A User-Centred Design Approach to Ubiquitous Computing and Framing Communication in Football

By

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ABSTRACT

As technology becomes increasingly ubiquitous in everyday life, it is also infiltrating professional sport. From media to software to sensory devices, technology is being used to communicate better, analyze better, and perform better. The communication and athletic performance interactions between coaches and athletes during a football game provide a rich user-centred opportunity for design research. The purpose of this interdisciplinary design research study is explore how technology may help the communication culture of a football game, while using design visualization tools to address the analysis. The research is approached through mixed design research methods including a survey, field observations and interviews. The data is analyzed using a graphical approach to representing the findings. The key insights from this research include apprehending a user need by identifying the problem space of communication errors during a football game, a user want by acknowledging motivation and acceptance of emerging technology, and investigating the potential design direction for wearable technology to enhance performance in football. This opportunity is addressed through the usability heuristics of reducing cognitive load, being aesthetically satisfying, and being easy to use for the transfer of vital information being communicated between coaches and athletes during a football game.

Keywords: User-Centred Design Research, Sport Performance, Ubiquitous Computing, Tracking, Sport Communication, Sensory Design Research

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GLOSSARY

Acceptance: in relation to the Technology Acceptance Model (TAM) where the user perceives the ease of use and usefulness of new technology (Chuttur, 2009).

Autonomy: Used in relation to kinetic movement, autonomy defines the active performance outcome of receiving a signal within a specific context.

Biosignals: Human physiological outputs that can be detected by external sensors and technology.

Communication: sensory signals used to convey information between users as well as between technology and users.

Contextual inquiry: An approach to user-centred design research that looks beyond the user to the surrounding system (Beyer & Holzblatt, 1998).

Heuristics: Key words that define features and functions of a service, interface or device that help identify problems in relation to user experience

Framework: A conceptual structure used to develop insights through visualization tools.

Multi-Modal: Using two or more senses in relation to either information processing or sport performance.

Performance: The outcome of information processing in the form of action based on learned culture, skills, and practice.

Problem Space: Problem Space refers to the entire range of components that exist in the process of finding a solution to a problem.

Proprioception: awareness of your own body's movements relating to balance and spatial orientation, based on external stimulus received through human senses.

Sensory Modalities: The various types of human senses used to perceive, process, and relay information. These include sight, sound, touch, and kinetics.

Semiotics: The study of signs, signals, and signification (meaning).

Sensemaking: The synthesis of data which combines design visualization to apprehend data, ideas, thoughts and reflections through tangible forms (p.16).

Somatosensory: The internal sensations (nervous system) relating to a stimulus through the external sense organs.

Sport Performance: The ability to execute, in a game situation, kinetic behaviours based on learned culture, practiced skills, and developed conditioning.

Touchpoint: A point of contact between the user (or person being observed/investigated) and the environment, product, or service with which they are interacting.

Translation: Relating to information, translation involves the process of receiving a sensory output, generating an understanding and relaying that understanding through a modified output.

Ubiquitous computing (ubicomp): Ubiquitous computing refers to the practice of embedding information processing and network communication into everyday, human environments to continuously provide services, information, and communication (Kuniavsky 2010)

User: someone who is using, or has the potential to use ubiquitous computing within the context of the study.

Wearables: Technology devices that are worn on the body, largely as a means to detect and process biosignals into actionable data.

Quantified Self: an advanced user community of people who have begun to explore and experiment with novel uses for personal data" (Watson, 2013)

1.0 INTRODUCTION

1.1 Rationale

The relationship between design and the fitness industry is not immediately obvious. Where design implies creative processes, and tangible outcomes like objects and services, fitness engages with scientific processes of human mechanics, anatomy, and nutrition. That is not to say one cannot benefit from the other. In fact, with the rising use of technology, in particular mobile devices, modern business ventures turn to design as a strategy for recognizing user identity, lifestyle, and values (Koskinen, 2012). The foundational principle of this study is that interdisciplinary design research methods may facilitate the creation of better technology, thereby improving human interactions in the context of athletic performance. The study began by investigating the landscape of ubiquitous computer and wearable technology, with the hypothesis that athletic performance would be the gap in ubicomp. Within athletic performance, the topic of communication was found to be the problem space, and the most essential user need. The topic of communication was addressed through the case study of a football game by breaking down its many facets, drawing out elements relative to design through a qualitative research exploration.

1.2 Scope of Research

1.2.1 Background

Research is never a linear process. One finding leads to a discovery that can steer a study in various directions. This study began with the subject of fitness tracking

technology. As this concept was explored, subjects such as the Quantified Self, fitness tracking, and performance analysis were uncovered, each with different prospective research questions and purposes. There are many tracking devices available from wrist bands like Fitbit, to Apple's smart watch, which use similar technology to produce actionable data. However, a fundamental recurring question pertained to the acceptance of technology from a sensory perspective, and understanding how users felt about the integration of technology in their lives. In addition, literature showed a gap in users: professional and competitive athletes who are not well-served by current digital applications. In the realm of professional sport, Research in this study starts with an inquiry of a broad use landscape, then focuses specifically on the contextual needs of football athletes and coaches.

1.2.2 Research Trajectory

The research process follows a cyclical process (figure 1). The focus, athletic performance, relies on user-centred human factors principles in relation to the proliferation of ubiquitous computing. Wearable technology and fitness tracking experiences tie these factors together. Wearables and other relevant computing devices are explored through functional and contextual analysis where human senses can be associated to user needs. This research trajectory sets the parameters of the content presented in the literature review, and sets the foundation for exploration in subsequent phases of research.

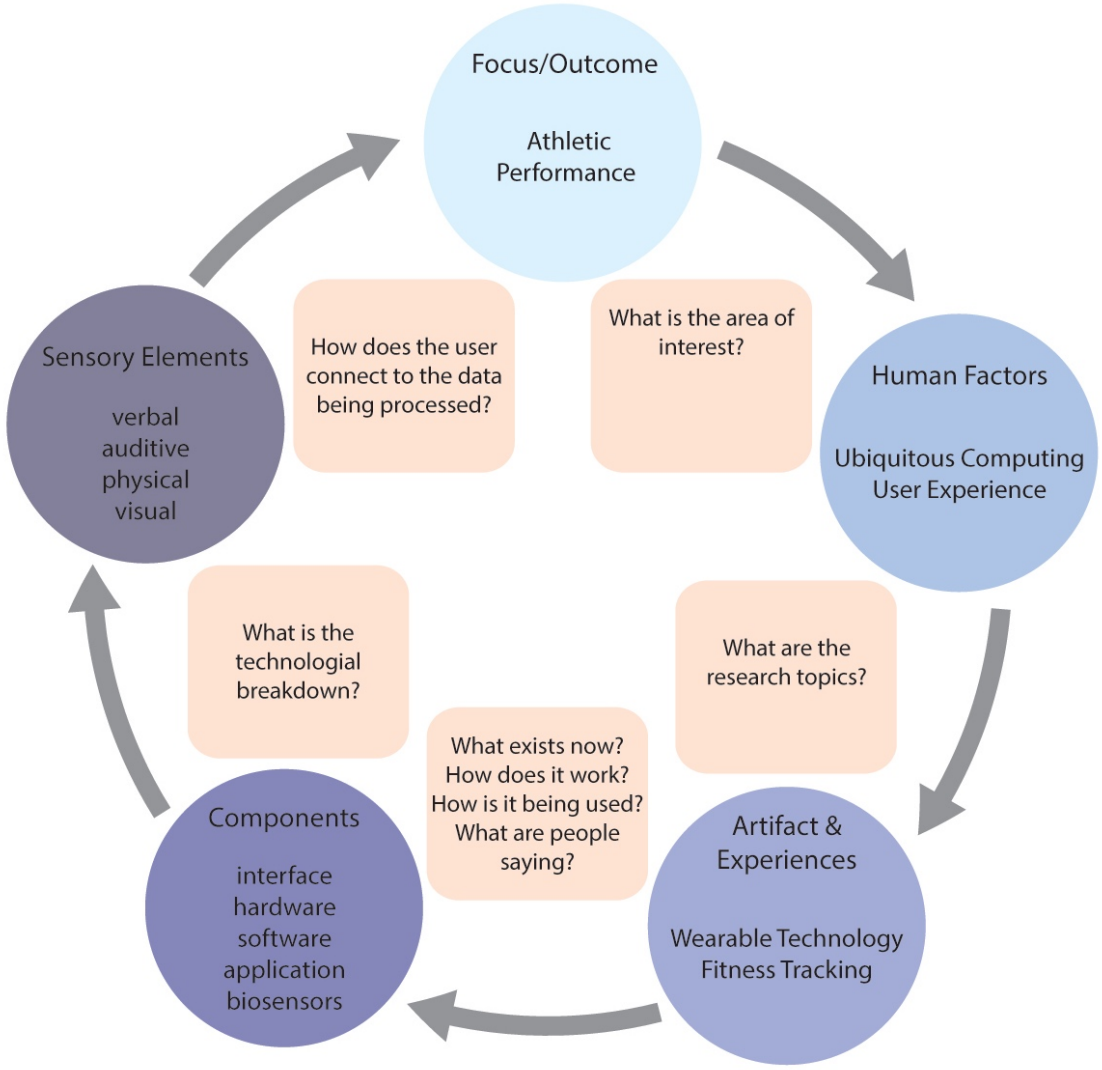

Figure 1 Research Trajectory

Area of Interest

The general area of interest for the study was athletic performance, chosen for its dynamic and therefore challenging relationship among human, environment, and behavioural outcomes. A secondary area of interest relating to athletic performance was the concept of ubiquitous computing, which has proliferated in multiple facets of human life as a tool to guide physiological outputs (Watson, 2013; Wolf, 2010).

Research topics

The relationship between the primary area of interest, athletic performance, and the secondary area interest, ubiquitous computing, set parameters containing key topics. These include human factors such as cognition and aspects of sports performance psychology, as well as interaction and communication methods through the senses. Addressing the second area of interest, the same human factors can be understood through the lens of user-centred design research, which includes key topics such as human-product interaction and user experience design heuristics.

Artifacts & Users

Wearable technology and fitness tracking devices set the landscape for the study based on their growing popularity and ubiquity (Fox and Duggan, 2013; Herz, 2014). User-centred design creates a relationship between personal data tracking and ubiquitous computing where biosignals created by the body are used by different people for different purposes including medical, security, general wellness, and competitive/professional sport (Beecham Research Limited, 2013).

Components

The human-product interaction between people and wearable devices involves hardware such as wireless sensors like accelerometers and GPS and software applications. The development of effective algorithms is the process by which the biosignal data is used and conveyed to the user (IDTechEX, 2015). As the hardware of wearable devices becomes less obtrusive (smaller and lighter) and therefore more user friendly, the availability of the internet has increased the accessibility of software

applications with which to interact with the data (Wolf, 2010).

Sensory Elements

Interactions between humans and computers involve senses on both ends. The devices use sensors to cultivate the data, generally through electronic signals (Cmiel, Janousek, & Kolarova, 2011), and the user relies on senses to apprehend the processed data (Desmet & Hekert, 2007). Depending on the context of use, the user prefers or is limited to certain senses, which dictates the sensory modality best suited to output information. Following the contextual establishment of ubiquitous computing and athletic performance, the research turned to team sport performance where, in a pilot observation, it was observed that communication was integral to performance in a non-athletic but strategic way. Further questions evolved by focusing on the theme of communication in football through additional observations and interviews, which created a qualitative environment within which to find design opportunities.

1.2.3 Football Context

This section highlights the fundamental aspects of football. For a more detailed description, see Appendix 1 or visit the official NFL website to review the NFL's official rulebook (NFL Beginner's Guide to Football, n.d.), both of which provide the game's descriptions and rules. Football is a team sport that requires strategy, teamwork, and communication between coaches and athletes. These processes are cognitively demanding, dependent on memory and information processing. Bragg (2010) provides an overview of the communication between coaches and teammates, both on and off the

field:

> From coaches calling plays…, to players making adjustments…Many times hand signals and a series of signs are used to indicate what a player is supposed to do on the field.…making sure that every player has memorized every possible signal, and ensuring that the signals are complicated and varied enough…, are extremely important aspects to effectively communicate during sports. (On Field; Non-Verbal sections)

Plays are determined based on current situations on the field such as ball position, possession, and score. Players have specific roles dependent upon each play call and plays are pre-planned and practiced during training. There are eight different offensive player positions and five defensive player positions (Long & Czarnecki, 2011). Plays are strategically decided during games, but they can also be changed seconds before the play begins depending on the opposing team's perceived course of action. The success of each play is therefore dependent upon all eleven players on the field executing their individual responsibility. Furthermore, it is imperative that players have a thorough understanding of all the possible plays that could be called, while also being aware and capable of making their own judgment calls based on reading the opposition's actions.

The main goal of football is to be the team to finish the game with the most points. Teams run offensive (point-earning) and defensive (point-preventing) plays during the 60 minutes of active game time (divided into four quarters) when they are, or are not, in possession of the football, respectively. The ball can switch possession in various ways, where the goal of the defence is to stop the offence from gaining distance (measured in yards) and potentially intercept and turn over the ball to their offence. Alternatively, the goal of the offence is to move the ball forward by passing the ball (normally thrown by the quarterback), running, or catching the ball at the opposite end of

the field, the end zone. The amount of points earned can be 1, 2, 3, or 7 and is dependent on the way in which the ball passes into the end zone (NFL Beginner's Guide to Football, n.d.). This adds an additional layer of strategy to the game where the point spread contributes to determining the play call. Notably, the Canadian Football League (CFL) follows slightly different guidelines; however, the dynamics, player positions, and communication methods remain the same. Due to the availability of information, explorations of literature in this study pertain mostly to NFL situations, whereas the methods of the study are conducted at a Canadian university, under CFL rules and regulations.

1.3 Research Questions

This study surveys the problem space of communication in football using design tools in order to understand the context for the specific athletic performance requirements and communication systems. The primary and secondary areas of interest, athletic performance and ubiquitous computing were approached through the literature review, which derived questions relating to contextual inquiry. The initial interest in fitness tracking saw a gap for multi-modal, dynamic sports. This lead to a second layer of focus: how can design research methods be used in the context of sports? Specifically, a sub-question addressed the sport of football: what are possible problem areas in football that design of technology might address? This question consolidates the phases of research that connect the areas of interest and their related topics, artifacts, and users. Furthermore, this question touches on relationships between sensory elements and

technological components that can be carried into further design opportunities and research.

1.4 Contribution to the field of User-Centred Design Research

By targeting elite athletes and coaches, this study may set a precedent for understanding how to create effective platforms for enhancing these users' experiences and providing a foundation from which future innovation and design may occur. Where user experience design practice pertaining to ubiquitous computing is constantly changing, designing new technologies is a constant challenge given the unique interactions of varying users (Kuniavsky, 2010). Many fields have come together to create the founding principles of user-centred design research (Koskinen, 2011). Additionally, the focused topic of athletic performance draws on the existing fields of sport psychology (Jarvis, 2005) and notions of semiotics (Craib, 2013) which contribute to contextual inquiry and design (Beyer & Holtzblatt, 1997). This study is, therefore, inherently interdisciplinary.

The intention of this study is to explore the challenging but high-potential context that joins sport performance and wearable technology. Schifferstein & Hekkert (2008) state that designer focus is on how "technological novelty can affect people. By envisioning how new technologies could take shape in the form of artifacts, systems and environments, designers mediate technological possibilities with what future practitioners identify as useful, useable, and understandable" (p. 27). This statement is reflected in this study's consideration of how, within the specific context of football, user-centred research could effectively bring ubiquitous computing to an under-served user group.

1.5 Thesis Structure

1.5.1 Overview

Chapter One introduces the opportunity to study how ubiquitous computing can improve sport performance. It begins by noting that individuals are already applying ubiquitous computing systems to monitor and improve sport performance. It then goes on to explain that teams of players can also benefit from ubiquitous computing systems to improve their overall game performance. It narrows down to the focal point of this study, improving on-field communications during football games. It provides a concise description of the game, roles, and responsibilities of the players on the field. The literature review in Chapter Two defines the context of existing research relevant to this study, leading to the research questions. The thesis then explains and describes the methods for gathering data pertaining to the research focus in Chapter Three and presents the findings from the data in Chapter Four. The results of aggregating, analyzing, and synthesizing the data are addressed in Chapter Five and a final discussion on the apparent truth that came from triangulating the literature review, methods, and findings is presented in Chapter Six, followed by concluding remarks in Chapter Seven.

1.5.2 Literature Review

The literature review explores the multiple facets of the study's research, seeking to find gaps and connections between the subject matter. First, sport performance is explored from a communication perspective, where information processing, learning, and semiotics are discussed. Second, user-centred design is explained by reviewing some of its prominent sub-disciplines, namely contextual design, user experience design, and

sensory and product experience design. The third section of the literature review that explores the subject of ubiquitous computing and the realm of wearable technology and wireless sensors. Applications in personal data tracking, fitness tracking, and the quantified self movement are contextualized as a founding setting for the thesis subject exploring user-centred design issues of communication in the sport of football. Due to the focused sport topic, applications and cases exhibited in the literature review pertain largely to football. This chapter ends with the relevant interdisciplinary design research questions that emerge from this literature review.

1.5.3 Methods

The user-centred, qualitative nature of the study pertains to the football game environment, where patterns and trends in behaviour were observed. A mainly qualitative approach to gathering data was used due to the unpredictable sequence of game dynamics: the amount of offensive and defensive plays is different from one game to another. Each section is addressed by presenting the setting, participants, data collection, and data analysis methods.

1.5.4 Results

The methods used in this study generated raw data in the form of survey responses, field observations (notes, video and images), and personal interview quotes. The results are presented using design and analysis tools such as charts, affinity diagrams, plans, and image sequences to aggregate the raw data. In addition, quotations

and snap shot images extracted from video footage are used to reinforce the statements presented.

Survey results express a general yet quantifiable value pertaining to behavior and interactions surrounding personal data tracking. For example, participants addressed how they record and retrieve their performance data, and their feelings towards using fitness tracking devices. Where most questions were answered using a multiple choice Likert scale, qualitative data was also gathered where the participants were invited to expand on their multiple choice selection, providing deeper context and key words used in the following phases of research.

Some processing was required in order to present the results of the field observations. Where two football games were recorded on video, snap shots were extracted and presented in charts and diagrams, evolving from a variety of communication methods, to specifying sending and receiving signals, to grouping sensory modalities used for communicating.

Interview data gathered through recordings and transcription is presented in charts that categorize the raw data in terms of specific quotations, the reference points of quotations, and rough insights to be further developed in the following phase. Prior to concluding the interview process, the themes of information processing, coaching, and team development, and artifact and technology were used to categorize responses. These themes were loosely implied in the interview's question structure, where the primary goal was to determine how athletes and coaches communicate, what tools they use to do so, and what notable problems occur and at which points during a game.

1.5.5 Insights

Following the visualization of results, insights are developed through further analysis and reworking of the previous flow charts, affinity diagrams, and plans. Findings create new knowledge and an understanding of the problem space where communication through sensory input, processing, and output is a key factor. Sequencing the methods' insights frames the key findings concerning user acceptance of technology, gaps in current communication and use of devices, which suggests a design opportunity. The graphical journey presented in the survey highlights the positive mentality, motivation, and needs of the user relating to ubiquitous computing based both on quantifiable statistics and explicit anecdotes gleaned from survey analysis. The following phase drew in environmental parameters such as soundscape and sensory limitations pertaining to the specific context of a football game situation. Senses were categorized and tagged, and this process identified visual and verbal communication as the primary modalities that lead to independent, autonomous action. Based on this information, interview questions addressed sensory modalities relating to communication between coaches and athletes. The final representation of insights is a journey map that contains information drawn from all phases of research. The journey map includes people, artifacts, sensory performance, as well as general distinctions of space and time. These maps lead to a greater understanding of the transfer of information and the way in which signals can be misinterpreted in a dynamic game situation.

1.5.6 Discussion

This chapter discusses the information process as it consolidates semiotics, signal input, translation, and output, in order to win a football game through deliberate, autonomous actions. Graphics presented in the earlier phases of research are revisited and reformatted into four sub-categories where the knowledge gained from the insights is turned into wisdom. First, the key topic of human and computer information processing overlaps with communication for sport performance, which is addressed by the usability heuristics of comfort/aesthetics, ease of use, and reduction of cognitive load. Second, the specific football environment is discussed through sensory analysis, where limitations in hearing, seeing, and acting are established by overlapping soundscape and player and coach activity. This leads into the triangulation of sensory modalities as they relate to learning, practice, and performance through communication within the limiting parameters of the football context. Finally, making sense of the problem space of communication in football triangulates the environment, the actions being performed, and the information being sent between coaches and athletes. A subsequent flow diagram adds time to the sequence of information translation, processing, and execution. The current model is juxtaposed to a proposal that ties ubiquitous computing to the information translation process. Finally, a summative user experience map outlines the entire study's process and ultimate outcome, where recommendations for ubiquitous computing systems are discussed as solutions to the problem space of communication between coaches and athletes during a football game. In addition, the limitations regarding the qualitative nature of the study and the focused case study of the Carleton Varsity Football team are reviewed.

1.5.7 Conclusion

The conclusion revisits the intention of the study, which investigates whether design recommendations could identify ways to improve on the efficiency and effectiveness of communication for sport performance. User-centred design research was used to conduct the contextual inquiry into the specific problem space of communication in football using the Carleton University football team as a case study. The outcomes of the study address two significant contributions to the design field: user-centred design concerns for integrating ubiquitous computing and wearable technology into the existing communication culture of a football team, and contextual inquiry visualization tools for portraying user-centred design issues.

2.0 LITERATURE REVIEW

2.1 Overview

As noted previously, communication is vital to the sport of football. As such, aspects of communication are reviewed from both a sport psychology and cognition perspective. Also, the focus of this review is sport performance, specifically in football. Where basic information regarding learned culture, structure, and communication methods are described, they are focused on football. The review then turns to the literature pertaining to two key areas: user-centred design and ubiquitous computing, which relate to the design research aspect of this study. They are broken down into user-centred design processes and issues through contextual design, user experience design, human senses, and product interactions in design research. Then, ubiquitous computing is explored by reviewing aspects of wearable technology, including a brief history, current applications in everyday life and in the sport performance industry. Following that, an inquiry into the types of technology that are currently being used in football relates the sport to the broader context of ubiquitous computing. Each section of this chapter explores the design aspects related to sport and football, with the intention of outlining areas of concern and gaps in the current research in the field as noted in the literature. These gaps lead to the creation of research questions.

2.2 Communication & Sport Performance

2.2.1 information Processing

Communication normally takes place through a number of simultaneous channels or sensory modes of interaction—gesture, verbal, making faces, and so on. (Anderson, 1996; Bandura, 1977; Brack, n.d.; Chandler 2002). In fact, according to the Association of Applied Sport Psychology, 70 percent of human communication is non-verbal. From a product experience perspective, "a communication simply requires someone who sends some information, and someone who receives and interprets it. Communication can occur through speech and text, but may also include non-verbal communication such as visual and iconic messages, together with sounds and gestures" (Schifferstein & Hekkert, p.185). However, it is easy to misinterpret or miss communications completely, and this can have a disastrous effect on sport performance. The fundamentals of semiotics stipulate users must share attributed meanings of signs in order to communicate effectively (Chandler, 2002; Craib, 2013). While attributing meaning to a sign is one part of the communication, the more dynamic part occurs at the time the signal is executed.

Design research draws on theoretical and philosophical sources from other fields of research such as psychology, sociology, philosophy, and the natural sciences (Koskinen, 2012). Sport psychology has generated several information processing models that seek to articulate the role of communication in sport. Pierce's semiotic triangle (1931-58) represents communication in terms of signs that are sent, interpreted, and unified into an objective meaning. Welford (1968) and Whiting (1969) refer to these signs as sensory input (stimulus) which is perceived or identified, and then translated and acted upon (Jarvis, 2005; Mackenzie, 2006). Anderson's model of memory (1983) uses a

similar structure, but with variations in terminology that emphasize the role of social context. In this way, Anderson borrows from Bandura's Social Learning Theory (1977), which focuses on social context in the information process. Finally, Baca et. al. (2009)

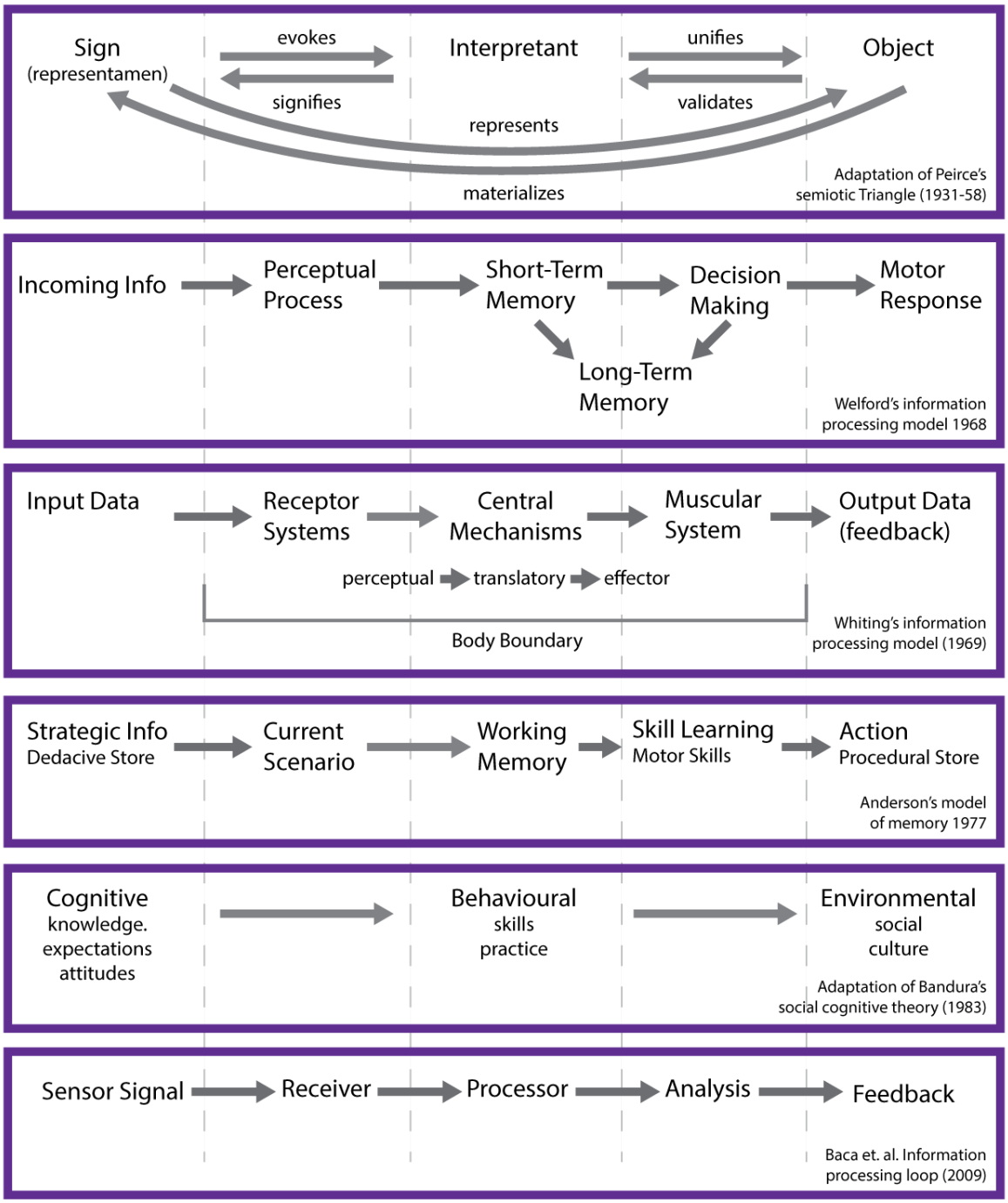

Figure 2 Interpretation of various information processing models
sources: 1. Chandler, 2002 2. Jarvis, 2005 3. Mackenzie, 2006 4. Anderson, 1983 5. Bandura, 1977 6. Baca et. al.

present an information processing loop derived from computer processing that involves a similar set of phases. Figure 2 demonstrates the similarities among this series of models, all of which involve input, processing, and output phases. The deep psychological implications of communication theory are beyond the scope of this study, but the key words used to describe communication processes (information input, processing, and output) are beneficial to a discussion of communication in football.

2.2.2 Context of Sport Performance

For the sake of clarity, the definitions of physical activity, exercise, fitness, and performance are described here. Physical activity involves *any* bodily movement that expends energy, whereas exercise is a planned, structured subcategory of physical activity aimed at improving or maintaining aspects of physical fitness (WHO, 2015). Fitness is the general notion of health and the ability to function efficiently and effectively in daily life. Physical fitness has health related and skill related components, which each have a relative importance based on the particular activity or sport (The Oxford Dictionary of Sport Science & Medicine, 2007). In terms of performance, context specific knowledge, skills, and abilities are adapted and learned over time, then applied during a specific event, such as a sports game (APA Division 47). This study's second area of interest, ubiquitous computing, is related to athletic performance through the same terminology because users interact with wearable devices for fitness tracking in order to enhance performance.

Team sports involve goals of excellence and a high level of human interaction where aspects of performance and psychology play key roles in game outcomes. The

Exercise and Sport Psychology Division (47) of the American Psychological Association defines performance as "the development of context-specific knowledge, skills, and abilities (KSAs) over time and then the recollection and use of these KSAs during a discrete performance event" (ibid. p. 11). Hays (2012) refers to performance psychology as "the mental components of superior performance, in situations and performance domains where excellence is a central element" (p. 25). The notion of sports "culture" includes the context of teams and relationships, referring to a community complete with sensory cues, language, expressions, and behavioural patterns. The culture of team sport is highly reliant on goal setting, where winning is the primary goal (Pinel, 2007). Sub-goals are often more individual, including improving performance (conditioning), executing learned processes, and communicating effectively (ibid.). In the team sport context, therefore, performance is the ability of individuals to work as a team through training and conditioning prior to the game and communicating effectively during the game, in order to maximize winning behaviour.

2.2.3 Hierarchy in Sport Performance

Leadership is part of the team dynamic. In sport, leaders are primarily the captain and the coaches, but other team members may also take on informal roles "in which they influence and inspire others" (Jarvis, 2005, p.104). Athletes are more likely to seek support and advice from people to whom they feel close. It is important, therefore, for coaches to develop effective relationships with their athletes, since these relationships have an impact on athletes' well-being and accomplishments. Emotion, cognition, and behaviour are important for coach-player communication (Jarvis, 2005; Jowett &

Cockerill, 2002; Hays, 2012), and this is amplified in team sports, which involves coordinating not only a group of individuals with independent roles who must work cohesively in order to reach a unified goal (Carron, 1997).

2.2.4 Learning

Research shows that learning through practice enhances performance; this is particularly the case when memory and information retention processes are engaged by sensory experience (LeVan, 2009). User-Centred Design methods have adapted psychology models in order to understand how users interact with systems. At a high level, design considers the integration of sensory, cognitive, and motor functions within the brain. These interactions affect how users perceive, think, and act (Schifferstein, Hekkert 2008). Interaction is best described as a "loop where sensory input is processed by attention and higher cognition, which generates a motor response" (ibid., p.168). Ultimately, the more deeply the information is processed, the better it is remembered. Similarly, the more often an action is practiced, the more easily it can be recalled and put into action. This "motor programme" conditioning is developed at the cognitive stage of learning where skills are built, enabling optimal performance (Knapp, 1963; Jarvis 2005). Motor programme learning can be accomplished with imagery and visualization tools; studies have shown that muscle fibers can be activated and trained by visualizing an action and a situational response (Gregoire, 2014; Jarvis, 2005). For example, during the 2014 Sochi Olympics, many athletes commented on the benefits of meditation and the positive physical impact of imagery, where they repeatedly imagined every sensory detail of their upcoming performance (Dahlkoetter, 2014).

Current research in sport psychology discusses the role of communication in the interplay between understanding and action (Aoyagi, Portenga, et.al., 2012). The key distinction between team and individual sport is the role of communication. Where more people are involved in striving to attain the same goal, their thoughts, behaviours, and actions must be in sync. Indeed, poor communication is often the cause of problems in team situations (Hays, 2009). As noted in Chapter 1, team cohesion is accomplished through both pre-game practice and in-game communication. Although some strategies are planned, situations arise during play that require players to behave spontaneously, relying on learned knowledge.

2.2.5 Codes & Coding

The term 'code' refers to "a set of practices familiar to users of the medium operating within a broad cultural framework" (Craib, 2013, p. 146) A medium (also known as a channel) is the way in a signal is transmitted (i.e., visual, auditory, tactile). In football, signs are used as a method of communication when the context does not allow for verbal cues. As noted earlier, semiotics is the study of meaning-making through signs, which can include words, images, sounds, gestures, and objects (Craib, 2013, p. 1). Semiotics is a qualitative mode of analysis rather than a precise science, given that it is an "approach to communication which focuses on meaning and interpretation" (ibid., p. 216) Principles of semiotics and sensory response are related to multi-modal perception. Thus Malnar (2004) states that "haptic perception is enhanced when combined with visual data" (p.44). Even human interaction with computers, devices, and systems, however, does not occur without some level of sensory response, so the consideration of haptic

perception is critical to any design outcome. “The specific societal context (the sensory ratio of that culture) needs to be addressed if it is to resonate with its users” (Malnar, 2004, p. 55).

During a football game, environmental and sensory factors create limitations in communication (Branch, 2006). Different types of situations allow and restrict the various senses, creating the parameters within which communication operates. The coach-athlete relationship involves decision-making, and this process includes hierarchical roles as well as situational and spatial variables such as time pressure, decision importance, information location, problem complexity, group acceptance, coach's power, group integration (Jarvis, 2005, p.107). These factors affect strategizing and making play calls during a game.

Currently, there are communication systems in place to accommodate contextual communication restrictions, such as the need for distance and secrecy from the opposing team. However, sensory limitations sometimes render these systems ineffective. For example, crowd noise and distance from the coaches prevent the athletes from communicating and receiving communications from the coaches on the sidelines or even their teammates on the field (Branch, 2006). This can cause miscommunication, as well as false starts and penalties (ibid.). Although the NFL is slowly making changes to technology restrictions and regulations, these changes have not kept pace with advances in ubiquitous computing (Harvard ilab, 2014).

As noted, people communicate through gesture, posture, facial expression, and intonation, among other modes. These means of communication are considered analog in nature and may address emotional subtleties such as emotions, drawing on visual images,

gestures, textures, tastes, and smells (Craib, p. 45). In contrast, digital communication emphasizes precision, unattached to emotional signification. While analog methods of communication are ingrained in human culture and behaviour, computers can react much faster than the basic level of human perception (Kuniavsky, 2010). Information translated and transferred through analog methods such as speech, graphics, and movement, comes at the expense of time (Schifferstein, & Hekkert, 2008). As a result, the Canadian media philosopher McLuhan's (1964) statement that, "technology is a tool that extends human capabilities and senses (communication, memory, expression)" (as cited in Joinson and Piwek, 2013, p. 2), may provide an argument for applying technology to sport performance.

However, Baca et. al. (2009) discuss concerns regarding the integration of technology in sport performance. For example, they point out that computer-based direct feedback in motor control can be counterproductive, overburdening coaches with complex data. This does not necessarily invalidate the argument for integrating technology into professional sport, but it does encourage careful consideration of how it is used. From a design perspective, correctly applying and implementing a new system, device, or service is accomplished by considering established processes in the field.

2.3 User-Centred Design Issues

Design research is a key factor for "innovative humanization of technology" where the designer has little or no previous awareness of the users' experiences and needs (Koskinen, 2012, p.18). Ethnographic inquiry processes adapted from the social sciences aid in this process. Effective data collection and design research contributes to the

success of a product by ensuring that it resonates with users and represents their subjective experiences (Koskinen, 2012; Kuniavsky, 2012). User-centred design research is multifaceted and often incorporates an interdisciplinary team. Depending on the service or product being developed, facets such as contextual user experience and sensory design (amongst others) might be relevant to the process.

2.3.1 Contextual Design

Contextual inquiry is an approach to user-centred design research that looks beyond the user to the surrounding system (Beyer & Holzblatt, 1998). This method emphasizes all the attributes of a particular setting, including cultural norms, people, artifacts, sensory elements, and so on (Beyer & Holtzblatt 1998; Koskinen, 2012). According to Beyer (1999), "contextual design starts by recognizing that any system embodies a way of working. A system's function and structure forces users to accept particular strategies, language, and work flow" (p. 32). Although Beyer discusses contextual design from a business perspective, the term 'work' can be replaced by 'athletic performance,' where strategies and action can be optimized if they are first understood by the designer. Contextual design methods take a holistic approach to user experience, emphasizing a system's operation rather than a person-object interaction view.

Figure 3 illustrates the relationship between the design process and context, where culture, skills and social factors (communication) are key components to the system. While figure 3 concerns a business environment and its interactions, sports can also be regarded in terms of systems function, given sports' specific sets of rules, language, and

culture. The *Sport, Exercise, and Performance Journal* notes that performance is reliant on a specific context (Aoyagi et. al., 2012). Therefore, a contextual design approach is appropriate for the design of services and products that facilitate sports performance. In the case of sports, the user's ecosystem includes changes such the integration of digital technological implements (e.g., fitness tracking wearable devices) within a currently analog system (e.g., journals or memory), and design research addresses these contextual features by attending to users' subjective experiences.

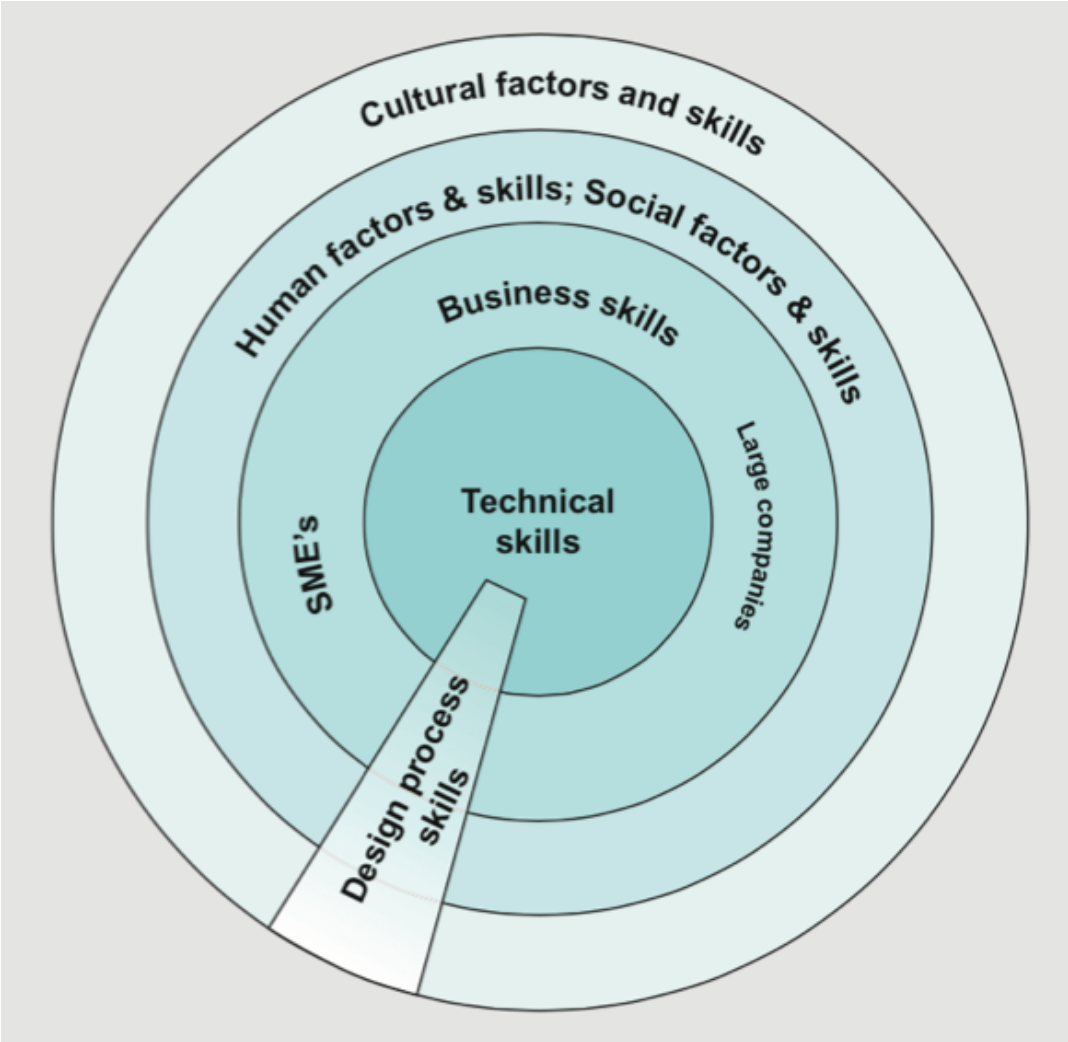

Figure 3 Relationship between the design process and context
source: Koskinen, 2012, p.157

2.3.2 User Experience Design (UXD)

User Experience Design (UXD) is both influenced by and useful in Human Computer Interaction (HCI) and industrial design, where all facets of design research are linked together and can be used interchangeably (Kuniavsky, 2012). UXD incorporates aspects of user-centred design as relevant to HCI and the study of affective experiences in human-product interaction relative to psychology (Desmet & Hekkert, 2007). HCI researchers and developers who once focused on a singular user's work performance have been transitioning their outlook to a broader perspective on overall lifestyle improvement (Zimmerman, Forlizzi & Koskinen, 2009). However, while UXD approaches derive from user-centred design, they are removed from the precise focus on pleasure, emotions, and empathy (Koskinen, 2012). The user experience approach to design research considers the product a means for the user to achieve goals, and addresses the user holistically, by considering the social, physiological, and physical context rather than focusing on the singular user's interaction (Ferraro & Ugur, 2011; Reily, 2012). Assuming a user-centred approach to design research "identifies common behaviours, places, and times where technology can intervene to help make things easier, better, or more entertaining" (Kuniavski, 2010, p.206). The field of psychology has studied behaviour in relation to memory and human cognitive theories extensively (Anderson, 1996; Bandura,1983; Chandler, 2002). Building on this, user experience design research takes complex social behaviour and turns it design constraints by addressing users' needs in terms of mental capacity, culture, knowledge, and environment (Kuniavsky, 2010). From a user experience perspective, usability means that the user, not

the engineer, defines the interaction with the product. The International Organization for Standardization (IOS, 1997) defines usability and its descriptors as follows:

> **Usability**: Extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.
>
> **Effectiveness**: Accuracy and completeness with which users achieve specified goals.
>
> **Efficiency**: Resources expended in relation to the accuracy and completeness with which users achieve goals.
>
> **Satisfaction**: Freedom from discomfort, and positive attitudes towards the use of the product.

Fundamentally, the purpose of user experience design is to enhance, simplify, or sometimes eliminate a given human action. Jakob Nielsen (2014), a prominent figure in usability engineering, uses the metrics *ease of use* and *pleasantness* in order to define the features and functions of wearable devices and applications that, in turn, connect to human behaviour and motivation. For example, cognitive loading is a recognized usability heuristic, where system designers acknowledge the limitations of human short-term memory by regulating the amount of information the user ingests. If too much thought process is required, or if an interface is too cluttered with information, usability is compromised. On a high level, the Technology Acceptance Model (TAM) relates the user's perceived ease of use and usefulness to whether or not they will adopt new ways of behaving through adopting the use of technology (Chuttur, 2009). Kuniavsky (2010) suggests "treating information as a material" (p. 44) and treating a device as a whole unit, rather than disjointed pieces of hardware. In order for a product to be successful, the user should experience minimal cognitive loading. In psychology, cognitive load is addressed

in relation to anxiety and memory, where the former negatively affects performance through the failure (or mere thought of failure) of the latter (Hays, 2009, p. 77). Heuristics such as satisfaction, efficiency, ease of use, and reduction of cognitive loading are tools employed in a user-centred design approach that enables the designer or design researcher to measure or study how well the user and system or interface fit together (Karwowski, Stanton, Soares, 2011).

2.3.3 Human Senses & *Product Interaction*

The design research context of this study is sensory based, where sensory design research is an interdisciplinary approach to addressing technical, aesthetic, and cultural user needs. It is an emerging field pertaining to the increased availability and presence of computing devices, looking for convergences between human senses (haptic, vibrotactile) and technology (flexible, modular surfaces) (Danjoux, 2009). Sensory Design also addresses both the input of sensory signals (heat, pressure, movement, and so on) and the output of information, which is received through human senses. Information output is produced in a deliberate code that signifies a specific piece of information appropriate in the context. For example, Gestalt theory in visual design explains how individual elements are organized into groups as well as explaining the way we perceive and organize patterns (Chang & Nesbitt, 2006). The Gestalt principle of figure-ground states that people will separate a figure, such as text or a symbol, from a background when there is a significant contrast, like a book's black text on a white page, or a combination of colours and shapes that form a logo, like software application icons.

Humans, like machines, follow a basic process of receiving, processing, and

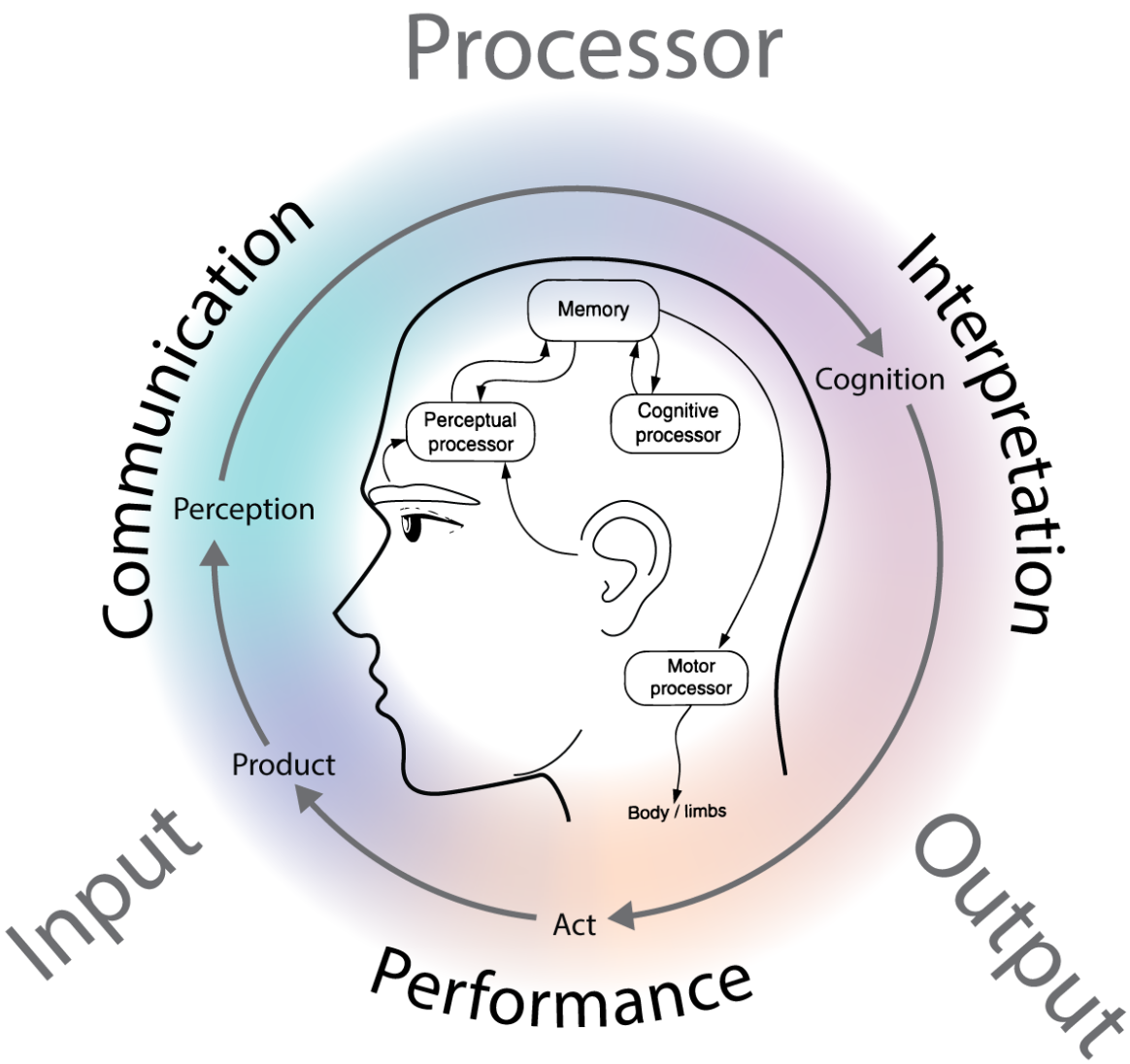

Figure 4 Visual expression of information processing relating to Pierce's semiotic triangle, Desmet & Hekkert's (2007) representation of information processing and Chandler's (2002) product interaction

outputting information derived from a sensory input (Koskinen, 2012). Information enters the information-processing system via the senses (eyes, ears, hands, body), as well as through proprioception (sense of space, movement and other barely noticeable things in the environment) (Jarvis, 2005; Koskinen, 2012). Figure 4 shows the range of multi-modal ways of communicating that must take place in order to process information. Here, input is a form of communication that is perceived through the senses, processed in the

brain, and interpreted cognitively. In a sports context, the output is the act of athletic performance. Schifferstein & Hekkert (2008) indicate that people always use their senses to perceive a product. They use their motor system and their knowledge to operate or communicate with a product. Figure 5 illustrates their view of human-product interaction, which encompasses cognitive, physical, and sensory parameters. Human systems, shown in the first enclosing box, receive information drawn from the environment. This information is used in action through the right box's skills and personal traits. On the product side, physical components on the right encapsulate the sensory means on the left, through which the human interacts with the product. Human sensory response is largely dependent on the "field of interrelated data" (Malnar, 2004) carefully designed in the product's sensory output. Although specific product composition is not the focus of this study, the user-centred framework is relevant for comprehending the context of sport performance and communication in football. The notion that similar cognitive and motor functions are used across products leads to the assumption that if context, behavior, and needs are effectively assessed, the problem space could equally be resolved.

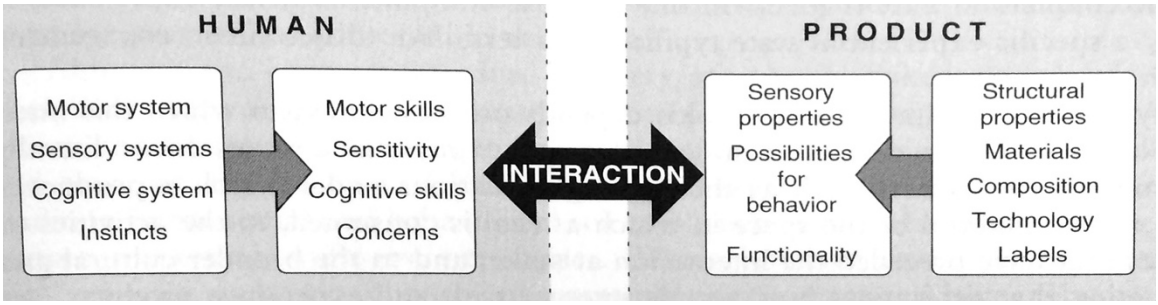

Figure 5 Human-product interaction
source: Schifferstein & Hekkert 2008, p3

2.4 Ubiquitous Computing for Human Performance Enhancement

Ubiquitous computing (ubicomp) is a term for the synergetic use of sensing, communication, and computing that arose by exploring the computer's place in the physical environment and in activities of everyday life (Baca et. al., Dabnichki, Heller & Kornfeind, 2009; Weiser, 1993). Ubicomp is a relatively young field with roughly twenty years of history (Kuniavsky, 2010). Miniaturization of devices and development of algorithms, in addition to the development of the internet and cloud servers, have contributed to the ubiquity of computing (Baca et. al, 2009; Wolf, 2010). The key purpose of computer 'ubiquity' is to render the physical computer "effectively invisible to the user" by offering "new substrates for interaction" (Weiser, 1993, p. 75). These substrates involve alternative forms of interaction from the conventional computer screen, including handheld and wearable devices (ibid.).

One feature ubicomp offers is the potential for users to use technology in order to assess and moderate their physiological outputs. For instance, wearable technology can detect and report on behaviour (biosignals) in terms of changes and fluctuations. Modern products are increasingly recognized as "smart things" (Kuniavsky 2010) because they consolidate various elements of design and technology such as sensors, hardware, software, and services (Kuniavsky 2010; McClusky 2009; Wolf 2010). These consolidated elements create intelligence by enabling a product to respond, interact, and process information. Ubicomp has not only created an environment for the production of smart things, but also the interfaces that visually express the data synthesis. The majority of wearable devices rely on an application that can be accessed by a computer or mobile device. Ubicomp therefore relies on several disciplines that study human interactions and

experiences with products, such as Mechanical/Material Engineering, Human-Computer Interaction (HCI), and Cognitive Psychology (Schifferstein & Hekkert 2008). User-centred investigations are vital to ubicomp's ability to create satisfying product experiences.

2.3.1 Wearable Technology

Ubicomp emphasizes not only mobility, but also integration into clothing or the human body (Danjoux, 2009), where it is known as "wearable technology," or "wearables." Understanding the rapidly changing landscape of tracking biosignals involves comprehending the development of ubiquitous computing. Data tracking started its outreach into wearables in 1961 with a shoe implement for cheating at roulette (Paulson, 2014). However, the first truly convenient, reliable device for portable machine-to-machine communication was the Bluetooth headset (Figure 6), introduced in 2000 (ibid.), shortly after the formation of the Bluetooth Special Interest group was formed (History of the Bluetooth Special Interest Group, Bluetooth SIG Inc., 2015). Since then, more attributes and features have been added to wearable technology, advancing at an accelerated pace. Nike and Apple introduced fitness tracking wearables when they teamed up in 2006 to allow users to track their movements with iPods. The iPod device provided the interface for the Nike running application to be accessed on the go, with the ultimate consolidation of

Figure 6 One of the first Bluetooth headsets by Nokia
source: Willians, J., 2012

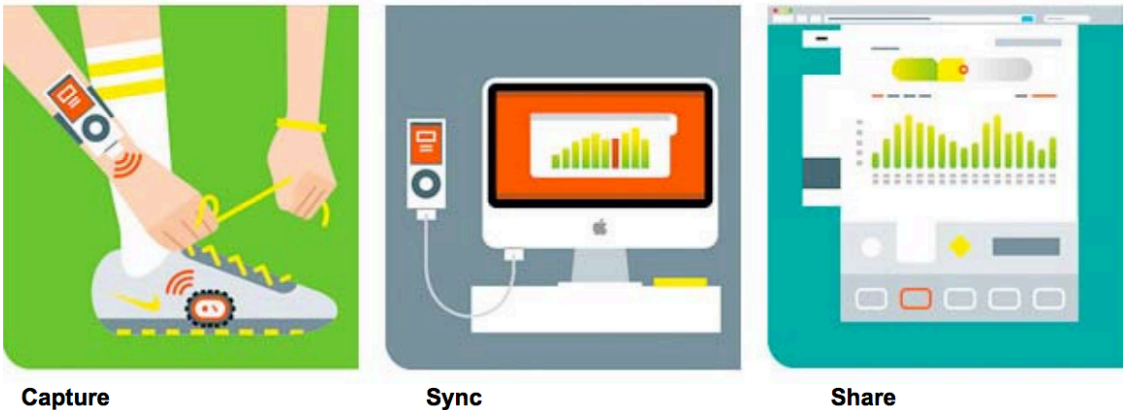

Figure 7 Nike & iPod collaboration
source: McClusky, 2006

devices and services into one unified ecosystem (figure 7). Only a year later, FitBit emerged, and in 2009 the first FitBit was released: a clip-on device that counted steps by means of an accelerometer (Paulson, 2014). The first wave of "Fitness Trackers" such as FitBit, Zip, Jawbone UP, Nike+ FuelBand, BodyMedia Fit Link, and MisFit Shine, were fundamentally glorified pedometers. Figure 8 shows FitBit's product range; it has evolved from a clip-on device to a complete service of mobile application (the user interface) and device(s). FitBit used the format of a wrist band containing the tracking technology for the now standard metrics of sleep, steps, and speed. A second wave of devices appeared within the past year showcasing collaborations between fashion and jewelry. For example, brands like Swarovski, TAG Heuer, and Gucci are teaming up with FitBit, Intel, Google, and Samsung (Figure 9) to offer wearables that are more than a piece of coloured silicone (Stables, 2015). Aside from aesthetics, this new wave of devices includes a new set of technological advances, including 'biosensing,' the collection of personal data related to health such as heart rate, hydration, and even muscle fibre activation (Yang, 2014). However, these advanced biosensing devices are mostly in the development phase, with research largely focusing on the technical structure of the

devices, including information architecture (algorithms) and engineering (electrical, industrial) (ibid).

Figure 8 Fitbit product line and software
source: Fitbit, 2015

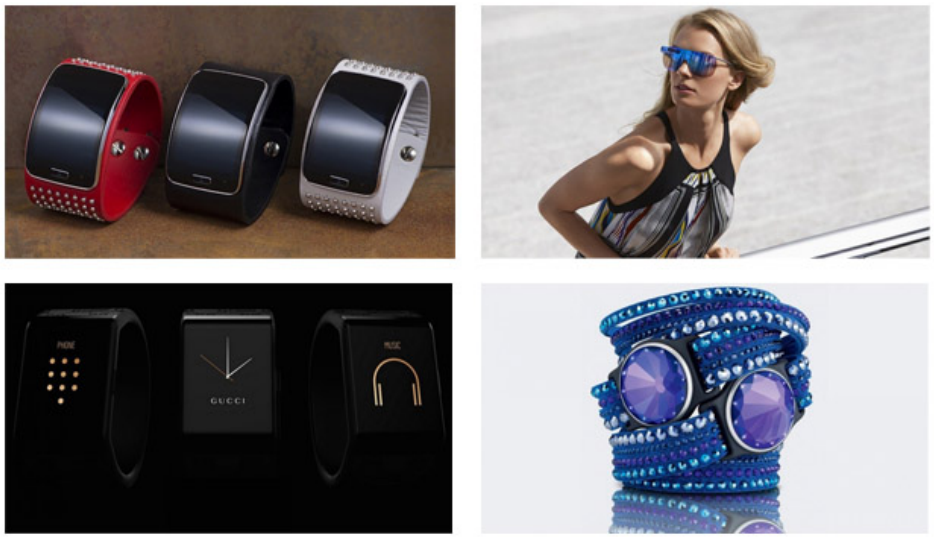

Figure 9 Wearable examples including collaborations between Samsung and Diesel; Google and designer Diane von Furstenberg; Gucci and Will.i.am Puls; and MisFit Shine and Swarovski. Source: Stables, 2015

A recent article on wired.com noted the redundancy of the fitness tracking industry, where, as of September 2014, out of the 266 wearable devices on the market, 118 were 'fitness wearables' (Herz, 2014). While the potential exists for quantifying any type of human movement, current devices are largely focused on cardio-dominant sports such as running, rowing, and cycling, and thus do not satisfy the needs of high level athletics and complex movements (Anderson et. al., 2007; Consolvo et. al. 2006; Sato, 2009). Brands such as Canadian-based Hexoskin and OMsignal have slowly started to explore 'smartwear' garments, with both companies playing "pioneering roles in the global smartwear industry with clothing that tracks the body's biometric activity, such as heart rate, breathing and calories burned" (Czikk, 2015). High-end brands are also recognizing the potential of the technology, and so for instance, Ralph Lauren has released the PoloTech shirt, which uses conductive threads to sense biosignals (Stables, 2015). However, smartwear currently looks and acts similarly, offering the same aerobic feedback previously mentioned and all are some variant of a sport compression garment (Kosir, S, Wearable Technology, 2015). A recent partnership between the large sport apparel company Under Armour, application developers MyFitnessPal, MapMyFitness, and Endomundo, and the technology company HTC might spark a new trend in tracking, potentially infiltrating the high performance environment (Digital Trends, 2015), but this collaboration has not yet been developed fully enough to allow for assessment.

2.3.2 Wireless Sensors

Feedback-generating sensors are at the forefront of wearable technology development. Fitness tracking devices such as MOOV promote their sensory capabilities

using terms such as '9-axis motion-sensing' and '3D-Tracking System.' These terms are also applied in scientific literature describing the intricacies of sensory device hardware and software (Macias, Torres, & Ravindran, 2012). Baca et al. (2009) break these terms down into the less glamorous reality: sensors that have existed for decades are used in novel ways in order to sense movement. Ultimately, the sensors receive the same information across different types of technology. For example, accelerometers and global positioning systems (GPS) are the leading sensors for movement detection. In an article posted on the IEEE Spectrum website, author Tekla Perry (Jan 4, 2014) wrote, "The tracker is just one part of the package, and its usefulness depends in large part upon the app that lets you review and analyze the data gathered." The connection between the data-gathering artifact and the data-synthesizing application is essential to the artifact's usability and usefulness, and ultimately acceptance of the system. Data synthesis (previously illustrated in the information processing section) involves a series of steps (Baca et. al, 2009):

1) sensor signal: (normally an electrical current) sensor detects movement
2) receiver: raw data sent to micro-processor
3) analysis: Short range wireless transmission sent to processor (smart phone, computer)
4) feedback: displayed via an application or software

Sensors are "the most diverse component type in wearable devices, and they also enable the key functions that will make wearable devices be worn" (IDTechEx, 2015).

The miniaturization of microchips, intelligent textiles, and advancement in biotechnology and cybernetics made possible the integration of sensory technology into

wearables (Baca, et. al, 2009; Yang, 2014). Miniaturization was crucial because the larger components of the recent past were simply too cumbersome to wear. Data collected from several different types of sensors (such as the aforementioned GPS, accelerometer, gyroscope, and so on) produces more detailed information than was previously possible (IDTechEx, 2015). Proper data fusion through the effective development of algorithms improves data accuracy, error handling, data reliability, and signal outputs (ibid. 2015, Yang, 2014). IDTechEx's technology report (2015) predicts that by 2025, there will be 3 billion sensors in use, 30% of which while include new and emerging technology. Cisco System's Forecast predicts a five-fold growth of wearable devices from 109 million in 2014 to 578 million by 2019 (Cisco VNI Forecast, 2015, p.15). These ambitious forecast suggest an expansion of the uses of wearable technology and invite more comprehensive sensory use studies.

2.3.3 Sensory & Biofeedback Technology

Sensory technology is part of the broader development of digital health care technology. Also known as electronic health (e-health) or mobile health (mHealth), digital health care technology ranges from web services such as digital health information systems and video conferencing to wireless wearable devices for physiological monitoring. Developments in e-health are spreading the concept of self-monitoring and self-care, which can diminish the amount of clinic and hospital visits and reduce overall healthcare costs (Lupton, 2013). Most e-health applications are geared towards wellness and the maintenance of good health, for monitoring, diagnostics, and therapies (Ma, Kim, McCormick, Coleman & Rogers, 2010). However, there are also more specialized

medical fields such as those involving prosthetics, mental and physical disorders, and diseases that have also benefited from cybernetics.

As part of this broader movement towards more sophisticated digital health care technology, wearable technology has witnessed a transition from basic motion sensing using accelerometers, GPS, gyroscopes, and so on, to the generation of 'biofeedback'. Three types of electrical outputs produced by the human body can be processed into biofeedback: electroencephalography (EEG) for brain function, electrocadriography (ECG) for heart rate monitoring, and electromyography (EMG) for muscle fibre activation (Cmiel, Janousek, & Kolarova, 2011). Emerging technology integrates these three forms of signals in order to enable users to track and receive feedback through methods that were once both invasive and limited to expensive laboratories and hospitals (Yang, 2014). For example, where diabetics currently need to draw blood as a glucose sample, sensory technology might determine their glucose level feedback (Yang, 2014). Other medical applications that benefit from sensor monitoring technologies include heart disease, asthma, and even cancer (ibid.).

Biosignal technology thus enables patients to take a more active role in the monitoring of their health, whether it is the vital physiological monitoring of serious conditions or general wellbeing. Sensor technology enacts a fundamental change in the context of where and how people track health data, moving from focused medical spaces like hospitals, clinics, and laboratories to the user's daily environments (Yang, 2014). These shifts in agency and location result in non-medical applications too, including the tracking of biosignals to enhance athletic performance.

2.4 Applications of Ubiquitous Computing and Wearable Technology

2.4.1 Context of Personal Data Tracking

The adoption of ubiquitous computing involves a transition from manual to automated methods of personal data tracking (Wolf, 2010; Watson, 2013). A common example is moving from handwriting in a journal to typing in a digital log. The emergence of wearable technology takes this further, however, turning the human body into a "transmitter of intangible data" (Ferraro & Ugur 2012, p.2). Ubiuitous computing pushes the boundaries of human experience where multidisciplinary design approaches create new social, physical, and psychological systems of interaction (ibid.).

Keeping track of aspects of one's life is nothing new. Taking notes, using a diary or log, and even marking dates on a calendar are various ways that people track information. Each method has an effect on actions and awareness. Athletes have kept training logs to quantify and analyze their workouts, just as counting calories has long been a popular and effective way to lose weight (McClusky, 2009). Tracking aspects of human performance enables people to substantiate their progress, which serves both as a memory aid and a validation of success (Anderson et.al. 2007, Consolvo, Everitt, Smith & Landay, 2006). According to Fox and Duggan (2013), the majority of the North American population claims that they keep track of progress metrics in their heads alone. A certain percentage use written records, however, and a smaller number, the early adopters, rely on technology for tracking. While most of the people from Fox and Duggan's (2013) survey tracked at least one chronic health condition (as opposed to tracking out of sheer curiosity or for athleticism), the fact still remains that about seventy percent of the American population is tracking something. As such, they enjoy a greater

awareness of their past behaviour, current status, and activity level performance (Consolvo, Everitt, Smith and Landay, 2006).

2.4.2 The Quantified Self

The Quantified Self (QS) movement is a response to self-tracking behaviours. The Quantified Self phenomenon is described as "an advanced user community of people who have begun to explore and experiment with novel uses for personal data" (Watson, 2013). In this user group, individuals track their personal behaviour in order to become sophistication of self-tracking through wearable devices, applications for tracking

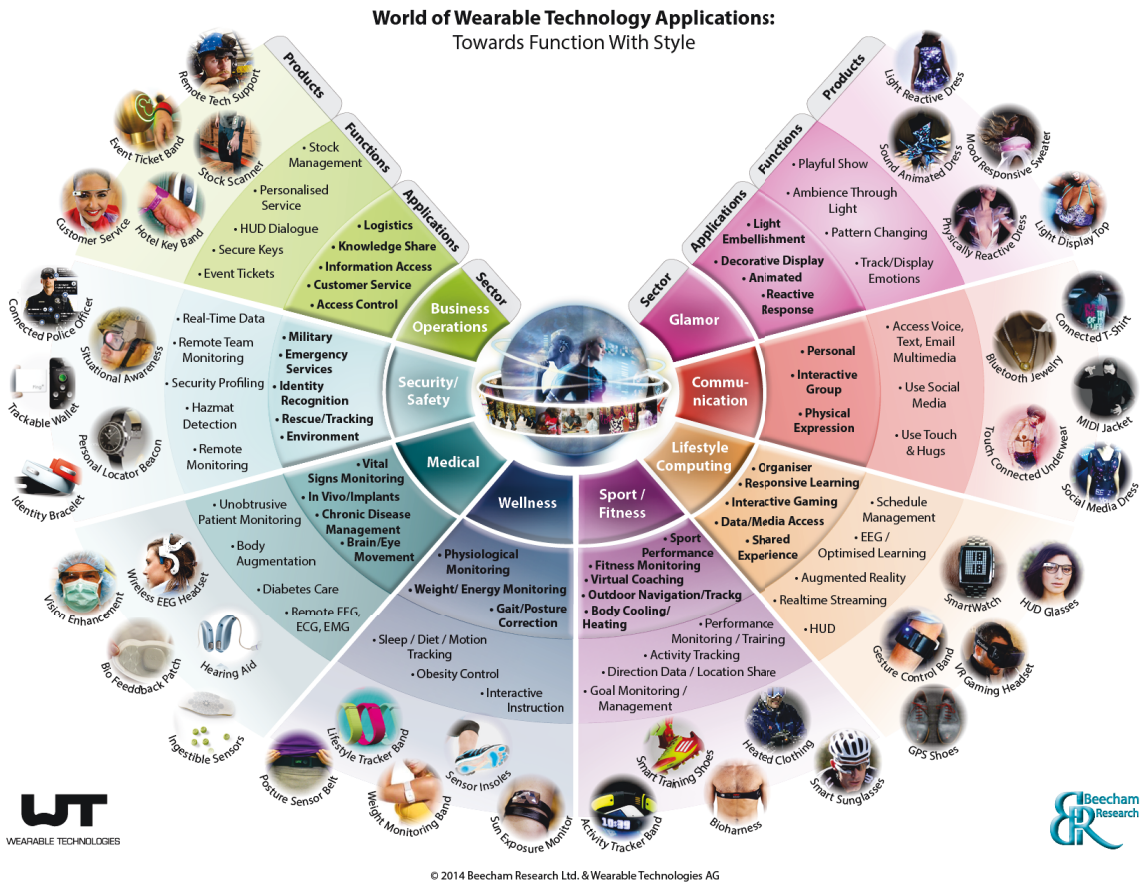

Figure 10 World of Wearable Technology
source: Beecham Research Limited, 2015

personal data, and mobile access to the internet and social media have expanded the Quantified Self movement (Wolf, 2010). Figure 10 illustrates a variety of wearables applied to various fields. This graphic visually expresses the wide range of applications for wearables and provides an overview of the range of activities, areas, and issues that people track. Some of the key issues are: the placement of the wearable device on the body in relation to the sensor, application and functions. Where the device is situated on the body contributes to its form, its function, and ultimately the way in which the user interacts with, perceives, and experiences it.

2.*4.3 Technology Applications in football*

The current wearable technology market consists mostly of sports and activity trackers (Rodgers, 2013). However, in a Harvard ilab (2014) panel discussion on technology and the modern athlete, Matt Hasselbeck, quarterback for the Indianapolis Colts, said "people would be surprised at how primitive football is in terms of technology; nothing's changed." Hasselbeck further stated that fitness tracking devices are great but cannot be worn during a game or in practice (ibid). This section explores current uses of technology in football in order to understand why it has so limited a role.

Communication Technology

Ubiquitous computing has not infiltrated professional games and matches largely due to organizational regulations prohibiting use during a game (Davis, 2013). However, the regulations are slowly changing. Earpieces were first allowed for the quarterback in 1994 and are now allowed for certain designated players on the defensive line. As long as

there is standardization and equality amongst teams, implementing additional technology during game time is feasible, although some fear that too much technology will negatively change the essence of a given sport (Branch, 2006). However, the football community agrees that the technology currently in use enhances the game.

Bose is currently the official headphone and headset provider for the National Football League (NFL). The audio equipment corporation previously made auditive technology for pilots and military use, but the football environment creates different technical challenges. User testing and engineering focused on producing noise-cancelling headsets that could not only withstand the usage context (the risk of dropping, extreme cold, aggressive manipulation) but also deliver sound through high levels of crowd noise (Battista, 2014). Bose's headsets are currently provided to coaches, medical staff, and officiating personnel. Some coaches and athletes have also called for technological improvements to provide better communication between the play-caller and quarterback (who does not have noise cancelling technology in his helmet) (Battista, 2014; Harvard ilab, 2014).

Currently, the only implement providing feedback to the athletes on field is an earpiece given to designated players (like the quarterback). While this auditive technology has improved communication, users complain that sound quality is lacking due to background noise and lack of advancement in technology (Branch, 2006; Harvard ilab, 2014). There is some evidence that crowd noise interferes with auditory communications on the field. A recent analysis by The New York Times (2006) determined that "penalties, particularly noise-related penalties like offensive holding and false starts, have been on the rise in recent years…more penalties, especially those for

false starts, are called in domed stadiums, which tend to be louder." The limitations to technology used by players demonstrate a disconnect between the advances made on the sidelines and the slow progress on the field. Live video feedback has become a training tool for all sports. Recent developments in technology, particularly the release of tablet computers, have made video capture and review tools accessible, affordable, and user friendly (Wyngaarden, 2012), and so coaches are able to analyze and strategize more quickly during games. Technological limitations, however, hinder their ability to communicate these strategies to players.

Broadcasting

One of the first uses of communications technology in football was a broadcasting tool to improve spectators' experiences. Sportvision's patented video overlay technology creates the illusion that a yellow first-down line is painted on the field. This technology, the Virtual Yellow 1st & Ten® line system, debuted in 1998 and quickly won an Emmy Award for technical innovation (Sportvision, 2014). Sportvision continues to broaden its services, which include an array of data analysis and broadcasting tools that offer both broadcasting and team analytics software for various sports. However, the company's website does not indicate whether the technology provides any real-time analysis software to assist with analytics during a game.

The 2014 NFL season saw the first use of RFID to track players during official games and offer insightful statistics for both fans and coaches in real time (Fox, 2014). The collaboration between the NFL and Zebra Technologies' MotionWorks system put

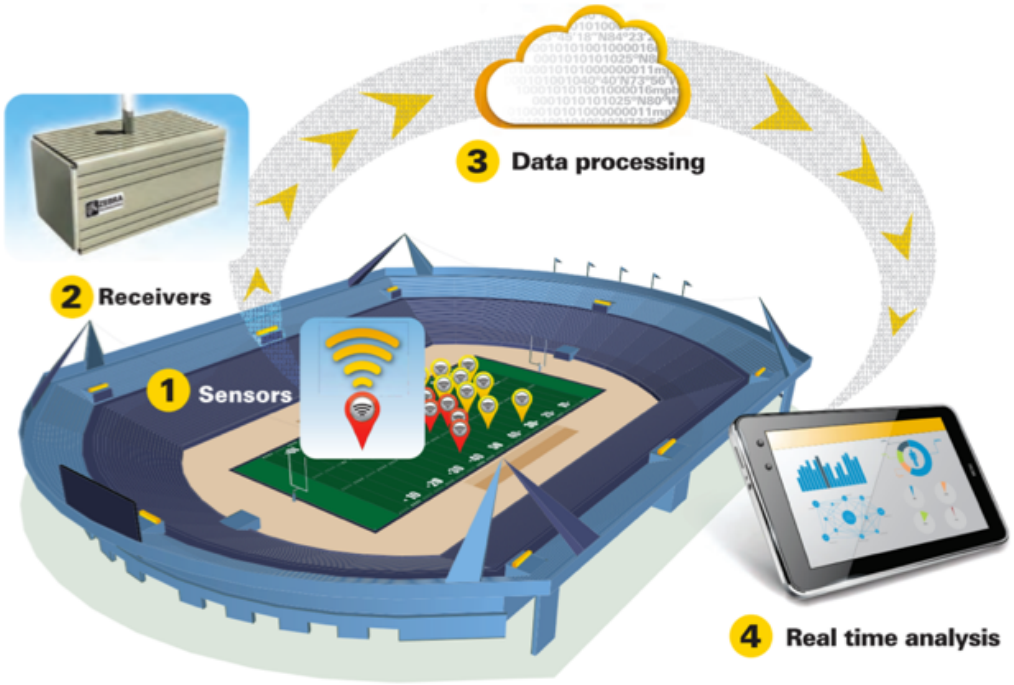

Figure 11 Zebra Technology integrated tracking system
source: ZIH Corp, 2015

quarter-sized active RFID tags on the shoulder pads of the players, and these tags registered data such as movement, distance, and speed (Zebra MotionWorks Sports Solution Data Sheet, 2013). Receivers installed throughout the stadiums receive and translate the data into usable information, which is generated in real-time broadcast overlays of all the action on the field and real-time visualizations for coaching staff (figure 11). In order to understand the impact of the new technology, the system's context was described in a press release (Before It's News, 2014) regarding the partnership:

> Viewers — not to mention coaches and team executives — will be able to track every players' movement in the often chaotic scrum of the typical NFL football game. When a blocking assignment is missed or a receiver is suddenly wide open in the end zone, fans will know precisely which player screwed up, and when and where.

The developers argue that those invested in competitive sports, including engineers, athletes, and stakeholders, will see a revolution in the industry where players' performances, coaches' strategy, and the resulting fans' viewing experience will be enhanced through ubiquitous computing (Springer, 2014).

Injury Prevention

In addition to RFID tags, sensors are being used in football for injury prevention. An ESPN article (2013) described the use of sensors that detect impacts sustained by players on the field and use wireless technology to transmit information to coaches and medical staff on the sidelines, who then determine whether the player is fit to continue playing. Riddell, the official NFL football helmet maker's InSite technology also includes player management software which tracks equipment assignment to players and offers player statistical analysis over time (Linendoll, 2013). Staying healthy is part of an athlete's job (Harvard ilab, 2014). While reducing concussions lengthens athlete careers and fosters lifelong brain health, avoiding overtraining and optimizing training levels contribute to injury prevention (Springer, 2014). Developers continue to seek innovative ways to adapt biosignal technology to athletic contexts. For instance, a Massachusetts-based startup, MC10, has developed not only a wearable device, but a flexible computing prototype where sensors can be applied to

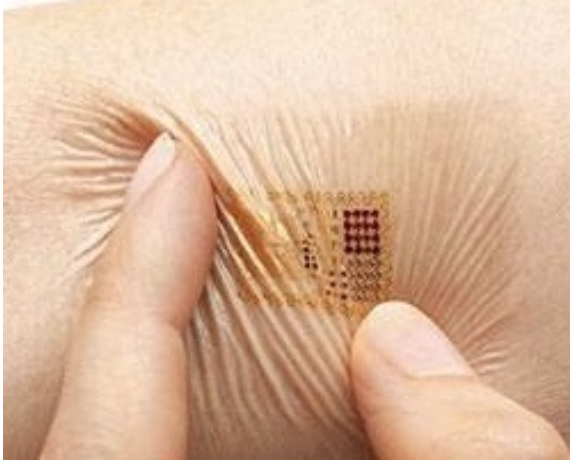

Figure 12 MC10 tracking technology
source: MC10 Inc., 2015

the skin like a tattoo (figure 12). Collecting data such as body temperature, heart rate, brain activity, and exposure to ultraviolet radiation, the 'Biostamp' uses "near field communication" (NFC) that allows data to be wirelessly transferred to an interface (like a smartphone or laptop) for analysis and visualization (Grobard, 2013). Athletes value the unobtrusiveness of this technology. For instance, professional lacrosse player Paul Rabil attests to the need to feel "weight free and quick" (Harvard ilabs, 2014). If an athlete's gear is unnecessarily cumbersome, or if it creates a hostile surface upon impact, it could increase rather than decrease injuries.

Athlete Analytics

Emerging technology enhances personal data tracking by providing what was once only available in labs and at a high price to coaches and athletes for real time use during a game (Harvard ilab, 2014). Catapult, an athlete analytics company developed at

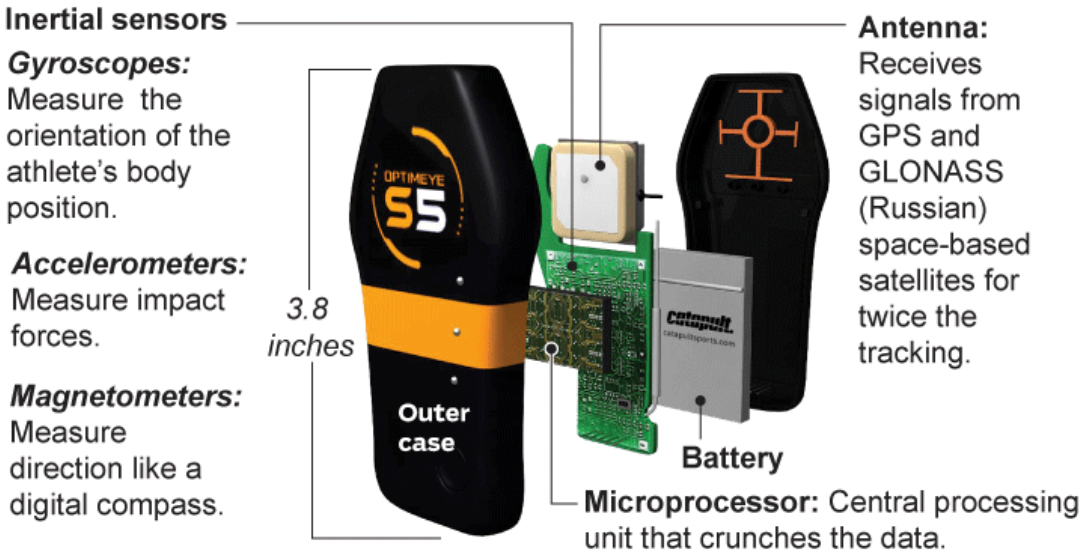

Figure 13 Catapult's on body biosignal tracker
source: Cataputl Sports, BEST Performance Group, 2014

the Australian Institute of Sport (AIS), is powered by GPS, and used by more than 500 global sports organizations, including the NFL. While the AIS has published many articles promoting their technology for performance peaking, injury prevention, rehabilitation, and real-time feedback (Davis, 2013; Davis, 2014; Gabbett, Jenkins & Abernethy 2012; Varley, Fairweather, & Aughey, 2012), there have been no studies from the user perspective. This is likely due to the fact that several teams have confidentiality agreements so that their opposition does not know if they are using the technology (Davis, 2014). An article on Mensfitness.com elaborates on the technology, stating that sensors track more than 100 metrics such as distance, speed, acceleration, deceleration, and heart rate. They also assess spatial changes in direction using 3-D accelerometers, 3-D magnetometers (essentially digital compasses), 3-D gyroscopes, an antenna for GPS, and a processor with a memory unit (figure 13). As the device collects data, the sensor transmits numbers wirelessly to coaches through software running on a mobile device

Figure 14 Catapult's software interface on tablet, smartphone, laptop
source: Sideline Sport, 2013

(figure 14). The 'command centre' software uses algorithms that consolidate the live information with the player's vitals and other biographical information into readable, actionable graphs and charts (Davis, 2014). The key word to the success of the technology is *actionable.* The information produced through the full service system enables the recipient to proceed with actions resulting in optimized performance.

2.5 Summary

Ubiquitous computing has created new ways of interacting both with the environment and with other people through virtual applications and interfaces. Virtual communities enable communication with others who are beyond sensory range (Joinson & Piwek, 2013). With the development and miniaturization of sensors, technology has become wearable to the point that what was once limited to high-profile systems or expensive medical care is now widely available. Although wearable technology has quickly infiltrated the fitness industry, the literature shows that there is a large gap where higher-level performance is concerned. This may be due to the rapid development of new technologies. Although they share technological principles, the context, attributes, and algorithms, as well as the encompassing industrial design, differs across devices (Kuniavsky, 2010). The notion that technology has the capacity to extend human capabilities, shape behaviour, and amplify social and behavioural responses (Joinson & Piwek, 2013) invites investigation of the complex and often problematic nature of communication in football.

Tracking technology for professional sport mostly uses the same sensors as those embedded in popular fitness tracking devices, including accelerometers, gyroscopes,

global positioning systems (GPS), cameras, opto-electronic devices, and Radio-frequency Identification (RFID) technology (Davis, N., 2014). New developments in technology for professional sport have enabled coaches to track their athletes' progress, set goals, and prevent or manage injury. In addition, the athletes' personal performance data can also be used for scouting and recruitment based on quantifiable data, rather than qualitative observations of the players, which are susceptible to inaccurate human interpretation (Davis, N., 2014). This represents a key difference between elite athletes and other users of this technology: whereas 'average' users are the recipients of the data they produce, athletes are not the immediate recipients of their data. This raises the issue of whether athletes could benefit from receiving information, as fitness tracking users do, during or after performance.

The research questions formulated as a result of the literature review are as follows: First there is the issue of how people may benefit from ubiquitous computing:

Q1: What is the context of use for ubicomp from a fitness tracking perspective?

Then there is the focused contextual inquiry:

Q2: What are the parameters of communication pertaining to a football game?

Finally, there is the technical inquiry:

Q3: How can ubicomp be applied to football?

These three research questions are consolidated into a summative inquiry:

Q4A: How can design research methods be used in the context of sports?

Q4B: What are possible problem areas in football that design of technology might address?

3.0 METHODS

3.1 Approach & Research Overview

This study takes an exploratory mixed methods approach, based primarily on qualitative research, which benefits from methodological triangulation. A loosely structured methodological process guides one phase of research, which influences and leads to the next phase (Creswell, 2003). Hayes (2001) defines quantitative methods as those "which involve manipulation of numerical data" and qualitative methods as "approaches [that] attempt to draw out the *meanings* of data" (p. 239). Creswell (2003) defines qualitative and quantitative methods similarly, but combines them into a new mixed method. The literature review showed that wearable technology is increasingly ubiquitous in multiple areas, including health care, media, and sport performance. The literature confirmed acceptance of wearable technology by forecasting a dramatic increase of use in the next few years alone. The research methods used in this study explore the questions derived from the literature review, applied to a specific context and case study. The nature of this study is also considered transformative, or exploratory, in order to mitigate researcher biases and allow for organically-produced outcomes.

Methods, processes, systems, and frameworks help guide effective research and positive outcomes. One of these systems is the Data Information Knowledge Wisdom System, which is explained in Jonny Saldana's (2009) *The Coding Manual.* This system involves cultivating data, using the data to extract information, using the information as a foundation for storytelling, using the storytelling to create understanding and knowledge, and finally applying that knowledge to gain wisdom. Simply put, the DIKW system seeks

to interpret data actively in order to create empathy and insights for innovation (Kolko, 2011, Chandler 2002, p. 35).

Kolko (2011) discusses the value of how the synthesis of data can drive innovation through "sensemaking," which combines design visualization to apprehend data, ideas, thoughts and reflections through tangible forms (p.16). Sensemaking involves using a particular frame, or point of view to perceive a given situation. For example, design synthesis attempts to make meaning out of data through interpretation and visual modeling which Kolko (2011) defines as experience frameworking. The approach to

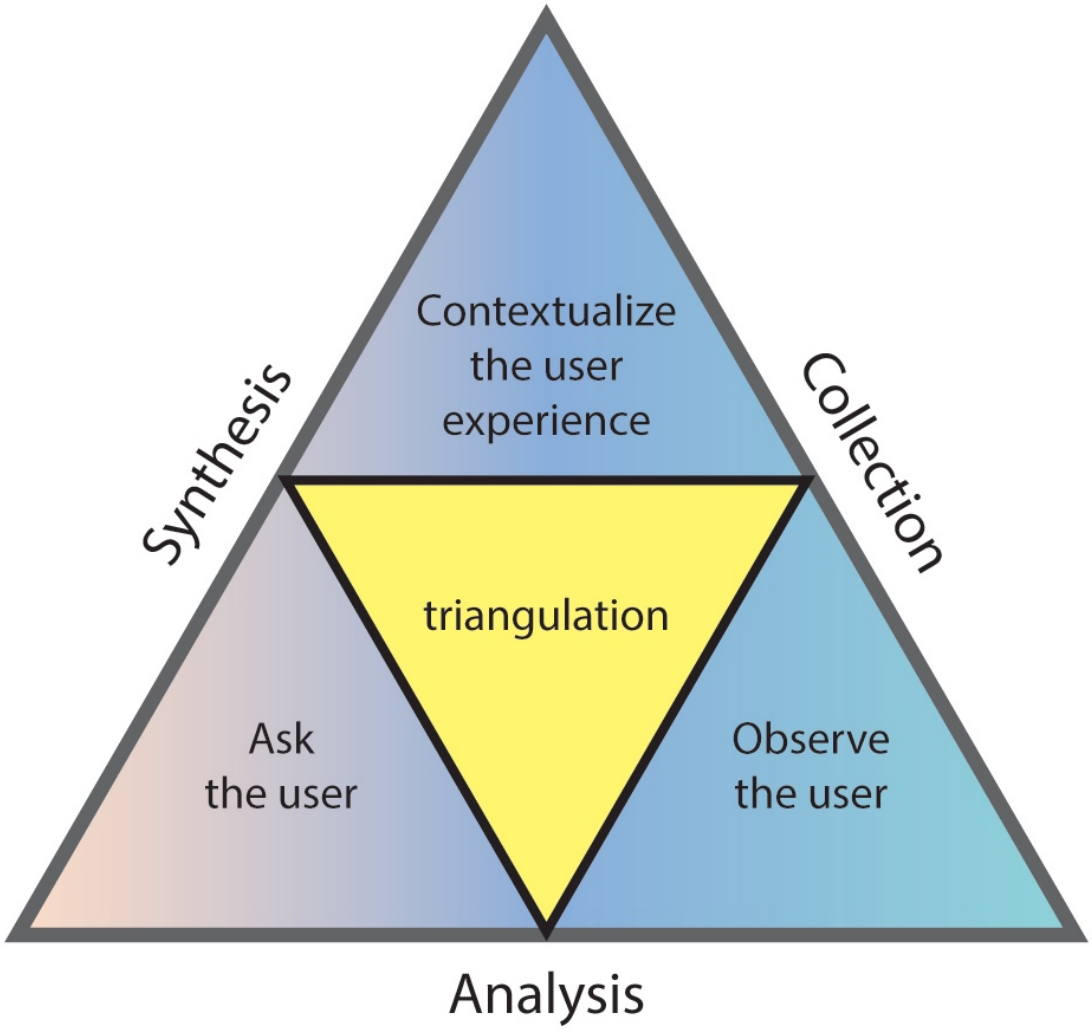

Figure 15 Research triangulation

analysis and synthesis of the data in this study relies heavily on the concept of sensemaking, which follows an exploratory approach to collecting data. The data from one phase is analyzed and the next method depends on what the data from the first method reveals. Methods are shown in figure 15, where the phases of research involve setting the context, observing, and asking. These methods are then triangulated in order to clarify and confirm their meaning.

3.2 Phases of Research

The initial pilot survey addressed fitness tracking and determined the area to be oversaturated and of minimal interest for design investigation based on the current state of the market and lack of available literature relating to the underserved population of performance athletes. Carrying the notion of sport performance to a new focus, the observation phase identified the problem space of communication in football, particularly signalling between coaches and athletes, and interviews highlighted the opportunity and potential ways in which technology could enhance human senses as a means to resolve the problem space of communication in a football game.

Figure 16 illustrates the sequence of research phases as the focus transformed. The first phase assesses the landscape of tracking human performance through an open,

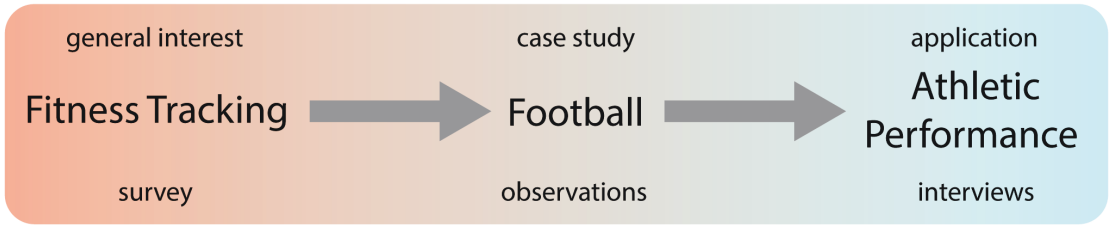

Figure 16 Phases of research

online survey. The second phase observes a specific user group, Carleton University's varsity football team, in order to understand their specific behaviours and needs. The third phase uses the insights gathered from the second phase and translates them into interview questions. These questions pertain to communication between the players and coaches with the intention of finding problems in current behaviour. All three phases of research are described here in terms of setting, participants, data collection, and data analysis. The methods for research with human participants were approved by Carleton University's Research Ethics Board.

3.3 Visualization

There are three useful methods for synthesizing data that promote actionable research (Kolko, 2011). The first is affinity diagramming, which can be defined as "adding contextual containers for discrete ideas" (ibid, p.78). This method occurs in the "information" step of the DIKW system where data is tagged, coded, and grouped. The second method for synthesizing data is Cultural Modeling, in which the cultural relationships within the context are illustrated in a diagram that helps to visualize how the participants achieve their desired outcomes (ibid., Beyer & Holztblatt, 1998). The third method for synthesizing data is the Contextual Inquiry Flow model, which provides an illustration or diagram of the movement or patterns of the participants' contextual activities (ibid). In addition to flow models, a Journey Map is used as a final, time-based contextual inquiry tool. It consolidates and sequences phases of research with key findings and design opportunities. According to Beyer and Holtzblatt (1998), graphical methods are used to analyze the observations in order to produce a set of design

constraints for the implementation of a technological solution, which directly correlates with the intentions of this study. Techniques of contextual inquiry use graphical language to focus thought even more intensely than textual language (Beyer and Holtzblatt, 1998). Observation and subsequent graphical representation techniques highlight users' interests, the technologies they are willing to accept, and the role those technologies can play in their lives. Combined, the latter two approaches for synthesizing data reveal constraints directly derived from the observation of complex social behaviour, which may mitigate the risk of not using a human-centre approach to generate novel design ideas (Kuniavsky, 2010, p.201).

3.4 Survey

The preliminary phase of the study aims to explore the context of personal data tracking. The main themes explored where why, how and what the participants were tracking and how they felt about their experience. Due to the broad nature of this phase, an online survey (Appendix 2) was used as an initial way of quantifying ubiquitous computing in the fitness context. This method corresponded to the first inquiry on wearable technology, prior to focusing the subsequent phases. The survey became secondary as the context of football was chosen for investigation, and its purpose was to direct the context towards the underserved user group of competitive athletes.

3.4.1 Setting

The survey was distributed online, through the web platform FluidSurveys. Participants answered the survey through the sampling method of snowballing (referral)

on social media websites and applications, therefore their exact location at the time of participation is unknown. However, geographic data provided by FluidSurveys indicated that the majority of participants reside in Canada, with some participation in Europe, the United States, and Australia.

3.4.2 Participants

A total of one hundred and twenty-four people submitted responses to the online survey, sixty six female and fifty eight male. They required access to the Internet and consented to the ethical implications prior to beginning the survey (included in Appendix 5). The unrestricted public nature of recruitment (snowballing) allowed for a broader survey of public opinion in order to diminish sample bias.

3.4.3 Data Collection

The survey was launched June 2015 and closed September 2015. There were 14 total questions which used a combination on Likert scale, multiple choice, and short answers. Survey results were collected through FluidSurvey's software, which also provided a report of results in the form of charts and graphs. Qualitative answers from respondents were also included in list format.

3.4.4 Data Analysis

By reading the detailed responses for all one hundred and twenty four, the results were compared and analyzed. Relating the insights gathered from the literature review, a qualitative perspective was developed using design tools such as flow charts and affinity

diagrams. The analysis lead explored the use and usefulness of current devices and applications contributed to understanding ubicomp for fitness tracking.

3.5 Observations and Field Study

The second research question exploring the landscape of communication in football was addressed in the literature review where there showed a lack of tracking and communication technology for sport specific and competitive sport performance users. In addition, in the literature, football is presented as a sport that is rich in culture, diverse communication methods, and ubiquitous computing. With this knowledge in mind, the second phase of research explored the context of communication in a game situation by identifying the setting, participants, artifacts, and interactions. The Carleton Ravens varsity football team was used as a case study in order to facilitate ethical approval, as well as the synchronism of their season with the study's timeline.

3.5.1 Setting

Two significant Ravens games were attended for observation. The first was the annual Panda Game played at TD Place, in Ottawa, against the Ottawa University GeeGees. The second game was the last of the season, and it determined the Ravens' advance to the playoffs. It was played on the Ravens' home field at Carleton University against the Queens University Golden Gaels.

3.5.2 Participants

The participants for observations included the members of the Carleton Ravens football team, as well as their coaches and supporting staff. There are roughly ninety total players on the Ravens football team, however, only half of them play any given day, while the others watch on the sidelines. During any series, there are twelve total players on the field, either offence or defence. The opposing team was also observed but not specifically analyzed. Due to the public environment, ethical approval to observe and film the participants was not required. Due to the nature of football, the outcome of the plays dictated which players were on field the most.

3.5.3 Data Collection

The first game was observed as a pilot test, taking a global perspective in order to identify issues that affected the team's overall performance; this set the foundation for a more focused analysis of the second game. Notes and pictures were the primary method of data collection, taken from the middle of the stands at TD Place, in Ottawa. During the second game, video recording was the primary form of data collection. With the help of an assistant, two cameras were used to focus on the field action as well as the communication occurring on the sidelines. Observations were performed standing by the fence separating the sidelines and the bleachers. This data contributed to understanding the atmosphere of the game, particularly of the communication between coaches and athletes. In order to present the raw data collected through video, still-frame images were extracted from the footage. These images were sorted into affinity diagrams that separated players, coaches, and their respective methods of interacting and

communicating. Affinity diagrams were used as a means to visually present data and quantify which types of communication were used more frequently. This frequency was based on general contextual groupings rather that explicit numbers. Due to the short time frame within which the study was conducted, qualitative data was chosen for the purpose of addressing user needs.

3.5.4 Data Analysis

Affinity diagrams provide a framework for laying out still frame images of the actions relevant to communication. Still frame images extracted from the initial task of filming a football game provide visual fragments of communication rather than a larger, dynamic film clip. The images identify types of sensory actions, sorted into themes that separate different communication methods performed by athletes and coaches.

3.6 Interviews

This final phase of research explored the participants' personal opinions regarding communication processes, as well as technology usage in football. Certain coaches and athletes were selected to participate in interviews regarding their experiences during a game as well as their habits and practices leading up to their football season. Interviews with the athletes and coaches on the Carleton Ravens football team were approved both by the Head Coach and by the Carleton's Research Ethics Board. The interview format was semi-structured, allowing the interviewees to express and share their stories, without being restricted to exact questions. However, the structure of the interviews was designed to elicit responses from the interviewees that would answer the final research question:

How can design research methods be used in the context of sports? And also, what are possible problem areas in football that design of technology might address? This was accomplished by prompting the interviewees to reflect on their behaviours, their methods of communication, as well as to recall negative experiences and explore the cause of problems. Separate interview templates were developed for the coaches (Appendix 7) and athletes (Appendix 8). Inquiring about communication directly also encouraged reflections about the types of sensory methods of communication the team uses.

3.6.1 Setting

Interviews were conducted in the main lobby of the Carleton Athletics Department. Food and beverages from the coffee shop on site were offered as incentive for participation. All interviews were conducted in a public space so as to protect both the participants' and the researcher's integrity. Although there was a high level of background noise, the interviews proceeded uninterrupted, lasting between 30-60 minutes.

3.6.2 Participants

The participants were chosen based on their diverse perspectives of the game of Football. It was important to interview a relatively equal number of coaches and athletes in order to balance bias in experience from the two potentially juxtaposing perspectives. The chosen participants included three athletes on the Carleton Ravens Varsity Football Team (quarterback, wide receiver/captain, offensive lineman) as well as two coaches

(offensive coordinator and defence/strength and conditioning coach). It was essential to interview the quarterback due to his special role as leader and key communicator on the team. The captain was also chosen, not for his position, but for his leadership role and insight into the team as a whole. The third participant, the offensive lineman, held a higher authority role due to his experience on the team. The coaches were chosen so as to distinguish between offensive and defensive processes. The people who were interviewed were acquaintances of the researcher prior to commencement of the study, but no hierarchical relationship exists between researcher and interview subjects. In order to mitigate against bias, the researcher included a release form in conjunction with the in-depth interview in which interviewees' attested to their honesty and sincerity (Appendix 5). Questions remained relevant to the topic and were focused on the interviewees' personal experiences rather than their relationship with the researcher.

3.6.3 Data Collection

The interviews were recorded in full and then transcribed for further synthesis. Audio was recorded with a cellphone application, and will be deleted once the thesis is complete. Notes were also taken by the researcher in order to remember important time stamps and interesting details during the interviews. In some cases, illustrations were made collaboratively by the interviewee and the interviewer using a pen and paper in order to provide a visual to accompany a description of a complex game scenario.

3.6.4 Data Analysis

The transcribed interviews were analyzed and sorted into tables that were developed based on the information gathered from the literature review and previous methods. Also, seeking to answer the research questions relating communication to technology, three coded areas were developed: information translation, coaching and team development, artifacts and technology. These coded sections corresponded to topics discussed in interview and separated the various contributors to the overall success of communication. The tables columns included a section for specific quotes, actions relating to sensory uses, as well as a space for insights to begin to develop associations with the previous methods and research questions.

4.0 RESULTS

4.1 Survey Results

The survey was conducted as an initial pilot study relating ubicomp to users. The results of the survey (Appendix 2B) served as a foundation to gauge user attitudes towards fitness and performance tracking technology as well as to gain insight into various use scenarios. The results are presented in the order of the questionnaire (Appendix 2A). While the results pointed to technology acceptance, the oversaturated market was too broad a context to pursue a design direction. The notion of sport performance as an underserved use scenario steered the focus towards sport specific communication as opposed to fitness tracking.

4.2 Field Observation Results

4.2.1 Overview

Observations during the first game provided key points that guided the focus of the second game's attendance. Coaches and players made gestures and specific movements between every play, which raised questions about the meaning, outcome, and effectiveness of those gestures. Figure 17 illustrates a simplified layout of the Carleton Ravens field in a game situation. Observations of the second game were performed from the bleachers, with one recording focused on the field action, and the other focused on the sidelines and targeting the various communications between coaches and athletes.

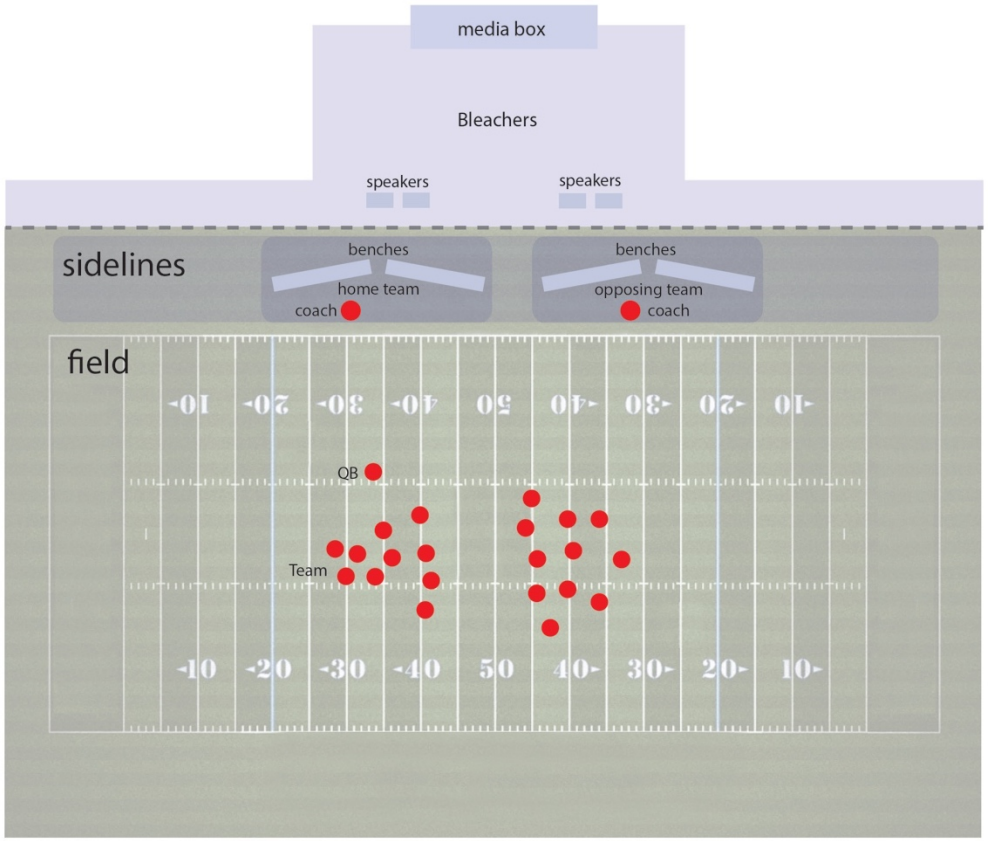

Figure 17 Field layout showing positioning of coaches off the field and players on the field

4.2.2 Visualizing Results

In the first affinity diagram (figure 18), athletes and coaches are separated due to their different methods of communication. The initial classification revealed differences in types of communication expressed by coaches as compared to the athletes. Coaches used a variety of signals ranging from simple (one hand gesture) to complex (three or more bodily movements), or yelled to athletes on the field. Athletes would look toward the sidelines, talk amongst each other in the huddle, and use simple, brief signals (like pointing) and simple code words yelled before the snap (start of the play) while on field. The verbal, face-to-face method of interaction did not seem to pose any communication

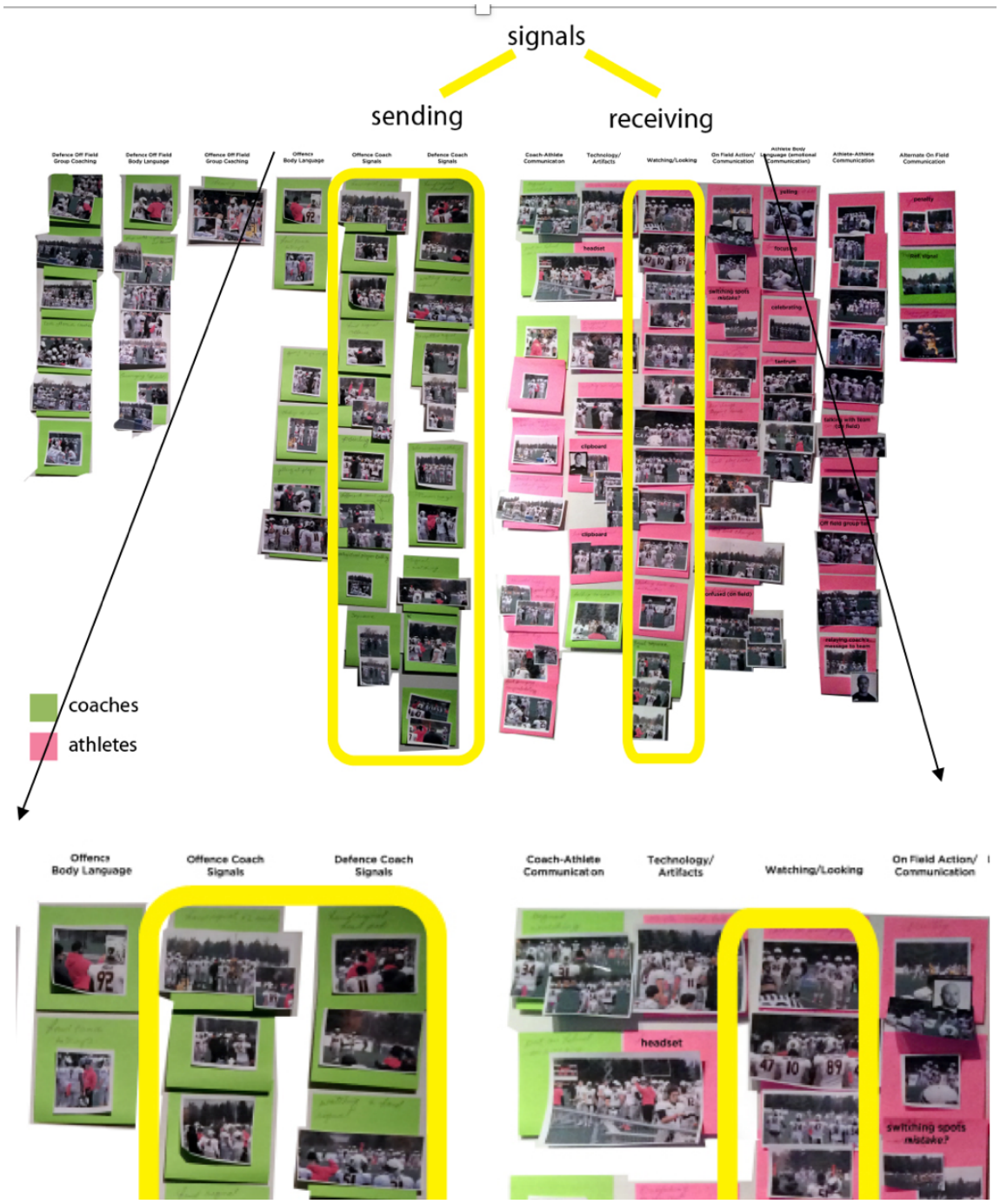

Figure 18 Coach and athlete diagram highlighting the prominence of sending and receiving signals

problems, as witnessed through video analysis. Looking to a different level of communication, the affinity diagram highlighted two quantitatively significant columns for the coaches and athletes: sending signals via hand gestures, and receiving or looking

for signs of communication. This level of communication was coded as sending and receiving signals, which represented a new way to present the images.

4.2.3 Coach and Athlete Diagrams

In order to distinguish the types of communication expressed by coaches as compared to athletes, two flow diagrams were created to visually express and tag specific aspects of sending and receiving signals (figures 19 & 20). The set of diagrams displays types of communication from a coaching perspective. The distinction between offence and defence was made due to the different nature and role these two parts contribute to a game. Although they have different goals, both offensive and defensive players looked to their coaches after each play. Communication methods were sorted into two prominent

Figure 19 Diagram of defence signalling

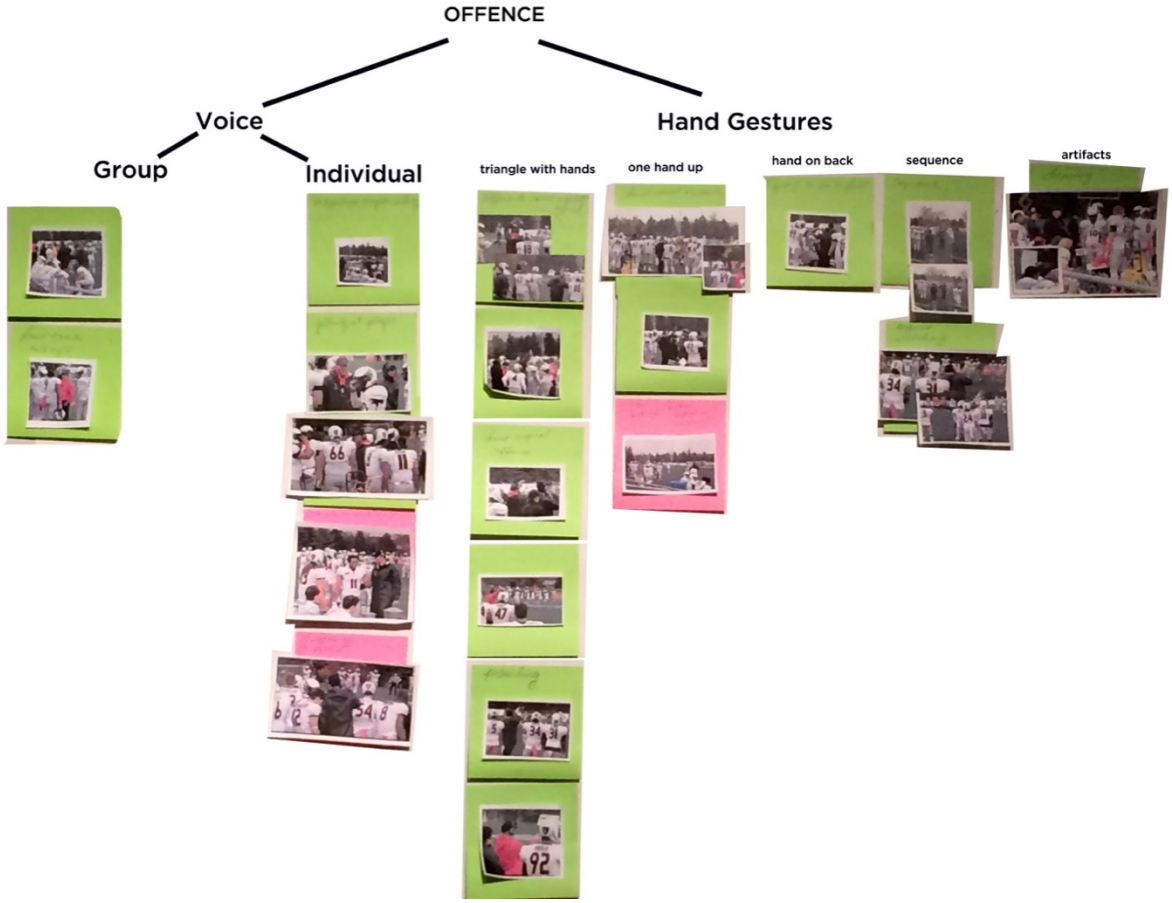

Figure 20 Diagram of Offence signalling

groups: voice and hand gestures. In this particular game, the defensive coaches were visibly more engaged with their athletes off the field, and almost always had a group huddle with either one or both defensive line coach after every line change. Occasionally players (either alone or with one other player) would approach a coach privately and discuss a particular matter. The offensive coaches and players seemed to talk less, but coaches used a drawing board occasionally, as well as referred to and wrote on a clipboard. Although coaching through verbal communication was constantly occurring on

the sidelines once the players came off the field, there was an even greater use of sign language in communicating with players on the field.

Players looked to the sidelines for guidance after almost every play. Coaches used various types of gestures, some types more than others, and sometimes they used a sequence of gestures to complete the message (figure 21). Coaches were seen repeating a single hand signal up to three times, with two to three different gestures constituting the entire signal. Players sometimes looked confused or were not able to see a hand signal due to distractions on the field (figure 22). Given these observations, the first affinity

Figure 21 Coaching signal sequence

Figure 22 Player looking confused

diagram was reformatted to identify specific types of signals and actions performed by the coaches and athletes. Defensive and offensive coaches did not use the same hand signals, although there were sometimes similarities among their signals.

The diagram of player communication methods (figure 23) shows that *watching* is most frequent, followed by *talking* and *huddle*. The athlete-specific diagram illustrates a

high number of images under the *watching* column, where they are looking to receive information. Although huddles happened frequently, the video analysis did not suggest this method of communication posed a problem and it was noted as a method of communication.

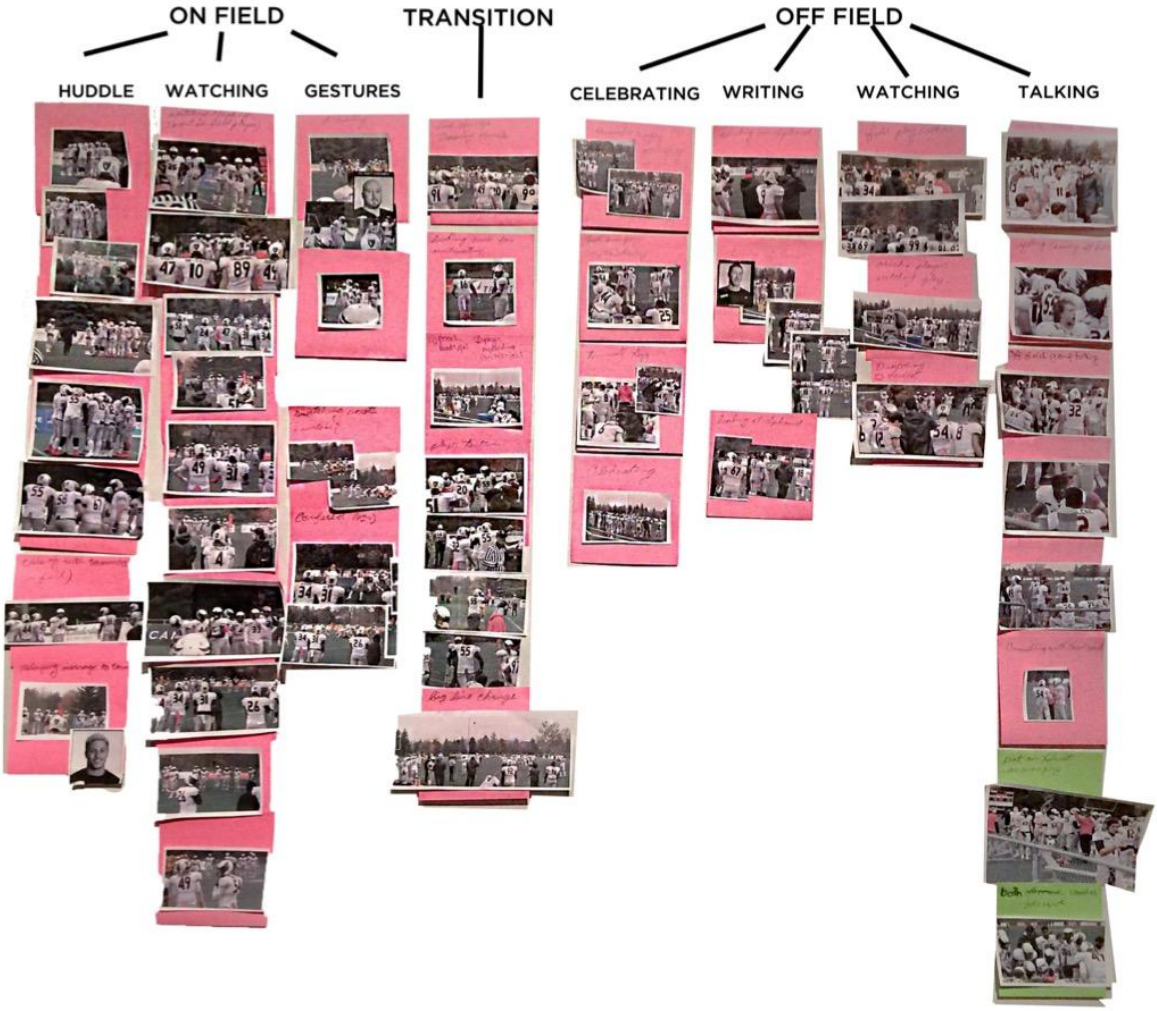

Figure 23 Methods of player communication

These diagrams represent the send and receive methods of communication, which use two different sensory aspects: movement (hand gestures) and sight (looking towards the movement). Questions involving athlete and coach communication arose from these observations, such as how signals are developed and coded, how the team learns the

specific communication culture, and how errors occur during a game. These questions set the foundation for the interview questions in the following phase.

4.3 Interview Results

Interviews with coaches and athletes were recorded and then transcribed. Using the transcriptions as well as notes taken during the interviews, charts were developed in order to categorize and consolidate the raw data (Appendices 8.1-8.5). The findings are classified into the following sections: information translation, coaching and team development, technology and artifacts. These sections summarize the data, which can be found in the interview charts in the appendices.

4.3.1 Information Translation

Communicating Through Signals

Football is more than a performance game: it is a game of strategy. The outcome relies heavily on predicting the opposition's plan and finding a way to thwart it. The Offensive Coordinator of Carleton University's Varsity Football Team put it simply: "The biggest issue is time. But that's what makes sports: having to make decisions and communicate quickly." In addition to time restrictions, teams must be secretive in their means of communicating their plans and strategy in order to out-maneuver their opponents. Since players are not within close proximity to their coach after every play, hand signals and code words are used as a means of communication.

The captain of the Carleton Football team described the process of communicating a play call as having six steps, which combine various sensory aspects that allow the call to be chosen, then translated from the coaches in the media booth to the athletes on the field. Coaches must process information quickly in order to decide on a strategy, and then relay that strategy to the players quickly (within about 10 seconds) in order to allow the players time to understand, prepare for, and successfully perform the play. With such strict time limitations and a lengthy process of information translation, errors in communication are inevitable. Most of the time, the players realize when a play doesn't make sense, and make the best of a bad situation. At the very least, the captain says they follow the basic principle of "don't get anyone hurt, don't turn it over." By "turnover" the captain is referring to allowing the opposing team to take possession of the ball on offence. This can result in a play being "killed" and the team also doesn't make any advances on the field.

Play Calls

There are a few ways in which errors occur in translating a signal. First, a coach could miscommunicate a signal. This is, however, the least frequent error, given that other coaches will likely catch the error before the signal is sent to the players on the field. The second way is through the quarterback. The quarterback communicates most frequently and with a higher number of coaches than the other positions. While this gives him large amounts of advice, it also results in a larger margin of error. The quarterback could miss the signal altogether, which is a rare occurrence. More commonly, the quarterback turns away before the signal is complete, or he is too far away to see

correctly. These scenarios put stress on the whole team, particularly on the quarterback, who ultimately chooses what to do. The quarterback can gesture to have the coach repeat the signal, but this is at the expense of time. If he thinks he received most of the call correctly, the quarterback may choose to head directly to the huddle in order to give the rest of the team more time to receive the call and prepare for the upcoming play. The quarterback on the Carleton team admitted that, in a game, there may be 60 plays out of which five will be misinterpreted and three will completely ruin the play. When converted into a percentage, 5% of play calls sent through signals are misinterpreted. Although this is not a large sum, there is a significant amount of pressure placed on the quarterback to correctly interpret around 60 signals, which can cause anxiety and detract from focus on performance. During his interview, the quarterback shared a particularly negative experience:

> The perfect example would be against Guelph this year. It was in the first quarter at the start of the game and they were doing stuff a little differently that what we had thought. We had just changed formation-like the personnel-so guys were asking questions on the sidelines and were trying to relay the call in, and the coach was trying to give me the call, answering the question and trying to get somebody else in. So it was a complete scuffle of everything. I actually got the call I thought it was supposed to be and the result of it was an absolute awful play.

Probing deeper into the scenario, questioning at which point the communication error occurred, he responded:

> It was misinterpreted but also we have a lot of signals that are similar so if you're not really paying attention or looking somewhere else something looks different than what it is. So when you call the play out and you're in the huddle we're like "wait a second, that doesn't make sense" but it's like "6-5-4- k we gotta snap this thing." So we get the ball, we run it, and there's like four defenders in one area, a guy's coming through on block because we had the wrong protection and we

> ended up throwing an interception. Pretty much the worse-case scenario that could have happened.

In this example, not only did the quarterback fail to receive the correct play, his uncertainty lead to disconnection among all of the players and to misunderstandings about their roles. This scenario also illustrates how coaches can play a role in the misinterpretation of signals. Coaches have many tasks and often need to manage the players off the field as well as keep in contact with the players on the field. When these two roles conflict, sending a clear, correct signal can be challenging. Due to time restraints, a poorly performed signal cannot always be remedied and can result in a disastrous play.

Advice Signals

In addition to play call signals, coaches also have advice signals. These are to inform the quarterback and the various positions about details in the play. Advice signals are more easily missed due to their spontaneous and imprecise nature. A quarterback always looks for the next play call as soon as a play ends, but may not look in the coach's direction when other pieces of advice are sent, especially when there are distractions on the field. Also, although there are generally few problems with communicating practiced plays and basic pieces of advice, coaches are not able to communicate precise tips and reminders.

Calling Cadence

The Quarterback gave his opinion on cadence calling, also referred to as “snap counts”:

> With the signals it's easy because you can see them. But snap counts with the offensive line and receivers…If we're going on 2 and you can't hear, you have to go on body motion.

Errors occur when the whole line, in particular those at the end of the line like the wide receiver, are unable to hear the snap counts. Not only are the snap counts sometimes difficult to hear at all due to crowd noise and distance, they are also coded with different words like "white thunder, white thunder - set - go” so as to keep the play strategy from the opposing defensive line.

Designing a Signal

The design strategy is to use the allotted time between the end of a play and the beginning of the next as efficiently as possible. Coaches want athletes to focus on strategy and the task at hand, rather than deciphering signals and codes. A strict structure makes it easier for coaches and athletes to memorize plays and systematically break them down in order to understand the whole picture. The Offensive Coordinator used this metaphor for signal design:

> I find it's all lego. You need the base legos, and the more legos you put in, the more crazy it gets. But it's just lego, it's just a tag. The tags modify the play in different ways. You know what a tag is you just have to apply it to the play. You can use 100 legos...and that's when we start to use wrist bands. When we use too many legos, it's not even that hard but there’s a 20 second clock.

The Defensive Coordinator stated that, "there's a lot of information that goes into the call." He named such elements as the down and distance, the opposition's predicted play based on their formation, as well as technique and strategy adjustments. He further elaborated with an example:

> Let's say we want to run a blitz where two guys go, you might say a word that has a double letter in the middle…so let's say we want to run a backer blitz in the middle, we call it ammo, so ammo, like guns...you think ammo-guns-so the creation of the signal is being creative and making things relate. So if you're running an ammo blitz you don't want to kick your leg, it doesn't make sense. So the creation of the signal is about making it make sense and having something easy to remember.

While the process of designing a play can seem overwhelming and complex to an outsider, the team is highly embedded in their culture and uses their coded language almost as freely as their mother tongue. None of the interviewees expressed discomfort with their developed culture or the methods used in developing a play call. Due in part to the team's deep knowledge of the sport, play calls are designed almost organically, which contributes to the entire team's ability to adapt quickly to various strategies. This confirms the assumptions developed during observation: the key gap in communication occurs on the field, rather than off the field. When asked if having the whole team learn the signals for play calls would be beneficial to the team dynamic, both the coaches and players responded positively. Both the offensive lineman and captain, who had taken the initiative to learn the signals on their own, said they were able to mentally prepare and strategize more efficiently. This resonates with the defensive coordinator's response: "I think it would help them to play faster, because the more you know the more you can do, and the more you know the less you have to think."

4.3.2 Coaching and Team Development

Pre-Game Preparation

Communication during a football game is based on more than a specific point in time. It is the culmination of hours of conditioning and the establishment of a bonded culture. Pre-game preparation is therefore vital to the success of the game. Little is left to chance and most of the work goes on before the game. After the preparation, a positive game outcome relies on correctly receiving play calls in order to practice into action accurately. Training Camp (attended on university campus, before the start of fall classes) and on-going team building is essential to developing the team's connections. As the team develops their knowledge and grows their cultural awareness, they learn strategies and tools that can be used to reduce negative effects of miscommunication or errors. The offensive lineman who was interviewed said: "pre-game preparation is unique to [each different] opposing team and changes week to week. Putting visual and verbal into practice brings it altogether." A few key steps that contribute to learning the culture, developing the team, and preparing for games.

Learning the Language

Using a combination of technology and classic note taking, the coach enables the athletes to learn and memorize the cultural framework they will employ during the season. Learning the foundations of the culture during the off-season allows the team to focus on learning the specific plays during the season. The offensive coordinator discussed his method for teaching culture during training camp, which occurs in the last few weeks before classes and before the football season begins. He holds online meetings

in which he gives a video lecture to the team. He uses software that enables him to talk while displaying his computer screen, which he uses as a visualization tool. Athletes are encouraged to take notes and make their own drawings in order to reinforce their understanding, as well as to study together or alone. Distinct expressions and vocabulary speed up the communication process and reduce misinterpretations. The captain gave an example of a typical description of a game scenario, which he articulated as if it were second nature: "The guy who was in the 3rd window of the second level is pushing to the second window, so this window is open." This sentence would have taken much longer to verbalize accurately without using the team's unique language.

Building Trust

The Defensive Coordinator for the Carleton Football Team is also the Strength & Conditioning Coach. As such, he has a unique bond with the team and spends more time with them off-field than other coaches. In his experience, "an athlete doesn't care what you know until he knows that you care." His method for building trust and brotherhood amongst the team members is a personal, empathetic approach where he recognizes the athletes as people and students. He strives always to be receptive to their emotions and to read their body language. By developing off-field relationships, he learns how individual players respond to different coaching cues: "Some guys need a pat on the back, some guys need a hug, some guys need a foot in the butt." The off-field time during a game helps the players refocus and move on to the next play. Coaches encourage athletes to distract their minds by doing something such as breathing or taking a drink of water. Part of strategizing also involves feedback from the athletes. Their willingness and ability to

share their opinions and especially admit to an error help the coaches to develop better strategies for the following plays. The Offensive Coordinator elaborated on this statement:

> A lot of the newer guys will have trouble speaking up and being wrong…A big example is when we come back to the sidelines and we try to see everything but it's hard. If they come back and we lost 5 yards but everybody says they blocked their guy, I don't design a lot of plays where everyone blocks and we lose 5 yards.

Building trust is a personal development and no distinct design opportunities were uncovered. However, understanding the relationship between coaches and athletes is a guiding factor for assessing and developing other components of communication.

The Line of Scrimmage

Players must have the ability to pick up the tendencies of the opposing line before the play starts. The ability to focus on basic principles, to remember individual roles, and to communicate effectively creates a positive communication environment. As an example, the offensive line has many sensory tasks to execute once they are on the line of scrimmage. They must look for the safety, find their matchup, listen for cues from the coaches as well as listen for the cadence call from the quarterback. If players have a system to remind themselves of their role, they will be more likely to execute effectively and not get overwhelmed with information, especially when there are changes to a plan or strategy. The offensive coordinator stated that players should use a checklist as follows: "1- where are my guys lining up? 2- where is the safety? 3- what is the cadence?" These simple questions help the players refer back to what they learned in practice and react almost automatically.

4.3.3 Technology & Artifacts

Identification Process

During observations and interviews, artifacts and technology in use were noted. Any type of artifact or technology was placed on a table where they were compared to the artifacts and technology of other teams, including those in the NFL, as mentioned either during the interviews or in the literature review (table 14). This allowed for a broader understanding of technology use and availability beyond the focus group of the Carleton Ravens Football Team.

Technology/Artifacts

Carleton Ravens	NFL/other teams
Gear - clothing - shoes - padding - helmets gloves	Sensory gear - heart rate monitor - wearable sensors
Wrist band (paper sheet on wrist with play calls)	Wrist band (velcro band with paper insert on wrist with play calls)
Headset (coaches and QB off-field only)	Headset (coaches, QB, 1 defence, 1 offence allowed use between plays on field)
Camera - film - pictures	iPad - film - pictures
Visual display - drawing board (off field coaching) - data chart (hand written) - analysis software (post-game data entry and analysis)	Visual display - drawing board (off field coaching) - large posters (off-to-on-field play call signal) - data chart - analysis software (post-game data entry and analysis)

Table 1 Technology & Artifacts used during a football game

Video and Data Analysis

The Captain of the Ravens Football Team talked about the software they use to view videos of their performance as well as that of opposing teams. He was positive about the available content, but expressed the need for something more interactive: “You can't talk to your coach about something you saw, you have to talk to your coach the next day. The program being more interactive would help.” During the interview with the

Offensive Coordinator, he stated that various statistics are recorded by the runningback Coach who is also in the media booth. The charts used to document the data are a custom design that was streamlined through trial and error. Although the coaches tried to use computers at first, they found pen and paper to be a faster data entry solution. Although the coach did not specifically mention dissatisfaction with the current method of data entry and analysis, he did state that the post-game task of inputting all the data into the software used for analysis the following day was tedious work.

Headsets

As discussed in the literature review, headsets have been used in the NFL for a few decades. While the varsity team is limited to off-field use of headsets only, the NFL has allowed for select players to have audio feedback implemented in their helmets to be used between plays. During interviews, both the coaches and the athletes expressed that keeping the line of communication open longer would improve communication and effectiveness of play call transfer and allow the coach to offer advice without having to use hand signals.

Wrist Bands

The coaches and athletes referred to a piece of paper tapped to the quarterback's wrist as a wrist band, which can be more realistically described as a "cheat sheet." Long play calls which are difficult to signal are written on the cheat sheet. The literature review also describes a manufactured Velcro wrist band into which the "cheat sheet" is inserted for reference. The wrist band play call is developed in practice, as strategies are

developed and pieces are added to plays. When the play becomes too complex to be signaled in parts, it simple becomes “wrist band 1” which has a shorter signal. The quarterback sees this, refers to his band, and continues with the communication process. Although the wrist bands can help in signal transmitting accuracy, they do not ensure privacy because a hand signal still has to be performed.

4.4 Summary

The research methods in this study follow an organic, exploratory trajectory. The initial inquiry into fitness tracking through an online survey deviated to focus on the sport performance context, where the needs of the high performance athlete are not being met. The following phased focused its inquiry on a specific sport, football, where the raw data from observing football games highlights the high frequency of both sending and receiving signals by the coaches and athletes in an off- field to on-field scenario. There is also a differentiation between offence and defence where different voice and hand gestures are used as the primary tools for sending signals. Also, the athletes have a distinct behavioural pattern depending on their physical location. For example, when they are on the field, they look to the sidelines after every play. In interviews, more information was revealed about the nature of communication between players and coaches. Both coaches and players agreed that limited time is a key determining factor in proper signal execution, transmission, reception, and action. A poorly received or interpreted signal could be detrimental to the whole game. From the players’ perspective, hearing the play call adjustments at the line of scrimmage is also vital to the success of the play. On a higher level, the basis of interaction is the team culture, which is learned

outside of a game. The culture guides the communication outputs through environmental parameters, as well as meaningful notions and terminology. There is a relationship among input, process, and output based on the results elicited by the research methods. The layers and limits of the information processing system relating to the football context are initialized by learning and practice, which leads to in-game signalling in order to produce autonomous action and achieve the outcome goal of stopping or moving the ball.

5.0 INSIGHTS

5.1 Overview

This section synthesizes the results from the previous chapter into cognitive and/or action insights. In some instances, participants' opinions regarding behaviour are considered in both the cognitive and action spaces. Cognitive insights involve any data that pertains to the participants' thinking, mental capacity, or opinion. This is seen primarily in the first phase, the survey, and the last phase, the interview. Action insights involve kinetic movements relating to field observations or statements made by the participants regarding their actions on the field.

5.2 Survey Insights

As discussed in the literature review, ubiquitous computing in sport performance is relatively new and still evolving. Due to their increasing popularity, fitness tracking devices were investigated as an initial pilot study to establish user needs. Figure 24 focuses on the main theme of the survey: tracking. It was structured using the subcategories of "tools," "experiences," and "acceptance" to identify the types of artifacts or technology implements the users are currently employing, their experiences with those methods, distinguishing between positive and negative, as well as the researcher's insights on the acceptance of technology. The "experience" and "acceptance" categories were colour coded in accordance with the tool used, where relevant, in order to demonstrate visually which tools resulted in either positive or negative experiences. The subsequent affinity diagram (figure 25) for the survey analysis was designed to detail the

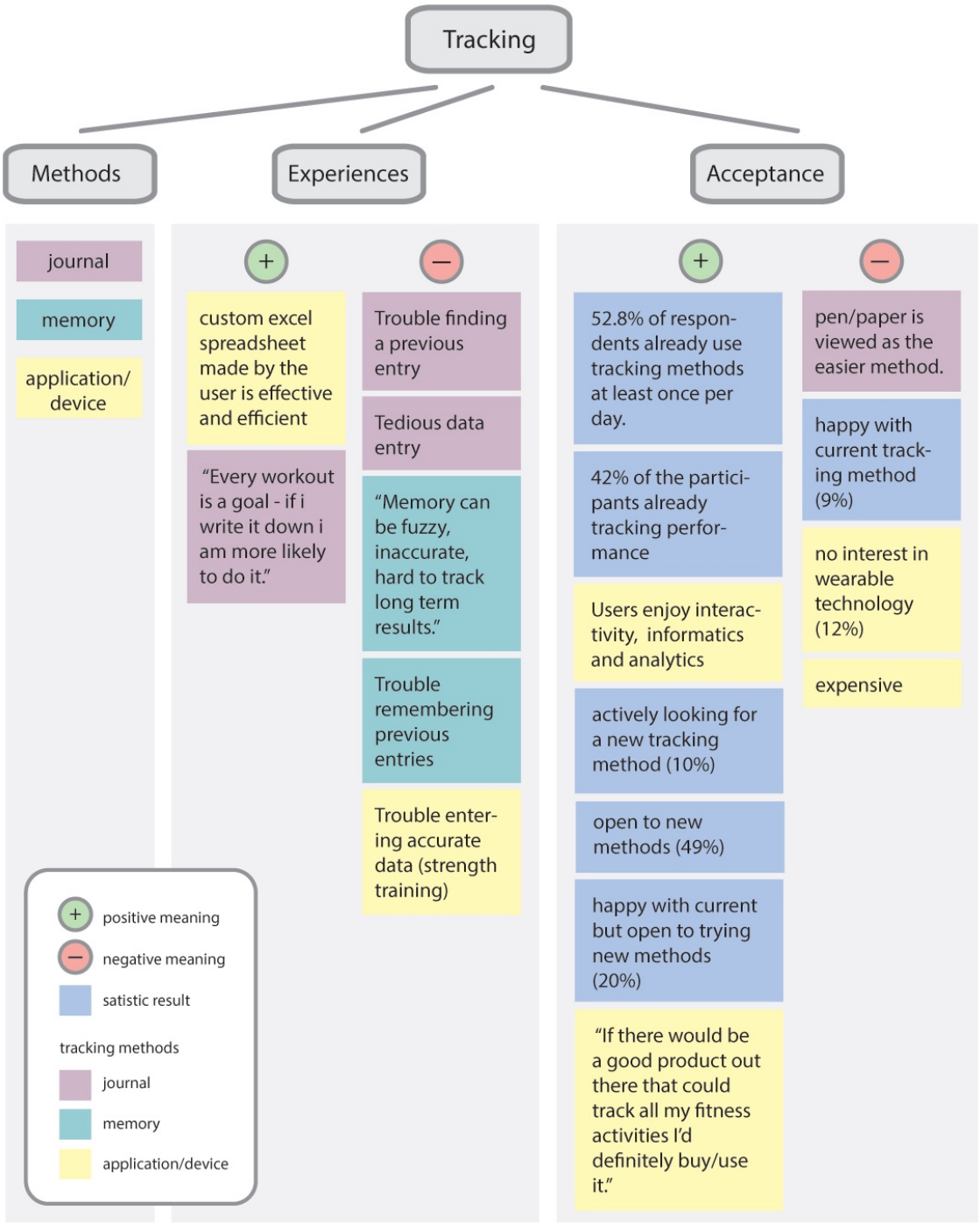

Figure 24 Affinity diagram of tracking

final tags of the preliminary framework. The replies to the last question of the survey asking the participants for any additional comments and criticisms were surprisingly insightful. They ranged from aesthetic appeal to recommendations on software, features,

and functions. Where not explicitly expressed, user needs and motivations were determined based on interpreting the tone of the comment. In general, the main motivation validated the hypothesis that users are seeking improvements in performance. Their needs, although varied, suggest an implementation that would be simple, unobtrusive, and express their performance data visually.

Motivation	User Needs	Comments & Criticism
analysis & learning	fast data entry	"If it's not pretty I'm not wearing it"
improve on previous performance (time, distance, strength)	post-workout review (data analysis)	"I likely would not wear a device but want some device/software to easily track workouts."
specific progression /training regimen	visuals (graphs & charts)	"I wore a heart rate monitor for a while but it got in the way during some lifts - plus I didn't like the watch on my wrist. I also don't like doing most of my workouts with my mobile device on me."
"To continue to improve upon past performance whether it be increased use of weight or times."	unobtrusive	
"I try and balance nutrition, sleep and exercise with a busy schedule."	simple	"Current technology seems very "algo-centric" i.e. data is inferred instead of being directly measured. Some tech. breakthroughs are probably required before they can adequately measure all body activity in a useful way."
"Increase weight used during exercise"	suit current lifestyle and habits: culture	"One app/place would be ideal"
	tracking method for strength training	

Figure 25 User motivation, needs, comments, and criticism regarding tracking technology

5.3 Observation & Field Study Insights

The ethnographic field study was synthesized through a sequence of methods. First, video was reviewed and screen shots of various communication patterns were

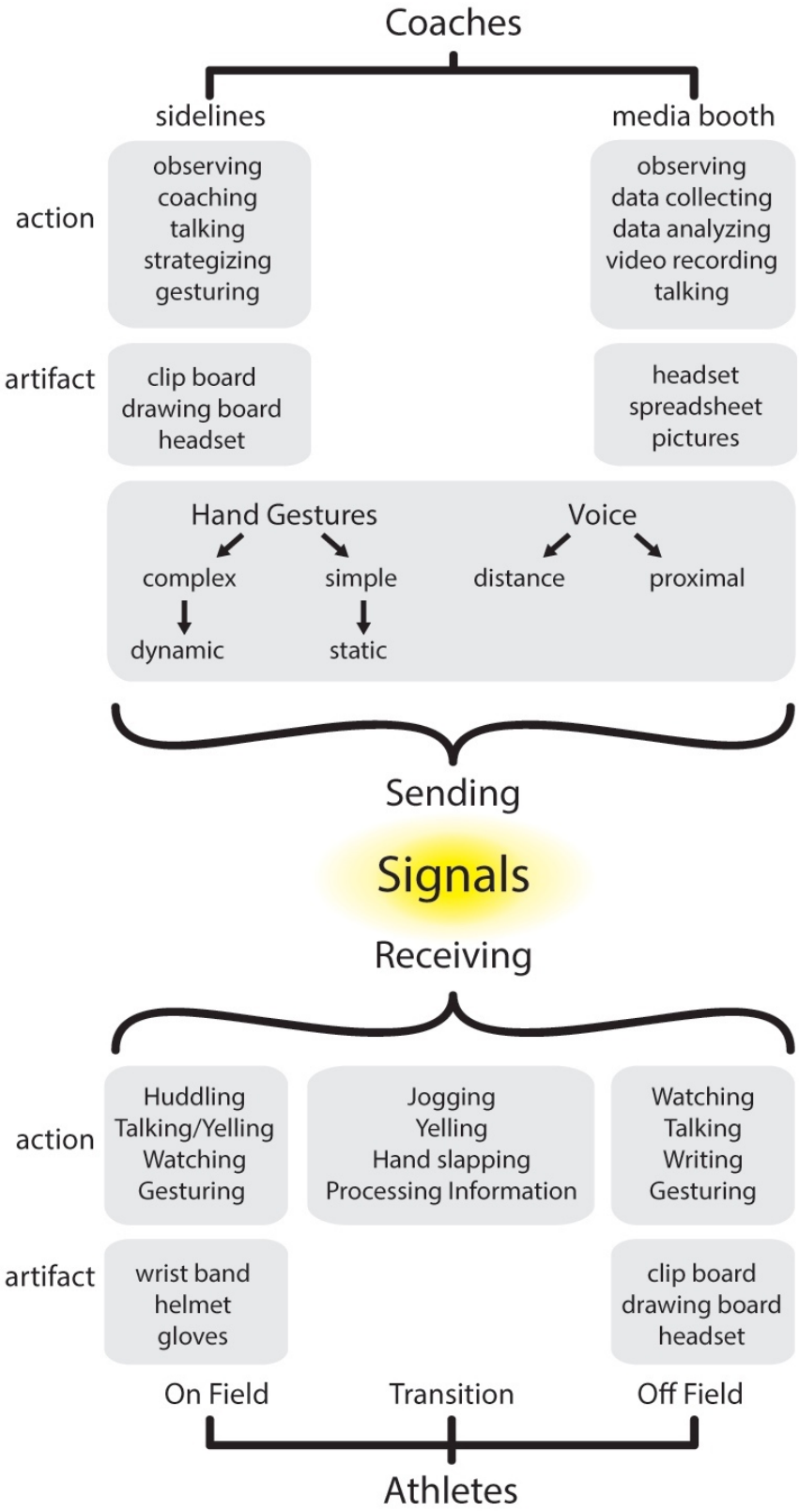

Figure 26 Sending & receiving signals between coaches and athletes

captured. Second, a flow diagram (figure 26) was made as a means to visually express observations relating to communication such coaches sending signals, players receiving signals, physical spaces, and artifacts being used. This first representation of signal structuring was a means to brainstorm the communication actions occurring during a game where the hypothesis that signalling plays a key role in communication is established.

5.3.1 Soundscapes

Prior to further exploring sending and receiving signals, another diagram was created as a visualization tool to conceptualize a football game's soundscape. Farina

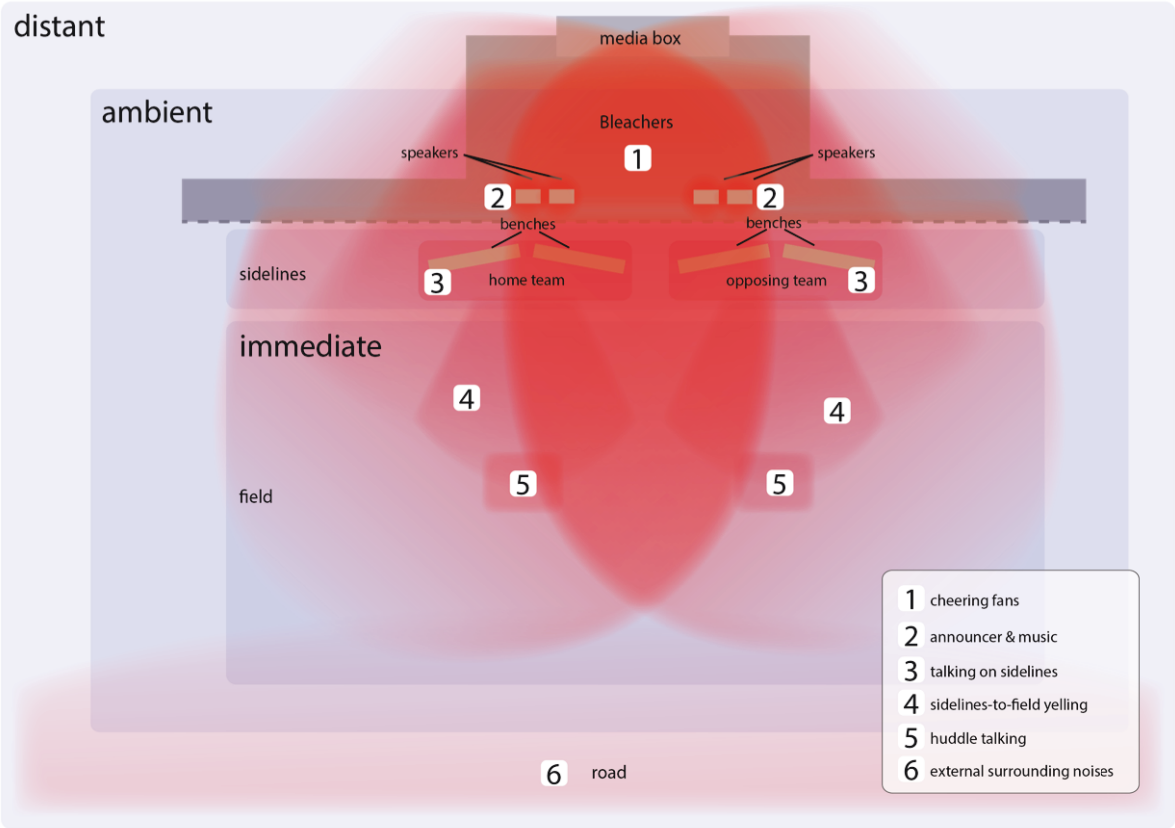

Figure 27 Conceptual representation of sound on the football field

(2014) states that "The soundscape can be simply defined as an acoustical composition that results from the voluntary or involuntary overlap of different sounds of physical or biological origin" (p.3). In figure 27, layers of sound are represented conceptually in order to begin to understand how communication between coaches and athletes might be hindered or helped depending on spatial constraints. Elements emanating sound are represented using a gradient to indicate diminishing sound quality over distance. The area receiving the most sound is the middle of the diagram, where there is overlap of cheering fans, players and coaches talking and yelling, and speakers blasting music and announcing the action on the field. In this area, coaches and athletes must yell at one another or use hand signals in order to be understood. Similarly, while the extremities of the field are quieter due to the limited outreach of the projected sounds, distance diminishes the quality of sensory reception, meaning players are unable to hear coaching cues and visibility of hand signals is reduced. The distance of players from their coaches seems therefore to reduce communication efficiency. This assumption derives from the notion that people perceive, understand and interpret information based on the acoustic environment (Farina, 2014). Through video analysis, depending on the whereabouts of the action on the field, once the play ceased, players did not appear to have time to position themselves optimally to view and hear cues from their coaches.

5.3.2 Sensory Use Analysis

Observations showed sending (by hand gestures) and receiving information was the area of communication with the most margin for misinterpretation based on spatial orientation and positioning of the athletes on-field, the frequency of use of hand-gestures by coaches, watching for signals by athletes, and general athlete behaviour. An affinity

diagram (Appendix 4) grouped actions under their allocated location, with the addition of colour coding to represent the type of sensory action as a visual reference to the types of signals being used to communicate.

Observations revealed types of senses used to communicate which are described and tagged to indicate location, specific person (player or coach), reason for communicating, and so on (figure 28). In the subsequent figure (29), primary communication is distinguished as essential, active, and deliberate communication with the purpose of yielding a specific outcome goal, which, in this case, is to move the ball (offence) or stop the ball (defence). Primary communication is mostly expressed in the form of sound and sight, where language and code words are either spoken or signaled from coaches off-field to players on field. Although the primary touch actions of huddling and payer-to-player collisions can also be considered autonomous actions, they are distinguished in their own section to separate their cultural nature (as opposed to a reaction to sight and sound signals). Where cultural patterns are mostly situated in the

sense	description/limitations	tags
Sight	the most important but the most easily missed based on distance and distractions.	Private Coaching Visualization tool
Sound	has limitations based on distance due to surrounding levelts of sound.	Long distance Direct
Touch	can only be used at proximity mostly to raise moral and positivity.	Encouragement Empathy Excitement
Autonomy	the active result of receiving and processing sensory information.	Active Movement

Figure 28 Sensory modalities in order of perceived importance along with with description and a contextual use tag

secondary communication column, huddling and player contact are highly influential to the game's outcome, and therefore considered primary. Secondary Communication is distinguished by body language and actions performed as a regular routine (line changes) or circumstantial (cheering, encouraging). Ultimately, sensory cues such as visual signals or auditive language lead to autonomous actions that contribute to the overall outcome goal of winning the game by moving and stopping the ball in order to score or prevent points from being scored. The purpose of distinguishing between primary and secondary communication is to create a focus on the primary methods, in particular sight and sound, with which to formulate interview questions for the next phase of research.

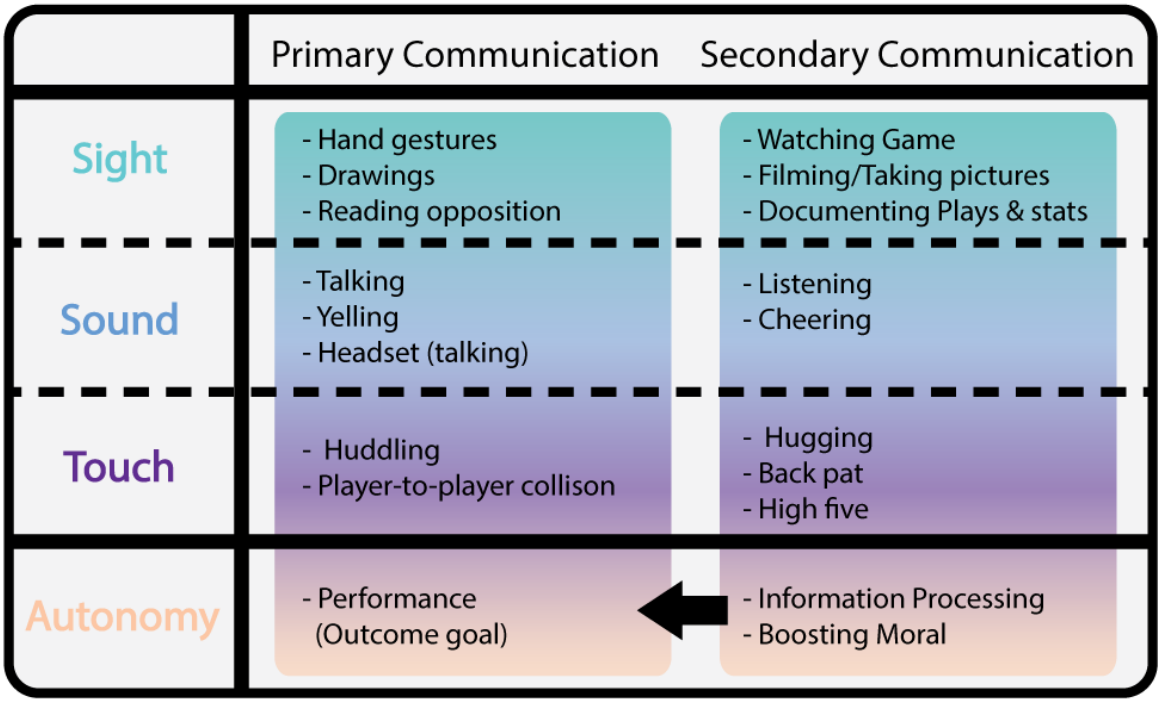

Figure 29 Separating senses into primary and secondary communication methods based on their influence on the outcome goal

5.4 Interview Insights

The final phase of this study's methodology, interviews, served as a summative inquiry into the problem space of communication in football. The interview phase identified three prominent times for the varsity football team: pre-season, in season pre-game, and in game. Using a similar structure as the interview charts, a journey map highlights communication touchpoints and their accompanying sensory actions (figures 30 & 31). The sensory actions relate to the findings from the observation phase, identifying visual, auditive, tactual, and autonomous actions. Location is included as a reference for the type of communication involved. The main question these diagrams address is how communication surrounding a football game transpires. From a sensory perspective, these diagrams expose both sensory modalities and artifacts used to enhance

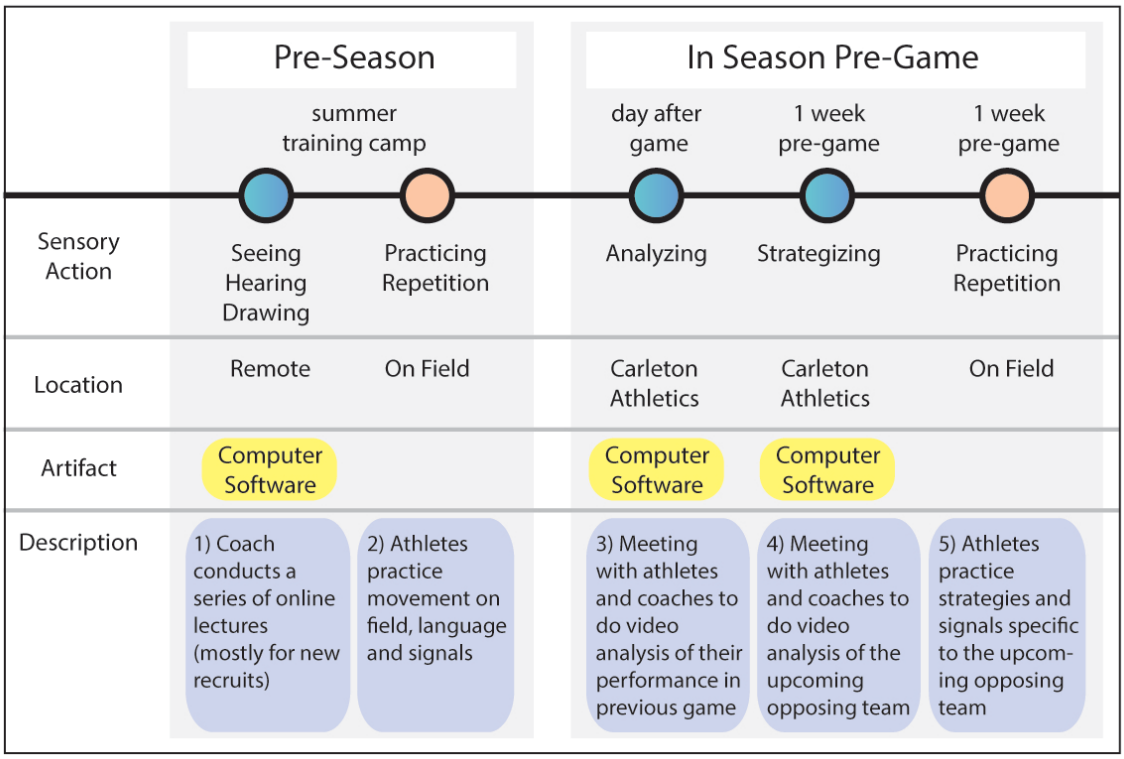

Figure 30 Pre-season and In-season pre-game journey map diagramming sensory actions, locations and artifacts

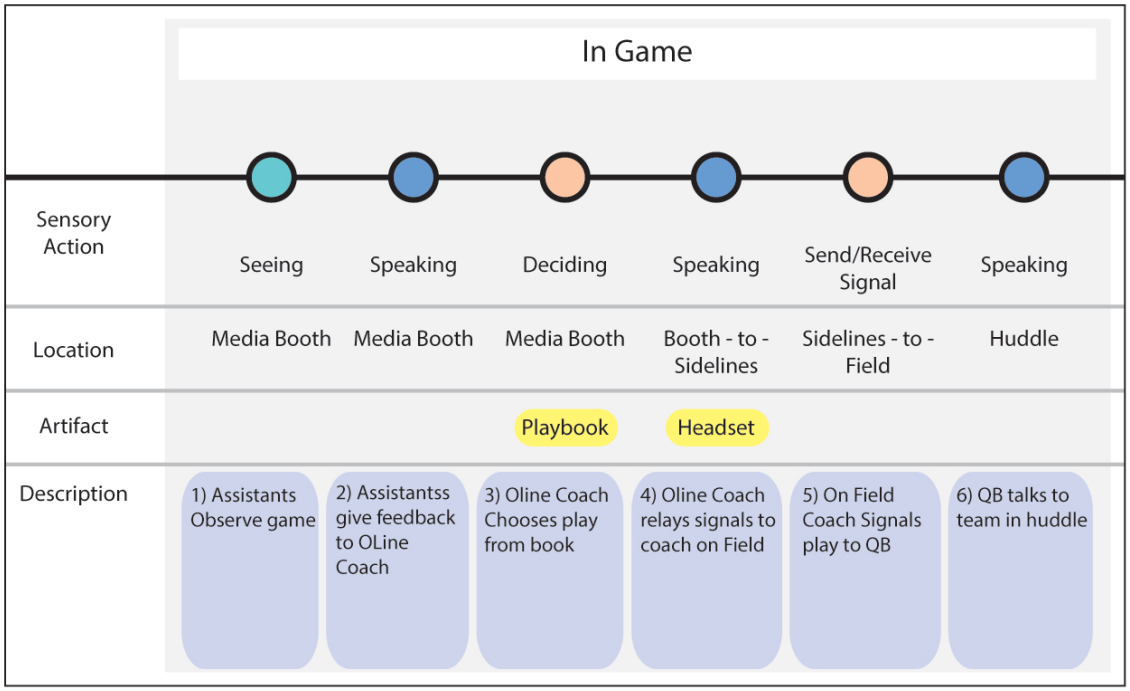

Figure 31 In game journey map diagramming sensory actions, locations and artifacts

those senses. Finally, the description in the last row provides clarification of the particular touchpoint, identifying who is acting.

Figure 32 shows the spatial configuration of the players and the coaches, as well as two scenarios in which play calls are transferred. In the first example, the offensive line is waiting for a turnover off field. They have direct contact with their coach and the quarterback uses a headset to discuss the play with the offensive coordinator in the media booth. The second example illustrates the plays that occur during the series, when the offensive line and quarterback do not come off the field. While the athletes are able to give and get feedback from their off-field coach in the first example, in the second example they rely on each other for support. In both situations, the cadence calling is the same because the call is finalized once the opposing team lines up.

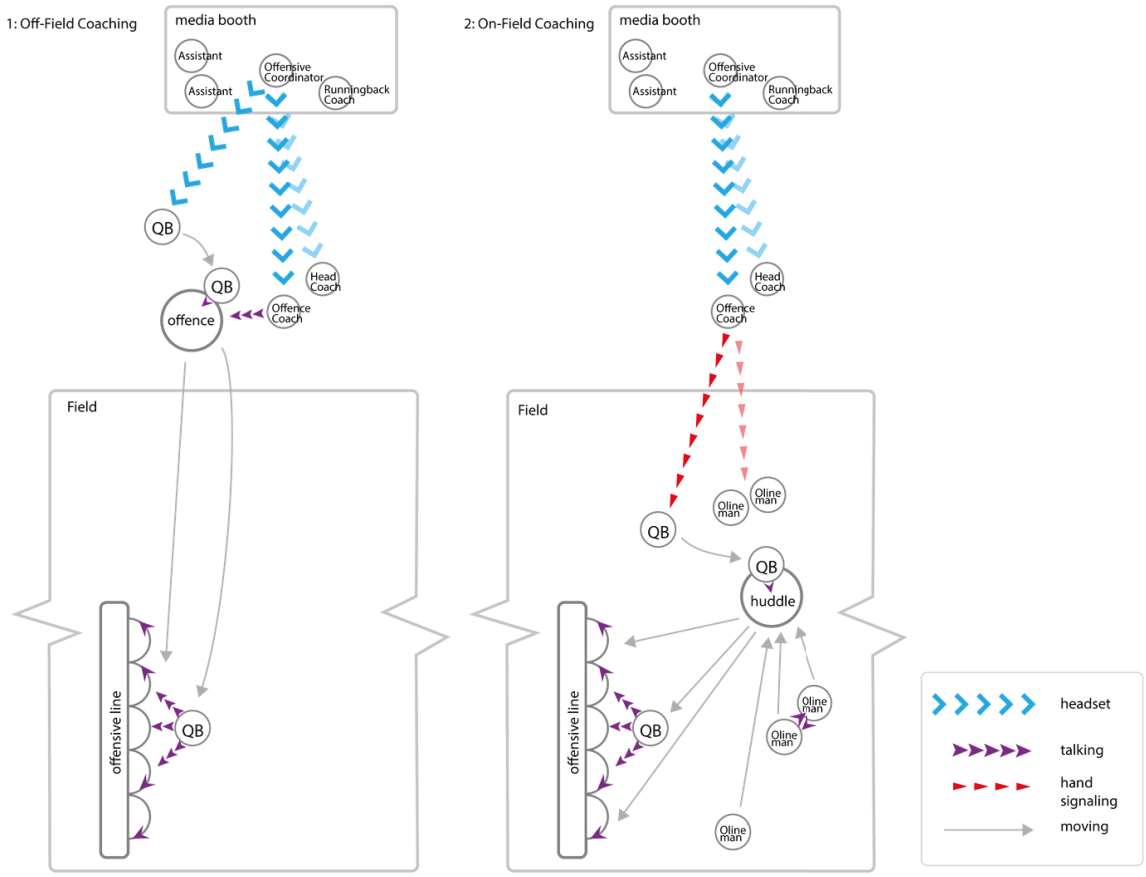

Figure 32 On-field spatial configuration visually conceptualizing information translation as players transition onto the field of play.

5.5 Summary

Following the layers of analysis and exploration of the three phases of research (survey, observations, and interviews), sensory actions were sorted and communication patterns were assessed. Essentially, as shown in figure 33, hand signals are used in a game situation both as a tool for privacy and a means to convey a message when distance prohibits using the easiest

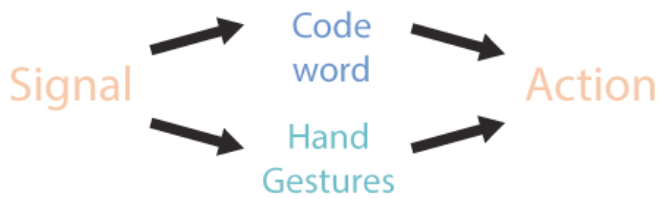

Figure 33 High level off-field to on-field communication process

method of communication, verbal language (sound). To further complicate the communication process, play calls, advice, and cadence calls are all conveyed in code so as to maintain secrecy from the opposing team. This code is further translated into hand gestures, which must be both not too complex and not too simple (again, to avoid opposition gaining an advantage), and finally these gestures are transmitted to the athletes on field via hand signals. On the receiving end, athletes, especially the quarterback, are tasked with receiving the signals, correctly interpreting them, and effectively communicating the call to the rest of the team. Although this intricate communication sequence does not result in large numbers of errors, anecdotes recounted both during the interviews and in current NFL news prove that even a few misinterpretations can result in drastic repercussions.

The findings drawn from the surveys, observation, and interviews highlight a few key concepts. First, technology is increasingly accepted and adopted in everyday life and in high performance sport. Second, people are looking for effective and efficient methods of tracking their personal data. In varsity football, technology may address the limitations and communication errors that occur during a game. They may reveal opportunities for improvement of the current communication system, which is hindered by sensory limitations. Finally, the insight that communication needs to be improved resonated in the interviews with players and coaches.

6.0 DISCUSSION

6.1 Overview

This study focuses on the problem space of communication in football in order to explore how it may be improved through the design of ubiquitous computing devices The findings in the previous chapter indicate that sensory cues are not optimized for performance during football games. Insights from the literature review about user environments is triangulated through synthesis with details about the ways that signalling cues are hindered in football. The key user-centred design issue is the sensory aspect of communication in football, and so invites a focus on interventions to overcome sensory limitations.

6.2 Information Processing

Human cognition determines the relationship between communication and athletic performance, and it can be augmented by emerging technology. As noted in the literature review, psychology models demonstrate the concept of sending (input), interpreting (processing), and making an objective meaning (output) out of the information being communicated (Anderson, 1983; Bandura, 1977; Peirce, 1931-58). Other models incorporate performance wherein a sensory stimulus (input) is perceived or identified (processed) and acted upon (output) (Jarvis, 2005; Mackenzie, 2006). Additionally, Bandura's Social Cognitive Theory Model (1977) and Bailey's (1996) Human Performance Model demonstrate the correlation between environment (context), cognition (person), and behaviour (action). Baca et al.'s (2009) simplified information

processing loop adds technology to the process, addressing the transfer of information from a sensory and biosignal standpoint. Merging these models (figure 34) reveals a correlation with information processing and learning in sport performance (Jarvis, 2005; Knapp, 1963; Jowett & Cockerill, 2002; Hays, 2012). The findings from the observations and interviews in this study also resonated with the process of "communication," "interpretation," and "performance" where information is coded, transmitted as a signal, processed cognitively and results in action on the field. Within the context of information processing in football, ubiquitous computing (ubicomp) provides feedback to augment

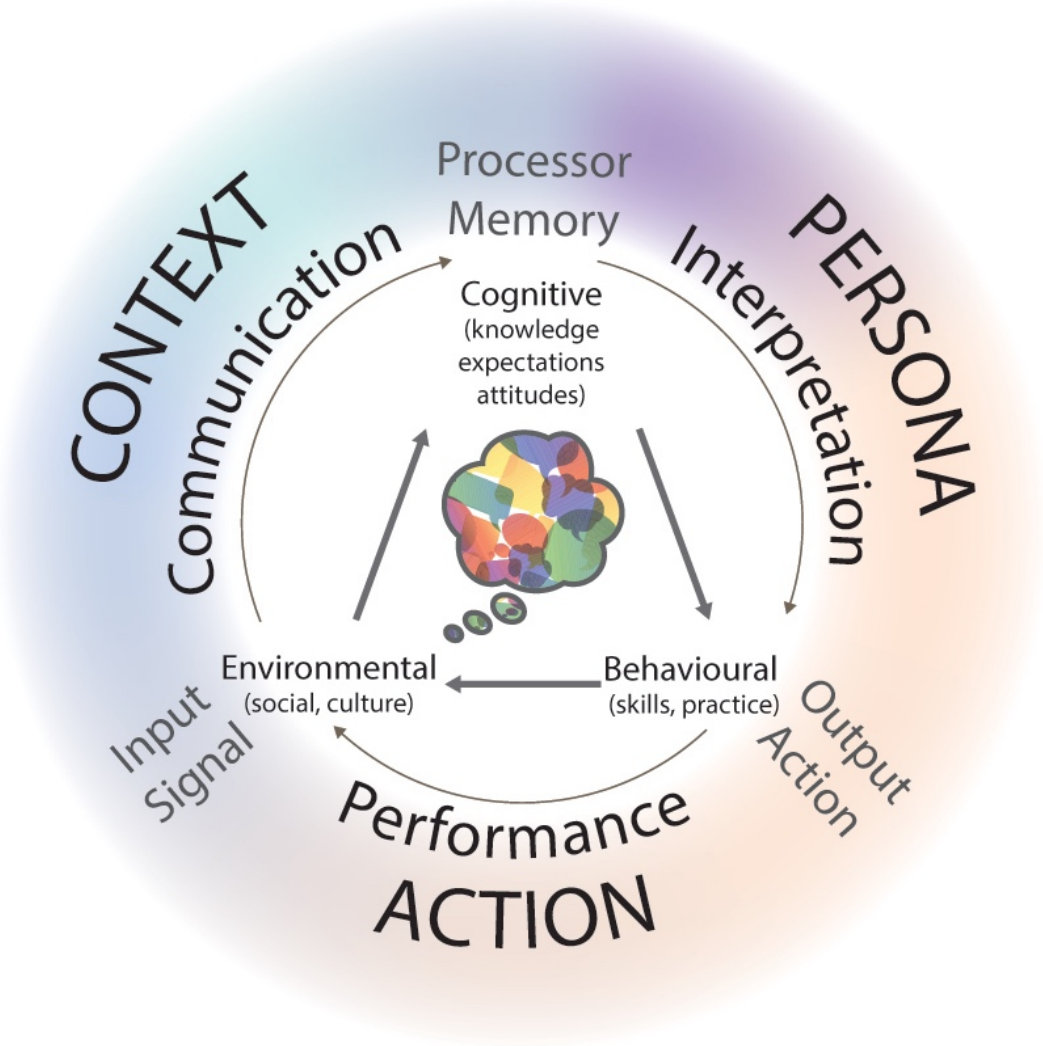

Figure 34 Interpretation of psychology information processing models

awareness of player's biosignals, assists in analyzing and strategizing plays, and enhances communication through auditive technology (Battista, 2014; Branch, 2006; Harvard ilab, 2014; Wyngaarden, 2012).

The first research question that guided this study was: what is the context of use for Ubiquitous Computing from a fitness tracking perspective? It seeks to explore how Ubicomp and fitness tracking are related to human information processing during sports activities. The survey findings support the information from the literature review (Fox & Duggan, 2013; McClusky, 2009; Watson, 2013), indicating that most people track multiple aspects of their lives, whether by memory or by use of technology. Figure 35 synthesizes the results from the methods where user needs are linked to fundamental usability metrics functioning as heuristics in user experience design (Bailey, 1996;

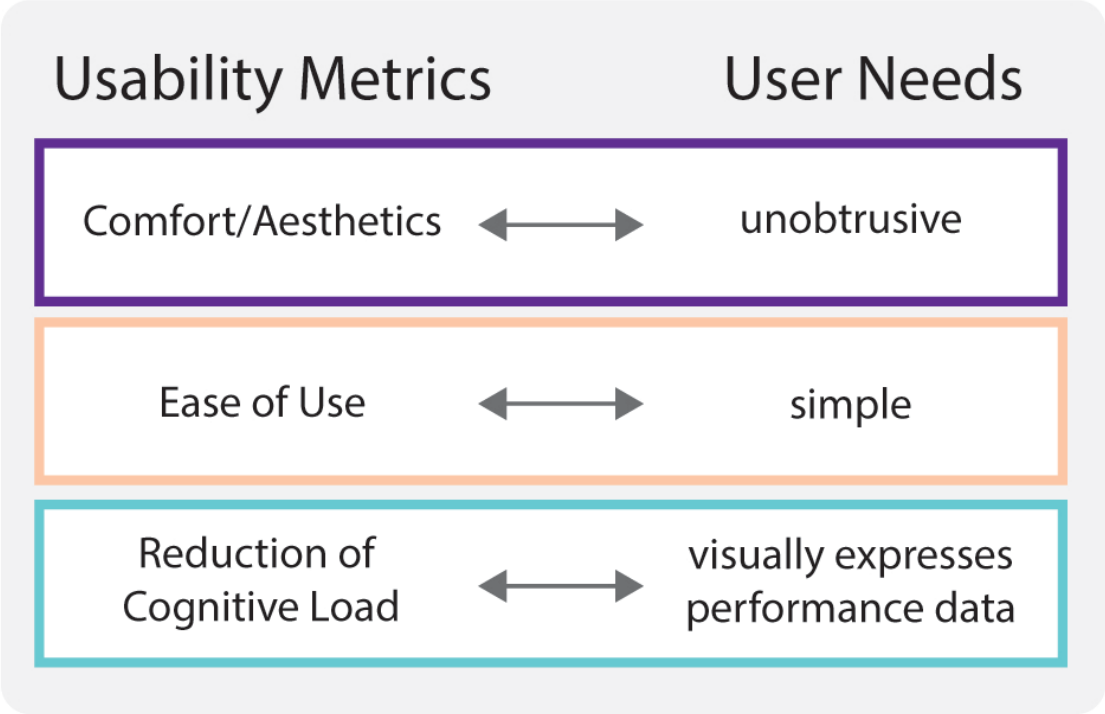

Figure 35 Key user needs interpreted as heuristics for optimizing performance

MacKenzie, 2013; Nielsen, 2014). The results of the survey showed that various tools and devices are used to track performance, resulting in varying levels of acceptance. Survey participants offered elaborations that were similar to interviewee statements expressing the need for something simple, unobtrusive, and visually expressive of performance data. The findings from the survey indicated participants had trouble recalling information from memory, as well as retrieving archived data from journals. Conversely, participants who used technology expressed ease of use and comprehension of their performance data. The subjective values, needs, and expectations of the survey participants reinforce the assumption that human error plays a role in the problem space of communication. Processing, both human and computer, determines effectiveness and efficiency of action. First and foremost, efficiently and effectively understanding the performance data being communicated and being able to apply it for future performance is the fundamental value of ubicomp in personal data tracking both for "quantified selfers" and athletes (Harvard ilab; Watson, 2013; Wolf, 2010).

6.3 Spatial Analysis & Sensory Uses for Communication

Human Computer Interaction (HCI) and User Experience Design (UXD) theories that relate human behaviour and processes to technology discuss human performance limits in terms of semiotics and sensory stimuli (Craib, 2013; Bailey, 1996; Malnar, 2004). Where a pure technological perspective to information processing is comparable to human processes (input, process, output), human behavioural factors add the complex psychological and cognitive variables such as stress and emotions, memory capacity and

cognitive load, as well as communication errors due to environmental sensory impedance (MacKenzie, 2013).

During the observation phase of research, soundscapes and environmental factors were documented in order to acknowledge the extent of sensory over-saturation both the players and coaching must overcome in order to execute plays. Based on their current methods of communication, information is translated multiple times by multiple people before it is converted to action. Figure 36 illustrates the field study observations in relation to information communicated during interviews. There is a great deal of sound impedance due to sound overload and distance, which makes verbal communication difficult to use for off-field to on-field communication. Although staff, coaches, and

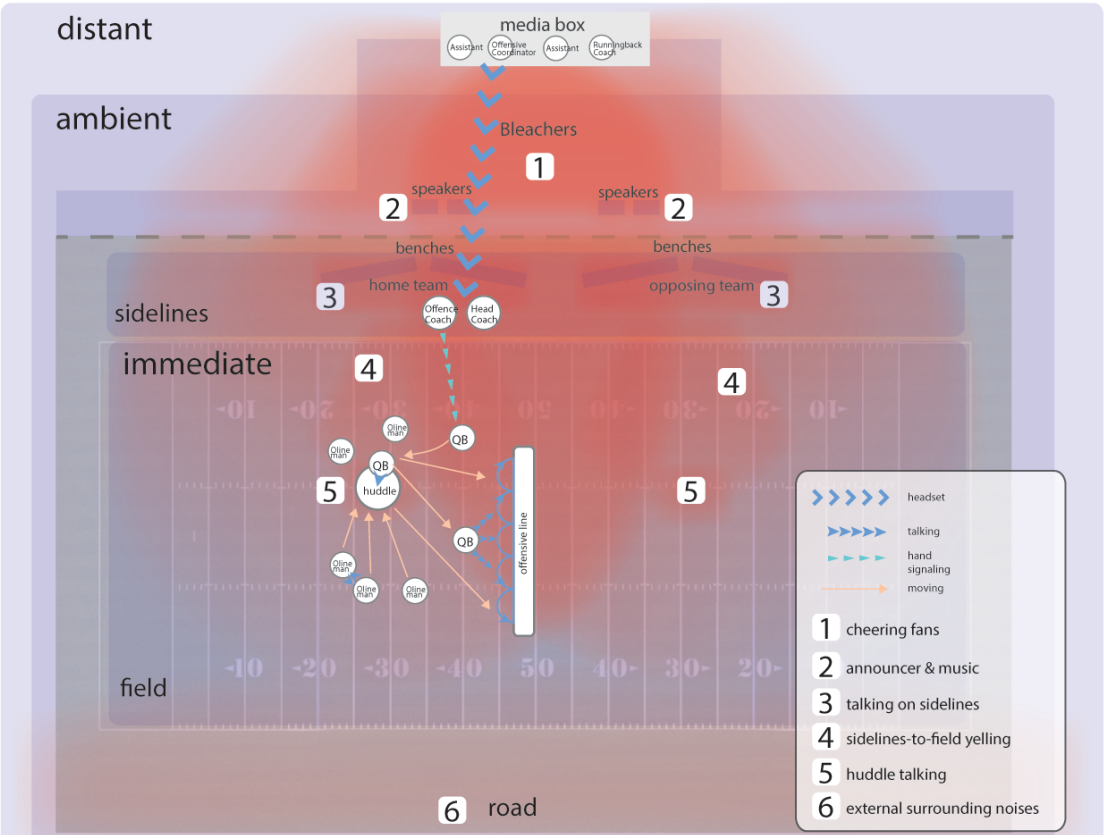

Figure 36 Conceptual representation of soundscape, movement, and information translation

select players use headsets and earpieces in order to enhance their verbal communication (their ability to transmit and receive sound), NFL news releases and interviews with the Ravens Football team indicate suboptimal effectiveness. The Offensive Coordinator of the Carleton Ravens stated that although the quarterback can misinterpret a signal, there are two more possible negative outcomes: the quarterback correctly receives the signal but conveys it incorrectly, or the quarterback correctly receives and translates the signal to the team, but one of the other eleven players does not hear it properly. Matt Hasselbeck elaborated on the inefficiency of the current audio technology during a Harvard ilab panel discussion (2014):

> The coach to quarterback system hasn't changed…he'll say [a play] into the helmet but you can barely hear it. It's like on a walkie talkie, the technology has not improved…there's a receiver and two speakers and AAA batteries in your helmet …we want the best and brightest minds in the world to take a look at what we're doing on the field - it's a huge industry - and make it better. (13:40)

Figure 37 illustrates the multiple steps involved in transmitting a signal, each of which carries the risk of misinterpretation. Where talking and listening (auditive) is the

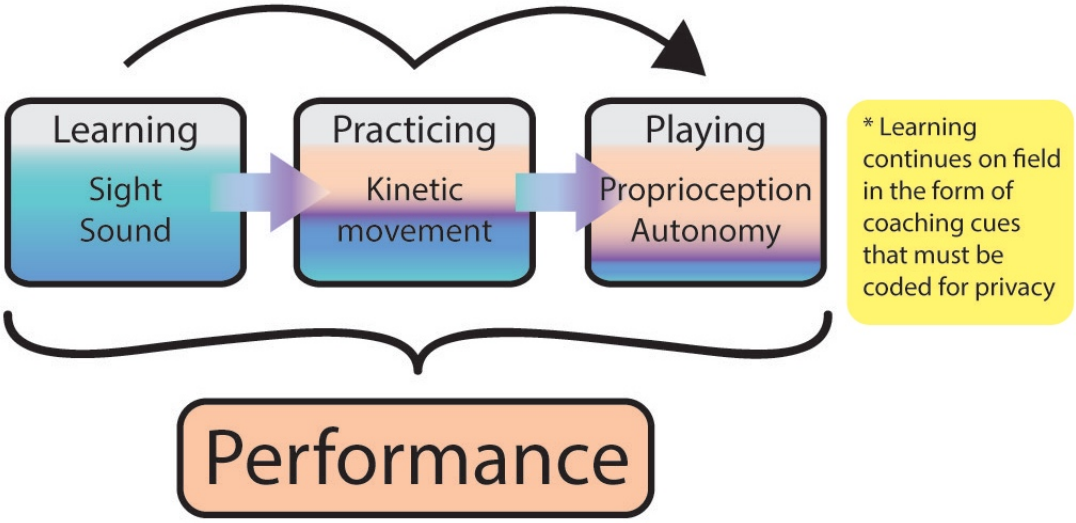

Figure 37 Sensory modalities related to learning, practice and performance

preferred method of communication, the technology used to enhance auditive communication is not optimal given the high level of background noise in and around a football field. Finally, the complexity of transmitting a play call through hand signals to be observed and interpreted can be overwhelming, confusing, and most importantly time-consuming, all of which can negatively affect the outcome goal.

6.4 Translation

Learning the culture and technical skills required for football, as in any sport or system, starts with conveying information through sight and sound. Following visualization and vocalization, physical practice involves kinesthetic and somatosensory movement in order to develop proprioception and autonomy (Desmet & Hekkery, 2007; Jarvis, 2005; Koskinen, 2012). The system of learning, practicing, and playing contributes to executing the outcome goal of moving or stopping the ball (figure 41). The performance is in constant flux due to the dynamic, strategic nature of the game. Where learning is controlled and put into practice in preparation for a game, it also continues to drive performance on the field of play in the form of coaching cues.

The second and third research questions focusing on contextual inquiry explore the sensory and technological parameters of a football game. Technology development in football mostly addresses safety (especially concussions and impacts) and broadcasting (Battista, 2004; Borys, 2014; Boy, Ball & Aughey, 2011; Branch, 2006; Davis, 2013; Fox, 2014). Aspects of technology are also used in analytics software that enables reviewing and strategizing through visualization of performance data. Data can be entered and expressed in charts and graphs, and video can be analyzed, slowed, drawn on,

and so on in order to enhance the learning experience. These uses of technology do not address the high-stress, dynamic in-game point of communication, where players and coaches still rely on outdated methods of signalling and yelling. In a panel discussion with Harvard ilab (2014), the Indianapolis Colts quarterback Matt Hasselbeck stated: "People would be surprised at how primitive football is in terms of technology; nothing's changed." During the interviews, all five interviewees (both coaches and athletes) described an identical communication process. Despite the fact that game situations will dictate, with no particular order or quantitative metric, the ways in which these processes unfold, the field study and interviews qualitatively validate the theme of putting practice into action. For example, the defensive coordinator was heard saying "do your job" three times to the players on the sidelines, which was a call to action for the players to remember and execute their roles. Due to human sensory limitations as well as the specific strategic context of football which necessitates privacy from the opposing team, visual cues and verbal codes are used in place of the standard English language.

Table 2 was constructed following the interviews in order to summarize the factors most influential to team success and overall sport performance. Following the assimilation of quotes and key words gathered from the study's findings, three categories were created: Knowledge & Culture, Trust & Teamwork, and Conditioning. These categories are tagged and described in order to understand the pre-game context of athletes and coaches. Interpreting the categories in terms of sensory modalities serves to demonstrate where and how sensorial uses guide team success. From learning, to building better communication, to game performance, sensorial success factors transition from language development, to autonomous trust, to multi-sensory conditioning, as seen

	keyword	description
LEARNING Knowledge & Culture	language	coding movement and spaces
	mapping	simplifying the field and body parts into coded sections
	adaptation	adjusting over time
COMMUNICATION Trust & Teamwork	confidence	ability to speak up, admit error
	development & maturity	tone down anger, brush things off, stay composed and focused
	reliability	knowing that everyone is on the same page
PERFORMANCE Conditioning	practice	kinesthetic/somatosensory movement
	talking & analyzing	using software to analyze past actions and strategize/plan for upcoming opponent
	visualizing	tools like drawing, watching video, looking at charts or graphs to help understand and remember movements, plays and strategies

Table 2 Key factors for team success

through the process of applying learned culture, though communication, to athletic performance. Observing the players on the field looking to the coaches off the field making hand raised concerns regarding signal reception. Coaches sometimes have to repeat complex signals repeatedly, and the result is sometimes a missed play or failure to achieve the desired outcome. From a UXD perspective, the outcome goal of moving or stopping the ball is achieved by correctly executing the tasks of sending and receiving

signals; in other words, communicating effectively despite sub-optimal sensorial conditions.

6.5 Sensemaking

Communication activities that support performance goals employ multiple sensory modalities. These modalities are autonomous in nature on the field of play. They

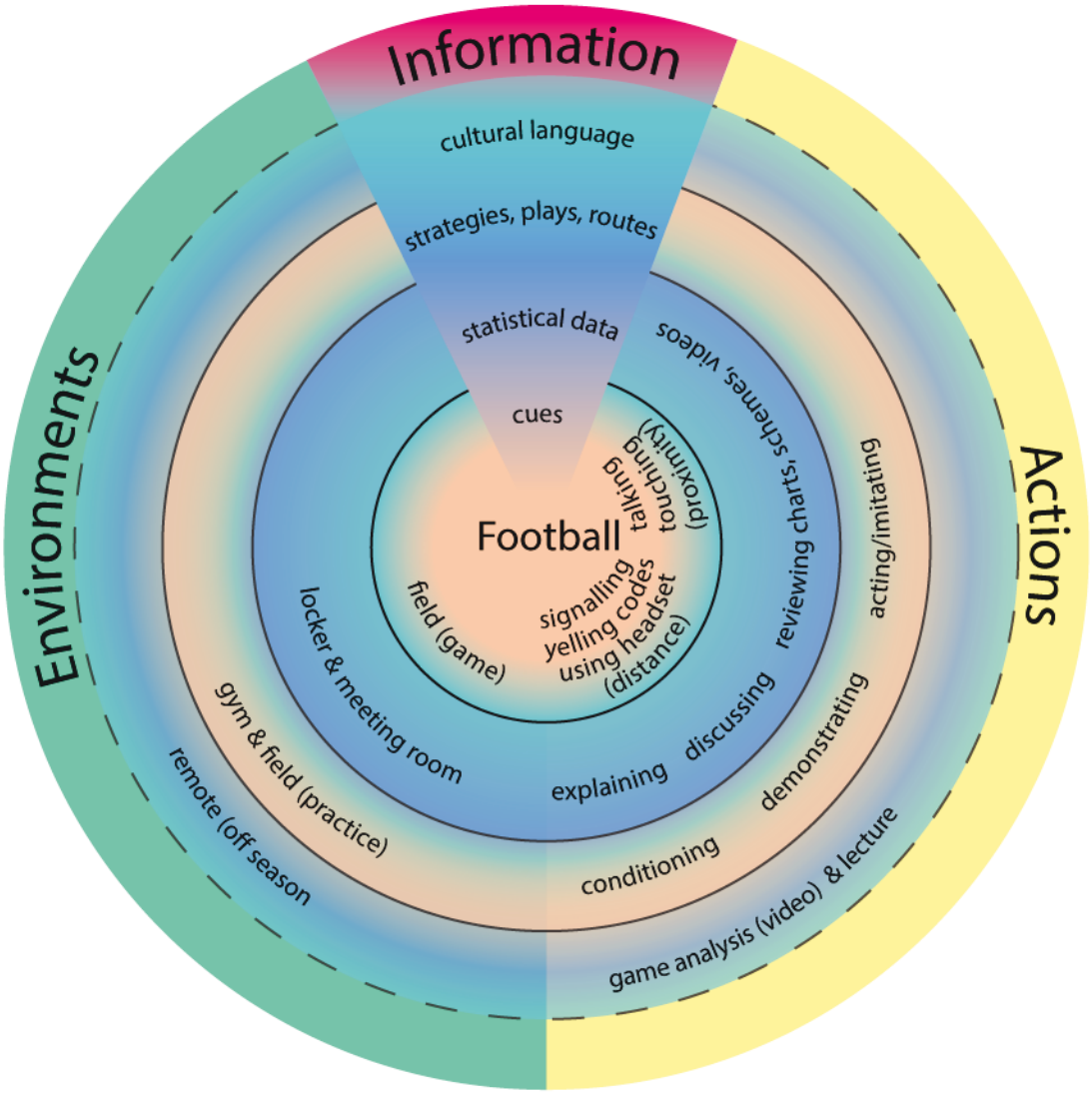

Figure 38 Environments, actions, and information

have, however, have been extensively developed off the field at various points in time and in various environments. Information is communicated in different ways depending on the point in time and space in which it is being conveyed (Figure 38). Although the goal of meetings, practice, and general learning tools contribute to team building and player autonomy, sensory limitations on the field prevent use of the fastest and most effective communication method, verbal language. The slower, less precise visual modality of hand signalling is implemented during game situations both as a mechanism for privacy and as a means to transmit cues over larger distances. From a spatial perspective, communication alternates between analysis (pre-game learning and strategizing) and action (practice and conditioning). During a game, the kinetic sensory output of athletic performance results following a stimulus of sight or sound. This stimulus is transmitted either as a deliberate communicated signal, or as an observation of the opposing team's organization. As previously mentioned, athletic performance in a game situation is based on planned, structured, and practiced strategies that are recollected with sensory cues. Literature pertaining to sport performance and psychology reinforces the problem space of communication in limited sensory environments like the football field. In addition, human behavioural reactions of stress and emotions increase the margin of error in a high-intensity game situation. Both coaches and athletes validated this statement during interviews and highlighted the time sensitive nature of formulating and transmitting play calls from one down to the next. For example, the Ravens quarterback explained the communication process during his interview:

> [From the time] the ref spots the ball to when you snap it you have 20 seconds so you can't ask for a signal over and over again and the signals can get pretty long.

> The other guys don't look at the signals and they don't know any them. So it's on us to know all of them, we have to look at the signals and translate those signals into words for the other players, and sometimes the communication in the huddle…there can be communication errors in the signals and that can absolutely destroy the play if you get 1word wrong or 1 thing in front of the other. So it takes a long time to get that down.

On the other end, the offensive coordinator explained his view of communicating a signal to the quarterbacks:

> When they start looking at the signal and they are trying to remember, that's tough. They know all the plays but then instead of seeing the play as it's being signaled, they're too concentrated on the individual parts to see the whole picture. If you're looking at each one and there's 9 of them, what was the third one? And sometimes the order changes the meaning of it.

As a means of visually expressing the timeline discussed during interviews, figure 43 separates communicative actions into timed segments. As the Offensive Coordinator expressed in interview: "the biggest issue is time, but that's what makes sports: having to make decisions and communicate quickly." Part of the challenge of football is the immanency of performance and the time limits imposed on decision-making. However, once a strategic decision is made, it must be conveyed to the team and executed effectively. Where communication occurs, so too do errors due to misinterpretation, especially given the reliance on codes and signals transmitted in a sensorial hindered environment (shown in red). The second column in Figure 39 is based on McLuhan's (1995) concept of optimizing touch points where human error occurs by enhancing, amplifying, or changing the current sensory modalities used to convey the message using technology. It offers an alternate scenario in which a series is carried through using electronic signalling as opposed to human hand gestures. This change,

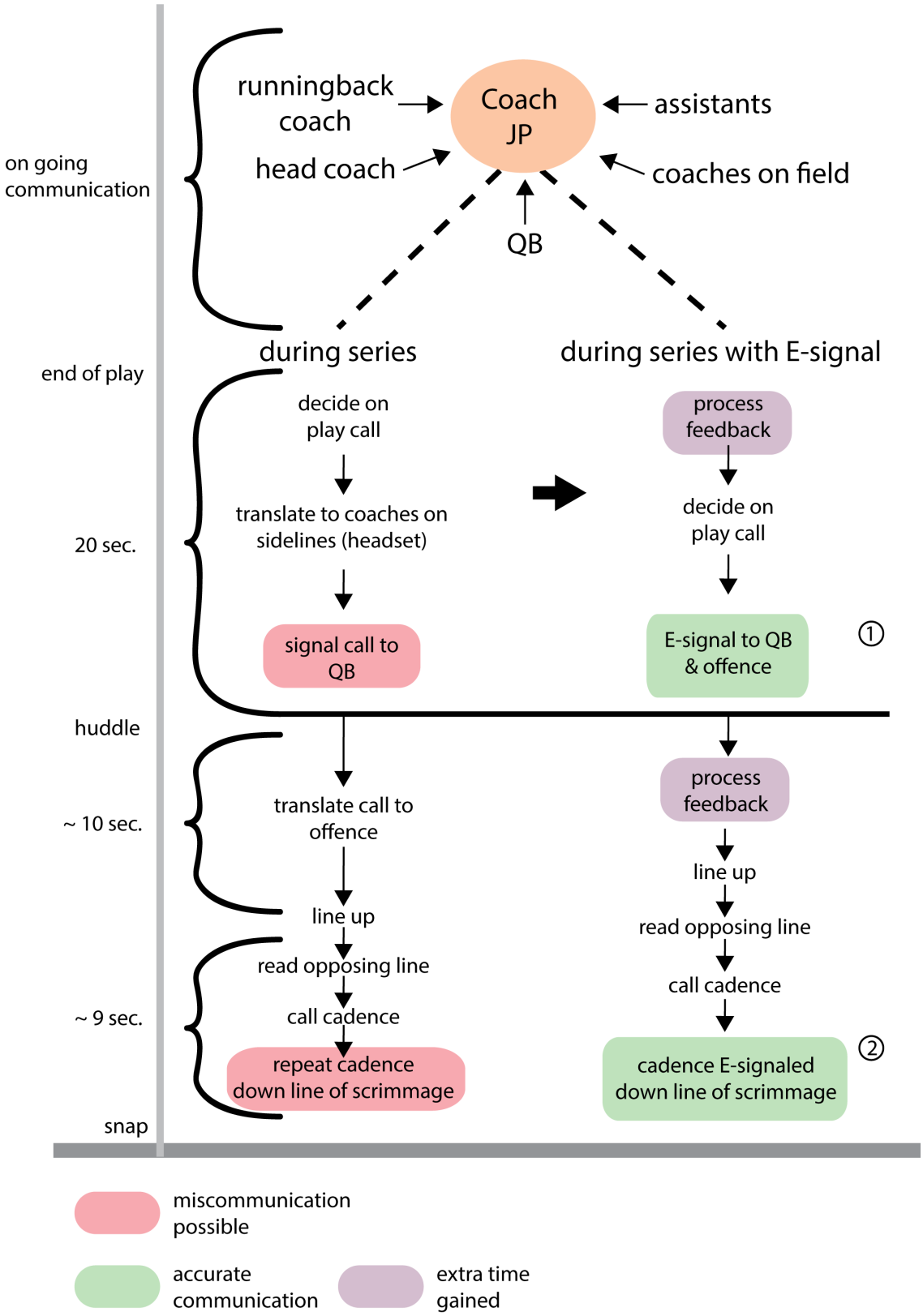

Figure 39 The segmentation of field communication

which may be accomplished through ubicomp, may not only improve communication (shown in green), but also gain additional time for processing the received information by reducing the number of translations necessary (shown in purple). Many factors such as individual behaviour, cognitive overload, and sensorial limits impair effective information transfer in current human-to-human interactions during a football game. The proposed ubicomp integration for information transfer becomes a human-computer interaction in which human behavioural factors, and therefore errors, can be reduced.

6.6 Summary

The problem space of communication in football was discussed in the previous sections by investigating the communication journey of information, taking into account the spatial and sensory limitations of the football environment, apprehending the translation methods of information transfer from coaches to athletes on field, and finally making sense of the context through usability heuristics. The summative research question exploring the connection between design and the integration of technology for communication in football is addressed from the perspective of an interdisciplinary design lens. Technology may inherently relate to human interactions, behaviours, and ultimately performance through the senses and semiotic communication as noted in psychology, sport, and user-centred design literature (Beyer & Holtzblatt 1998; Desmet & Hekkert, 2007; Danjoux, 2009; Koskinen, 2012; Kuniavsky, 2010; Schifferstein & Hekkert, 2008). User-centred contextual inquiry methods for synthesis of data collection through field study include user experience frameworks such as affinity diagrams, flow charts, and other heuristic visualizations. In this study, these tools illustrate the

parameters of communication within which ubiquitous computing could be integral to the culture of football. These parameters include the sensory environment that supports the phases of communication athletic performance during a football game. But while game-time communications are the primary subject of this study, pre- and post-game team development also shapes the team's communication culture.

The user experience map in figure 40 illustrates the contribution of the study through the various phases of research. In the first section, the information journey, human perception, and cognition are related to ubicomp by exploring people's current relationship with fitness tracking devices. The journey starts with the user accepting technology and therefore demonstrating willingness to learn new procedures and make behavioural changes. Once the technology is accepted and implemented, the user produces sensorial data derived from simple movement to complex biosignals, which are detected and processed by various electronic sensors. This information is turned into meaningful data that is displayed to the user through an interface where the final interaction occurs and the user is able to act on the output. The overarching relationship between input, process, and output can be seen in the information journey relating both to product and person, where the digital system receives, processes, and displays useful data, and the person (the user) receives, processes, and acts on that data. In terms of football performance, the process of sending and receiving signals is visually represented as a problem space due to the potential for errors and miscommunications (highlighted in red). The sensory modalities correspond to the phases in the information journey. Although the dynamic environment of a football game can affect the sensory modalities

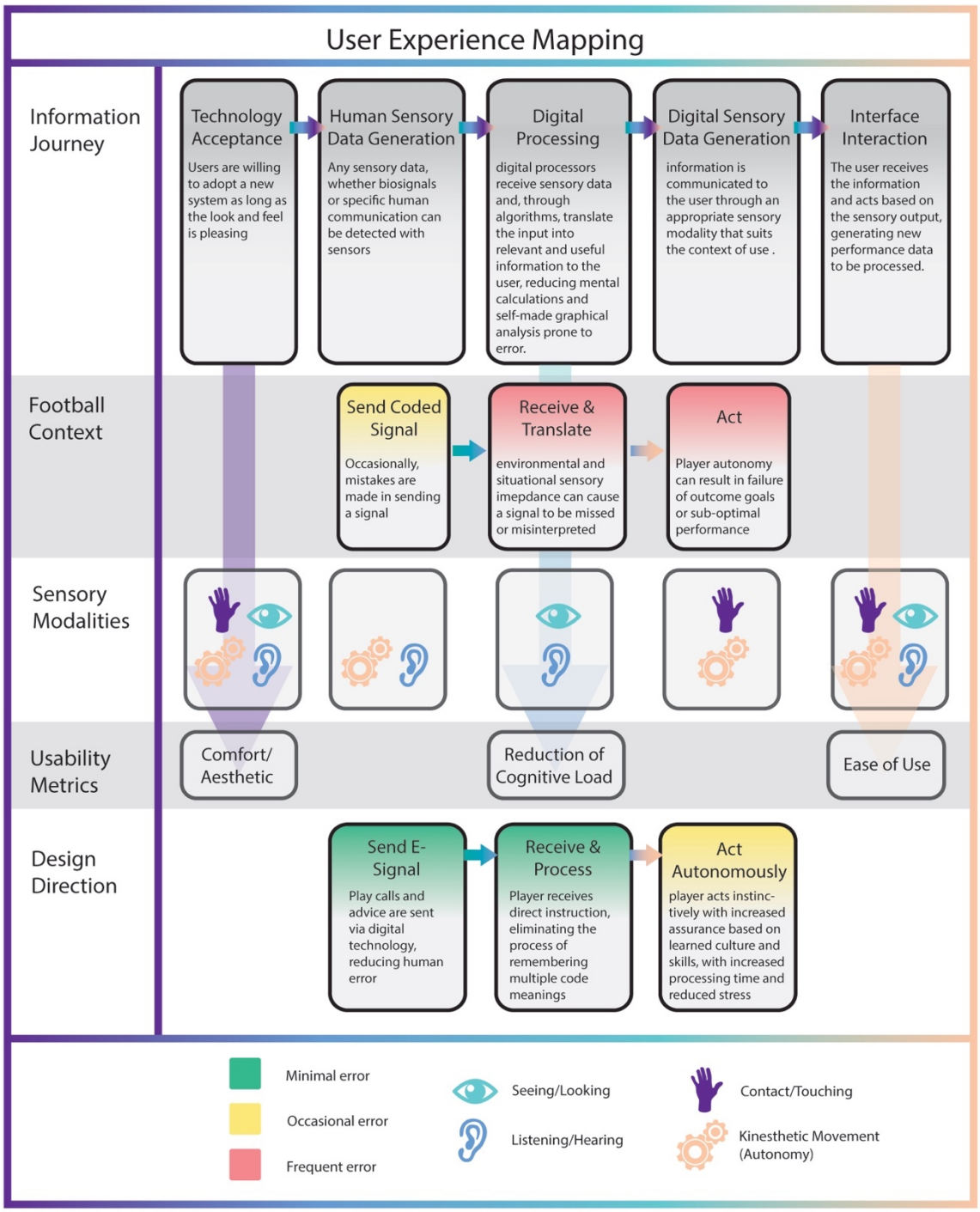

Figure 40 User experience map illustrating the outcomes of the study

used, the trends observed and confirmed in interviews indicated a transition from multi-sensory learning to reliance on auditive feedback (verbal language), to incorporating kinesthetic movement (hand signals), followed by seeing and hearing those signals which are interpreted cognitively, and finally acting on the processed information using multiple senses, which restarts the sensory sequence.

Key usability metrics defined in literature as well as in the survey and interview participants' responses indicate how the design of a product can have a positive impact on the user (Kuniavsky, 2010; Karwowski, Stanton & Soares, 2011; Schifferstein & Hekkert, 2008; Zimmerman, Forlizzi & Koskinen, 2009). If the heuristic of comfort/aesthetic is satisfying to the user, it will be accepted. If the digital processing of data occurs effectively, the user's cognitive load will be reduced, optimizing performance. Finally, if the technology operates efficiently, so as to produce a seamless, simple interaction for the user, the overall usability of the product and overall response to the information output will facilitate and enhance the outcome goal of moving or stopping the ball during a football game. Interviews revealed that efficient communication during a football game is essential for reducing errors and optimizing performance. The design of better interactions relies on thoughtful incorporation of existing team success factors, including the learning culture, use of communication to build trust, and improvement of performance through conditioning.

6.7 Future Research

Technology that incorporates sensory data may remedy current impediments to effective communication. The opportunities depicted in the previous section in figure 45 were generated by triangulating the data gathered through the methods of the study. The usability metrics of comfort/aesthetic, reduction of cognitive load, and ease of use set the parameters for addressing the suggestions and findings gathered in interviews. Using evidence gathered in literature pertaining to sport performance psychology (Aoyagi et. al., 2012; Hays, 2012; Jarvis, 2005; Pinel, 2007), user-centred design (Beyer & Holtzblatt, 1998; Schifferstein & Hekkert, 2008), and ubiquitous computing (Baca et.al., 2009; Koskinen, 2012; Kuniavsky, 2010), opportunities are based on the concept that improved communication will better meet user needs and help users achieve goals more effectively. Each of the three following design directions (shown in figure 41) would require usability testing and further research in iterative design phases.

6.7.1 First Design Direction: Wrist Band

As it now stands, the number of steps involved in communication increase the risk of errors. Replacing the current wrist-band worn by players for an electronic wristband may eliminate some of these steps. This would reduce the risk of errors and reduce time spent performing and interpreting signals. Since most actions during a game are pre-planned and practiced, the players are already prepared for most of the play scenarios that could occur, and only requiring a cue to put a given play into action. A simply transmitted code to a wrist band (like a pager) could eliminate misinterpretation of hand signals and increase the privacy of play calls. During pre-game preparation, more time

could be invested in conditioning, rather than creating and memorizing signals. This would reduce stress and the risk of cognitive overload for both the coaches and players.

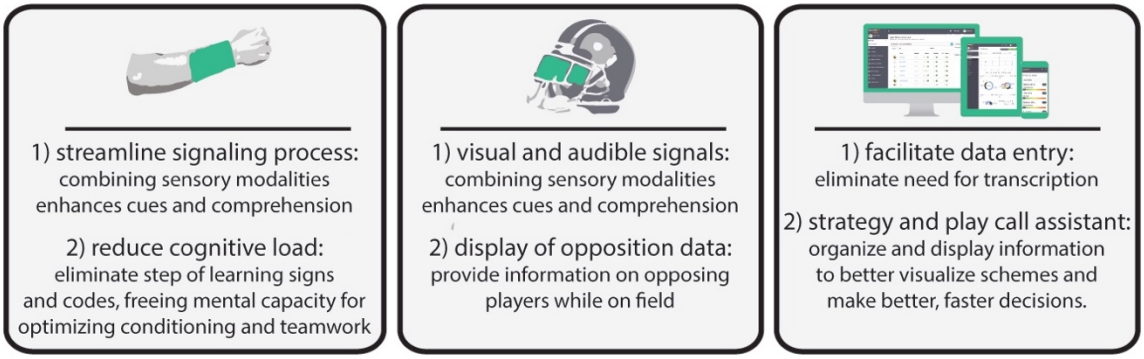

Figure 41 Future design research directions

6.7.2 Second Design Direction: Helmet Visor Screen

Although this was a suggestion from the researcher and therefore carries some bias, the concept was well received by both the coaches and athletes. They were excited and inspired by the potential to send and receive both visual and audible signals. There are many opportunities to expand on the use of the helmet visor, from sending simple signals and cues to providing the offensive line with information about the opposing line. In the context of sport performance, there is potential for the role of user-centred design to connect semiotics and ubicomp by exploring the use scenario and relating the way users perceive information to digital interfaces.

6.7.3 Third Design Direction: Application & Software

Data analysis software could be used more effectively during games, which would eliminate the need to transcribe written data into the software to analyze during post-game meetings. This might also allow for better game time analysis and strategizing.

While this opportunity does not include the central concerns of this study, given that it does not directly influence communication between coaches and athletes, it does have the potential to be a time-saving play-call generating system. This concept would necessitate an entirely different study focused on human computer interaction and system design to further understand the specific needs and relevant data analysis processes. However, this study has provided the basis for this research in its empathetic research into why the improvement is needed, who the user is, and how the software would be used.

Further investigation into design metrics such as materiality and user interface design would take the context and content generated in this study to the next phase of design. In addition, the context of football could be expanded to include other sports and their specific methods of communication, which would require additional user-centred studies and contextual inquiries. Future similar explorations may also benefit from the visualization tools that were used and developed in the course of this study.

6.8 Limitations & Lessons Learned

Due to the exploratory nature of the study, many lessons were learned throughout the process that could facilitate a second exploration. Although the exploratory nature of the study allowed for an organic research trajectory uninhibited by a strict structure, the data gathered was heavily reliant on the researcher constructing an understanding of her subjective observations, rather than quantitative statistics. Limitations include the breadth of research in relation to wearable technology and fitness tracking, the general means of data collection during observations, and the number of participants interviewed. In addition, where the Carleton University football team was used as a case study, it does

not necessarily represent the opinions, needs, and problems of all football athletes and coaches. Although the literature was used to establish a foundation of understanding of the research in the field, news articles and reviews of technology applications used in football served as examples, not as a complete investigation into all the information currently available. Although gaps were found and addressed through exploration in this study, technological advancements not uncovered in the literature review could be developing solutions to the problems this study considers.

6.8.1 Survey Limitations

Due to the fact that the survey was based on the preliminary focus of fitness tracking, it does not directly address the problem space of communication in football. In addition, once the focus of football was established in the second phase, the survey was not administered to the varsity football team in order to associate their opinions to the notion of ubiquitous computing and immerging devices for performance enhancement. In some instances, survey participants were asked to select all options which applied to them, with the intention of gaining a wider understanding of the types of devices being used. However, this created an imprecise statistical outcome due to the fact that the percentages of device use no longer corresponded to the number of participants.

The insights gathered from the survey were largely based on interpretations and researcher biased based on the information gathered in the literature review. Although this comparative method served to make connections with the survey's results, the interpretations could have been better quantified through a more precise methodology of survey formatting and administration. Finally, quotes were interpreted by assessing the

participant's general tone. This interpretation method is not quantifiable, but is supported by the data from other methods.

6.8.2 Observation Limitations

Two games may not provide an accurate representation of quantifiable data due to the varying number of plays on either offence or defence that can occur from one game to another. Therefore, the exploratory method of review used in this study provides a general context as a basis for the final interview phase. The study of an entire season, or multiple seasons, where each game could be addressed through an analysis framework, may provide a more assured basis on which to found design decisions for the implementation of future research. The lessons learned through this study, although preliminary, provide justification for pursuing a deeper layer of design research.

6.8.3 Interview Limitations

Researcher bias is likely to emerge during interviews; in this case, the risk was that the researcher's bias favoured associating wearable technology with the communication culture of a football team. In addition, proposing technology as a solution to the current problem space in order to address the heuristics established by identifying user needs does not account for the potential new problems created by the technology. The change in communication and new use scenarios require further design investigation.

7.0 CONCLUSION

The intention of this study transformed as research unfolded. First, it investigated the use and usefulness of fitness tracking devices, which identified an underserved user group of performance athletes. Second, the specific sport of football was chosen and observed with the intention of observing behaviour and uncovering areas where technology might be used to enhance performance. The varsity football players' and coaches' methods for communicating during games were identified as the problem space. User experience mapping brought awareness to two areas: efficient communication is essential for reducing errors and optimizing performance, and the design of better interactions relies on thoughtful incorporation of existing football culture and understanding of the game context. Triangulating the understanding of the football communication culture as well as the current landscape of wearable technology founded in the literature review revealed two key notions. First, current communication systems in football do not effectively or consistently produce the desired performance outcomes. Second, wearable technology is not being applied for in-game communication.

7.1 Contributions

This study makes two significant contributions to the field, which are summarized below. First, it highlights user-centred needs that ubiquitous computing devices may be able to address. Second, it demonstrates how contextual inquiry visualization tools can be used to capture and portray user-centred design issues.

7.1.1 User-Centred Concerns

Within the context of professional sport, in particular football, team performance is dependent on efficient communication. The literature suggests this is a vital aspect affecting a team's success, yet the potential for improving communication through ubiquitous computing remains largely unexplored. This study explores the similarities between human and computer information processes, where the needs of human cognition in a particular sensory environment may be enhanced by translating and digitizing human sensory modalities to technological applications. It focuses on the exchange of information through codes and signals during a football game that occur in a context in which layers of sensory elements such as sound and distance (sight) inhibit the reception of the signal. This creates a margin of error wherein communications can be missed or misinterpreted. There is therefore a design opportunity for the integration of technology into sports games to improve communication.

Through the user-centred design method of contextual inquiry, sensory limitations such as sound oversaturation, distance, and the high-speed, high-impact nature of football are identified as causing interference with sensorial fluidity and signal acquisition between coaches and athletes. Currently, the technology and artifacts being used to address the problem space of communication in football are limited, and wearable technology may provide a tangible opportunity for combining the design research insights presented here into team sport performance devices. These technology-enhanced devices may target efficiency on the field of play by facilitating and simplifying the communication system between players and coaches in football games.

7.1.2 Contextual Inquiry Visualization Tools

This study is an example of how design methods such as contextual inquiry, user experience heuristics, journey mapping, and graphical analysis can effectively explore a complex problem space. Figure 44 makes use of these design tools by graphically outlining the trajectory of the study:

- A horizontal flow chart sequences the information journey of biosignals as they relate to wearable tracking devices.
- The 3 points of information processing (input, interpret/process, output) are applied to sending and receiving signals in a football context.
- The sensory modalities are depicted with icons and colours in relation to the first row's information journey.
- Usability heuristics of comfort/aesthetics, reduction of cognitive load, and ease of use are placed deliberately under the points of technology acceptance, digital processing, and interface interaction, respectively.
- Technology implements are suggested as opportunities for future research
- The three points of information processing are revisited, applying the suggested implementation of wearable technology to the Football context.

7.2 Closing Statement

The relationships and interactions between coaches and athletes during a football game provide an complex environment to study user-centred design for communication and athletic performance. By acknowledging the similarities between human and computer information processes, the limitations of human cognition in a particular sensory

environment can be supported and amplified by taking human ways of communicating and transforming them into digital signals. This study not only uses design research methods to explore a problem space, but also suggests areas for future design research into the types of technology that could enhance, amplify, and improve communication in football, and other athletic performances.

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APPENDICES

Appendix 1

Football Context

This section highlights important cultural aspects of the sport, as seen through an AEIOU (Activities, Environment, Interactions, Objects, and Users) framework to provide a basic understanding of the football context.

Activities

The official NFL rulebook can be found online (NFL Beginner's Guide to Football, n.d.), and provides the game's descriptions and rules, which are summarized here. In the game of Football, the main goal is to be the team to finish the game with the most points. A game is divided into four 15-minute quarters, with a 12-minute half time break. Returning from the break, the game starts with a kick-off. After the first and third quarters, there is a 2-minute break allowing the teams to change ends of the field. Following these quarters, the team with the ball retains possession. The game starts with a kickoff where the ball is placed on a tee at the defence's 30-yard line and a special kicker kicks the ball to the offence. The offence will try to catch and advance the ball by running. Where he is stopped is the point from with the offence proceeds with a series of plays, or strategies for passing or running. In order to score points, a team will execute a series of plays, consisting of either running or passing the ball. The offence has four downs, or chances, to move the ball 10 yards. If the offence gains 10 yards, it earns a first down, and another set of four downs. If the offence fails to gain 10 yards in 4 consecutive downs, they lose possession of the ball. When the offence reaches the fourth down, it usually punts the ball (kicks it away), which forces the other team to begin its first drive

further down the field. Scoring points can occur in 4 ways:

1) Touchdown (6 points): the biggest single score in a football game is achieved by carrying the ball across the goal line into the end zone, catching the ball in the end zone, or recovering the ball from a fumble or untouched kick in the end zone.

2) Extra Point and the Two-Point Conversion: immediately following the touchdown, the ball is placed at the opponent's two-yard line, where the offence can either attempt to kick the ball through the goal posts (1 point), or run/throw the ball into the end zone (2 points). Generally, the first option is executed because it is much easier to score.

3) Field Goal (3 points): If the offence cannot score a touch down, it might attempt to kick a field goal by kicking the ball through the goal posts. This usually takes place at the defence's 45-yard line on a fourth down. The defence tries to block the kick in order to prevent the goal.

4) Safety (2 points): A safety occurs when the offensive ball carrier is tackled behind his own goal line.

Environments

The Field: Figure 42 illustrates the breadth of a typical football field, which measures 100 yards long and 53 wide. The ends of the field are an extra 10 yards called the end zone. Points are scored when the team in possession of the ball gets the ball into the opponent's end zone. The line of scrimmage is the position on the field where a play begins. This line changes as the ball is moved after each play.

Figure 42 TD Place field

The Sidelines: This is where the members of the team who are not on the field congregate. There are generally benches, water dispensers, and medical equipment. Coaches will coach their team, watch the game, and communicate with other coaches either on the sidelines or in the media booth.

The Media Booth: Along with broadcasting, video and audio staff, a number of coaches will be in the media booth where they get an elevated view of the whole field. They are able to strategize and make play calls from the booth and communicate directly with the quarterback or with the other coaches on the sidelines. There is also normally a member of the coaching staff documenting the game outcomes.

Interactions

There are a few different ways in which players physically interact on the field while attempting to move or stop the ball. The NFL Beginner's Guide to Football (n.d.) briefly explains these interactions. First, a play begins with a snap at the line of

scrimmage. The Quarterback (QB) loudly calls out a play using code words and the player in front of him, the Centre, snaps (passes) the ball under his legs to the QB. The QB has the choice to either run or pass. On a run play, the QB will pass the ball to a Running Back, who tries to gain as many yards as possible before he is stopped by the opposing Defence. The QB may also choose to run the ball on his own. Alternatively, the QB will throw or pass the ball. Other team members may also pass the ball, as long as the pass is thrown behind the line of scrimmage. If the ball hits the ground before it is caught, the pass in incomplete and the play ends. On the defensive side, players attempt to stop the ball from advancing by bringing the offensive player in possession of the ball to one or both of his knees, which constitutes a tackle and brings the play to an end. A play also ends when a player runs out of bounds. Throughout the game, there are a few possible game scenarios that cause a turnover, or change of possession:

- Fumble: The ball gets dropped but can be retrieved by another player by diving on it or running with it. The team that recovers a fumble either gets or retains possession of the ball.
- Interception: Defence can regain possession of the ball by catching (intercepting) passes meant for payers on the other team.

Both types of turnover can be run back into the end zone for touchdowns (Official Playing Rules of the National Football League, 2013).

Objects

Football players are heavily equipped with protective gear to prevent injury due to the high physical contact of the sport. All the equipment must meet the organization's standards. The necessary equipment includes a helmet, face mask, shoulder pads, mouth guard, and football cleats (spiked shoes) (Figure 43). Other apparel worn include gloves, numbered jerseys, high socks and in some cases a wristband. The wristband is essentially a portable playbook worn by the QB and sometimes other select players, where a 3x5 index card with printed play calls is inserted and can be referenced on the field for complex calls (Long and Czarnecki, 2011; QB Wristband tool, 2010) (figure 44).

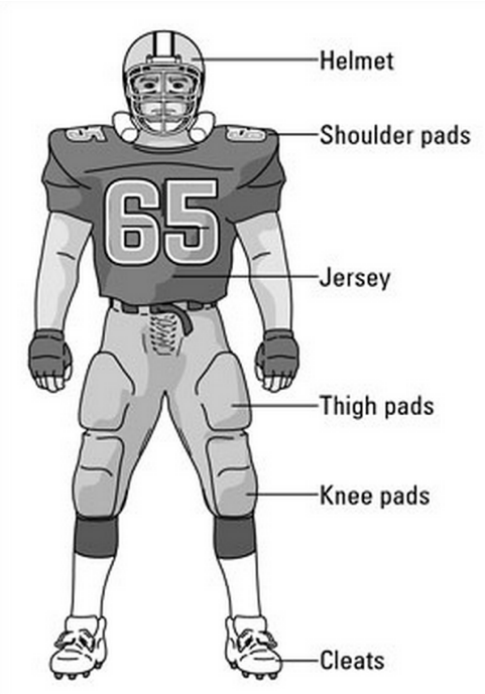

Figure 43 Illustration of player gear

Figure 44 Players checking wrist bands for play calls

Users

A football team consists of 11 players on the field at any given time. There are 3 types of separate units:

Offence: When the team has possession of the ball, the offence tries to advance the ball

to the other end of the field by either passing or running with the ball. There are many different players playing different roles on offence. Ultimately, tasks are divided into blocking the defence, and moving the ball by catching, passing, and/or running. It is important to highlight the role of the QB. While he is not necessarily the captain of the team, he is in charge of receiving the ball from the snap then throwing or running, and also outlining each play to his team. An excerpt from *Football for Dummies* (2011) details the role of the QB:

> In American football, the quarterback relays to his teammates in the huddle what play the coach has called. The play is a mental blueprint or diagram for every player on the field. Quarterbacks are also allowed to audibilize, or change the play at the line of scrimmage…Quarterbacks usually audibilize when they discover that the defence has guessed correctly and is properly aligned to stop the play…A quarterback may also use an offensive strategy known as *check with me*, in which he instructs his teammates to listen carefully at the line of scrimmage because he may call another play, or his call at the line of scrimmage will be the play. p. (61-77)

Defence: Players line up to try to stop the opposing offence from advancing the ball. There are 3 ways the defence can stop the opposing offence: defend against the pass and push forward to stop the run or tackle the QB; go head-to-head against the offensive line; defend the throwing pass from the QB to a wide receiver (Long and Czarnecki, 2011).

Special Teams: only come out in special kicking situations. (NFL Enterprises 2015).

Coaches are also part of the user group surrounding the players. Depending on the level of the team, there can be a coach and an assistant coach for almost every specific position; sometimes upwards of 10 different coaches and assistant coaches (Long and Czarnecki, 2011). The primary coaches, however, are the head coach, defensive coordinator and offensive coordinator, who have the job of making play calls and

relaying information to their concerned athletes. During a game, each team has medical staff and officiating referees. Finally, non-directly contributing attendees are media staff, facility employees, team managers, and spectators (Battista, 2014).

Appendix 2A

Online Survey Questions

Self-Tracking for Health & Fitness

Thesis Title: Design Implications of User Experience for Tracking with Technology: Semantics of Self-Tracking and the Quantified Self Movement

Date of ethics clearance: June 6th, 2014
Ethics Clearance for the Collection of Data Expires: May 31st, 2015

Description: This is a study on User Experience for Self-Tracking. This study aims to investigate aspects of design that contribute to the effective user experience of self-tracking using wearable devices and mobile applications. The researcher for this study is Maya Lourenco Levin in the School of Engineering and Design at Carleton University in Industrial Design. She is working under the supervision of Lois Frankel and Leonard MacEachern in the School of Engineering and Design at Carleton University in Industrial Design and Electrical Engineering.

This study involves one 10 minute survey that will take place online. You have the right to end your participation in the survey at any time, for any reason, up until you hit the "submit" button. You can withdraw by exiting the survey at any time before completing it. If you withdraw from the study, all information you provided will be immediately destroyed. (As the survey responses are anonymous, it is not possible to withdraw after the survey is submitted.) All research data will be encrypted and password-protected. The company running the online survey is FluidSurveys based in Canada. The survey company will keep a copy of the survey responses on its servers in Canada. This data will also be encrypted and will be deleted once the survey is complete. Research data will be accessible by the researcher, the research supervisor and the survey company. No names or IP addresses will be linked to any of the data provided. Once the project is completed, all research data will be kept for one year and potentially used for other research projects on this same topic. At the end of five years, all research data will be deleted. If you would like a copy of the finished research project, you are invited to contact the researcher to request an electronic copy, which will be provided to you as long as the safety of all participants will not be comprised by doing so.

This project was reviewed by the Carleton University Research Ethics Board, which provided clearance to carry out the research. Should you have questions or concerns related to your involvement in this research, please contact:

REB contact information:
Professor Andy Adler, Chair; Professor Louise Heslop, Vice-Chair
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Name: Lois Frankel
Department: Industrial Design
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By clicking "submit", you consent to participate in the research study as described above.

1) Are you:

- ◯ Male
- ◯ Female

2) What is your age group

- ◯ Under 18
- ◯ 18-25
- ◯ 26-35
- ◯ 36-49
- ◯ 50 +

3) How would you define your level of athleticism?

please choose which statement best describes your opinion

- ◯ i. not very active
- ◯ ii. recreationally active
- ◯ iii. athletic [Type here]
- ◯ iv. competitive (please specify your sport) [Type here]

4) How often do you train, play your sport, or go to the gym?

- once a week or less
- 2-3 times a week
- 4 or more times a week

5) Do you currently use a method to track any aspects of your life or training routine?

please select all that apply

- wearable device
- mobile application
- website
- computer software
- journal/log book
- memory
- Other, please specify... Type here

6) What are you tracking?

please select all that apply

- weight
- food
- water
- sleep

- [ ] mood
- [ ] workout
- [ ] training program (sport specific)
- [ ] Other, please specify... Type here

7) Do you use tracking methods to set and work towards a goal(s)?

- ( ) Never
- ( ) Rarely (provide an example) Type here
- ( ) Sometimes (provide an example) Type here
- ( ) Always (provide an example) Type here

8) How often do you use your tracking method (ie consult or enter data)?

- ( ) Multiple times a day
- ( ) Once a day
- ( ) A few times a week
- ( ) Once a week or less
- ( ) N/A

9) Generally, how much time do you spend entering data or consulting your tracking method?

- i. A couple minutes per entry/consultation
- ii. Between 5-10 minutes per entry/consultation
- iii. More than 10 minutes per entry/consultation
- N/A

10) Are you satisfied with your method of tracking?

- i. not at all satisfied (please explain) Type here
- ii. somewhat unsatisfied (please explain) Type here
- iii. neither satisfied or unsatisfied (please explain) Type here
- iv. somewhat satisfied (please explain) Type here
- v. very satisfied (please explain) Type here

11) How do you feel about the amount of time you spend tracking?

please choose which statement best describes your opinion

- i. my current method of tracking is time consuming
- ii. My current method of tracking takes little time but could be improved
- iii. My current method of tracking is extremely efficient
- N/A

12) Would you consider using a new or different technology such as a wearable device and/or mobile applications as a method of self-tracking?

please choose which statement best describes your opinion

- i. No, I have no interest in wearable technology and extra gadgets
- ii. No, I am happy with my method
- iii. I am happy with my method, but might consider an alternative
- iv. I am open to trying various methods of self-tracking
- v. I am looking for a new method of self-tracking

13) What is your opinion about wearable devices and mobile applications for self-tracking?

please choose which statement best describes your opinion

- i. They are a fad and a waste of money
- ii. They are ok but I'm not sure how well they work
- iii. They are useful for some people but do not serve my purposes
- iv. They could be useful for me, provided the setup and use is easy
- v. They are very useful for me

14) Do you have any other comments about using wearable devices and mobile applications for tracking?

Type here

thank you! :)

Appendix 2B

Online Survey Results

Q1) Are You (male or female):

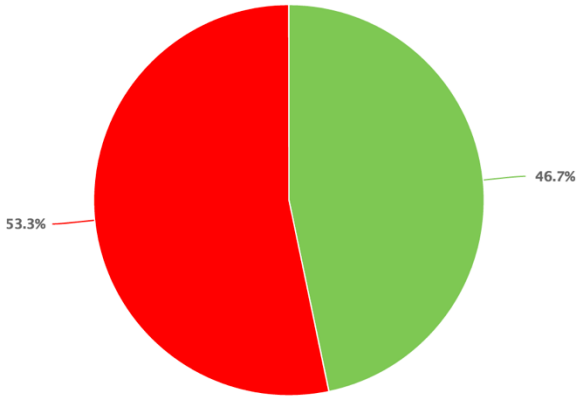

Table 1 Survey question 1

The entries received were fairly even distributed between males (46.7%) and females (53.3).

Q2) What is your age group?

Response	Count
50 +	9 *7.3%*
36-49	17 *13.7%*
26-35	33 *26.6%*
18-25	64 *51.6%*
Under 18	1 *0.8%*
	Total: 124

Table 2 Survey question 2

The most common age demographic, 18 to 25 years old (64 total participants), matches the primary users of sport performance technology: college and university

athletes as well as professional athletes. Other age demographics, 26-35 years old (33 total participants), 36 to 49 (17 participants) and over 50 (9 total participants), take into consideration both older athletes, and coaches.

Q3) How would you define your level of athleticism?

Response	Count	
iv. competitive (please specify your sport)	47	37.9%
iii. athletic	39	31.5%
ii. recreationally active	28	22.6%
i. not very active	10	8.1%
	Total:	124

Table 3 Survey question 3

The participants were asked to define the type of sport they played as well as their view of being "athletic." 49 respondents stated they were competitive in a sport and 39 respondents stated they were athletic. Where the focus of the study is on athletic performance, 69.4% of the survey participants were highly relevant to the study. The remaining participants did not have the same kind of performance goals, with 22.6% (28 total participants) stating they were recreationally active and 8.1% (10 total participants) stated they were not very active.

Q4) How often do you train, play, or go to the gym?

Response	Count	
4 or more times a week	85	69.1%
2-3 times a week	24	19.5%
once a week or less	14	11.4%
	Total:	123

Table 4 Survey question 4

69% of the people who responded train, play a sport, or go to the gym four or more times per week.

Q5) Do you currently use a method to track any aspects of your life or training routine? (select all that apply)

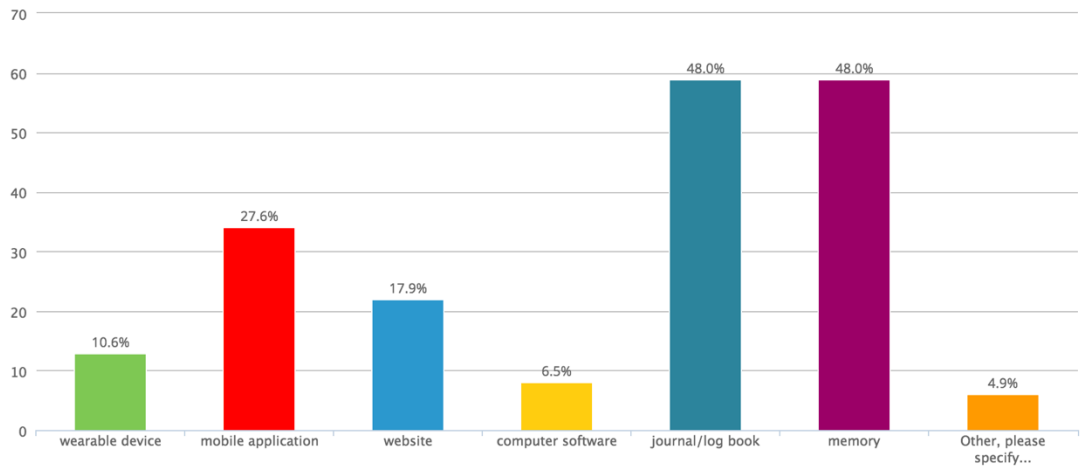

Table 5 Survey question 5

Almost half the respondents (48%) use a journal and/or memory to track aspects of their life and training routine. This method of tracking is followed by the use of a mobile application (27.6%), then a website (17.9%), then a wearable device (10.6%), and finally computer software (6.5%).

Q6) What are you tracking?

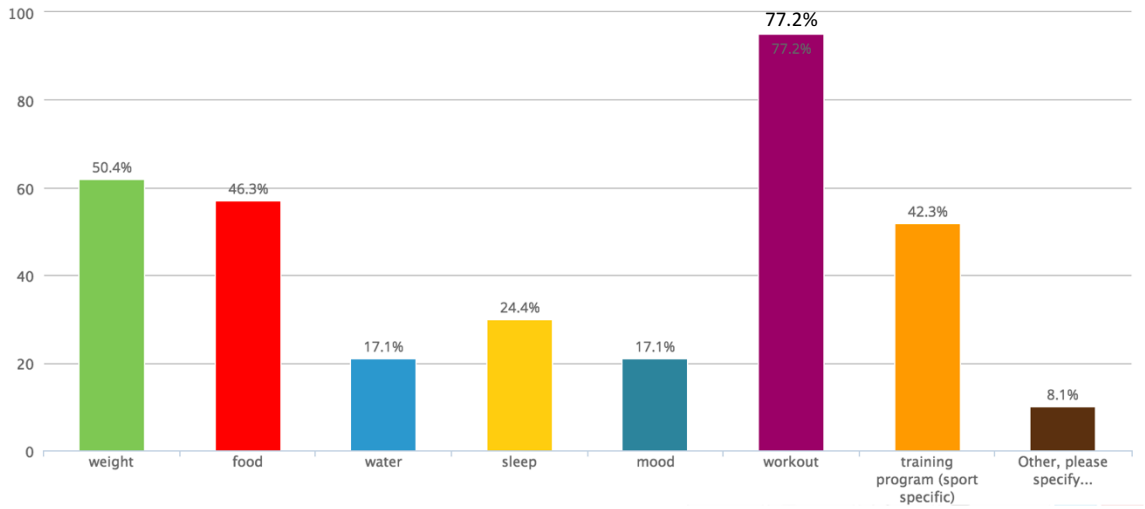

Table 6 Survey question 6

77.2% of participants track their workouts, followed by 50.4% who track their weight, followed closely by tracking food (46.3%) and sport-specific training programs (42.3%). Sleep (24.4%), water intake (17.1%), and mood (17.1%) were tracked less often, and notes on performance, jogging route distance, and golf scores were mentioned by single participants.

Q7) Do you use tracking methods to set and work towards a goal(s)?

Response	Count	
Always (provide an example)	40	32.3%
Sometimes (provide an example)	35	28.2%
Rarely (provide an example)	18	14.5%
Never	31	25.0%
	Total: 124	

Table 7 Survey question 7

75% of participants use tracking methods to set and work towards goals by gauging performance and as motivation to improve on their last entry. The more the participants use tracking methods, the more detailed and precise their usage is (from general weight management and weights used, to program progressions, notes, macro-nutrient counting).

The 40 participants who responded *always* were precise in what they were tracking, indicating an interest either as an athlete, a "Quantified Selfer", or someone following a specific program with a weight or training goal. One participant described goals thus:

> I use MyFitnessPal to track food and aim to hit my macro goals as well as long term weight loss. Also use a formulated spreadsheet for my training to make sure I'm hitting my prescribed weight and rep goals and ultimately my goals for meets.

The 35 participants who answered *sometimes* were more broad in their answers and goals: "To continue to improve upon past performance whether it be increased use of weight or times;" and "every workout is a goal - if I write it down I am more likely to do it."

The 18 participants who *rarely* used tracking methods sometimes had similar answers to those who answered *sometimes*, such as "increase weight used during exercise" but also indicated that tracking performance was more of a game: "Logging down weight, and beating running times on MapMyRun." Tracking was not for performance enhancement but for general health and wellbeing: "I try and balance nutrition, sleep and exercise with a busy schedule."

Q8) How often do you use your tracking method (i.e., consult or enter data)?

Response	Count	
N/A	19	15.4%
Once a week or less	14	11.4%
A few times a week	25	20.3%
Once a day	39	31.7%
Multiple times a day	26	21.1%
	Total: 123	

Table 8 Survey question 8

This question further confirms the responses from the last question. Statistically, roughly the same percentage of participants use their tracking method once a day or more (52.8%), as compared to those who claimed to be active users of tracking methods (60%). This confirms the validity of their previous response. The majority (52.8%) of respondents already use tracking methods at least once per day.

Q9) Generally, how much time do you spend entering data or consulting your tracking method?

Response	Count	
i. A couple minutes per entry/consultation	70	56.5%
ii. Between 5-10 minutes per entry/consultation	25	20.2%
iii. More than 10 minutes per entry/consultation	6	4.8%
N/A	23	18.5%
	Total: 124	

Table 9 Survey question 9

The majority of participants (56.5%) spend only a few minutes entering data, followed by 20.2% who spend between 5-10 minutes per interaction. Only 4.8% stated

they spend more than 10 mintues entering data or consulting with their tracking method, and 18.5% stated the question was not applicable to them.

Q10) Are you satisfied with your method of tracking?

Response	Count
v. very satisfied (please explain)	32 26.4%
iv. somewhat satisfied (please explain)	43 35.5%
iii. neither satisfied or unsatisfied (please explain)	25 20.7%
ii. somewhat unsatisfied (please explain)	12 9.9%
i. not at all satisfied (please explain)	9 7.4%
	Total: 121

Table 10 Survey question 10

A small percentage of participants expressed dissatisfaction with their tracking method (17.3%). Re-evaluating the statistics by eliminating the number of participants who were completely satisfied with their tracking method (26.4%), the cumulative amount of participants who experienced some level of dissatisfaction with their method increases to 73.6%. Participants' tracking methods were categorized into a new chart of choices (Table 11), where use of an app (38 participants) was the most frequent; however, 33 participants did not specify what they used.

Very satisfied trackers:

- "The way my excel sheet is set up makes things very easy to track, and switch between my personal bests, future goals, training schedule, etc."
- "fully interactive with informatics and analysis."
- "I've adjusted to what the device can do, may use more of its functionality later and will use other methods to track progress in areas like weight training where it is useless."

Somewhat satisfied trackers:

- "I'm too lazy to spend much time on fixing minute details but it works at least."
- "I like to think and write about what I'm doing - it's tough to go back and find things at times though."
- "It's possible to forget when not written down, but usually I'm fine with just memory."
- "Tracking food and calories is very simple, as well as calculating your BMR [Basal Metabolic Rate]. However, tracking your calories expended through weight training is next to impossible which always makes estimating calories left to eat in a day troublesome. Also for tracking workouts, its [sic] a hassle keeping a written log and trying to transfer it all onto the computer so tracking and examining patterns etc. is a timely process."

Neither satisfied or unsatisfied:

- "One app/place would be ideal…I use multiple apps and methods to track"
- "It was fine when I was working towards a goal (triathlon), but too much hassle to use all the time."

Unsatisfied trackers:

- "Memory can be fuzzy, inaccurate, hard to track long term results."
- "Cannot easily alter workouts when necessary."

Q11) How do you feel about the amount of time you spend tracking?

Response	Count
N/A	21 16.9%
iii. My current method of tracking is extremely efficient	39 31.5%
ii. My current method of tracking takes little time but could be improved	61 49.2%
i. my current method of tracking is time consuming	3 2.4%
	Total: 124

Table 11 Survey question 11

Most participants (49.2%) indicated that their current method of tracking takes little time but could be improved. 31.5% indicated their current method of tracking is extremely efficient, and 16.9% indicated this question did not apply to them. Very few participants (2.4%) indicated that their method of tracking was time-consuming.

Q12) Would you consider using a new or different technology such as a wearable device and/or mobile applications as a method of self-tracking?

Response	Count	
v. I am looking for a new method of self-tracking	12	9.9%
iv. I am open to trying various methods of self-tracking	59	48.8%
iii. I am happy with my method, but might consider an alternative	24	19.8%
ii. No, I am happy with my method	11	9.1%
i. No, I have no interest in wearable technology and extra gadgets	15	12.4%
	Total: 121	

Table 12 Survey question 12

A high percentage of participants (58.7%) are either actively looking for a new tracking method or are open to trying new methods, followed by 19.8% who are happy with their method but would consider an alternative. 12.4% of participants are not interested in wearable devices and extra gadgets, and 9.1% of participants are satisfied with their current method.

Q13) What is your opinion about wearable devices and mobile applications for self-tracking?

Response	Count	
v. They are very useful for me	18	14.5%
iv. They could be useful for me, provided the setup and use is easy	48	38.7%
iii. They are useful for some people but do not serve my purposes	24	19.4%
ii. They are ok but I'm not sure how well they work	27	21.8%
i. They are a fad and a waste of money	7	5.6%
	Total:	124

Table 13 Survey question 13

14.5% of participants find wearable devices and mobile applications very useful for self-tracking. 38.7% of participants think a wearable device or application could be useful, provided setup and use is easy. 19.4% of participants do not think current wearables and applications serve their needs, 21.8% of participants are apprehensive about how well they work, and 5.6% of participants think they are a waste of money.

14) Do you have any other comments about using wearable devices and mobile applications for tracking? (quotes)

- "If it's not pretty I'm not wearing it."
- "Current technology seems very "algo-centric" i.e. data is inferred instead of being directly measured. Some tech. breakthroughs are probably required before they can adequately measure all body activity in a useful way."
- "If there would be a good product out there that could track all my fitness activities I'd definitely buy/use it."
- "Design focusing on small, unobtrusive and easy set up devices is something I would look for."

- “I think they are very expensive for the product you receive. I haven’t found one that tracks heart rate which to me would be key in accurately predicting energy output.”
- “I likely would not wear a device but want some device/software to easily track workouts.”
- “I wore a heart rate monitor for a while but it got in the way during some lifts - plus I didn’t like the watch on my wrist. I also don’t like doing most of my workouts with my mobile device on me.”
- “Not sure if they can replace the simplicity of paper and pen.”

Appendix 3

Survey Insight Diagram

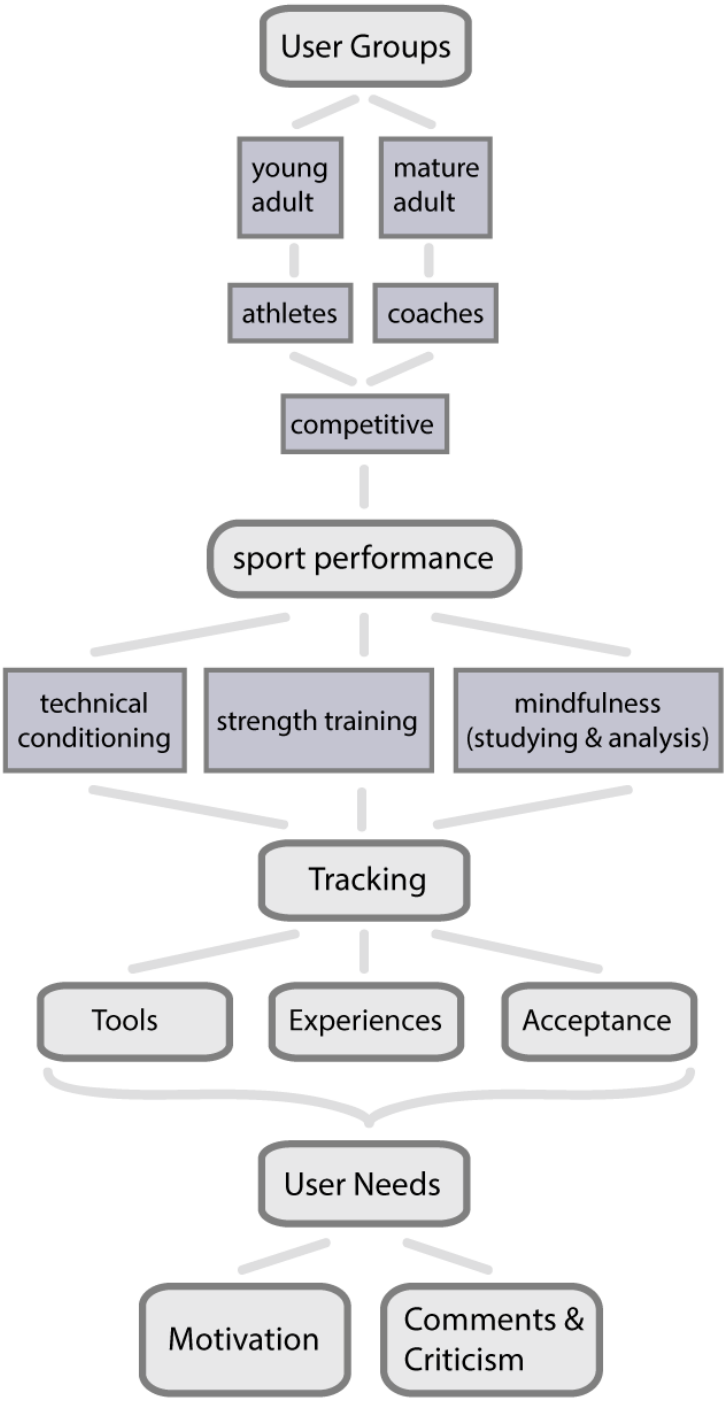

Figure 45 Flow diagram of survey key words

Appendix 4

Observation Insight Diagrams

Figure 46 communication snap shots on-field, off-field and in transition

Appendix 5

Interview Consent Form

Carleton UNIVERSITY
Canada's Capital University

Interview Consent Form

Title: Design Implications of User Experience for Tracking with Technology: Semantics of Self-Tracking and the Quantified Self Movement

Date of ethics clearance:

Ethics Clearance for the Collection of Data Expires:

I _____, choose to participate in a study on User Experience for Self-Tracking. This study aims to investigate aspects of design that contribute to the effective user experience of self-tracking using wearable devices and mobile applications. The researcher for this study is Maya Lourenco Levin in the School of Engineering and Design at Carleton University in Industrial Design. She is working under the supervision of Lois Frankel and Leonard MacEachern in the School of Engineering and Design at Carleton University in Industrial Design and Electrical Engineering. **I acknowledge that I may know the researcher on a personal and/or professional level outside of this study.**

This study involves one 60 minute interview. With your consent, interviews will be audio-recorded. Photographs may be taken and used for demonstration purposes in final documentation. **There is minimal risk associated with this project but the researcher will take precautions to protect your identity at your request. This will be done by keeping all responses anonymous and allowing you to request that certain responses not be included in the final project. Should you experience any distress during the interview, you will be provided with contact information for counseling services available nearby.**

You have the right to end your participation in the study at any time, for any reason, up until December 31st, 2014. You can withdraw by phoning or emailing the researcher or the research supervisor. If you withdraw from the study, all information you have provided will be immediately destroyed.

All research data, including audio-recordings and any notes will be encrypted and password-protected. Any hard copies of data (including any handwritten notes or USB keys) will be kept in a locked cabinet at Carleton University. Research data will only be accessible by the researcher and the research supervisor. Once the project

is completed, all research data will be kept for one year, after which time all research data will be securely destroyed. (Electronic data will be erased and hard copies will be shredded.)

If you would like a copy of the finished research project, you are invited to contact the researcher to request an electronic copy which will be provided to you.

This project was reviewed by the Carleton University Research Ethics Board, which provided clearance to carry out the research. Should you have questions or concerns related to your involvement in this research, please contact:

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Do you agree to be audio-recorded: ___Yes ___No

Do you agree to have your photograph taken and used for documentation purposes? ___Yes ___No

If no, would you agree to have your photograph taken and used for documentation purposes with **your face blurred**? ___Yes ___No

_____ _____
Signature of participant Date

_____ _____
Signature of researcher Date

Page **2** of **2**

Appendix 6

Interview Questions for coaches

1- What is your coaching title?

2- Which athletes do you typically deal with?

3- How often during a game do you communicate with your athletes?
- How do you communicate? (sensory)
  - when they are not in verbal range (when you're on the field?)

4- Have you ever had problems communicating with your athletes, such as not effectively transmitting your signals?
- How do you teach the hand signals that you use a during a game?
- Do they change every game?
- Do you ever find yourself not remembering a signal?
- Are you always able to make eye contact with specific athletes between plays?
- How do you know your signal has been received?
  - Would it be helpful to know your signal has been received?

5- How much time do you typically have between plays when the line doesn't change?
- Do you find that sufficient for the players to receive information from you and focus on the next play?

6- Do you find that surrounding noises like the crowd and music prevent you from sending and receiving information from the athletes on field?
- Do you use any wearable technology during the game? (headsets)

7- Tell me about how you communicate with your teammates?
- Can you tell me about a time where there was miscommunication?
- What happened?
- Is there anything you can think of that would have helped you in that situation?

8- Can you think of a situation where a player reacted negatively following a miscommunication?
- Can you think of anything that would have helped them refocus their energy?
- Are there any mental game tools or sport psychology techniques you notice the players using to optimize your performance? (music, self-talk, visualization, pinching, jumping, slapping…)

9- How do you personally deal with difficult situations?
- Is there a particular situation that stands out in your memory?
- do you find yourself getting angry with the players?
  - how do you deal with or express that anger?

10- Are you familiar with some of the new wearable devices and mobile applications?
- Do you currently use any devices?
- What features can you think of that would enhance communication during game time?
- What times of senses do you most easily relate to? Hearing, Seeing, Feeling?

11- Do you have any other comments about communicating during game time or wearable technology?

Appendix 7

Interview Questions for Athletes

1- What is your position on the team?

2- Which coach do you typically deal with?

3- How often during a game do you communicate with your coach?
- How do you communicate? (sensory)
  - when he's not in verbal range (when you're on the field?)

4- Have you ever had problems communicating with your coach, such as misinterpreting or not seeing signals?
- How do you go about learning the hand signals that your coaches use during a game?
- Do they change every game?
- Do you find them difficult to remember when it comes to game time?
- Are you always able to see your specific coach between plays?

5- How much time do you typically have between plays when you don't change lines?
- Do you find that sufficient to focus on the next play?
- Who do you communicate with during those short times and how?

6- Do you find that surrounding noises like the crowd and music prevent you from receiving information from your coach and team on the sidelines?
- Do you use any wearable technology during the game? (headsets)

7- Tell me about how you communicate with your teammates?
- Can you tell me about a time where there was miscommunication?
- What happened?
- Is there anything you can think of that would have helped you in that situation?

8- Can you think of a situation where you or another player reacted negatively following a miscommunication?
- Can you think of anything that would have helped refocus your energy?
- Are there any mental game tools or sport psychology techniques you use to optimize your performance? (music, self-talk, visualization, pinching, jumping, slapping…)
- Do you feel you can summon those tools on the field?
  - Why/why not?

9- Are you familiar with some of the new wearable devices and mobile applications?
- Do you currently use any devices?
- What features can you think of that would enhance communication during game time?
- What times of senses do you most easily relate to? Hearing, Seeing, Feeling?

10- Do you have any other comments about communicating during game time or wearable technology?

Appendix 8

Interview Answer Charts

8.1 Wide Receiver (Captain)

description/tag	Experience/Anecdote	Action	Needs	Insights
information translation				
sequence, communication, senses, translating	1) Assistants Observe game Seeing 2) Translate performance to OLine Coach Speaking 3) Oline Coach Chooses play from book Strategizing/ choosing/seeing 4) Oline Coach Communicates to coach on Field Speaking (TECHNOLOGY: headset) 5) On Field Coach Signals play to QB Signalling (Send/ Receive) 6) QB talks to team in huddle Speaking	1) Seeing 2) Speaking 3) Strategizing/ Choosing/ Seeing 4) Speaking 5) Sending/ Receiving 6) Speaking	- Ability to process info quickly - Make quick, confident decisions - translate info to coaches and athletes - Privacy from opposition	Privacy, Efficiency and Accuracy of Translations are vital to the success of the play.
signal, missinterpretation	Experience: If a play comes in wrong and it doesn't make sense in the current situation, the play will be killed. - "Don't get anyone hurt, don't turn it over." - "Sometimes if there's just a little problem with the call it can still work, we just run it a little differently, depending on how we execute it it can still work." - "If the coaches see a personal fowl, they'll take you off and normally keep you off the whole quarter."		stay calm, make the best of the situation	
signal, error	ways to make an error receiving a signal: 1- miss (not see it) 2- come in wrong 3- misinterpret 3.1 cuts short (looks away too soon) 3.2 too far to see		site line, quick thinking, conditioning	although total misinterpretations are not common, the anxiety created from the potential to misinterpret is of interest

Coaching & Team Development				
Language, code words, culture	Language sample: "The guy who was in the 3rd window of the second level is pushing to the second window so this window is open."	talking	proper conditioning, time to develop and learn	distinct expressions and vocabulary speed up the communication process and reduce misinterpretations
feedback, encouragement, coaching	Positive feedback from coaches during a tense situation: "Just breathe" "Drink some water"	positive feedback	n/a	coaches will encourage athletes to distract their minds by doing something
team development, maturity	"Last year we were too young to know how to communicate, now we know a little better. Being able to communicate on the sidelines is a big thing."		n/a	
Artifacts & Technology				
learning, software, pre-game, culture	Online video database: "You can't talk to you coach about something you saw, you have to talk to your coach the next day. **The program being more interactive would help**"	video analyzing, learning	to leave and receive comments at the point of contact, rather than discuss another day.	something for future research: exploring the methods athletes are conditioned to learn.
Headset	Headset: "NFL you're allowed headsets so in the huddle the coach can talk to the QB. When huddle ends the signal gets cut off. And that's the easiest and the most effective."			
Wrist Bands	"Can get wordy. If you look at the wrong one you're screwed."		Quickly understanding a complex play	
	Suggestion from researcher: visor screen reply: "Ya a lot of guys need visor already. I could see that working. We wouldn't even need to huddle. I think it would 100% be beneficial"			positive reception of a communication device in helmet

8.2 Offensive Lineman

description/tag	Experience/Anecdote	Action	Needs	Insights
information translation				
off field communication	Talk with coach after EVERY PLAY	Talking/ Discussion	Trust, Comfort, Verbal Communication	Talking about match ups and how things are working is important.
Huddle, translation	Get into huddle and receive play from QB	Learning	Time to process information	- Relying on QB to **translate play correctly**. *too many people making decisions is too messy and time consuming.
line of scrimmage, cadence	Want to be in the line of scrimmage at 11 seconds for the QB to call out cadence	Line up, Listening, Observing, Processing info	- See opposition - Know opposition's strategy - Know personal role - Hear cadence	Big part of the game is figuring out what opposing team's strategy is and beating it. This also involves **quick thinking**. However, any extra time and info that can be given to the players is helpful.
timing, process	Generally the time clock is 20s. but as soon as the clock is indicated we want to be in the line of scrimmage at 11s for the QB to call out cadence (so we want to do it in 9s)	transitioning	n/a	outlines where the players will be and what they are doing at what time. Any design guidelines generated must work within these time parameters.
Coaching & Team Development				
Learning, signals, pre-game	Taken upon himself to understand…helpful and saves time	Learning	- respect & trust QB - initiative	- Time is key - Knowing signals saves time (before hearing in huddle)
miss-plays, chemistry, *on-going	"miss-plays do happen a lot…chemistry on the Offensive Line is key"	Empathy	Bonding: - practice - maturity	Training Camp and **on-going team building** is key to developing team's connection

Practice, conditioning, learning, team meeting, field practice	Prep is unique to the opposing team and changes week to week Putting visual and verbal into practice brings it all together	Practice, Conditioning (verbal, drawing practice)	- Repetition - Visualization - Listening to coaching	**Pre-game prep. is vital to the success of the game**. Little is left to chance and most of the work goes in before the game. The rest is up to correctly receiving play calls to be able to accurately **put practice into action**.
reading opposition, making predictions	Reacting to opposing defence's stunts and confusing manoeuvres	Reacting, predicting, processing info, communicating	- Conditioning - Mental clarity	Player must have the ability to pick up the tendencies of the opposing line before the play starts. Ability to bring it back to basics, remember individual role and effectively communicate with other linemen.

8.3 Strength & Conditioning and Defensive Line Coach

description/tag	Experience/Anecdote	Action	Needs	Insights
information translation				
reacting	**"A lot of the time football is about reacting to what you see."**	seeing, reacting	.	- reacting to what you see is based on what you learned in practice.
signaling	"As far as going on the field and trying to execute…Everything we do is practiced" "we don't want them thinking about too much for signalling" . "I think it would help them to play faster, because the more you know the more you can do, and the more you know the less you have to think"	practicing, conditioning	quick thinking, information processing	-> signals = a way to communicate when sound isn't an option (distance, noise) -> wrist band = simplification of a complex play (reducing time and error of interpreting signals)

play call design	"there's a lot of information that goes into the call." 1) down & distance 2) opposition predicted play based on observed formation 3) technique & strategy adjustment designing a signal: "let's say we want to run a blitz were two guys go, you might say a word that has a double letter in the middle."		creativity, consistency, system	Communication isn't simply based on that specific point in time, but rather a cumulative point from hours of conditioning and establishing a bond and a culture that formulates the call.
play call design, code words, culture	"so let's say we want to run a backer blitz in the middle, we call it ammo, so ammo, like guns...you think ammo-guns-so the creation of the signal is being creative and making things relate. So if you're running an ammo blitz you don't want to kick your leg, it doesn't make sense. So the creation of the signal is about making it make sense and having something easy to remember. when you're actually implementing the signal to the guys, that comes with the film study. There has to be a reason why you make a certain call. If I wanna run an ammo blitz, well why? Well it's second down and short they like to run up the middle, so I'm gunna blitz in the middle. So that comes with understanding what the opponent is trying to do to you. that will make you call certain plays."	strategizing		
signal, information, play call	"The signal isn't as important as the concept." "One signal could tell four different players four different things."			There are 2 types of signals: **play calls and advice**.
Coaching & Team Development				
team building, trust	- some guys need a pat on the back, some guys need a hug, some guys need a foot in the butt." - "An athlete doesn't care what you know until he knows that you care." - hand signals = non-verbal cues that the guys are going to follow to make sure we're on the same page	Talking, Touching	Frequent contact with players	- creating trust happens off field. As the strength and condition coach, this relationship is enhanced through the additional time in the gym.
play analysis	Play analysis: 1) what happened 2) how to fix it 3) move on	analyzing (thinking)	Ability to analyze plays quickly and move on.	
mistakes	Problem: 1) youth 2) trust 3) experience			

reading the opposition, coverage	if the opponent lines up in a certain spot you'll call out a certain word saying "this is the coverage we're going to do or "this is the route concept that they might be running."	looking		The offensive line has many sensory tasks to execute once they are on the line of scrimmage. They must look for the safety (normally signalled by one of the centre linemen), find their matchup, listen for cues from the coaches as well as listen for the cadence call from the quarterback.
Artifacts & Technology				
wrist band	opinion on defence men with wrist bands: "Maybe the middle line backer and the free safety."	n/a	n/a	more players could benefit from seeing the play calls than just the QB.
heart rate monitors	"some teams use heart rate monitors"			
acceptance	any amount of extra time can make a difference between making a play or not. "Even if it's just 2 seconds."		save time	any amount of time that can be gained can have a huge impact on the game. This emphasizes the user need for this study.
headset	keeping the **stream of verbal communication open** = extra **time** to process information 1) QB can talk to coordinator **longer** 2) mike linebacker can talk to coordinator for **advice** - opposing tendencies, plays, blocking scheme, route combination			
opinion	Ideal: "Bond style" = coach talks, all players have ear piece. No headset. No wires.			

8.4 Quarterback

description/tag	Experience/Anecdote	Action	Needs	Insights
information translation				
coaching, communication	- Coaches: - 1) Coach JP - 2) Coach Colby - 3) Coach Coulson On field coaches = constant communication	communicating		The quarterback communicates the most frequently and with a higher number of coaches than the other positions. While this gives them the ability to gain confidence through large amounts of advice, it also poses a larger margin or error.
signals, meaning, sequence	importance of signal: 1) signal meaning (individual parts) 2) part sequence (order of parts) "there can be common errors in the signals that can absolutely destroy the play if you get 1 word wrong or 1 thing in front of the other.	analyzing, thinking	To correctly interpret all the meanings and parts of the signal	
errors	**5/60** wrong 8% **3/5** will ruin a play 5%	interpreting		When looked at as a percentage, 5% is a significant amount of error. In addition, there is a large amount of pressure that is placed on the quarterback to correctly interpret around 60 signals, which is a significant amount of moments of anxiety.
signals, misinterpreting	misinterpreting a signal = **panic** option to "gesture" to redo the signal at the expense of **time**	interpreting		
code words, signals	Signal example: "2-2-green-red-skin-gorilla"			
misinterpretation, error, signals	*Can you think of a time where something wen terribly wrong?* "The perfect example would be against Guelph this year, we were- it was in the 1st quarter and the start of the game and they were doing stuff a little differently that what we had thought. We had just changed formation-like the personnel-so guys were asking questions on the sidelines and were trying to relay the call in, and the coach was trying to give me the call, answering the question and trying to get somebody else in. So it was a complete scuffle of everything. I actually got the call I thought it was supposed to be and the result of it was an absolute awful play." *Did you mis interpret or did he give you the wrong signal?* "It was mis interpreted but also we have a lot of signals that are similar so if you're not really paying attention or looking somewhere else something looks different that what it is. So when you call the play out and you're in the huddle we're like "wait	interpreting		This scenario illustrates that coaches also play a role in signals being misinterpreted. The coach has many roles and often need to manage the players off the field, as well as keep in contact with the players on the field. When these two overlap, sending a clear, correct signal can be problematic and due to time restraints, a poorly performed signal cannot always be salvaged and can result in a disastrous play. . While implementation of wearable technology would improve reception of the proper play call, having a distinct "play caller" who's only role would be to send signals would diminish error as well.

	a second, that doesn't make sense" but it's like "6-5-4--- k we gotta snap this thing." So we get the ball, we run it, and there's like 4 defenders in 1 area, a guy's coming through on block because we had the wrong protection and we ended up throwing an interception. Pretty much the worst case scenario that could have happened."			
snap counts	"With the signals it's easy because you can see them. But snap counts with the offensive line and receivers…Like if we're going on 2 and you can't hear, you have to go on body motion."	calling cadence	Hearing	Errors occur when the whole line, in particular those at the end of the line (like the wide receiver) are unable to hear the snap counts.
cadence	cadence sample: "white thunder, white thunder- set-go"			cadence is called using code **words** which have specific actionable meanings.
play call	"stack-2-2-switch-swim- white-falcon-hot-gorilla-thunder"			Code words are symbolized using hand and body gestures, which have to then be reconstructed into english by the quarterback and relayed to the team.
sending signals, play call system	"I'm actually coaching a team in the summer, and we've just put in our play call system, we're going to have two guys on the sidelines, one wearing bright orange and one wearing bright yellow. And they're going to start with a signal meaning either I have the play call or he has the play call and everyone's going to have to know them so we can go fast pace, so we can snap the ball out of the play, line up, get the play, go right away. So we're going to see how it goes…I saw it used in American colleges."	signaling		This is an example where communication would be improved simply by allotting the task of signalling to someone other
Coaching & Team Development				
culture, formations, plays	formation = automated from day 1 new play = learn in meetings	Learning	positive learning environment	
teamwork, signal learning	communication: "I think it would be better for us if everybody knew the signals so we could all be on the same page."			
Artifacts & Technology				
wrist band	"It definitely does [work very well] because that way there's no error in what the play is. But the problem is there's only a certain amount of plays you can run. so if you wanna run one play out of a different formation or set or tag it with something else, you can't do that if it's just written on your wristband."			Signals are more versatile than "premade" wrist band play calls but more prone to error. ->recommendation: every play (short or long) is received on the wrist band

wrist band, visor	"It would definitely be pretty cool. I like your visor idea, though, that would be amazing!"			There is excitement, motivation and need for communication aids in football.
headset				* argument that having a headset in the huddle all the time might not be the solution to the negative elements of crowd noise, etc.
sensory design				* Interesting research; what is faster to process of the 2 used senses? sight or sound?

8.5 Offensive Coordinator

description/tag	Experience/Anecdote	Action	Needs	Insights
information translation				
communication, game situation	"The biggest issue is time. but that's what makes sports. having to make decisions and communicate quickly."	deciding, communicating	time	The design strategy is to use the allotted time the most efficiently possible. Focus should be on strategy and the task at hand, rather than deciphering signals and codes.
play call structure	play call structure 1) formation 2) protection/direction 3) play (pass/run) field = strong/weak talk about strong side first			Following a strict structure makes it easier for the coaches and athletes to memorize plays, and systematically break them down in order to understand the whole picture.
play call structure, code words, word association	"I find it's all lego. You need the base legos, and the more legos you put in, the more crazy it gets. But it's just lego it's just a tag. The tags modify the play in different ways. You know what a tag is you just have to apply it to the play. You can use 100 legos...and that's when we start to use wrist bands. When we use too many legos, it's not even that hard but there's a 20 second clock."	strategizing		along the lines of that metaphor, the players know how to use the lego, they just need to be sure they are using the right piece; which is where design innovation can occur.
extended communication, on field	"It would be good to be able to talk to him instead of just signalling him, because then you could remind him of what to look for, because I can't signal that."	communicating, talking		although there are generally few issues communicating practiced plays and basic pieces of advice, coaches are not able to communicate precise tips and reminders.

miscommunications	Miscommunications: 1- got it right but didn't say it right 2- says it right but 11 other players don't hear it right	Translating		there are quite a few steps to effectively communicating a play call all the way from the media booth, to the coaches on the sidelines, to the QB, to the rest of the team on the field.
process	player sample checklist: 1) where are my guys lining up 2) where's the safety 3) what's the cadence QB: extra step: look for signal -> receive signal -> **decide how to react** (know and **choose** best possible reaction)	Process Information, React		If players have a system to remind themselves of their role, they will be more like to execute effectively and not get overwhelmed with information, especially when there are changes to a plan or strategy.
Coaching & Team Development				
coaching, role	"How the offence works comes from me"	decision making		
off field coaching, kinetic learning	"show offensive line who they're blocking: line up the 5 guys side by side, line up the defence, walk through specific fronts they need to block."	Mimicking		Walking through a sequence is a **learning tool** for the players to understand their task and **quickly condition** themselves to perform.
learning, culture, pre-game, off season	**visualization** -> software to see video **memorization** -> write and draw . **learning a play:** 1) talk 2) watch 3) practice	visualization. memorization	video analysis software, drawing supplies	Using a combination of technology and classic note taking, the coach enables the athletes to learn and memorize the **cultural framework** they will employ during the season. . learning the foundations of the culture allows the team to focus on learning the plays
trust, confidence	"A lot of the newer guys will have trouble speaking up and being wrong…A big example is when we come back to the sidelines and we try to see everything but it's hard. If they come back and we lost 5 yards but everybody says they blocked their guy, I don't design a lot of plays where everyone blocks and we lose 5 yards."	Discussion, assuming responsibility	Trust, confidence, maturity	Part of strategizing involves feedback from the athletes. Their willingness and ability to share their opinions and especially admit to an error help the coaches to develop better strategies for the following plays.
Artifacts & Technology				
video, pictures	"It's legal to record but video isn't as good because you have to play and rewind it. With a picture you can look and draw on it and talk about it."	recording, picture taking		Taking pictures during the game is a lot more useful for immediate feedback than video. Transferring pictures from the media booth to the coaches on field help to strategize.

data analysis, documentation	Runningback coach: documenting data - custom templates (designed through trial and error) - Xos ("software, analytics, services)	documenting data	framework (chart)	Coach developed a custom chart for **fast data entry** that he found to be **more efficient than using a computer**. There is a potential opportunity for current data analysis software to be more "game time friendly" which would eliminate the need to **transcribe** all the written data into the software to analyze during the team meeting the following day. This might also allow for better **game time analysis and strategizing.**
wrist bands	- "I think it would be something too look into for sure. I think the main thing would be at half time to put in more plays. It would be interesting to know, from the booth, how complicated it would be to send a play. I want to make sure play 18 is the same as on their wrist band." - *"It would be like sending a picture or a text message."* - "In that case I would want them to be preprogrammed, and have a chart of all those plays and just choose one."			