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Exploring Different Experience Modalities of Tennis Electronic Line Calling

Key elements of the interaction between players and the system

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Abstract
New technologies have made sports more entertaining, safe, and fair in recent years. This study focuses on electronic line calling, a technology that is revolutionizing tennis. A set of sensors and complex algorithms enable umpires and players to determine with a certain degree of precision whether the ball has bounced inside or outside the court. Numerous technological solutions have been developed in this ambit, but little research has been conducted on the interaction between players and the system during a match. The research follows the Research trough Design approach and the Double-Diamond design process. I collaborated with the company PlayReplay AB, that has developed an electronic judging system. At first, I used research methods such as interviews with experts to understand the user needs and narrow down the problem. Secondly, I explored different modalities and iterated on several user interfaces to generate a final design proposal for PlayReplay's system. The findings demonstrate that the player experience with an electronic line call system depends on various elements. First, the system must adhere to certain requirements like discretion, punctuality, and reliability, otherwise will feel unreliable or disturbing. Second, the interaction modalities should comply with some specifics: the output should be easily identifiable but not obtrusive, and the input must be easy to use but also well incorporated into the game.

Keywords Sport, Human-Computer Interaction, Electronic Judging System, Tennis, Electronic Line Calling.

Contents

List of Figures

Chapter 1

Introduction

Sports are progressively incorporating more technology. As of example of this, smart tools can be found in cricket, baseball, rugby, ice hockey, tennis, baseball, football, and even artistic gymnastic [8, 22]. It is altering how the sport is arbitrated, broadcast, and experienced. Big screens are now present in the majority of stadiums or arenas to enhance the experience for live spectators, and it has shortened the distance between the game and the viewers at home, sometimes improving the viewing experience over that on the field [31]. In terms of training, it has given athletes tools to improve their performance [31]. In terms of judging, it has improved sports fairness by giving officials tools to better comprehend situations and facilitate decisions [20]. The COVID19 pandemic has sparked innovations in a variety of industries, including sport. In many situations, the installation of cameras and intelligent technologies has assisted in reducing the number of spectators on the field, minimizing close contact, and making the game and the participants' employees de facto safer [6].

The technologies used to help arbitrate the match are called Electronic Judging Systems (EJS). In football, we can find Video Assistant Referee (VAR) that provides detailed replays and virtual simulations of the ball in peculiar actions. Similarly, in tennis, we can find Electronic Line Calling (ELC) that provides information on whether the ball landed inside or outside of the playing area. Even though tennis has one of the greatest umpire-to-player ratios of any sport (up to nine umpires for a 1 vs. 1 match), the necessity for digital tools remains: for practical reasons, not every tennis match can be officiated by an umpire, and even when it is, the high velocity of the tennis ball (up to 260 kilometers per hour) makes it difficult for the human eye to judge a bounce

[25, 33]. Numerous businesses have created solutions for tracking the ball (section 2.2.2), but some argue that this technological trend is expanding with poor research on the User Experience (UX) [6].

This study responds to the question: **”What are the key aspects of the Electronic Line Call experience for tennis players?”**. I have provided a response to the question by following a Research through Design process and generating a series of design iterations [40]. I examined the use case of the company *PlayReplay* [27] that has recently developed an Electronic Line Calling system and needed support to improve the UX of their system. I had three goals to accomplish in order to carry out the research: (1) evaluate the general issues associated with Electronic Line Calling, (2) establish the changes for PlayReplay system, and (3) design a prototype to test the improvement. The final prototype of this dissertation can be seen as a design contribution to the prominent field of Electronic Judging Systems and Electronic Line Calling systems.

Given that this research includes information about tennis but also about other sports, some terminology is grouped to simplify the reading. In fact, different sports use different names to call similar roles or phenomena. The following definitions will be used throughout this document:

- ”match”, ”session”, ”game”: refer to the actual sporting event; ”tennis game” will be used out of context to refer to the tennis scoring (the one won after four points);
- ”official”, ”judge”, ”umpire”, ”referee”: refer to the individuals responsible for making decisions during the match.

This document is structured as follows: chapter 2 presents relevant background information about tennis and its technological evolution, chapter 3 presents the methodology and methods used to understand the user needs and elaborate a design proposal for PlayReplay, chapter 4 contains the results of the analysis and the most pertinent insights, chapter 5 presents an elaboration of the outcomes, chapter 6 is the final chapter that contains reflections about the study.

Chapter 2

Background

This chapter provides a summary of tennis, challenges, and umpiring theory. In addition, it analyzes human limitations and the advent of technology in sport.

2.1 Tennis

2.1.1 Rules

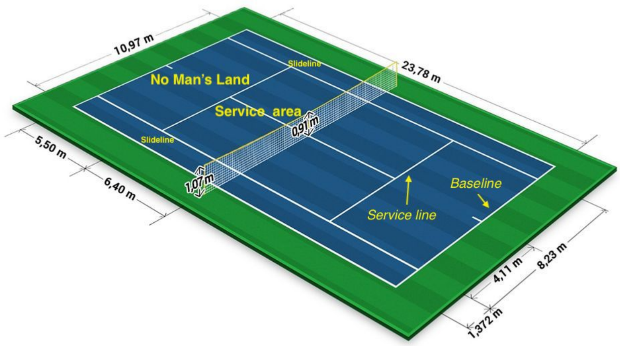


Figure 2.1: Dimensions and zones of a professional tennis court [5]

According to the International Tennis Federation "rules and regulations" documents (valid for all genders), tennis is a sport played on a rectangular court that can be made of clay, concrete, or grass [16]. A standard court is 23,78 meters long and 10,97 meters wide (see Fig. 2.1), and the lines are 2.5

to 5 centimeters wide [32]. A net divides the court in half on the long side. A match can be played either 1 vs. 1 (single) or 2 vs. 2 (double). The players stand on opposing sides of the court and hit the ball back and forth. Single-game competitions are played without the use of lateral sidelines. The scoring consists of points, games, and sets that are added together. The winner of a tennis match is the player who wins two sets. To win a set, a player must win six games, seven games if the opponent won four or more games, or two more games than the opponent in the case of a tiebreak (6-6). In order to win a game, a player must earn four points, or two more than their opponent in the event of a 3-3 tie. When the opponent throws the ball into the net or when it bounces outside the designated area, a point is scored. If the ball bounces more than once on the opposite side of the court, the player who hit the ball scores. Notably, lines are considered part of the court, so if the ball touches a line in any way, it is considered inside the court [32]. The match begins with a serve, in which a player from behind the baseline hits the ball targeting the opposite side's service area (if the serve is from right, the service area to target is the left one and vice versa). If the initial serve hits the net or lands outside of the service area, the player may serve again. If the second attempt also fails, the opponent will score.

2.1.2 Challenges

Monitoring balls that bounce close to the lines is known as "line calling." In amateur settings, each player calls the line for his or her own court side, so players must rely on one another and yell "OUT" when they notice the ball bouncing out. One to nine umpires are responsible for calling the ball in tournaments. It is not uncommon for the ball to bounce close to the line, frequently at high speed, which can render the shot's outcome debatable. For this reason, Electronic Line Calling tools have been invented. When ELC is in use, the ball is tracked by a set of sensors, and whenever a specific action occurs, a player can challenge (i.e. contest) the umpire's call and receive the machine's verdict. Electronic Line Calling can really make the difference: according to Mather's 2008 study on over 1473 challenges during 15 ATP tournaments in 2006/2007, approximately 40% of the umpire calls were incorrect and corrected by an Electronic Line Calling [20]. Abramitzky et al. obtained similar results (38%) in a study from 2012 [2]. The majority (94%) of disputes between players and referee's decisions occur on bounces within 10 cm of the line, regardless of whether they are IN or OUT, as statistical data reports [20]. Players may challenge the umpire's decision an unlimited number of times, provided that the challenge is successful. After three incorrect challenges in a set, a player can no longer challenge [11].

2.1.3 Umpiring

Being an umpire in tennis is not an easy job. First of all, tennis balls (which have a diameter of only 6.5cm) served by professionals can travel extremely fast, acquire peculiar spin, and generate trajectories that make judging a bounce close to a line extremely difficult [20, 33]. In addition, the angle between the umpire's position and the ball can produce optical illusions and errors [31]. Second, tournaments organizers frequently schedule multiple matches on the same day, and a few officials follow all the games. This prolonged activity can cause officials to become fatigued and less vigilant, resulting in inconsistent decisions between matches. Visual evaluation and perception are impacted when visual sensors are at their limit, according to studies [20, 22]. Third, umpires are susceptible to biases like other people. For instance, they may be susceptible to ”recall bias” in which an action is taken based on a significant decision from the past, or ”similarity bias,” in which a decision is made based on a similar context from the past. All of these issues and complications can affect the manner in which the game is played and even change the final result. Wrong decisions can also have a negative effect on the referee's authority since nowadays spectators at home can easily identify officials' mistakes and gaffes thanks to replays and slow motions offered by TV broadcasters [31].

2.2 Technology in tennis

2.2.1 AI-powered evaluation

New tools have emerged in response to the numerous challenges umpires face today. The most sophisticated systems are fueled by Artificial Intelligence (AI) that comprehends specific context and generates highly reliable analysis. These potent tools enable the identification of minute details such as skidding balls, and make the sport more accessible to all. In fact, with AI-powered evaluation, it is possible to receive specific and individualized training without a coach or play a match arbitrated by a computer when a referee is not available [37]. Some people believe that intelligent tools in sports are fundamental to achieve genuine fair play, which is considered by many the most valued and respected quality of sport. They believe that without current tools and the transparency of their use, it would be difficult to guarantee fair opportunity and unbiased adjudication [18, 31].

2.2.2 State of the art

Figure 2.2: Hawk-Eye bounce review [13]

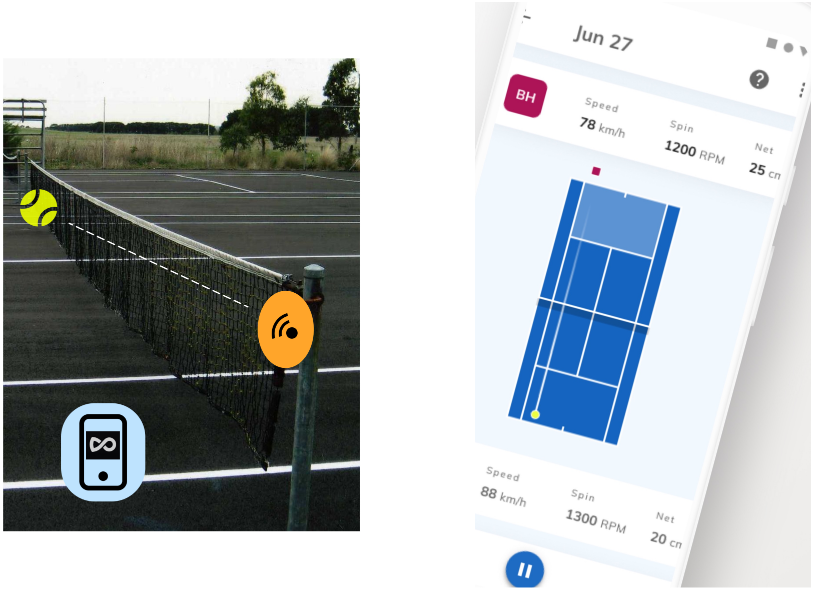
There are various providers of Electronic Line Calling, each with distinctive capabilities, prices, and UX. Since 2005, when it was officially approved by the International Tennis Federation, Hawk-Eye has regularly been utilized in major tournaments. Their system consists of six or seven sensors placed around each court and a control room staffed by an administrator. Given the hardware, the installation and maintenance costs are expensive (up to 70.000 dollars per court [35]). An algorithm calculates each shot's trajectory and predicts where the ball will land with a precision error of 3.6mm [2, 37]. A virtual video simulation of the bounce is typically displayed on a large screen at the court whenever a player contests an umpire's decision (Fig. 2.2). In addiction, Hawk-Eye has developed a ”live” version of its system called ”Hawk-Eye Live”. It is a system that employs similar hardware to the basic Hawk-Eye, with the exception that every outside bounce is automatically announced by a recorded voice. Particular shots are also displayed on a large screen, similar to the standard Hawk-Eye. With this ”live” version, tournaments can be played with a single chair umpire; this became especially useful during the COVID19 pandemic, when gatherings of people were deemed unsafe.

Another noticeable Electronic Line Calling tool is produced by FOXTENN and it consists of a set of 40 ultra high-speed cameras and 10 lasers tracking the ball at 2.500 fps to capture the real bounce in slow motion [14]. Similar to Hawk-Eye, it is expensive (up to 50.000 dollars [30]) and it utilizes replays: when a player challenges, a real slow-motion video of the bounce is displayed on screens. In 2021, it became the first system to be approved for tournament played on courts made of clay, where the technical limitations prevented the usage of Hawk-Eye.

The market also provides cheaper and more semi-automated options. These options have made Electronic Line Calling more accessible for everyone by allowing even novice players, who frequently lack access to expensive and exclusive technologies, to receive assistance during the game. These typically require monthly subscriptions from players (10-20€ per month). One is manufactured by PlaySight and is known as SmartCourt. One to ten sensors are positioned around the court. There is no control room because the sensors data is transmitted and processed by an algorithm in the cloud. They offer numerous variations of their system, but the majority of them display the match's information on a screen (including line call) [28, 37]. Another option available in this category is called Zenniz and it consists on a large device, equipped with sensors and a screen, that is placed on the side of the net. It functions for line calls and displays the results on the large display [39].

PlayReplay belongs to this group of low-cost standalone products [27]. They have developed a tool that is mounted on the net post (Fig. 2.3a). The system monitors the ball and provides data through a mobile application (Fig. 2.3b). During the match, the application displays the ball's trajectory, where it bounced, as well as its speed and spin. The system analyzes the match's data post-match to produce statistics such as average speed, bounce placements, fastest serve, etc. To use the system, one player must check in using the app on one court. Prior to my recruitment, PlayReplay's Electronic Line Calling experience consisted merely of using the phone to detect where the ball bounced. Therefore, in matches with an umpire, the umpire held the phone and monitored the game; in matches without an umpire, a phone was typically left on a chair near the net post and was checked by the players whenever a challenge occurred. The app UI is showed in figure 2.3b and 4.1.

In addition to market-available products, there is some literature about mobile



(a) Representation of PlayReplay system

(b) PlayReplay app showing the ongoing match information

Figure 2.3: PlayReplay system and app

apps that call the line (e.g. BallCaller [37]), however, the accuracy is questionable due to the inability of smartphone cameras to track fastballs.

2.2.3 Limits of technology

We have seen how technological tools can enhance or even improve sports, but they are not perfect. For instance, the majority of judging tools rely on statistical estimations of what has actually occurred, and thus cannot be considered 100 percent accurate. Collins contends that these tools are too "perfect" and not adapted to the imperfect physical world, such as Hawk-Eye, which computes the bounces in a 3D virtual space without taking into account the small imperfections of the ball and the lines. He also argues that technology can create inconsistencies between matches where it is used and matches where it is not: for example, a skidding ball in tennis is typically ruled OUT by an umpire, but IN by a Electronic Judging Systems [8]. Due to the time required to elaborate the data (Hawk-Eye takes 30 seconds to compute), these tools can also hinder the game's continuity and dynamic progression [18, 31]. Moreover, these tools' algorithms are kept secret by their manufacturers, making it difficult to identify logical fallacies or bugs. Furthermore, studies demonstrate that algorithms can be biased: developers can transfer their biases to algorithms, or in the case of Artificial Intelligence, biases can compromise the algorithm learning process [21]. In a more recent study, Mazurova et al. affirm: ”AI-powered systems may acquire, replicate, and even amplify (implicit) human biases present in the training data used for learning from past performance–evaluation” [22].

2.2.4 Hybrid approach

Despite the fact that Artificial Intelligence already outperforms humans in several cognitive and perceptual domains and is on the verge of doing so in many more, a large number of authors in the literature recommends to proceed with caution [22]. Sport is fun and technology should not interfere with that. There are context where the absolute precision is needed (e.g. world tournaments), however in the majority of cases, human performance is more than adequate [6]. The hybrid human-AI approach seems to be the most effective to manage the game rather than administering the rules and regulations during the game [18, 22]. Collins argues that tools should not be viewed as a technological solution for achieving exact precision, since inaccuracy will always exist, but rather as a solution for obvious injustices [8]. Therefore, the emphasis is on developing assisting tools rather than substituting systems.

Chapter 3

Methodology and Research Methods

This chapter's objective is to provide an overview of the methodology and the methods employed. Section 3.1 describes the approach and the design process that was used to conduct the research. Sections 3.2, 3.3, 3.4 describe the primary methods employed to collect insights. Finally, section 3.5 contains the limits of the study.

3.1 Methodology

The methodology employed in this study is based on Research through Design in the field. Research through Design is a practice where design concepts are used to generate new knowledge. It involves the creation and critique of artifacts that serve as proposed solutions to a problem [40]. In practice, it aided in defining the players' needs and uncovering their behaviours in various contexts. It also helped with the creation of User Interface and explore the interactions. Finally, it generated new evaluations of discoveries in the field of Electronic Judging Systems.

To structure the process, I used the Double Diamond design process model [4]. It is composed of four steps that represent the various stages of the design process. The four steps are separated into two phases: research (Fig. 3.1) and design (Fig. 3.2). In each phase, the first step encourages divergent (broad) thinking, whereas the second encourages convergent (narrow) thinking. The step indications are primarily theoretical and therefore difficult to adhere to in a practical setting. However, going through these four steps gave me greater control over the study and highlighted missing elements and understated areas.

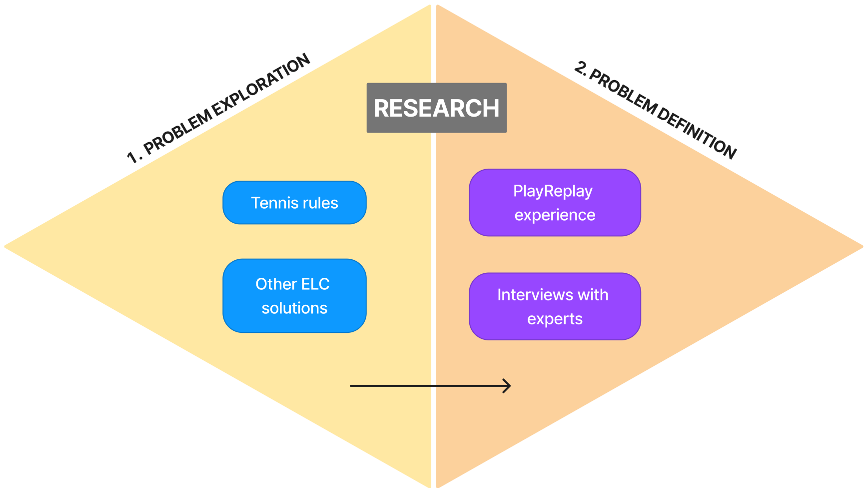


Figure 3.1: Research Phase of Double Diamond [10]

Step 1 - Exploration

The goal of the first step is to identify the user needs [4]: what do users find currently hard to do and why? In the context of this study, the objective was to comprehend the current player issues using Electronic Judging Systems and more specifically Electronic Line Calling. This step also give me the information to, for example, evaluate the tests I conducted. To accomplish this, I began by researching the evolution of tennis rules since the arrival of new innovations, including articles about the controversial introduction of these new technologies (e.g. [7, 29, 34]), and gained additional insights from the User Experience of Electronic Judging Systems used in other sports. I researched the solutions offered by other Electronic Line Calling producers and read online user reviews to determine what players like or dislike.

Step 2 - Definition

The purpose of this step was to identify the most significant problems that the design phase will address. Among all the user needs learned from literature and web articles, there were a few that were pertinent to the local context and, therefore, more important for PlayReplay's Electronic Line Calling. There were some different alternatives: I could have interviewed or sent a questionnaire to a large number of random PlayReplay users, but it would have taken too much time and it would have been difficult to obtain constructive reliable insights; alternatively, I could have chosen the primary issue myself and conducted an autobiographical design study to confirm it, but my limited knowledge of tennis and Swedish tennis tournaments would have likely produced misleading results [24]. I ultimately decided to interview a small number of experts instead: professionals in a given field are typically knowledgeable, motivated, and reliable sources of information [12]. I also found it constructive to converse with PlayReplay employees who had been considering and experimenting with their Electronic Judging Systems for months.

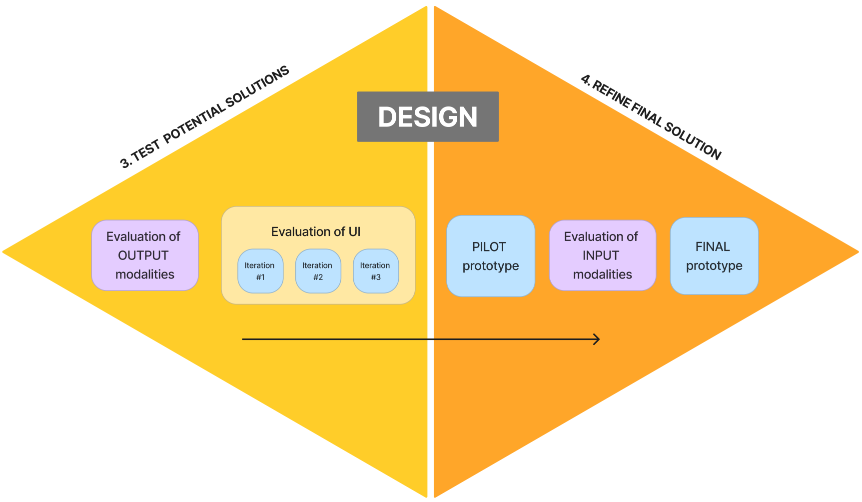


Figure 3.2: Design Phase of Double Diamond [10]

Step 3 - Testing

I primarily used this step to eliminate solutions that will not work. With the assistance of Erik Häger (UX designer at PlayReplay and amateur tennis player), I went to a tennis court and tested some input/output modalities as well as some graphic interfaces that could be considered for PlayReplay's future Electronic Line Calling system.

Step 4 - Refining

The final step is an iteration on potential solutions that leads to a refined solution that is approximately deliverable. In this step, I created a first pilot prototype and tested it at the court together with two tennis players. With the insights collected, I designed the second and final prototype for PlayReplay's Electronic Line Calling system.

3.2 Interviews with experts

The interviews with experts took the form of thoughtful dialogue. Before the interview, I formulated a list of questions to guide the discussion. The questions asked fall into four distinct categories: personal (age, experience, etc.), related to line calling without technology, related to Electronic Judging Systems, and related to the future of these tools (see Appendix C for the list of questions). The interviews took place in Stockholm in May and June 2022 and were conducted in English. I recorded the interviews in order to analyze the transcripts later. Each interview lasted between thirty and forty minutes. Before each interview and registration, I explained the purpose of the study and requested the permission to use and elaborate the transcripts. However, I decided to keep respondents' last names private in order to prevent any unwanted exposure.

3.2.1 Participants

To get relevant data about tennis and Electronic Line Calling, the interviewees had to be professional tennis players (those who have played in more than five years in official tennis tournaments) or official umpires (those recognized by a tennis federation). Contacting experts can be a challenging task. However, thanks to PlayReplay and its professional network, I had the opportunity to interview three specialists:

Peter Former professional tennis player of 31 years and current tennis coach from Sweden. He has played tennis since he was 11 years old. He attended numerous tournaments in Europe, competed in the ATP, and played in international tournaments (mostly USA). Since leaving his professional career at age 23, he has coached at a professional level. He has once used PlaySight and uses PlayReplay regularly during training.

Mathias Swedish official ITF umpire of 42 years of age. Since he was 4 years old, he has played tennis, and he began officiating at the age of 12. He completed umpiring courses and became an ITF-recognized umpire. He has served as a line umpire at some of the most prestigious tennis tournaments in the world, including the Wimbledon Championships in London. He has officiated matches in which Hawk-Eye was utilized.

Victor Swedish professional tennis player, 30 years old. Since he was a child, he has participated in tennis tournaments. He has tried Zenniz and PlayReplay.

3.3 Evaluation of interaction modalities

Each ELC system consists of two interaction elements: INPUT, i.e., the acts that result in the system displaying the line result; OUTPUT, i.e., the means by which the system notifies the players of the result. To evaluate the benefits and drawbacks of various usable modality, I visited a tennis court two times (one for each group of modalities) and ran some tests. Each modality was evaluated separately to simplify the experiment and gain a greater understanding of the positive and negative attributes of each.

3.3.1 OUTPUT

I selected to test and evaluate the screen, flashlight, and sound output modalities since they were compatible with the existing PlayReplay system and thus respected their desire to limit expenses.

Screen The data can be displayed on the screen that can be of different sizes. The information can be shown using an optimized User Interface for the PlayReplay app.

Flashlight An event can be communicated using the blinking of a flashing light.

Sound A recorded voice or a noise could announce an event via a speaker installed on the court.

Each option was evaluated on the four different circumstances under which the system has to communicate: (1) idle state, thus communicate that the system is running and ready, which is an important aspect suggested by literature [17]; (2) what shot, to avoid errors in the event that the shot challenged is not the last recorded by the system; (3) positive outcome or ball IN; and (4) negative outcome or ball OUT.

3.3.2 INPUT

I analyzed three input modalities that are simpler to implement in the PlayReplay system: touchscreen, gestures, and event-based.

Touchscreen The players could interact with a touchscreen display that captures the request. Options include the screen of a smartphone and of a tablet.

Gestures The players could interact with the system through gestures. Noting that PlayReplay sensors already track players' movements, therefore gesture will not bring extra costs or hardware.

Event-based The system could work without any action from the players. The outcome could be presented whenever an event occurs (like a ball bouncing outside).

These options have been evaluated based on (1) simplicity, or how simple it is for the user to request the information, (2) ease of learning, or how easy it is for the user to learn the command, (3) game integration, or how well the action can be integrated into the game without changing its dynamics, and (4) error proneness, or the likelihood that the system will fail or provide incorrect results.

3.4 Iteration on prototypes

Prototype iteration has been a useful and efficient method for determining what could and could not work in a potential User Interface. For each sketched interface, I tested and noted the issues. In a brief period of time, numerous rapid interactions yielded valuable observations, as suggested by the Research through Design authors [40]. Minor problems were fixed immediately to run another test. Larger pain points needed more time to be elaborated and eventually led to another interface. This procedure generated five distinct versions of UI, each with updated features and specifics. The first three iteration can be considered an evaluation of fundamental UI elements such as shape, color, and size. I utilized an iPad PRO 12.9-inch with Apple Pencil to rapidly make these low-fidelity sketches. The last two iteration were prototypes made with Figma that incorporated some aspects of the interaction [9].

3.5 Research limitations

Tennis is a sport played all over the world and by all categories of people, from kids to seniors. This research focused on singles games (1 vs. 1) played indoors in Sweden by people aged 20 to 30 years old. Observing that indoor venues might considerably vary in size, proportions, and equipment. Moreover, different countries may have different tennis rules, so the Swedish rules are the ones taken into consideration. Due to the fact that the research was conducted within an organization, there were time, financial, and technical constraints on the realization of the design proposal. I collaborated with PlayReplay for a period of five months, from February to June 2022. I was aware from the outset that the design should not incur excessive costs and be compatible with the existing hardware. In addition, the design proposal should have been relatively easy to develop (to avoid high costs of development) and not too different from the current app User Interface (Fig. 2.3b and 4.1). Furthermore, my tests had to rely on a dynamic system that was updated daily due to the company's use of the Agile workflow methodology, in which small but frequent changes and improvements get released daily [1].

Chapter 4

Results and Analysis

In this chapter, I present the results and their analysis in the chronological order of execution. Fig. 3.1 and Fig. 3.2 resume them. Each method has provided insights that have allowed to better comprehend the problem, identify its limitations, and provide a design response that is both practical and meaningful. I collected all data in a single vast virtual canvas using FigJam [9].

4.1 Interviews with experts

4.1.1 Analysis

To analyse the interviews transcripts and extract patterns and hidden meanings, I used the Affinity Diagrams [26]. For each interview, I created a section (container) in FigJam. Then, I proceeded to the transcription of the audio recording and created virtual post-its containing the most important points and quotes. After completing the notation, I went through the container and sorted the post-it notes according to subject. At the conclusion of all three interviews, I created a circular container for each finding and noted it in a new section titled ”Findings”. I finally adhered support post-it notes around each finding (Fig. A.1).

4.1.2 Findings

The examination of the notes and quotations from the interviews revealed six primary results, some of which were more relevant than others. The topics of cheating, system mistakes, system precision, player attitude, timing, and training were among the most interesting and controversial of the collection. The findings are discussed in greater detail in the following paragraphs.

1. Electronic Line Calling shapes moral judgement

All three interviewees concurred that Electronic Line Calling promotes a fair game. There are numerous causes. First, they explained that disputes occur frequently and that it is extremely difficult for the human eye to catch fast-moving balls (especially under certain angles). Second, a poor decision or call from the opposing player or the umpire can significantly affect the outcome of the match, as Peter affirms that he has lost matches due to incorrect line calls throughout his career. Also, he said: *"I rather prefer to lose on machine error than human error"*, claiming to have encountered both skilled and incompetent umpires, such as those who acted unprofessionally or had poor eyesight. Finally, cheating seems to happen frequently in matches without an umpire: *"Cheating is a thing in tennis"* (Peter) and *"I do sometimes compete with players that cheat and that is super irritating"* (Victor). According to studies, there is a direct correlation between moral attitude and tennis cheating [19, 37]. However, Electronic Line Calling can discourage it: *"Cheaters won't cheat [with Electronic Line Calling] because it's super embarrassing for them to be called wrong. Like if I challenge the call twice, or three times and they are constantly wrong, they would look bad to the audience and no one wants to look bad, right?"*(Victor).

2. A single error can compromise the credibility of the whole system

Electronic Line Calling must be accurate, or the entire system could be rejected. Mathias argues that a single erroneous call could cause the players to debate every call made by the system, rendering the system completely pointless. Victor also believes that a misinterpretation can be fatal and could tempt players to revisit previous shots in search of other mistakes: *"if you have a sense that the application is wrong you think 'no, that [shot] was out', and then the other player may start browsing different shots... at that point, uncertainty builds even more"*. On the other hand, if the system feels trustworthy, Mathias argues that minor inconveniences such as system delays would be acceptable: *"If the application is so good and calls correctly, then it's no problem that the call comes a bit late"*.

3. If players are fine, PlayReplay should be fine

According to the interviewees, the purpose of the game is frequently to have fun. If no player has noticed a slightly out-of-bounds ball and the game continues, everything is fine: *"[when the player is cheating] then I would like to have it [the ELC], but most people are quite nice. Most people rather call the ball IN than OUT. So, when I play with them, I'm like: whatever you say, I'm fine"* (Victor). The conclusion drawn from this point is that creating a system that calls every ball out with millimetric precision may not be necessary in the majority of situations.

4. Tennis players do not like to be disturbed

Mathias, the umpire, explained that in certain tennis tournaments, the use of phone flashlights is restricted because it could affect the performance of the players. In fact, tennis is a sport in which concentration is crucial and distractions must be minimized: "*a thing in tennis is that the players don't want to be disturbed*" (Mathias). This sets constraints on the realization of the Electronic Line Calling that thus must be discrete for the players and the others: "*I really enjoyed the Zennis system because it had the screen that you could ignore*" (Victor) or "*You don't want to disturb the other courts (with sounds, etc)*" (Peter). However, even if a player might disagree, it is essential to recognize that sports are always evolving and embracing new technologies. After the introduction of Hawk-Eye, for instance, the tennis rules were updated to enable challenges. Consequently, the objective of this discovery should not be to avoid technologies that affect the game, but rather to avoid those that actually divert the player's focus.

5. Tennis players prefer to avoid discussions

Discussions and arguments seem to happen very often during a match: *"when we talk about even junior tennis, there's so much tension"* (Peter) or *"some people can get quite aggressive on court"* (Victor). Peter and Victor both emphasized the negative effect of debates on the game and they proposed two distinct solutions: Victor believes that a single device shared between the players can be a valid solution, whereas Peter believes that communication and contact between players should be avoided in the first place, hence his solution would be *"something that you can check without interfering with the other player"*.

6. Players use the system to train themselves on line calls

This is arguably the most significant discovery. In all of the interviews, I observed that players use Electronic Line Calling not only to play a fair match, but also to understand when and why they are in the wrong: *"when I have used digital systems, I learned. Maybe balls that fly with that [a certain] angle are IN."* (Mathias) and *"I use playreplay to understand my calls and also to understand my opponent"* (Peter). In other words, players and umpires gain a better understanding of the shots and learn how to judge them thanks to technology. Peter affirmed: *"If I make a call OUT, but he [the opponent] is challenging and it happens to be inside, then I know and next time I'm not gonna make that call again."* and *"if it's two first serve [challenged], which are very similar on pace, similar on placement. I don't double-check unless I feel I wanted to double-check"*. This discovery indicates that it is essential to provide players with as much information as possible so that they can comprehend the physics of the shot and eventually learn from their wrong calls.

7. Line call is strictly time-related

A line call is only reliable if it occurs on time. What is not explicitly and immediately considered OUT is considered IN: *"If you haven't said OUT, you need to interpret it as IN"* (Peter). Nonetheless, you cannot judge what occurred in the past: *"he [the player] can't continue playing and then when the point is over, he can't go back to the mark, so he has to stop directly and show the mark"* (Mathias). This highlights an additional facet of the Electronic Line Calling that, as Victor suggested, is significant: *"shouldn't allow browsing old shots so debates are avoided"*. Perhaps the number of shots displayed by the software during a match should be limited to four or five, so that learning is still possible but arguments are avoided.

4.2 Evaluation of output modalities

To test the feasibility and limitations of each output option, Erik and I visited a tennis court and tested screen, flashlight and sound. Appendix B contains some photographs of the test. The interviews suggested that the ideal output should be highly noticeable without being intrusive, meaning that it should not distract the players or annoy those nearby. For this reason, each option was evaluated in terms of noticeability and intrusiveness.

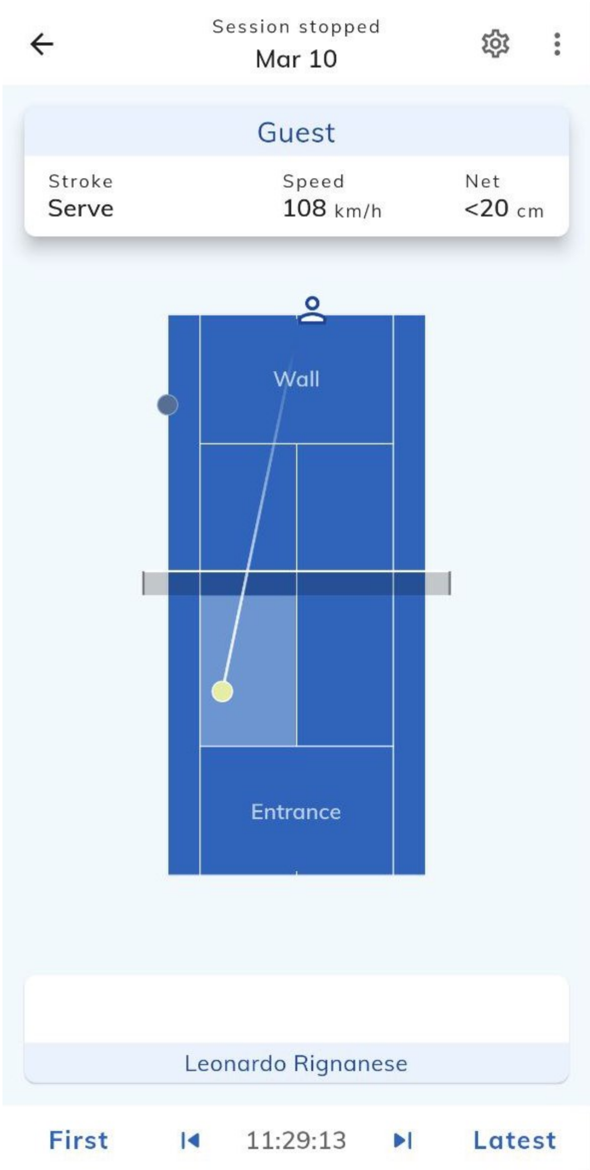


Figure 4.1: PlayReplay app shots view

Screen

First, we conducted tests with a 6-inch smartphone by setting the brightness to 100 percent and then placing it in various locations. From each location, the visibility of three different colors was evaluated: green, to simulate an incoming call; red, to simulate an outgoing call; and blue, to simulate an idle state. When the phone was placed on the net post with the screen facing the player (see B.1b), the display was highly visible but possibly too distracting. We attempted to position the phone over the umpire's chair, facing the net (see B.1a), and the screen was less distracting but still visible from any distance, with red being slightly less visible than the other colors. Acknowledging that the optimal viewing position was near the net post facing the net, we conducted additional tests with a larger screen (12.9 inches). The visibility improved significantly, and the larger display even allowed for the inclusion of text. Noting that reflexes may cause visual issues, so an opaque screen is preferred. Before dismissing the large screen, we also evaluated the visibility of the live view offered by the PlayReplay mobile app (Fig. 4.1).

Flashlight

We evaluated the flashlight using the one found in a mobile device. We tested various positions and blinking rates, which resulted to be really catchy, but also very distracting from the player's perspective.

Sound

We then tested the sound signal. We tested the sound ”beep” and a virtual voice saying ”ball out” and ”Erik ball out” created using the website NaturalReaders [15]. We played the sounds from the MacBook PRO 2021's speaker at 75% volume. Erik preferred the ”beep” sound over the voice because the latter could be annoying and even demotivating to the player. The sound was unmistakable, but the volume was so loud that it echoed throughout the entire arena (which has seven indoor courts adjacent to one another). The echo was not eliminated by lowering the volume, and we came to the conclusion that this modality is potentially disturbing for other players.

4.2.1 Analysis and Findings

After assessing the general characteristics and limitations of each output mode, we drew a table (table 4.1) to examine the capacity of each mode to display the idle state, the type of shot, call a ball IN, and call a ball OUT. The results for each category are discussed in the following sections.

	Idle state	What shot	Ball IN	Ball OUT
Current App	Very good	Very good	Bad	Bad
Colored screen	Good	Bad	Very good	Good
Flashlight	Bad	Very bad	Bad	Very good
Audio	Bad	Bad	Bad	Very good

Table 4.1: Evaluation of outputs based on their capacity to display the state in a clear and discrete way (*Very Good* = possible, really visible and not intrusive, *Good* = possible, visible and not intrusive, *Bad* = possible, but not visible or intrusive, *Very Bad* = not possible)

Idle state

The current application was the most effective at displaying the idle state, as all relevant information, including timing and speed, is displayed in the view (see 4.1). It was always clear to the user what the system's state was. Following was the colored screen that could use a neutral color (e.g. blue), to show that the system is in an idle state. Finally, the flashlight and audio from the speaker were last because we could not find a way to communicate the idle state without making the system intrusive.

What shot

To convey what shot it is, the application was once more the best method. The app clearly depicted the trajectory of the shot, and if the one challenged was not the last, it allows users to retrace their steps. Following was the colored screen that was insufficient because it could only eventually display a simple interface with an arrow and speed, making it difficult to distinguish between multiple shots. The speaker could technically indicate the shooting by stating the shooter's name, but the result was overly eloquent. Last was the flashlight, that made it impossible to determine which shot was fired.

Ball IN

As of calling the ball IN, the best solution was offered by the colored screen which could turn green whenever the ball bounces inside the court. A green screen was not doomed distracting to the players. The application did not display the result of the shot (IN/OUT), only the area where it rebounded. We judged the blinking and audio signals to be too disturbing to be utilized during a game.

Ball OUT

Regarding the balls OUT, the audio output was the best option. There was no need to look at any device in order to determine when the ball was out, as you would hear the audio regardless. A second viable option was the blinking flashlight, which is highly visible and captivating. On a 12” screen, the red screen clearly displayed the ball’s outcome, but it was not particularly catchy. Last was the application, which did not have the functionality to explicitly display the outcome of the shot, but only the bounce position.

Figure 4.2: Visibility test from a distance

Figure 4.3: Visibility test of idle state

4.3 Evaluation of User Interfaces

The modality evaluation of outputs revealed that a large screen mounted on the side of the net post was the most reliable, modular, and functional solution. Throughout this phase, I was at the tennis court with Erik and we conducted some on-field tests. The goal was to understand graphical sizes, shapes and colors for the best visibility. I made and displayed the sketches on a 12.9-inch tablet with screen brightness set to 100 percent (Fig. 4.2, 4.3).

First iteration

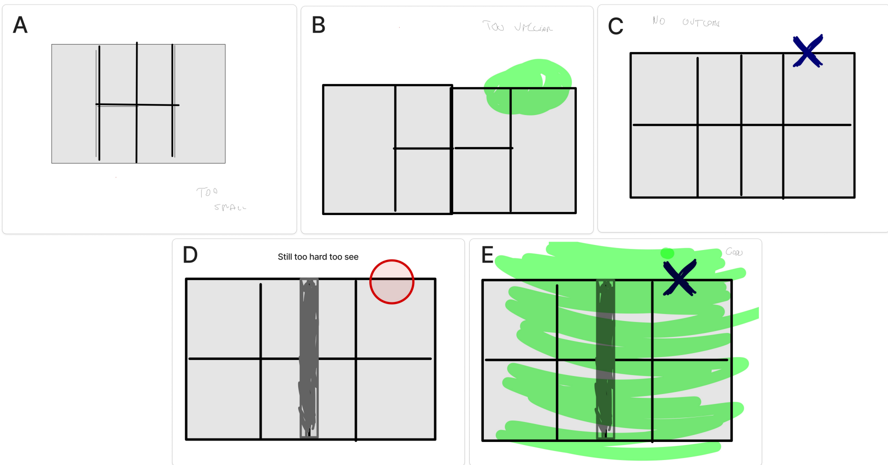


Figure 4.4: First iteration sketches

The screenshots of the sketches used for the first iteration are shown in figure 4.4. The first version (A) represented the court in low fidelity as it appeared in the PlayReplay application. It was too small and hard to see from a distance. Version B featured a larger rectangle for the court as well as a green area that emphasized the bounce. The color green indicated that the ball was in play. This version produced a visible but unclear representation of the outcome. Version C depicted the bounce position with a cross but omitted the result. Version D displayed the result with a well-defined circle, but it was difficult to recognize. Finally, we concluded that a cross could represent the position of the bounce, while the screen's background could indicate the result (version E). This version was visible from a distance, but it was also too raw.

Second iteration

In the second iteration, I experimented the reduction of the complexity of the interface to favor its visibility (Fig. 4.5). I eliminated the court and indicated the shot using only text and an arrow. View D provides a summary of the most recent outcomes. This version relied on the fact that in tennis, the ball travels alternatively in both directions. However, in the some cases, another bounce follows the shot challenged. Victor stated in the interview: "*Oftentimes, you*

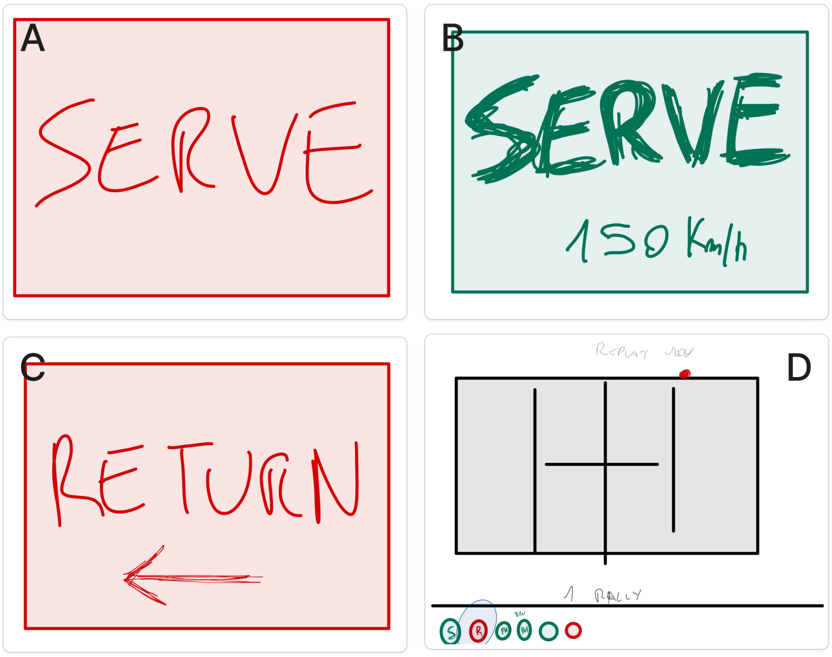


Figure 4.5: Second iteration sketches

hit the ball and call it out at the same time. Because you don't want to stand and watch. You hit the ball and then say out. Or actually even worse: you might hit it back again after that shot. So the last bounce on the app is not the last.". Thus, presenting only the last shot would be inappropriate. In addition, identifying the type of shot can be a challenging task for an Electronic Line Calling system.

Third iteration

To address the issues of the second iteration, the shot name was eliminated and a small rectangle indicating the previous shot was added (Fig. 4.6). Other details about the shot, such as speed and spin, could help the user identify the type of shot and instruct players on shot trajectories (see 4.1.2). The background colors indicate the outcome of the shot (red OUT, green IN). The issue with this strategy is that a flaw in the recognition of a serve, could make the outcome unreliable. In fact if a shot is not labeled as serve, any bounce

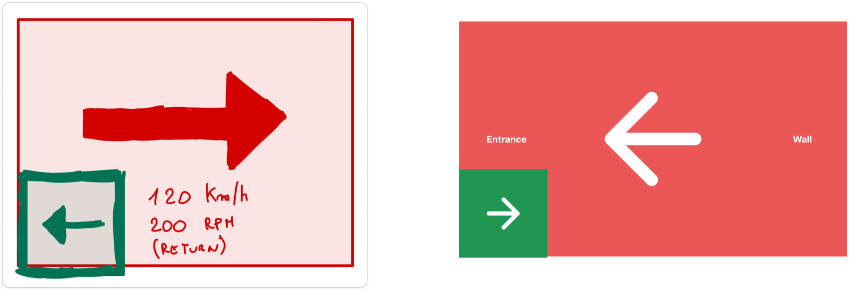


Figure 4.6: Third iteration sketches

in the opponent's side (instead of the service area) will result as a positive outcome (ball IN). If a clearly out ball (e.g., one that bounces one meter from the serving line) is shown as IN, the players may view the entire system as inaccurate.

4.4 Pilot prototype

For this iteration, I created a high-fidelity version using Figma (Fig. 4.7) [9]. Given the third version's feedback, I took a step back and displayed the court. This time, it is not shown entirely; rather, the focus area is magnified to improve visibility. Optimized User Interface and high contrasts colors allow players to see the outcome from a distance. Important information (speed and spin) is clearly displayed on the court rectangle's side to support players learning on line calls, as discovered in the interviews (section 4.1.2). To circumvent the issue of inexact outcome, the court is divided into zones, and each bounce will highlight a zone in yellow (a neutral color), allowing users to determine the outcome independently.

After the User Interface was completed, I envisioned the potential interaction between players and a Electronic Line Calling system that interprets gesture or a system that is triggered by events (see Fig. A.2). The touchscreen input case was not considered because it was similar to what was offered by the current version of the app.

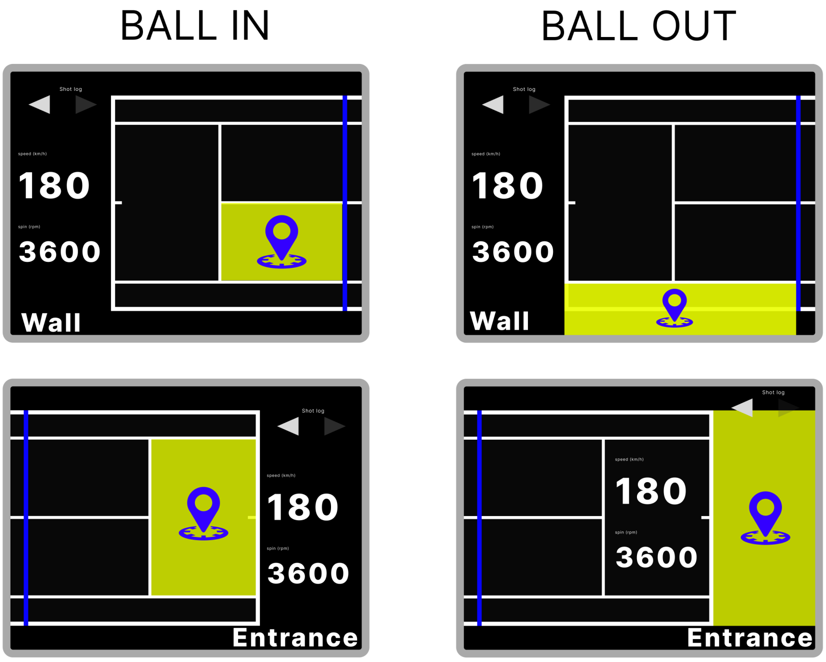


Figure 4.7: Pilot prototype

As Areyur et al. suggest, the gestures we considered were those spontaneously used in tennis, such as lifting the arm to the sky [3]. When using the system with gestures, the tablet's screen will be dark with white text *"LIFT YOUR ARM TO SEE THE LAST 3 EVENTS"* along with the icon of a person with their arm raised (left case in Fig. A.2). This screen indicates the idle state of the machine (a text on the top says *"PlayReplay is tracking your match"*) as the literature suggests to always provides clear instructions to the players [17]. If no player raises their arm, nothing will occur. When a player wishes to challenge a ball, he or she can raise the arm and the screen will automatically turn on and display the previous bounce. After 5-10 seconds, the screen will display the second-to-last bounce, followed by the third-to-last bounce after another 5-10 seconds. In this way, the players can obtain the information regardless of their location and without having to interact directly with the screen. Given what Victor said in the interview (highlighted in the second iteration), displaying the last three bounces should suffice.

Similar to the version activated by gestures, the version triggered by events displays the last three shots automatically when a rally ended (right case in Fig. A.2).

In both versions, if the player wishes to learn about the shot, or simply get more information, he or she can tap the screen and the current app will open, displaying the shot's trajectory and other details. After a few seconds of inactivity or after the match has been resumed, the screen returns to its idle state to not distract the players.

4.5 Evaluation of input modalities

After designing the pilot prototype, I visited the court with two members of PlayReplay and Victor the interviewee. We tested the inputs described in section 3.3.2 by simulating a match (see photos 4.2, 4.3).

4.5.1 Analysis and findings

Based on the knowledge gained from studying other Electronic Line Calling solutions and performing the interviews, an ideal input should (1) activate the system on demand, (2) be simple for the user to master, (3) be fully integrated into the game, and (4) protect the system from errors. The results of the test on the inputs are summarized in table 4.2 and the findings are explained below.

	Simplicity	**Ease of learning**	**Game integration**	**Error proneness**
Gesture	High	Low	High	High
Event-based	High	High	Mid	Mid
Touchscreen	Low	High	Low	Low

Table 4.2: Evaluation of inputs depending on how effectively they can be incorporated into the system or game

Simplicity

The player can challenge most easily through a gesture or by doing nothing (because the system gets triggered automatically). The touchscreen necessitates direct interaction with a screen placed distantly from the players, which adds a degree of commitment.

Ease of learning

The ease of learning is optimal for the event-based system because it is automatic and the players have nothing to learn. Follows the touchscreen because most users already have past experience with it and the User Interface can always be improved to become more user-friendly. According to some authors, working with gestures can be difficult since learning, recognition, and gestures updates might be troublesome [36, 38]. Therefore, gestures received a low ranking.

Game integration

The gestures offer the best game integration because players can challenge from a distance and the screen turns on only when necessary. In the event-based scenario, the screen turning on at the conclusion of each rally, even when not truly necessary, can be distracting and even irritating. The touchscreen's integration into the game is scarce, as the game must be paused for a player to reach the screen.

Error proneness

The worst system in terms of error proneness is the one with gestures: the system must be highly calibrated to avoid external context influences, which can be various during a tennis match, as the literature suggests [38]. The best is the touchscreen that works after the direct intention of the player. The only potential issue could be the player's sweating, which could make the touchscreen less precise and the display dirty. The event-based system falls between the other two options: delays or even errors may occur if the system does not correctly intercept the end of a rally.

4.6 Final prototype

The final prototype corresponds to my design proposal for the PlayReplay Electronic Line Calling system (Fig. 4.8). It was created after the final court session and it incorporates all of the insights gained during the research process.

The pilot prototype (or fourth iteration) resulted in being theoretically appropriate but too uncorrelated to the current app in practice (Fig. 4.1). This would result in a long and expensive implementation as well as a potential

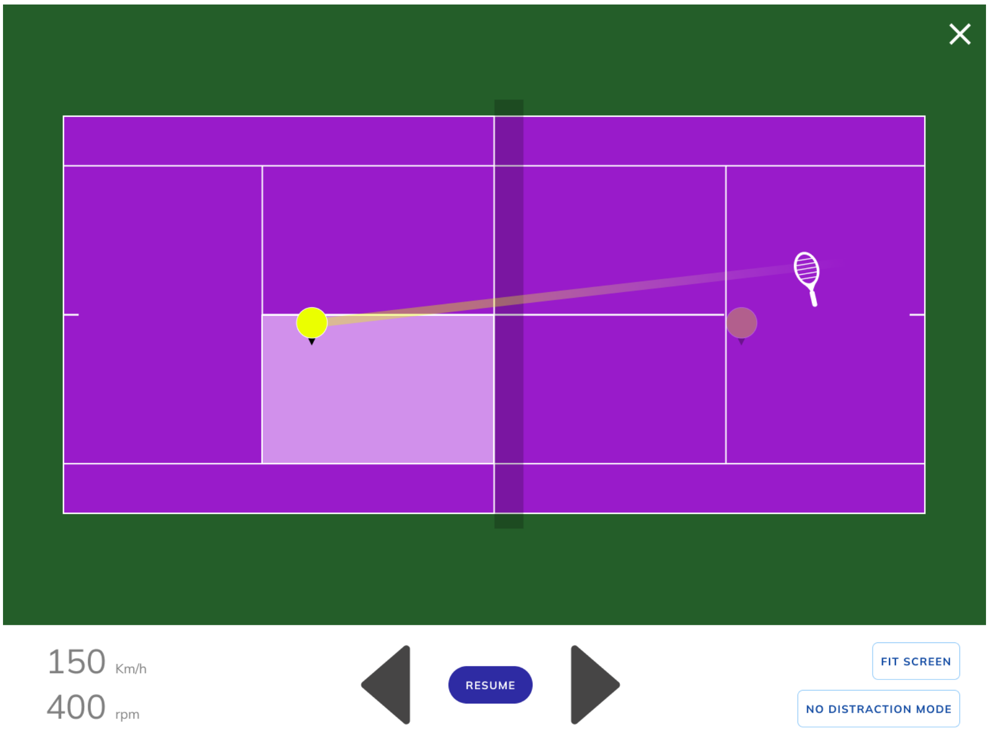


Figure 4.8: Final prototype

barrier for users who could find the User Interface unfamiliar. Therefore, the final design proposal re-adapts the best aspects of the fourth iteration to the app's aesthetic.

The final system will employ a horizontal display placed near the net post and facing the net. The screen will be touchscreen and at least 12 inches wide and will stay on throughout the match. The User Interface (Fig. 4.8) will display the exchange of the ball from one side to the other, allowing users to see that the system is live. The high color contrast makes the display visible from a distance. To create a greater sense of integration and precision in the details, the colors of a court (which are typically made with contrasting hues) could be reproduced in the app when playing on that court. Once a challenge occurs, a player will approach the screen to view the highlighted area where the ball bounced and interact via touchscreen if needed.

The touchscreen was ultimately chosen as the primary interface method due of its low mistake probability. Error propensity is the most essential of the four features investigated in Table 4.2 because, as stated by the expert interviews (section 4.1.2), an Electronic Line Calling system must feel accurate and consistent first and foremost. Touchscreens scored poorly in simplicity and game integration, as the game must be paused and a player must physically approach the screen. Nonetheless, this assessment was proven incorrect when, during the actual match test, Victor claimed that tennis players make little effort to approach the screen: given the nature of the sport, a brief sprint towards the net appears reasonable.

The majority of potential misinterpretations or challenges of a Electronic Judging Systems could be concealed without compromising the Electronic Line Calling experience. For instance, if the system recorded additional bounces after the challenged one, an opaque indicator would display the second-to-last one on the display. By tapping the opaque bounce, the screen would display that shot trajectory and make the bounce previous to that opaque. However, a limit should be placed on the amount of former shots that can be viewed in order to discourage debates about earlier shots, as interviewee suggested. After a few seconds of inactivity or when the match has resumed, the app will once again display live tracking.

At the bottom of the screen will be a bar with on the left some important information about the shot (speed and spin) to allow players to train on calling the line, on the center two arrows offer an alternative and easier way for players to navigate through the last shots (instead of tapping on the opaque old bounce), and on the right two functional buttons. The first button, "FIT SCREEN," enlarges the court rectangle so that it fills the screen, making it more visible from a distance (see Fig. 4.9). The second button, "NO DISTRACTION MODE," enables a mode designed for players who wish to focus on the game and play without interruptions: a grey screen saver is displayed during the idle state and can be dismissed by tapping anywhere on the screen (Fig. 4.10). In this way, the players have complete control over the system, and any potential system misunderstandings will not be displayed.

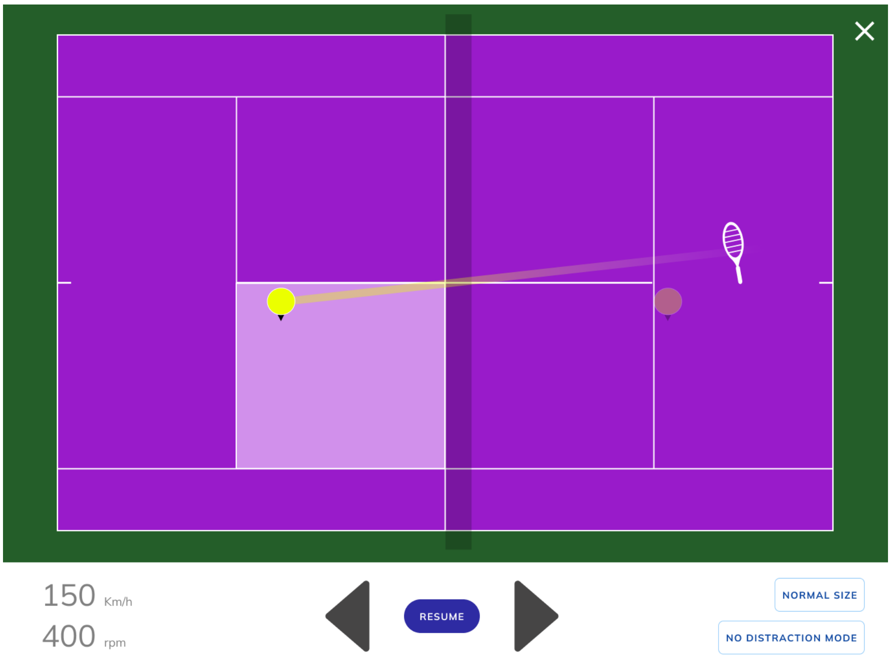


Figure 4.9: Final prototype: wide mode

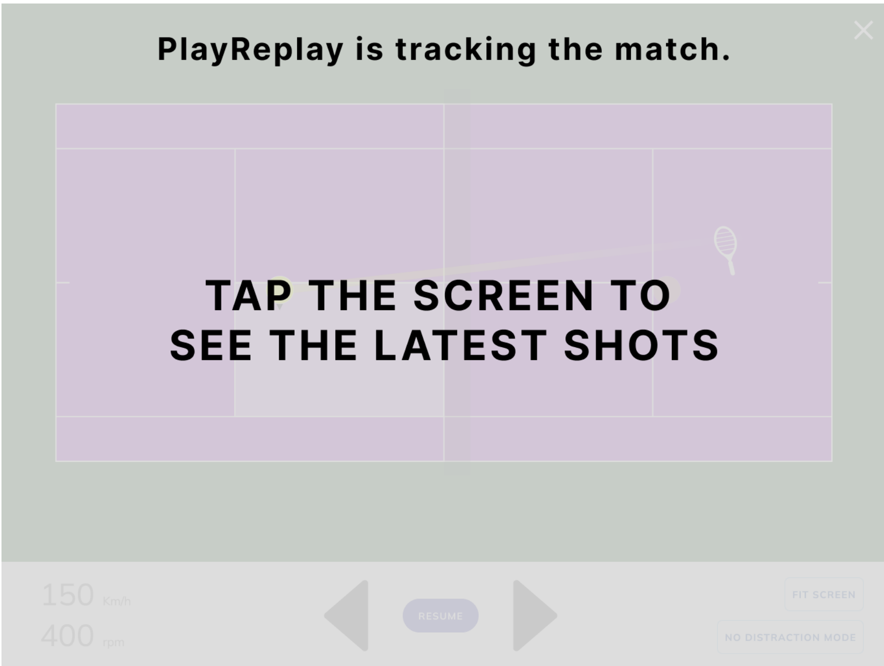


Figure 4.10: Final prototype: no disturb mode

Chapter 5

Discussion

The interviews and iteration on prototypes provided answers to the research question ”What are the key aspects of the Electronic Line Call experience for tennis players?”. The knowledge contribution of this research is represented by the design exploration and evaluation of different interfaces.

Expert interviews revealed that the aspects to consider when building the User Experience of an Electronic Line Calling system include error handling, the incorporation of tools to enhance players’ understanding of line calls, and the refusal to be so meticulous as to be intrusive. It is also important to avoid player discussions, not disturb the players and minimise the outcome delays. However, additional research on a larger group of more diverse experts may be required to confirm the validity of these claims.

The manner in which the system is enabled and communicates information also affects the way players experience the system. The testing of modalities contributed to a better understanding of the limitations of the screen, flashlight, and sound in terms of information transmission. The primary conclusion of the experiment is that outputs should be direct but non-invasive as interviewees demonstrated appreciation for a system that can be disregarded. As long as it is large enough, the display proved to be the most flexible method for displaying data. Multiple-court facilities do not appear to be compatible with audio. A flashlight is enticing but may become irritating over time. The exploration of the inputs showed that while gestures and event-based modalities can be simpler, easy to learn and well integrated in the game, they are prone to generate or show system errors which could make the whole system unreliable. On the contrarily, the touchscreen can be considered a solid and functional way to interact with the system, given that tennis is a dynamic sport and players seem to find it natural to reach the screen on the side of the net post. Besides, the combination of input and output modalities could result in a more versatile and functional system. However, this requires further research together with the evaluation of other possible modalities like Augmented Reality (AR), voice recognition, proximity sensors, etc.

The design phase of the research started with the evaluation of different UIs and ended with the creation of two prototypes (pilot and final). This allowed me to work without preconceived notions and obtain insights that could be applicable to any Electronic Line Calling system. For instance, discovering the optimal screen size for good visibility or highlighting the fact that the ball is frequently returned by a player after bouncing out may lead to system confusion.

The final prototype was designed to be a helpful tool for tennis players rather than an all-encompassing obtrusive tool. It includes the elements identified over the course of research: it is intended to function on a large screen (at least 12 inches) mounted on the side of the net and it uses high-contrast colors so that it is visible from all angles on the court; the interaction occurs via touchscreen, making it accurate and reliable; it clearly shows the state of the machine, together with the last shot trajectory, and where the ball has bounced; the communications are discrete but noticeable when necessary, and there is a mode to not disturb players if they wish to play undisturbed. Nonetheless, the final prototype includes a feature that displays detailed shot information in order to reduce discussions and permit players to learn from their wrong line calls.

Even though Electronic Line Calling systems are extremely precise and accurate tools, literature reports that they may misunderstand particular situations due to the dynamics of the sport, such as returning a challenged bounce (see section 2.2.3). I believe that a good User Experience should address and circumvent those hence a considerable effort has been devoted to concealing or inventing solutions for such misinterpretations. For instance, large arrow buttons enable the display of an older shot in case the most recent shot is not the one being challenged. Ideally, a system with flawless gesture and perfect rally recognition would offer excellent game integration or rapid learning, as shown in the table 4.2.

Due to time limits, some concerns have been left for future research: for example, all the ones regarding accessibility (for example considering the case of a color-blind player). Moreover, some assumptions have been made: for instance, the fact that calling balls IN is not essential to the first prototype of the system.

Future research should be also made on the type of users that use this system and the corresponding personas: the interviews with experts partially detected that there are different expectations on the platform based on the user, the context, or both [23]. For instance, professional players or umpires seem to appreciate the precision and use the tool to learn from mistakes, whereas amateur players who play for fun seem to resent a system that is too ”strict” and interrupts the game dynamics. It is important to keep in mind that the offered approach to the issue of line calling is simply one option. There are alternative approaches to the problem of line calling, such as focusing on a logic that considers only bounces 10cm away from the line, which would cover the vast majority of edge cases (94% according to Mather’s study [20]).

Chapter 6

Conclusions

There are numerous elements to consider when developing the experience offered by an Electronic Line Calling system, and this research has helped shed light on some of them. The Research through Design approach supported the development of knowledge through repeated prototyping and field testing. The Double Diamond design process facilitated the organization of the research procedure. The conversations with experts allowed for the rapid acquisition of various significant insights. The examination of interaction modalities has produced knowledge that can be applied to further research related to Electronic Judging Systems. The pilot version featured the theoretical characteristics of an ideal User Interface for Electronic Line Calling; nevertheless, certain modifications were required to make it more correlated to the current PlayReplay app, hence, an ulterior prototype (final) was created.

The main challenge has been to think about solutions that are resistant to the unpredictable games dynamics, that can be potentially misinterpreted by the system. Electronic Judging Systems are ultimately intelligent measuring systems, hence they must be accountable for their function. Therefore, it is crucial that the system feels sturdy and solid.

In subsequent steps, additional testing should be undertaken on the final design proposal mock-up, and a working version should finally be produced and tested. A few additional iteration may be required to obtain a truly usable solution. In addition, the examination of separate input and output modalities can assist in locating an optimal combination. In conclusion, this study highlighted the important elements to consider while designing an Electronic

Line Calling system, and the significance of developing assisting, rather than obtrusive, tools. It also supports the development of technologies that can be included into sports without sacrificing the enjoyment and, by extension, the substance of the game.

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Appendix A

Figures

Figure A.1: Interviews findings on FigJam

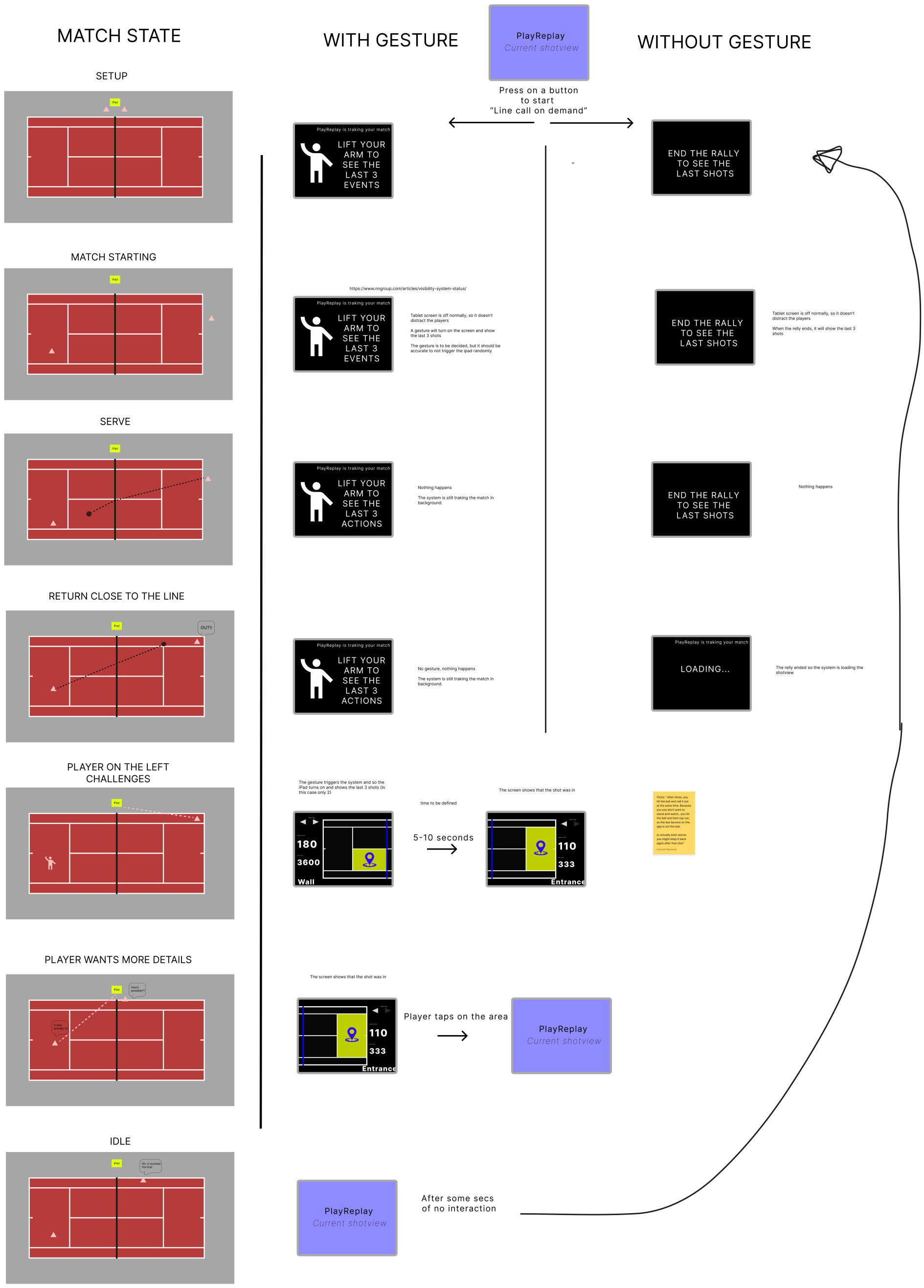
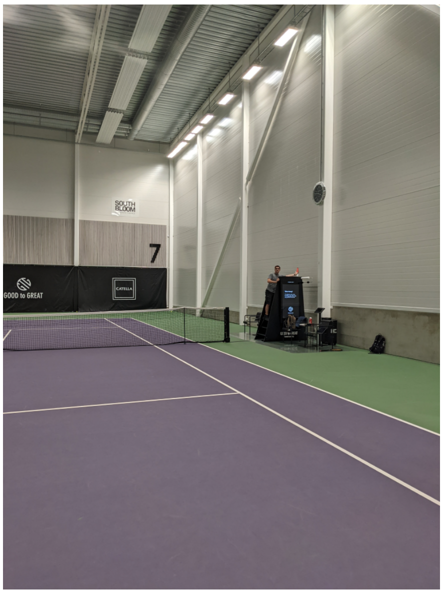


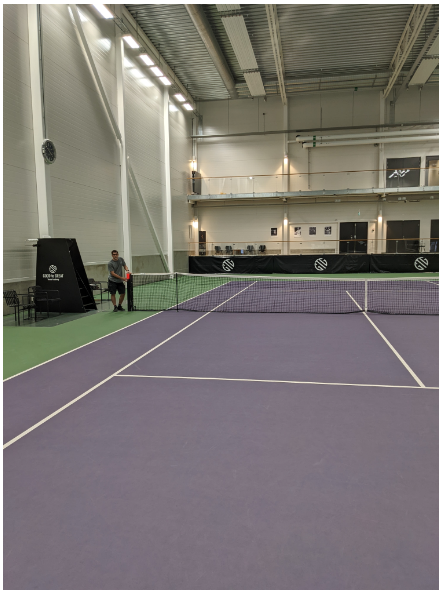
Figure A.2: User journey using gestures (left) and events (right)

Appendix B

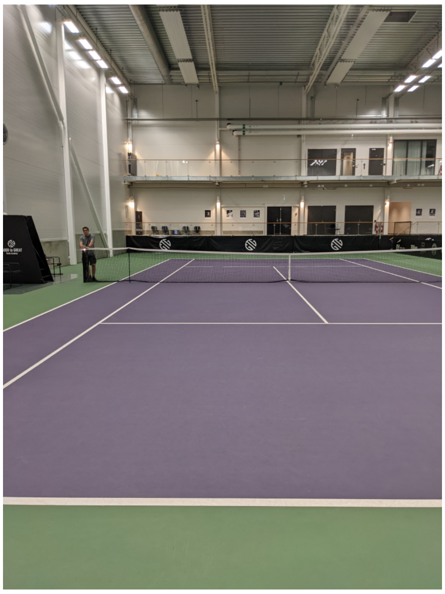
Photos



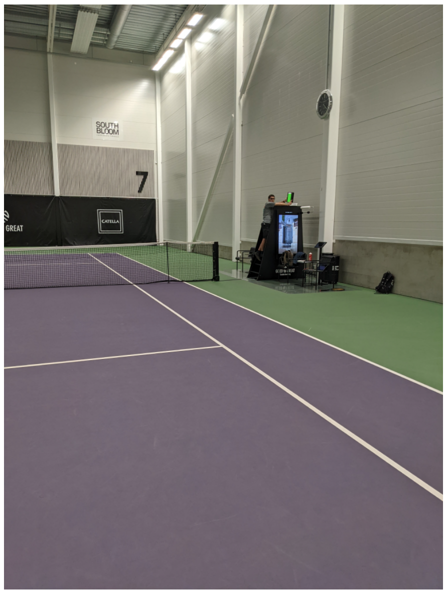
(a) Visibility test of a red screen displayed on a phone from the umpire chair



(b) Visibility test of a red screen displayed on a phone from the net post



(c) Visibility test of a smartphone flashlight from the net post



(d) Visibility test of a green screen displayed on a tablet from the umpire chair

Figure B.1: Testing output modalities at the court

Appendix C

Interview

Demographic

1. What is your age?
2. How long have you played tennis?
3. Tell me more about your career
4. Have you ever used Hawk-Eye or similar?
5. Do you play other sports? If yes, is there a digital tool you use there?

Without Electronic Line Calling

1. How do you call the line today?
2. What are the dynamics related to it?
3. How often is there a line call dispute?
4. If there is an uncertain line call, what do you do?
5. Do you always trust the other player?
6. Do you have in mind situations where it is hard to call the line?

With Electronic Line Calling

1. How do you think Electronic Line Calling has changed the line call experience?
2. What is your behavior after a challenge made with Electronic Line Calling?

3. How many times do you check the system for line calls?
4. Do you consider it a waste of time?
5. How do you deal with false calls or system errors?
6. Do you check past bounces or calls?

Future Electronic Line Calling

1. How do you imagine the Electronic Line Calling system of the future?
2. What is missing from the current one?
3. What do you think about an Electronic Line Calling that uses ligshts to call the line?
4. What do you think about an Electronic Line Calling that uses sounds to call the line?
5. What do you think about an Electronic Line Calling that uses a big screen to show info about line calls?