the moments in the original format and the visualized format, which one do you prefer? In what situations would you prefer each format? Why?
4. How does viewing the moments in slow-motion affect your perception of your individual / team / teammate performance in the moments discussed earlier.
   4.1. What aspects are you observing?
5. Please let me know your thoughts on each angle.
   5.1. How did each view affect your perception of your individual / team / teammate performance?
   5.2. If multiple angles are provided, as in the examples, which one would you prefer? Why?
6. Please let me know your thoughts on each layout.
   6.1. How did each layout affect your perception of your individual / team / teammate performance?
   6.2. If multiple layouts are provided, as in the examples, which one would you prefer? Why?

Step 7: Full video viewing.

Conjecture: *When viewing full videos, BV players seek instances in which: (a) they correctly use their motor skills, (b) they make frequent motor skill or tactical mistakes, (c) game events affect their motor skills, (e) their observed performance or preparedness is different from what they perceived, or (e) they do not stick to their fundamentals/form throughout matches.*

1. What did you think/feel about this part of the match when it happened?
2. Why didn't you highlight this part of the match with the clickers?

3. What aspects of your individual / team / teammate performance stood out to you? What aspects needed improvement?
4. If performance improvement was needed:
   4.1. How often does that happen?
   4.2. How did you address it (with each other/with your teammate)?
5. What key events in the match stood out to you? Why?
   5.1. How did they impact your individual / team / teammate performance?
6. What outcomes did you desire in this part of the match? What outcomes did you achieve?
   6.1. How did you achieve this outcome?
   6.2. How did you feel after you achieved this outcome?
   6.3. What stopped you from achieving this outcome?
7. Now that a video of this part of the match is provided to you:
   7.1. What aspects of the video are you observing? What aspects of it are significant to you?
   7.2. How did viewing the video affect your perception of your individual / team / teammate performance?
   7.3. How did viewing the video affect your perception of (a) the key events of the match and (b) their impacts on your individual / team / teammate performance?
   7.4. How do you observe your form throughout the video? How do you observe it in relation to your teammate / opponents?
   7.5. What are you learning from viewing the video?
   7.6. How would you use this video (with each other/with your teammate)?

Summary

Reconfirm Key / Key-To-Learning / Teachable Moments Characteristics:

- What types of moments do you desire to capture and view through this setup?

Reconfirm Value of Capturing and Viewing Such Moment:

- How does capturing and viewing such moments through this setup affect your individual or team performance?

APPENDIX E

COMPARATIVE EVAUATION SESSION GUIDE

This is the guide used for the comparative evaluation sessions in Study IV, the Comparative Evaluation of Collaborative Lifelogging Solutions and Quantified-Self systems.

Subject's Name: _______________ Moderator: _____________________ Date: ___________

Comparative Evaluation Session Guide

Step 1: Get to know a little bit about your subject.

1. Demographics:
   - Age ___________
   - Occupation ____________________________________
   - Years playing beach volleyball ____________________
   - Beach volleyball activities ________________________

2. How did your beach volleyball journey start?
   2.1. Did you play beach volleyball in college?
3. How often did you play beach volleyball before the pandemic? How often do you play now?
4. What is your Men's / Women's beach volleyball level?
   - Social: playing in B or BB levels routinely and in A level occasionally
   - Competitive: playing in A level routinely and in AA level occasionally
   - Advanced-Competitive: playing in AA and Open levels routinely
5. What was the most recent competitive event in which you participated?
   5.1. In what level did you participate?
   5.2. What was the outcome?
8. How has your participation in beach volleyball activities with others impacted your life?
9. With whom do you play beach volleyball?
   9.1. How often do you play with them?
   9.2. What activities do you do with them?
   9.3. What is your connection with them?
10. Are there skills that you would like to learn/improve individually?
    10.1. What are those skills?
    10.2. How would/have you do/done that?
11. Are there skills that you would like to learn/improve with each other / your teammate?
    11.1. What are those skills?

11.2. How would/have you do/done that?

Step 2: Brief introduction of prototypes for Quantified-Self systems and Collaborative Lifelogging solutions

1. We will explore two types of prototypes in this session. Our aim is to (a) compare them, and (b) understand how they could complement one another.

2. Are you clear about the differences between the prototypes?

3. Do you have any questions about the prototypes?

Step 3: Loop through scenario-based video prototypes for Quantified-Self systems.

<u>Conjecture:</u> *Quantified movement metrics are of value to advanced-competitive players when: (a) their goal is to assess their individual or their teammate's physical preparedness, (b) their goal is to combine such metrics to examine their individual or team performance during teachable moments, (c) such metrics cover specific aspects of their individual performance with which they are unfamiliar, or (d) they have routinely used such metrics in their training.*

<u>Conjecture:</u> *Quantified movements metrics are of value to social and competitive players when: (a) their goal is self-motivation, (b) they have access to advanced-competitive players to seek feedback on such metrics, or (c) such metrics are self-explanatory not requiring background knowledge.*

1. Please describe your thoughts about the metrics provided to you.
   1.1. What are the advantages or disadvantages of the metrics?
2. For what purposes will you use the metrics? How will you do that?
   2.1. How about assessing your teammate's performance?
   2.2. How about assessing your individual performance?
   2.3. How will the metrics impact your learning?
   2.4. How about assessing your teammate's performance?
   2.5. How about assessing your team performance?

3. Are there additional metrics that you desire in these prototypes?
   3.1. What are those metrics?
   3.2. How will they impact your performance and learning?
   3.3. For what purposes will you use those metrics?
   3.4. How will you use those metrics?

4. Are there additional metrics that you desire in these prototypes to use with your teammate?
    4.1. What are those metrics?
    4.2. How will they impact your performance and learning?
    4.3. For what purposes will you use those metrics?
    4.4. How will you use those metrics?
5. How will you use the community feed?
6. With whom will you interact using the community feed? What will you interact with them about?

Step 4: Perceived benefits of Quantified-Self Systems.

1. What overall benefits do you see in using these prototypes?
    1.1. In what aspects do you see these benefits?
2. How will using these prototypes affect your connection with your teammate?
3. How will using these prototypes affect your feelings towards the community?
4. How will members using these prototypes affect the community?

Step 5: Loop through Scenario-Based Video Prototypes for Collaborative Lifelogging Solutions

1. Please describe your thoughts about the data in the form of videos that is provided to you.
    1.1. What are the advantages or disadvantages of the videos?
2. For what purposes will you use the video-snippets? How will you do that?
    2.1. How about assessing your individual performance?
    2.2. How will the metrics impact your learning?
    2.3. How about assessing your teammate's performance?
    2.4. How about assessing your team performance?

Step 6: Perceived benefits of CLL Collaborative Procedural Learning Processes

1. How will you use these features for exchanging feedback?
2. In what areas will you provide feedback?
    2.1. To whom?
    2.2. About what?
3. In what areas will you seek feedback?

3.1. From whom?

3.2. About what?

4. How will you use these feedback exchange features with your teammate?
5. How will these feedback exchange features impact your:

5.1. Your individual performance?

5.2. Your learning?

5.3. Your teammate's performance?

5.4. Your team performance?

6. Please describe your thoughts about the collaborative video capturing feature.

6.1. What may stop you from contributing your GoPro?

6.2. What would motivate you to contribute your GoPro?

6.3. How about others? How do you think they would do?

7. How will you use the community feed?

7.1. With whom will you interact using the community feed? What will you interact with them about?

Step 7: Perceived benefits of Collaborative Lifelogging solutions.

Conjecture: *Augmented and contextualized video-snippets of teachable moments through CLL are of value to advanced BV players when: (a) their goal is to have rapid access to their biomechanical data showing the quality of their movements, (b) their goals is to use such data in practices with their existing connections or training groups, or (d) their goal is to find players from their level with whom they can practice.*

Conjecture: *Augmented and contextualized video-snippets of teachable moments through CLL are of value to novice and intermediate BV players when (a) their goal is to use such data to seek feedback on their motor skills from advanced players, or (b) their goal is to use such data to seek feedback on their teamwork and tactics from advanced players.*

Conjecture: *To seek feedback, novice and intermediate BV players: (a) choose to reach out to the entire community for cold introductions, or (b) request feedback from their existing connections familiar with their skill and performance levels.*

1. What overall benefits do you see in using these prototypes?

1.1. In what aspects do you see these benefits?

2. How will using these prototypes affect your connection with your teammate?
3. How will using these prototypes affect your feelings towards the community?
4. If community members use this app in long-term, how will it affect the community?

4.1. Social aspects?

4.2. Performances?

Step 7: Comparative utility of Quantified-Self systems and Collaborative Lifelogging solutions.

<u>Conjecture:</u> *The perceived benefits of CLL solutions outweigh the perceived benefits of QS systems when: (a) advanced BV players want to exchange feedback with their training peers, (b) novice and intermediate BV players want to analyze the quality of their movements and improve their motor skills, or (c) novice and intermediate BV players need feedback on the quality of their movements.*

<u>Conjecture:</u> *The perceived benefits of CLL solutions outweigh the perceived benefits of QS systems in developing and strengthening social ties and supporting senses of community.*

1. How do you compare the overall benefits of each type of the prototypes?
2. In what situations will you use each type of the prototypes?
3. How do you compare the effectiveness of each type of the prototypes in these domains?

   3.1. Supporting learning?

   3.2. Supporting feedback exchange?

   3.3. Assessing and improving your individual or team performance?

<u>Conjecture:</u> *Players desire integrations of CLL solutions and QS systems to (a) obtain the benefits of both technologies for their learning, (b) achieve a deep and multi-layered understanding of their individual and team performance during their teachable moments.*

4. In what ways do you think these two apps need to be combined together?
5. Please provide examples of scenarios or contexts in which you would use a mixture of these apps:

   5.1. Supporting your learning and performing?

   5.2. Supporting feedback exchange?

   5.3. Assessing and improving your teammate performance?

   5.4. Community bonding?

Summary

Reconfirm the compared utility of CLL solutions and QS systems.

Subject's Name: _______________ Moderator: _____________________ Date: ___________

- Please navigate through both prototypes and think aloud as you use the features discussed in the session

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