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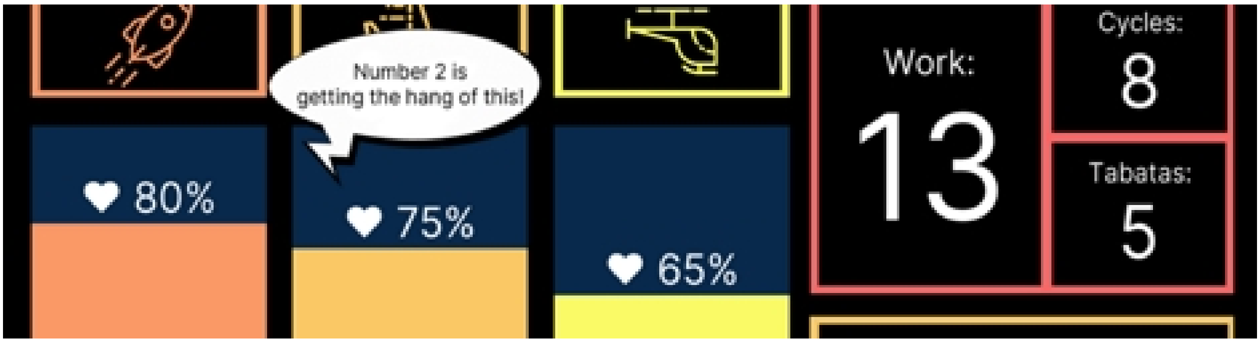

PlayHIIT: Augmenting Remote Exertion Experiences through Playful Interaction

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Para o meu pai.

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Abstract

We have observed an uprising trend of remote approaches to group physical activity, yet these strategies lack social dynamics due to the limited communication scope they provide to participants. In this dissertation, we develop a social augmentation to video conference-based group exercise to increase the enjoyability of the activity while motivating users to increase their effort input. In particular, we leverage different social dynamics and balancing methods in exertion experiences and playful interactive systems. Following a user-centred design approach, our prototype shares performance information between group elements during High-Intensity Interval Training and provides scaffolds for social interactions through the inclusion of playful-oriented elements. We conducted an experimental study to observe the effect of our system in the enjoyment and effort of participants while providing an in-depth analysis of the playfulness dimensions that were affected. Results show an increase in *Competition* and *Sensation* dimensions of the Playful Experience framework regarding the activity. Regarding enjoyment and effort, results were nonsignificant, while displaying positive trends. Our findings empower interaction designers with implications regarding the design space of video conference group exercise interfaces.

Keywords

Physical Activity, Exertion interface, Social interaction, Playfulness

Resumo

Temos assistido a uma tendência crescente de abordagens remotas a actividades físicas em grupo, porém estas estratégias detêm dinâmicas sociais carentes devido à capacidade de comunicação limitada que providenciam aos participantes. Nesta dissertação desenvolvemos uma melhoria social dedicada a exercício em grupo feito através de videochamada de modo a tornar a atividade mais aprazível, enquanto motivamos os utilizadores a aumentar o seu nível de esforço. Em particular, recorremos a diferentes dinâmicas e métodos de balanceamento social em interfaces de esforço, e sistemas interativos lúdicos. Seguindo uma abordagem de desenho centrada no utilizador, o nosso protótipo partilha informação de desempenho entre elementos de um grupo durante Treino Intervalado de Alta Intensidade, criando oportunidades para interações sociais através da inclusão de elementos lúdicos no sistema. Posteriormente conduzimos um estudo experimental para observar os impactos do nosso sistema no prazer e esforço dos participantes, fornecendo uma análise em profundidade das dimensões lúdicas que foram afetadas. Os resultados mostram um aumento nas dimensões de *Competição* e *Sensação* da *framework Playful Experience* quanto à atividade. Em relação a aprazibilidade e esforço os resultados foram não significantes, exibindo tendências positivas. Os nossos resultados providenciam a *designers* de interação implicações quanto ao espaço de desenho de interfaces para exercício em grupo por videoconferência.

Palavras Chave

Atividade Física, Interface de Esforço, Interação Social, Ludicidade

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Acronyms

API Application Program Interface

ATB Activity Tracking Band

BLE Bluetooth Low Energy

BPM Beats per minute

BSPE Borg Scale of Perceived Exertion

EMG Electromyography

GATT Generic Attribute Profile

HIIT High-Intensity Interval Training

IOS Inclusion of Other in the Self

PACES Physical Activity Enjoyment Scale

PLEX Playful Experience

PLEXQ Playful Experiences Questionnaire

PPG Photoplethysmogram

REST Representational state transfer

RPM Revolutions per minute

UCD User-Centered Design

VCS Videoconferencing Software

VR Virtual Reality

1 Introduction

Contents

The COVID-19 pandemic has brought a vast and overwhelming amount of changes to the lifestyle of everyone all over the globe. One of the consequences of the several security measures being undertaken worldwide is the amount of people being subject to home-confinement. Recent studies have suggested that this factor can be responsible for increasing physical inactivity, with underlying effects such as higher cardiovascular disease rates and other health consequences [6–8], alongside the absence of the several mental health benefits that exercise provides [9].

In response to these limitations, there has been an uprising trend of embracing a remote approach to physical activity, with several gyms worldwide providing online group classes and personal trainer coaching sessions through video conference. Even governmental entities such as the United States Department of Health recommend joining streaming groups for group fitness classes as a way to stay active while consolidating social distancing[1]. This approach of community-based exercise activities has been shown to be beneficial, both in terms of mental health, by providing a peer support network and a sense of belonging [10], and also of physical health, through the benefits that are inherent to exertion activities of all kinds.

1.1 Problem

While it is evident that video-based group exercise has clear advantages over individual exercise or no exercise at all, there are still several factors that make up the gap between this approach and face-to-face group exercise. The main difference is the limited number of information channels available during a video conference.

In-person, everyone can distinguish the location where different sounds come from due to spatial hearing. It is easier to pinpoint which training partners are breathing harder, putting in more effort, or even quickly assess who is talking, just by noticing where the voice is coming from. Communication is also made more accessible in person due to visual body language which would not be otherwise available during a video conference [11].

When we consider a remote environment, all these factors are affected. Sound now mostly comes from the same source, the connected device, making it harder to understand overlapping voices. Visual feedback is also reduced to small parts of the screen, diminishing available visual cues and making it more difficult to assess how well other participants perform. All these details eventually contribute to the same issue. **The lack of social dynamics is one of the disadvantages of video-based physical exercise**.

[1] https://health.gov/news/202004/staying-active-while-social-distancing-questions-and-answers

1.2 Approach

Numerous approaches have been taken to augment physical activity with dedicated interfaces [12, 13]. From all these, a few are worth highlighting due to their effects on the social dimension of the experiments. Some authors develop *exergames* (exertion games) or interactive exertion experiences that make sure everyone's participation is evaluated similarly [2, 14, 15]. These balanced approaches positively affect the engagement of users, as they allow tighter competitive or cooperative scenarios where no participants feel useless due to possible skill differences. From these, we establish our first premise:

- **Balanced exertion experiences lead to more engaging social experiences;**

Other studies have focused on altering the way information about their partners is delivered to the user. Either by displaying heart rate through wearable devices [1] or providing clearer insight on how much effort other participants are putting in [16], this otherwise unavailable information provides users with the opportunity to motivate, tease, and interact with each other, as they become more aware of the performance and physical state of their partners. From this, we establish our second premise:

- **Sharing individual performance data provides opportunities for social play;**

However, previous research has focused on experiences that rely on co-located environments [1, 2, 4, 17, 18], while video-based group exercise has remained vastly unexplored. In this work, we tackle the lack of research in the augmentation of group video-based exercise through the following research question: **can an exertion interface foster a positive impact on the social and enjoyment dimensions of a video-based group exercise session?** To address this question, we have developed a system through user-centred design, basing ourselves on the propositions mentioned above and on established playfulness design principles [5]. This work aims to analyse the impact our system may have on this scenario, specifically in the way users interact with each other, the enjoyment of the overall training experience, and the effort they put into the activity.

To expand our scope beyond individual hand-picked activities, and to be inclusive to different preferences, we chose High-Intensity Interval Training (HIIT) as a default scenario, where the only fixed condition is the training structure. This training is done by alternating higher intensity and rest periods and does not depend on the exercises themselves, granting the additional time flexibility benefit of being a short session training regiment [19].

1.3 Contributions

With this dissertation, we investigate whether a system that supports video conference-based group exercise sessions leads to a more enjoyable experience. Our contributions are:

- A playful composite system[2] to complement video conferencing software, dedicated to HIIT training sessions.
- An experimental study analysing the different effects of this same system regarding the effort, enjoyment, and playfulness on the participants.
- An analysis of the results of the executed study, aiming to understand the different dimensions of video conference based group exercise applications.
- A submission to the CHI 2021 conference in the Late-Breaking Work category pending evaluation.

1.4 Document Structure

This document is organised in five chapters. Chapter 2 provides insight regarding relevant studies which intersect the domain of our work. The first section includes research regarding interactive systems that use heart rate, either in one of its mechanics, balancing formulas, or in other less common ways. The following section reviews relevant works in different social dynamics in exertion experiences, including comparisons between cooperative and competitive scenarios. The third section is composed of exertion studies in the domain of playfulness and open-ended play, the definition of this domain, and other assorted relevant non-goal-oriented systems. Finally, the chapter ends with a discussion of all referred work, alongside an analysis of their relevance to this thesis.

Chapter 3 consists of two sections. We first analyse the context of our work, elaborated through previous formative studies, which results in the design goals that served as a starting point for the development of our system. Lastly, we provide an in-depth description of this same system, “PlayHIIT”, including its architecture, the different features that compose its two main components, the design decisions behind the inclusion of these features, and the design process that lead its whole development.

Then, Chapter 4 depicts a user study that we conducted to evaluate our system. It includes the research questions that we intend to answer, the design of the study itself, who participated in it, the apparatus that we made use of, the procedure of each session, the analysis of the gathered data, the results of our study, a posterior discussion regarding these same results, and lastly the limitations of our work. Finally, the document finishes with Chapter 5, which reports the conclusions of our work, and analysis on the future work.

[2]https://github.com/fmteotonio/social-augmented-hiit

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Related Work

Contents

As our primary goal is to provide an enjoyable and improved exercise experience for several users in a remote environment, it is useful for us to start by analysing what the relevant domains in the design of group exertion interactive experiences are. Park et al. [20] have developed a set of guidelines for transforming single person exercises into social *exergames*, or gamified experiences, which can be useful to complement the thought process of designing our solution for this work. Through their work in a team-based competitive exertion game called "Swan Boat", the authors argue that while designing these experiences, one should first obtain the primitives from the exercise in question. For example, in the case of running, this could be either steps, distance, speed, or even heart rate. Afterwards, designers should pick which they are going to focus on for their primary interaction. They further add that for an interaction to be intuitive, the primary actions (i.e., running) should be kept as the core mechanic, while other secondary actions (i.e., raising your arms while running) should be used carefully and with some level of contempt.

Considering the setting for our work, when dealing with people exercising in their homes through video conferencing, we have to consider that many people do not own the necessary equipment to perform static aerobic exercises such as running on a treadmill or cycling on an exercise bicycle. As such, adaptability to different types of exercise, such as burpees, crunches, or push-ups, is a requirement to make a feasible way to complement home exercise. Having this into account, we can identify a common element that connects all these different exercises. This element is the heart rate of the user, which is a viable option for the primary measure for our experience. Considering that we are dealing with a limited setup dependant on the home equipment of each user, we have chosen HIIT training as the activity for our setup, as the variability in possible exercises and focus in achieving higher heart rates during the periods of higher intensity [21] are consistent with the limitations we are dealing with. Therefore, we start by overviewing how heart rate has been used in different interactive experiences in previous studies and what are the challenges behind its usage.

2.1 Heart Rate and Balancing Physical Interactions

Nenonen et al. [22] is one of the earliest relevant examples of using heart rate as a core element in an interactive exertion experience. Their work consists of a skiing and a shooting interactive game, which are directly influenced by the heart rate of the player. A higher heart rate increases the speed of the skiing section, but in return, reduces the accuracy during the shooting section, while a lower heart rate reduces the speed of the first game but makes shooting easier, providing a strategic element to the gameplay. Players can either choose if they should improve or reduce their effort to affect their performance in each sub-game. A notable aspect of this study is the adaptability to whatever physical exercise the user prefers, with only the heart rate value itself being relevant to the outcome. While this work cemented heart rate usage as a measure independent of any exercise machine, its sprint-oriented approach (between two to five minutes) would not be compatible with an actual exercise-oriented training session.

We can find a recent relevant example of designing interactions around heart rate in Ketcheson et al. [23]. When facing the problem that many exergames were not compatible with sufficiently intense physical exercise to replace traditional activities, they argued that rewarding a player that reaches a desired heart rate through in-game upgrades was an effective way to increase their exertion levels, and making the whole experience more enjoyable. Their study found that these power-ups did improve the exertion of their coupled activities, especially if these tended to require lower exertion levels in the first place. Players have also shown a preference for the versions that had the power-ups available. In contrast to the previous example, while this approach did enable longer activity times, making it closer to an eventual substitute for routine physical activity, the power-ups still need to be coupled to a game that is controlled by the player while simultaneously pedalling a stationary bicycle. A more free-form training type would make it harder to accommodate the input and display methods of this required parallel gameplay loop. This happens due to different limitations for each exercise type regarding availability to look at a screen or interacting with a tactile input device. For example, lifting a dumbbell may allow the user to choose where he is looking at, but still renders him unable to use his hands for any other task.

When inspecting other interactive experience formats besides exertion games, we also find compelling cases of heart rate used as a core mechanic, typically through its display in different methods and abstractions. Walmink et al. [1] introduce us to a wearable helmet that displays the heart rate of a bicycle rider to his cycling partner behind him. This novel system forces the rider to rely on his companion in order to be aware of his own condition, carving an opportunity for participants to make playful social interactions, either through signals to speed up or slow down, cheering, or even closing the distance to their partner to force them to speed up. This study also contributes with a list of dimensions that one should be aware of when using heart rate displaying in interactive experiences: *Do we show the heart rate only at particular instants, or should it always be available? Where should we display it? Should we show it as an absolute value or a visual interpretation or abstraction?* And finally, *what factors do we allow to influence the user? Do we only want them to change their heart rate through their efforts alone, or do we want external factors to contribute as well?* All these questions are useful tools for analysing the design of this kind of experience.

Another relevant contribution was the work done by Sonne and Jensen [17]. Their smartphone application "Race By Hearts" provides all participants of a cycling gym class with an ordered list of the participants' heart rate. The position of the users in this leaderboard changes depending on whoever has the highest during the activity. The collective display of the different heart rates creates a feeling of group awareness in which people are more inclined to feel related to each other due to being aware

Figure 2.1: Helmet displaying heart rate as featured in Walmink et al. [1].

of how much effort their colleagues are putting in, creating an opportunity for stronger social relations. Despite this, there is also the unintended effect of having constant pressure derived from the suggested competition. This effect may turn into a negative experience for the users and cause them exasperation, as any health or exhaustion issues that are unrelated to their skill or effort might lead them into a lower position in the leaderboard, leading to discouragement. One of the features of this work that is most relevant to us is the way the authors dealt with organizing the list. Considering that typical heart rate values vary from person to person, instead of ordering them by their absolute values, Sonne and Jensen order them through an intensity level, which is derived from the percentage of the maximum heart rate of the user, instead of the beats per minute. This way, they intend to let users compete for a top spot in the leaderboard despite their physical limitations. Balancing interactive experiences between users is a common and recurring challenge, especially in exertion environments, where the discrepancies between different skill levels become more visible, as they are often associated with the users' physical abilities. These differences can affect the participants' motivation or the ability to stay engaged due to non-balanced challenge levels, making users unable to enter the "Flow" zone, an ideal balance between the challenge presented and the skill level of the person being challenged [24].

To better understand the social effects of balancing exertion experiences, we need to analyse the different options we have. To do so, we need to temporarily diverge from heart rate usage and refer to Jensen and Grønbæk [2]. In their work, they studied three different balancing approaches for a competitive one-on-one exertion game that consisted of throwing a ball in turns at the targets displayed by a projection on a wall. The three approaches they studied were physical, explicit-digital, and implicit digital. **Physical balancing** consists of changing something in the physical environment. Some examples could be having leg weights for a treadmill run, or in the case of their work, changing the distance from which players throw the ball. **Explicit-digital** consists of changing parameters in the interactive context itself while making the changes visible to the players. Some examples could be a running avatar going fast depending on different heart rates instead of being directly correlated to speed in a treadmill run while showing the speed handicap between both players. In the case of this study, the size of the targets and the time during which they were displayed were affected by the accuracy of previous turns to reduce the score difference. **Implicit-digital** balancing is the same as explicit-digital, except that the changes made in the digital setting remain hidden for players instead of being visible. Despite the effects of explicit versus implicit digital balancing being similar, having the information available contributed to greater user acceptance towards the balancing mechanisms.

Figure 2.2: Representation of the setup for "The Bouncer" game and subsequent study [2].

Mueller et al. [14] present an example of the application of implicit-digital balancing in a setting surrounding the usage of heart rate through "Jogging Over a Distance". This application allows two users to jog simultaneously while in separate places. Using a recorder and headset, users can listen to each other while the position of their voice in the stereo audio is adjusted depending on their target heart rate, giving the illusion of running side by side. People ended up adapting their speed depending on how tired their partner was due to hearing their breathing through the headphones. Despite this, some users ended up competing instead of collaborating, trying to stay ahead of their partner. Balancing, in this case, was achieved through user input, as they are the ones who chose their desired target heart rate before the activity. From this experience, four design dimensions were also presented for balancing these types of system:

- **Measurement**, as in what is measured in the activity, such as speed, steps, or heart rate;
- **Presentation** as in what is shown or hidden, as the example above;
- **Adjustment** as how the values are tweaked in the balancing process;
- and finally **Control**, as in what is controlled by the user, or by the designer.

Bayrak et al. [15] further studied the usage of heart rate as a measure for achieving balance in exertion experiences in the context of a cycling-based competitive game for two people. Their objective in this study was to evaluate the effect of their novel balancing technique in the motivation of the participants and possible differences between performances on the races. Their methodology had several primary objectives. The first was that a player with a low fitness level should be able to race against a better player in a close way. The second objective was that the game provides a fair chance of winning to both players. The third was that adjustments made should feel natural. And finally that this can be achieved while preventing exhaustion and the possibility of injuries. The original balancing formula they used from Stach et al. [25] accounted for the cycling speed while at target heart rate, how far from the target the user is, and a "nimbleness" factor that takes into consideration a five-second interval due to heart rate not changing immediately in response to sudden moments of exertion, to address sudden acceleration boosts. They went further with this formula and upgraded it, accounting for both the heart rate of the user and the bicycle's Revolutions per minute (RPM) as a value of momentum instead of the acceleration. After a thorough evaluation, they concluded that participants felt that the race was fairer, although the player with a greater average heart rate still ended up winning most races.

Going back to our context, we want to develop a system that can augment existing training schemes instead of developing a whole new exertion activity. To do so, we need to take the necessary measures to avoid a sprint-like approach such as Nenonen et al. [22], as most training regiments people adhere to consist in sessions with far longer duration than a few minutes. A sure way to do this is to avoid establishing a direct correlation between effort and success. Players should not feel that they need to put as much effort as possible from the start, so overexertion limiting is an essential factor to promote. We also need to consider that to adapt to different exercise types in a more free-form manner, occasions to interact with the system by means other than the heart rate of the user will be limited, as different exercises provide distinct levels of availability. While a squat may allow the user to have his hands free while looking at a display, a push-up can make both of these rather more complicated.

Regarding balance, when using heart rate, the approach featured in Sonne and Jensen [17] of using the percentage relative to the maximum heart rate of each individual rather than as an absolute value is a possible way to ensure that any interaction that has heart rate in consideration is balanced between participating users. Explicit-balancing is also a relevant methodology to us, as its benefits towards user acceptance [2] are a critical factor in motivating users to adhere to physical activity. Having now an idea of the different possible approaches surrounding the usage of heart rate and how important balance can be to social experiences, the next step is to evaluate the design concepts of the social dimension in our work. What are the features that propel users to interact with each other during the activity? What are the kinds of social dynamics that we do or do not want to encourage? We explore the relevant work done in this area in the following section.

2.2 Social Dynamics in Exertion Experiences

A pivotal reference regarding the inclusion of technology in physical activity can be found in Consolvo et al. [26]. Their early prototype of a mobile application to count steps and share between friends led to the definition of various key design requirements for this type of technology. One of these requirements is to be able to **support social influence** between the participants. This element is further defined as three different classes of influence: (i) **Social pressure**, by making progress or goals visible between users and creating opportunities for commitment to tasks; (ii) **Social support**, through facilitating recognition or encouragement from their peers; (iii) **Communication**, by allowing users to express themselves to each other, instead of only sharing limited or quantified data between them. These have a clear focus on facilitating different kinds of interaction between users. Mueller et al. [16] later reinforced this by heavily contributing to early efforts of studying how social dynamics can be affected through interactive exertion systems and expanded this design space to concepts other than based on direct communication.

In one of the later versions of their work, "Jogging Over a Distance" allows two users to jog simultaneously while in separate places. Their system allows two users to communicate through a headset, adjusting the perceived position of their voice depending on the heart rate they defined as their target, providing the sensation of running side by side with someone else. They argued in favor of the importance of social participation in this type of experience and further provided three theoretical concepts to foster design creativity of exertion interactive systems for multiple persons:

- **Communication Integration**, as in how is the communication between users integrated with the rest of the physical activity?
- **Effort Comprehension**, as in how does the system contribute to users being more aware of their and their partners' effort?

- **Virtual Mapping**, as in how is the exertion represented in the digital domain?

While these works establish fundamental tools to drive social-oriented design, there is another relevant dimension that we should take into account. Going back to Park et al [20], there is still a guideline that was not referred until now, which asks the designer to consider the roles players take on between themselves. Is their interaction driven by a common goal, creating a cooperative environment, or do individual goals create the setting for a competitive experience? The way existing goals are arranged and divided should reflect the setting designers are going for so that the players' interactions fit the experience in the best way.

One of the frequently asked questions in social interactive experiences studies is the effect of having a competitive versus a collaborative setting in a multiplayer experience. While not as exertion demanding as other later examples, the balloon popping game based on motor performance featured in Peng and Hsieh [27] provided relevant information regarding the effect of different goal structures. The game is played through a computer mouse, and players have to click as fast as possible on incoming balloons to score. Despite not involving any traditional physical activity in its core, it shares a standard feature with exertion games of a better performance being associated with greater motor effort. As a result, they found that a cooperative environment had a more noticeable impact on the effort players put in. They also noticed that having a preexisting social relation between the participants provided a stronger reason for committing to the provided goals than having participants who did not know each other beforehand.

Peng later went on to study the effects of different multiplayer structures [28]. Resorting to a more traditional exertion game scenario, they used a Kinect motion camera-based mini-game, in which players popped soap bubbles in a room where they moved by waving their arms. This time, when comparing a co-located cooperative setup with a remote competition one, results found that the remote competition setup provided not only greater enjoyment and motivation to keep playing but also in higher physical intensity throughout the physical activity, even though no further conclusions were made, due to the different spatial settings between both conditions.

Chen and Pu [3] explored different gamification settings in a fitness application for two people to use called "HealthyTogether". The application consists of a step and floor counter and shows the data for both people during the day. The setting can be either competitive, where each counter is put against each other, or cooperative, where they contribute to a set common goal, but Chen and Pu also introduce another option. A hybrid setting is also analysed, where there is still some competitive incentive despite an existing common goal. In this setup, while each user's total score was calculated taking the score of their partner into account, their personal score had a higher multiplier, affecting the final count. While all three social setting conditions resulted in a significant improvement in physical activity compared to the control setting, both cooperation and the hybrid setting had a far more impacting effect than the competition one. Cooperation also surpassed both other settings regarding raising the number of social

Figure 2.3: Interface of the "HealthyTogether" system [3] for both users, alongside the Fitbit tracker interfaces used.

interactions between the pairs, while competition was the setting where the least improvement was registered.

Marker and Staiano [29] further explored the different outcomes between cooperation and competition in social exergaming. After analysing several competitive and cooperative components from multiple literature and commercial examples, they concluded that despite competition being more suitable in shorter sessions, cooperation is the better way to promote adherence over time, producing long-term results and enabling pro-social behaviour. Nevertheless, this serves only as a rule of thumb, as individual preference has precedence over this. A person who typically prefers competition will still have greater satisfaction from this kind of setting, and vice-versa. A piece of advice in terms of design that is also due noting is to consider if heart rate, intensity level, or other variables are shown either individually or as a combined score to promote either cooperative or competitive behaviour, respectively.

Another study that shares this conclusion of cooperation and competition being dependent on the individual differences of the users involved is Novak et al. [18]. They compared both a single-player and multiplayer version of an arm rehabilitation air hockey-based game, as well as a cooperative and a competitive version. While it was clear that the multiplayer version was the preferred one, opinions were mixed regarding the type of player interaction, as it depended on their preference. The study concludes that long-term analysis would be needed to see the impacts of social interaction over time in the rehabilitation process.

There is no definitive answer regarding whether competition is better than cooperation or the other way around for social exertion activities. Mixed results suggest that these results depend on external factors such as if users share the same physical space, if they previously know each other, the nature of the physical task itself, and the unpredictable matter of the individual preference of the users.

When evaluating the possible dynamics to insert our work in, we need to consider that thorough research has been done regarding the reasons that lead people to exercise, and it is well known that enjoyment and social interaction are the more powerful reasons associated with adherence over time [30]. This can be promoted by enabling users to focus on their own personal goals and enjoyment of the activity instead of providing pre-decided goals. To better understand how we could support different types of user interaction and better accommodate for the preferences of users, in the next section we take a look into a more open-ended approach that can give space for users to establish their own objectives without being limited by default ones provided by the systems they interact with. This approach is playful design, a commonly used method in interactive physical experiences, that contrasts with the more goal-oriented gamification.

2.3 Playful Interactive Systems

Arrasvouri et al. [5] define "Playful Experience" as an experience that is non-goal-oriented and emerges through the fun or pleasurable aspects of using a product. This can be seen as a contrasting methodology to the far more common gamification approach, which often associates goals and rewards to particular experiences. Unlike gamification, the much broader concept of playfulness, which not only can be interpreted as an approach to an activity but also as a psychological state of an individual, can be evoked through a multitude of different methods. To better understand the different avenues that can lead to playfulness, Arrasvouri et al. devised the Playful Experience (PLEX) Framework [5, 31], a product of literature review which defines twenty-two different categories which compose playful experiences, which can be seen alongside a short description in Table 2.1.

Ma et al. [4] is one example of augmenting a pre-existing defined physical activity with playful elements. A shuttlecock is a weighted object typically bounced in the air by hitting it with different body parts such as knees, feet, and torso. It is often used in group play, as players try to keep it in the air by passing it to each other. The designed augmentation named "Shuttlezap" consists of inserting different sound effects that play depending on the feedback received by an accelerometer inserted in the object. This way, different sounds play depending on the number of times the Shuttlezap has been hit while kept in

Table 2.1: The 22 different categories of the PLEX Framework [5]

Experience Category	Brief description: the Playful Experience emerges from...
Captivation	Forgetting one's surroundings
Challenge	Testing abilities in a demanding task
Competition	Contest with oneself or an opponent
Completion	Finishing a major task or reaching closure
Control	Dominating, commanding or regulating
Cruelty	Causing mental or physical pain
Discovery	Finding something new or unknown
Eroticism	A sexually arousing situation
Exploration	Investigating an object or situation
Expression	Manifesting oneself creatively
Fantasy	An imagined situation
Fellowship	Friendship, communality or intimacy
Humor	Fun, joy, amusement, jokes or gags
Nurture	Taking care of oneself or others
Relaxation	Relief from bodily or mental work
Sensation	Excitement by stimulating senses
Simulation	An imitation of everyday life
Submission	Being part of a larger structure
Subversion	Breaking social rules and norms
Suffering	Loss, frustration or anger
Sympathy	Sharing emotional feelings
Thrill	Excitement derived from risk or danger

the air or if it is dropped on the floor. This system provided users with an explorative experience, where they might be motivated to keep attempting a higher score to find out the different auditory responses from the object itself. The posterior analysis of the results of their study shows that the playful factors most influenced by their system were *relaxation*, *expression*, *discovery* and *sensation*. Physical-based experiences may be more prone to *relaxation* and *sensation*, due to these being related to physiological responses by default. The influence in the *discovery* factor was a predictable observation due to the explorative design of the experience. Lastly, they conclude the existence of auditory augmentation as a design space to induce playfulness in exertion experiences.

HIIT training is no stranger to audio augmentation as well. We found two different studies on this theme. The first one, "HIIT The Road" [32] by Haller et al., attempts to raise user performance and motivation in this type of training through the development of a Virtual Reality (VR) exertion game solution. In this game, played through an exercise bicycle, players must cycle along a road as fast as possible during the high-intensity intervals to avoid their score going down. During the low intensity or rest periods, the resistance of the bicycle is increased if the player attempts to raise their speed too much. The novel factor of this game is the inclusion of simulated spectators along the side of the road clapping for the player at the same rhythm they are cycling. The goals of including these spectators were to motivate the player to increase their efforts and serve as a distraction for the soreness caused by the exercise itself.

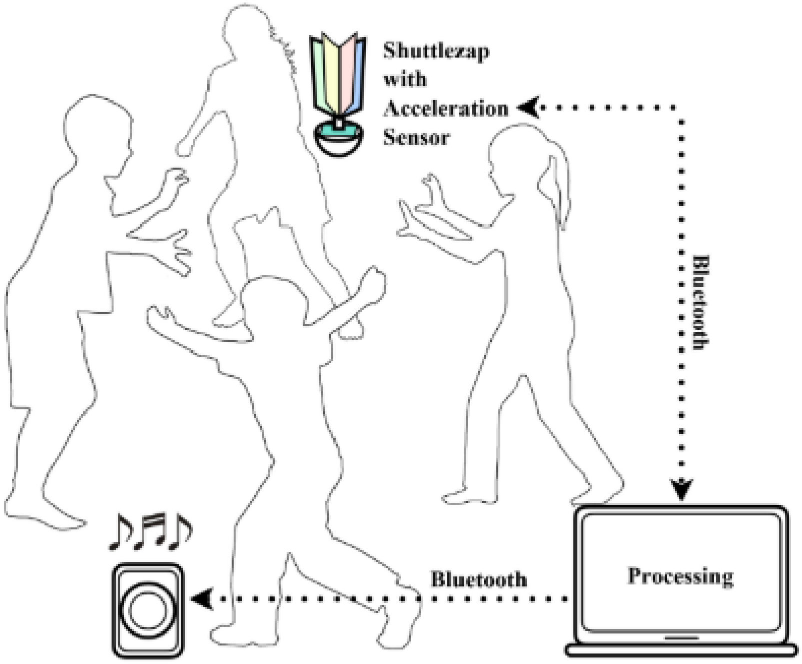

Figure 2.4: The “Shuttlezap” system, as depicted in Ma et al. [4].

While they found that the virtual crowd did impact the participants’ performance, no relevant effect was observed regarding their motivation, enjoyment, or perceived effort.

The second study is “HIIT With Hits” [33] by Keesing et al. Also a VR exertion experience, it consists of a rowing game augmented through music synchronised to the physical activity itself. This is done by having its tempo corresponding to the alternating higher and lower intensity intervals of an HIIT session. In the game, players row a boat through several in-game rings that must be collected. To persuade players into naturally entering a HIIT rhythm during the activity, the intensity of the in-game music is used to define the distance between rings. To further contribute to this, visual feedback regarding how synchronised the player’s rowing is to the music is also shown on the screen. The following study results showed that their system was successful in leading players to assume a HIIT rhythm during the activity naturally and that it had an impact on the way players perceived their effort. The increased enjoyment players felt in the game scenario led to a reduced perceived exertion level.

Visual augmentation of existing physical activities is also a common theme between some previously conducted studies. Described as an interface for digitally-augmented cooperative play, “PingPongPlus” by Ishii et al. [34] is a system comprised of a video projector connected to a computer equipped with ball-tracking technology, alongside microphones hidden beneath a ping-pong table. Through this setup, they provide several different ways of interacting with the table itself, such as projecting water ripples wherever the ball hits, a painting mode in which users can collaboratively color the projection on the table with the ball, or even displaying a school of fish which gets scared when the ball hits too close to them. Their exploratory work served as an early example of different possible interactions provided by visual augmentation of exertion experiences.

Another example with a similar theme is “The Augmented Climbing Wall” [35] by Kajastila et al. Through graphics projection, different routes can be highlighted in a climbing wall, alongside animated obstacles, used to increase possible challenges, and generating procedural content for a sport that is otherwise dependant on the physical environment it occurs in. This study found that school groups participating in climbing events kept doing the activity for a longer time when using the system. A notable aspect of the gathered user feedback is that the diversity factor contributed to motivating users to keep using the system and a general feeling that the activity was more fun with it.

Even though it is not associated with an exertion activity, Follmer et al. [36] is also relevant to our research due to its design of a playful experience being held in a video conference environment. Their objective was to provide a scaffold in which children, their parents, and other family members can interact and play together despite their distance. Their work introduces several different exploratory activities, including an augmented book that alters elements in the video display, depending on which page is open. Their results did show that their experiences were effective in engaging children and adults in shared play. The idea of providing open-ended experiences as a catalyst for social interaction in a video conference setting is a concept which may also be useful to us in order to break the social difficulties brought upon by this mean of communication.

When considering the possible applications for us, the PLEX Framework is a useful tool to guide the design process of different features for a playful interactive system, as it provides clear goals to strive for. In terms of video conference experiences, the concept of providing a stage to facilitate communication between users is compatible with our overall goal of achieving a more enjoyable experience through improving the social dimension of group video conference physical exercise. Regarding the different possible approach options, video augmentation is a difficult concept to implement in a home-based environment due to equipment availability, eventual setup time for each user, and significant differences between physical spaces, so our efforts will go towards an interface to complement the video call itself, being displayed simultaneously. Regarding audio augmentation, it is something to strongly consider, due to the compatibility with different exercise scenarios, as it does not rely on having the user directly watch a screen throughout the activity. In the next section, we take these factors into account alongside the ones previously mentioned in this chapter and discuss the related work presented during this chapter.

2.4 Discussion

In order to provide an in-depth discussion of all the work described in the previous sections, we categorised them according to different domains and features, as presented in Table 2.2. The first category

Table 2.2: Comparison between features of the studies related to this work.

	Exertion Type		Social Dynamic	Balance	Heart Rate Usage	
	Prim. Action	**Primitives**			**Goal**	**How?**
"Race by Hearts" [17]	Cycle	Heart Rate	Competition	Explicit Dig.	Display	Absol./Abstr.
Mueller et al. [14]	Run	Heart Rate	Open-Ended	Explicit Dig.	Balance	Derivation
Bayrak et al. [15]	Cycle	Heart Rate	Competition	Digital	Balance	-
Walmink et al. [1]	Cycle	Heart Rate	Open-Ended	-	Display	Absolute
Nenonen et al. [22]	Anything	Heart Rate	-	-	Display	Absolute
Ketcheson et al. [23]	Cycle	H.R./Speed	Competition	Digital	Display	Abstract
"HIIT the Road" [32]	Cycle	H.R./Speed	-	-	Balance	Derivation
"HIIT with Hits" [33]	Row	H.R./Speed	-	-	Goals	-
Novak et al. [18]	Swing paddle	Joint Angle	Comp./Coop.	Explicit Dig.	-	-
"The Bouncer" [2]	Throw ball	Ball Position	Competition	All	-	-
"PingPongPlus" [34]	Swing racket	Ball Position	Competition	-	-	-
Peng and Crouse [28]	Move body	Body Position	Comp./Coop.	-	-	-
"Shuttlezap" [4]	Pass object	Acceleration	Cooperation	-	-	-
"Swan Boat" [20]	Run	Speed	Mixed	-	-	-
"HealthyTogether" [3]	Walk/Run	Steps	Comp./Coop./Mix.	-	-	-
Consolvo et al. [26]	Walk/Run	Steps	Open-Ended	-	-	-
Kajastila et al. [35]	Climb	Body Position	-	-	-	-

is **Exertion Type**, and it provides information regarding both the chosen primary actions of the different exertion experiences and the primitives that are measured during its usage. The second category is the **Social Dynamic** of the activity, which is relevant to all studies that involve more than one simultaneous user and depicts the target interaction type between the users of a system. The third category is **Balance** and identifies the type of balancing mechanism that is present on the system according to the classification used in Jensen et al. [2]. The final category is **Heart Rate Usage**, which provides information regarding the goal for which heart rate is used in a system, and how it is portrayed to its users.

When looking through the social exertion design methodology Park et al. [20] presented, we can observe that most of the work that we have referred to until now is focused solely on an individual activity. While heart rate is a commonly used as a measured primitive for the experience, being essential in eight of the studies we have discussed [1, 14, 15, 17, 22, 23, 32, 33], the primary action for these activities does not make use of the ubiquitous nature of this measure. Cycling is one of the most common activities for exertion experiences, being used in static environments in "Race by Hearts" [17], "HIIT the Road" [32], the study regarding *Heart Rate Power-ups* from Ketcheson et al. [23], the virtual reality game present in Bayrak et al. [15], and in an open environment in the streets only through the wearable display helmet from Walmink et al. [1]. Systems dedicated to either running or walking are also common, generally using steps as a primitive when providing a choice to the user to either run or walk, as in "HealthyTogether" [3] and Consolvo et al. [26], or using heart rate when the focus is in running, as "Jogging Over a Distance" [14]. Other primary actions include throwing a ball [2], passing an object [4], and performing established activities such table tennis [34] and climbing [35]. The only study providing a free choice in terms of activity was the single-player game Nenonen et al. [22], where the user could do what he wanted in order to change his heart rate for the skiing and shooting mini-games. As we previously referred, the home equipment availability to perform many of these activities typically chosen as primary actions is often scarce. Choosing a free form of primary action that is not restricted to an individual exercise helps solve this problem. Regarding possible measures, it is not a coincidence that heart rate is commonly used, as any physical activity that requires a relevant amount of exertion reflects it in the heart rate of the person doing it. This is also a reason for heart rate to be an adequate measure when considering an exercise-independent exertion experience.

The way heart rate is taken into account in the studies is much more varied, though, as we can see by inspecting the dimensions presented in Walmink et al. [1]. From the analysed studies that display information about it at all times, two of them display it in the game screen [22, 23], one of them displays it in a wearable device only for one of the participants [1], and the last one shows it in absolute and relative values for every participant [17]. The other four never show it directly, only using it for balancing calculations [14, 15, 32], or calculating target rotations per minute shown instead in a cycling activity [33]. Representation is done in either absolute values [1, 17, 22], abstract progress bars [23], percentage [17], intensity level [17], or through derivations, such as audio representing the difference between target heart rates of both participants in “Jogging Over a Distance” [14], or of the user and its target through the clapping rhythm of the crowd in “HIIT the Road” [32]. From all of these, only “Jogging Over a Distance” and Walmink et al. happen in the outside, allowing external interference to the user’s heart rate.

Regarding balancing, six of the referred studies refer to how they were balanced. Jensen et al. explores the three different approaches in their ball throwing game, “The Bouncer” [2]. ‘´Jogging Over a Distance” [14] and “Race by Hearts” [17] are explicit digital by nature, as in the former users are the ones who choose their heart rate, and in the later, all heart rates and percentage about every user are shown in the screen. Even though Ketcheson et al., [23] and Bayrak et al. [15] use heart rate to balance their experiences, they are not clear regarding if the user knows the details behind the formulas used for balancing or not. Novak et al. [18] allows its rehabilitation patients to choose their range for shoulder joint movement, to allow them to play comfortably, digitally, and explicitly balancing the experience as well. Explicit digital balancing provides the advantage of being oriented towards user acceptance due to no information being hidden from users, which could make them unsure if their success is due to their own abilities or only to unknown balancing features. When considering exertion experiences in a home video conference environment, having users motivated to engage with the activity is essential, as it is not a common way to exercise in a group. We need to create a comfortable experience, as any effort to combat physical inactivity is futile if users do not feel comfortable using it.

When looking into the existing social dynamics in the studies that include exertion experiences designed for several people, competition is the biggest focus, being present in eight of these [2, 3, 15, 17, 18, 23, 28, 34], followed up by cooperation, with four [3, 4, 18, 28]. "Swan Boat" [20] features a hybrid setup due to it being a competition between different teams of two, and "HealthyTogether" [3] explores a mixed scenario where two elements both compete and cooperate simultaneously on their objectives. Walmink et al. [1], Consolvo et al. [26], and "Jogging Over a Distance" [14] provide more open-ended experiences, with the latest featuring reports of elements both trying to compete or cooperate with each other. Enabling users to chase their personal goals has the advantage of not limiting how much effort or how intense the activity they are engaging with is. While the novelty of providing a more specific goal-oriented activity may be useful in making it more fun and tempting to experiment for the first time, to keep users interested and effectively combat physical inactivity, it is needed to accommodate different needs users might have during several days of training.

Finally, we can also inspect what playful elements are relevant to the design of these experiences. While only Ma et al. [4] features a formal analysis of how its augmentation influenced the playfulness of the original experience, some of these are easily identifiable as being common in the exertion experience design space when resorting to the definition provided for each of them in the original report regarding the PLEX Framework [5].

- **Captivation** is one of the most notable features in the examples that resort to Virtual Reality [15, 32, 33], as the simulated environments allow the sensation of a user being in a different location than their own;
- **Challenge** is a relevant aspect in any physical experience that requires greater exertion than usual, being especially relevant to consider in the HIIT based examples [32, 33] that push players to reach their limits;
- **Competition** naturally occurs in whichever experiences feature competition between different participants [2, 3, 15, 17, 18, 23, 28, 34], or when the player competes with himself [35];
- **Discovery**, through experiences that reward players with sound [4, 34] and visual effects [34], gamification elements such as badges [3], or upgrades to their avatars [23] for certain actions or goals;
- **Fantasy**, commonly interlinked with *Captivation*, through the fictional environments featured in these experiences;
- **Fellowship** is contrast to *Competition*, naturally occurring both in experiences that feature clear cooperative objectives [3, 4, 20], or a more open-ended approach with several participants [1, 14];
- **Sensation**, either through visual [2, 15, 32–35] and audio effects [33, 34] included in the experiences, or the tactile nature of activities where interacting with a physical object is needed [2, 4, 35].

- and **Simulation** as often these experiences make use of representations of real-life activities, such as cycling in a specific location [15, 32], or other sports [20, 22, 33].

While these are the most easily identifiable due to many being already present in the physical activities themselves despite any augmentation, other elements are not as clearly linked to exertion experiences but are also used, sometimes in more novel approaches that may not be as obvious as the previous ones:

- **Nurture**, in Walmink et al. [1], by having one element responsible for informing the other if he is doing well or not, or in "Shuttlezap" [4] through the collective effort to keep the object in the air without letting it fall;
- **Relaxation**, although one could argue that physical exercise in itself is a form of relaxation, "Jogging Over a Distance" [14] and Walmink et al. [1] are notable for not influencing the users to exert more than their will,
- **Submission**, in the cases where actions of players are dependant on both elements, such as the cooperative navigation in "Swan Boat" [20], or running side-by-side in "Jogging Over a Distance" [14],
- and **Suffering**, through the deliberate highlighting of undesirable events, such as the failure sounds included in "Shuttlezap" [4] when the object falls to the ground.

Being aware of what elements are useful to induce a playfulness state will help guide the design of the features of our system. The direction of our work will be the development of an exertion experience to be done in a remote video conference environment. To be serviceable as a complement to actual physical exercise instead of providing just a novel activity, it will accommodate a free form exercise regimen, unlike most previously discussed related work. Using explicit digital balance and an open-ended environment designed with the different playfulness factors in consideration, we intend to have a positive impact on the social and enjoyment dimensions of exercise sessions. In the next chapter, we will expose the approach behind the design of our system, including the observation and interview sessions we have done and the design goals and implications we concluded from them.

3

PlayHIIT

Contents

During our work, we developed “PlayHIIT”, a composite application to complement video conference-based exercise sessions. In this chapter, we start by describing the design approach that we took, which was based in User-Centered Design (UCD) and on the formative research that we conducted previously to development. Afterwards, we will provide a detailed description of the development process of our system, including the different iterations that it went through, and all its features.

3.1 Approach

When conceptualizing our system, we chose a design approach that could put us closer to the people who would benefit from our work, as relying on previously published information would not be sufficient to understand the underlying problems that are brought about by this means of communication to physical activities. The core of the design philosophy was therefore decided to be based on several UCD methodologies.

3.1.1 User-Centered Design

UCD is an umbrella term that comprises several techniques and methodologies that share the common trait of being focused on involving users in the design process of an artifact [37]. Generally, its objective is to expand the understanding regarding the users of a system, the environment in which it will be used, and the tasks or interactions facilitated or complemented by it. The overall advantages of these methodologies include greater proximity between the designer and the users, allowing designers to directly check their assumptions regarding the behaviors and needs of the users during the design stages of a project, instead of just relying on pre-existing information. The common trade-offs of resorting to these techniques are the additional time and effort that researchers need to allocate during the design phase.

In our work, we used several UCD methods to make sure that our design was suitable for the environment of people who practice exercise through video conference. **On-site observation** consists of actively collecting data regarding the environment in which a system will be used. Despite not being a physical site itself, early on during the design stage of our work, we observed and actively participated in an online exercise group that performed their training sessions through video conferences for one month. In a later stage of our project, we used **Iterative Design**, by alternating short duration prototyping phases with active testing ones with a small focus group of users. During these iterations, we also performed **Semi-structured Interviews** to understand the positive or negative impact that the different features of our work were having on the experience of participating users, and we participated in these testing sessions ourselves to have first-hand information regarding the usability and impact of our prototypes in a live group. All these techniques were essential in expanding our knowledge regarding the context of our work, but the observation sessions, in particular, were paramount during the early formative research stage of this thesis, which is described in the following section.

3.1.2 Formative Research

In order to better understand the context in which our work is inserted, it is necessary to understand the environment of an exercise session being held through a video conference. To this effect, we resorted to the ethnographic method of **participant observation** [38] as an active participant. We observed and participated as a member of an autonomously organized exercise group over one month. We held conversations with other participants regarding the advantages and disadvantages of video conferencing over being in person and experienced some of the challenges ourselves.

During this month, sessions were held either two or three times a week, with a duration between 30 and 60 minutes each depending on the different training programs. The number of people who participated varied depending on individual availability, most often between four and six members. The age group of members was 20 to 40 years old, both male and female members participated often, and all members performed regular exercise more than once per week. Each of us would most often be in a room of our choice in our own homes, with some rare exceptions in a public space while resorting to mobile data. Participants would connect to a video conference through our personal computers, setting up our cameras to point at us while performing the exercise. Some participants also used their mobile phones to this effect, although it was infrequent due to the added difficulties brought upon by the reduced screen size and was mostly only done as a necessity.

One of the relevant factors to note is the information that was shared between everyone during the session. One participant would share their screen showing two different windows simultaneously. One of them was a list of exercises on the program for the session of that day, and the other one was timers in case they were needed, depending on the training type being done. When these were needed, screen display space had to be divided between both windows and the participants' video thumbnails from the video conference software, which often corresponded to just a small portion of the screen.

The training sessions chosen by our particular group were varied but often fit in two distinct categories. The first of these is **strength training**, which were longer sessions, between 45 minutes and an hour long. Only the number of repetitions of each exercise was shown in these sessions, alongside the resting times between exercises and exercise groups. These often included additional material such as dumbbells and exercise benches. These exercises were done in a personally chosen rhythm, most commonly in a slower fashion, as lower speed-based repetitions are a known practice to improve strength in physical activity [39]. An example program from one of the strength training sessions we observed can be seen in Figure 3.1

The second type of sessions we performed were HIIT **programs**. This training type consisted of shorter sessions, between 30 and 40 minutes, and the duration of the exercises was timed, with the timer being simultaneously shared between all participants. HIIT training consists of short burst intervals of high intensity being alternated with even shorter rest periods. In the group we participated in, exercises were commonly done alternating 30 seconds of high-intensity physical exercise with ten second long resting periods. Exercises are then organized in sets with more extended resting periods between them to allow muscle resting time. While some exercises also resorted to additional material, these were much less frequent compared to strength training programs, with most being typical calisthenic exercises, such as push-ups, squats, burpees, and several different variations of these. Unlike strength training, this type of training is associated with cardiovascular improvement and weight loss as its main advantages [40]. In Figure 3.2 we can observe a sample program from one of the HIIT training sessions we observed.

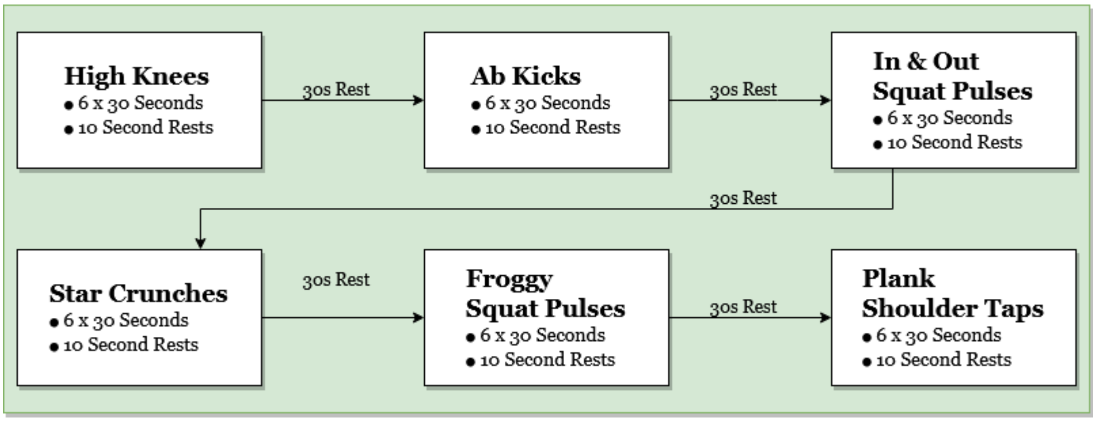

Figure 3.1: Observed **HIIT Training** session example.

One of the most notable differences when comparing the sessions held through video conference to typical ones held in a gym or a public space by any group of people who do exercise together is **the increased difficulty of group awareness** brought by the medium. During the training sessions, many exercises did not allow us to keep looking at the display at all times, which means that, unlike an in-person scenario, during these times, we cannot observe how our partners are performing. Even when we can look, the limitations imposed by the display being shared between the video conference, list of exercises, and timers, significantly reduce the amount of detail that can be quickly perceived from the displayed footage. Small details such as sweating, effort in each movement, and other immediate visual cues stop being available, lead to a more individualistic experience. This can reflect itself, for example, in being more difficult to realize whether a particular exercise is being more difficult just to us, or if it is a transversal feeling to the whole group. Another case is that if a participant is doing an exercise incorrectly, it is harder for one of his peers to intercept and advise him on the correct way to do it.

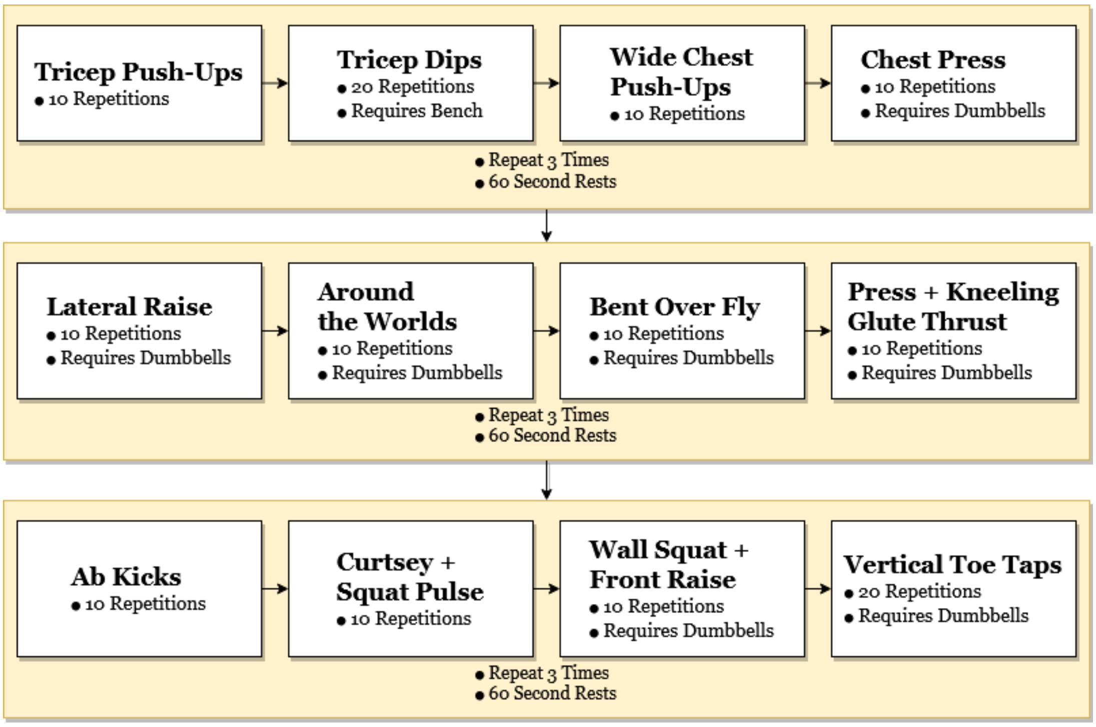

Figure 3.2: Observed **Strength Training** session example.

Over the course of this month, we also observed that participants relied on sound much more to gather and transmit information, possibly to compensate for the limitations of the video conference digital environment. One example of a way in which this was notable was a situation that commonly occurred whenever the connection failed temporarily for one of the participants during the exercise. As they relied on the beeping sounds included with the timer to know when they should rest or when they should work out, sometimes participants would become uncoordinated with the rest of the group whenever the sound did not play or was delayed due to network issues. Another example that we observed is that short social interactions regarding the physical condition of participants and the toughness of their exercises were some of the most common social interactions. Comments regarding how tiresome a specific exercise is or jokingly referring to the resting time being too short may be a natural way to compensate for the previously mentioned lack of natural group awareness, in an attempt to make the exercise a more social experience by expressing themselves regarding how they are feeling about the activity.

As a noteworthy part of our research as well, in a later stage of our design phase, we wanted to ensure that our system would not interfere with the primary objectives of the exercise regimen we chose. To make sure that any impact our system had in the physical experience was positive, we reached out to a professional sports technician, working as a personal trainer for the past nine years, so that he could provide information and feedback regarding this topic.

3.1.3 Design Goals

As a result of our research, we were able to determine several design goals that we aimed to achieve during the design and development of the “PlayHIIT” system:

Leverage HIIT Regiment: The delimited interval times of a HIIT regiment provide the advantage of ensuring all participants are coordinated regarding which exercise they are doing, making it easier to provide a common experience to all users. It will also ensure that any measure that we gather during the experience will not be influenced by possible differences, allowing us to more easily provide a balanced exertion interaction, which has been previously shown to provide for more engaging social experiences [2, 14, 15]. Besides this factor, HIIT has other advantages: (i) greater compatibility with calisthenic exercises that do not require users to have any other equipment in their homes, facilitating participation and (ii) lower monetary barriers of entry. The lower workout duration also requires less time to be given from the personal routine of users.

Encourage Adequate Effort Level: As soon as we settled on the type of exercise to which we would be targeting our work, the aforementioned collaboration with a professional sports technician allowed us to understand what were the design goals regarding the physical dimension of the experience. HIIT training has the objective of reaching the anaerobic heart rate zone during the short periods of high intensity, while being careful to not induce overexertion, and to not sacrifice the correct posture of each individual exercise. Regarding the effort of the users, our system should keep these objectives in mind by not encouraging users to slow down during these high effort intervals, while at the same time informing them if they are exerting themselves beyond a safe level.

Facilitate Social Interactions: Considering the lacking social dynamic inherent to videoconferencing scenarios, our goal is to design a system that can suppress this by making it easier for users to communicate the information that would be otherwise lost due to the lack of in-person presence and visual cues. By sharing and making use of their performance data, we attempt to boost the opportunities for social interactions, and their group awareness, providing a more enjoyable and fun experience.

Use Intelligible Visuals: Through our observation sessions, it is clear that visuals should not require much attention from the users, to not disturb workout posture from participants, and accommodating for different kinds exercises that do not allow users to be looking at all times. In particular, we focus on keeping visuals easily perceptible, which allows users to get the information they want with just a glance during a resting moment in a workout.

Careful Usage of Sound Cues: Regarding sound, it is clear that is is a useful tool in this environment, but its use should be conducted with care. As users rely on sound cues to identify the progress during their workout, any additional usage of this dimension should be made in such way that it does not disturb this pre-existing task. Nevertheless sound will be a useful tool in transmitting the information we find relevant for users during the experience.

3.1.4 Playful Interaction

Our main goal of creating a system to complement remote physical exercise sessions is to make the experience more enjoyable for participants. During the conception of the "PlayHIIT" system, we decided to achieve this goal by supporting playfulness [5] instead of opting for the more traditional solutions of inserting the physical activity in a gamified structure [41] or converting it to an exertion game [42]. When designing a system that provides spontaneous fun we needed to consider the broad spectrum of simultaneous actions that users may perform at whim for pleasure while using the system, instead of just defining structured rules or goals for the experience.

To properly assess the several existing possibilities, we resorted to the PLEX framework when framing what the actions that we want to encourage or facilitate through our system are, and the playful experiences that we intend to promote through them. The goal of this framework is to be able to accurately catalogue and examine the different playful elements provided by a particular interaction. The PLEX framework consists of 22 different categories that are based on different perspectives and catalysts for playful experiences. These categories are based on different states of mind and body, concepts, or actions. They also share the common element of lacking clear defined objectives and being generated by the fun or pleasure of interacting with an object or partaking in an interactive experience. The several categories that compose the PLEX framework are displayed in Table 2.1.

We can divide the concepts we used to transform the experience into a playful one according to the respective PLEX elements we had in mind as goals:

- **Competition:** For users to be able to compete against others or themselves, we need to have comparable measures associated with the activity. By providing these tools to users in real-time during the physical activity, we can promote them to alter their effort levels based on the performance of their peers, and stimulate competitive behaviour.
- **Nurture:** By giving relevance and easy access to their performance metrics, we can encourage players to be aware of their and their partners' progress, and increase their emotional investment to the activity and to how well the elements of their group are performing.
- **Discovery:** Providing users with different visual or auditory effects on the system depending on their effort levels throughout the activity allows us to hint and appropriately reward curious behaviour in a way that does not remove the focus from the activity itself, and that is compatible with several exercise types.
- **Humor:** By highlighting events and opportunities for users to tease each other and cheer their performances, we can not only lighten the challenging environment of a physical exercise session but also stimulate social interactions that would not naturally happen with the ease that exercising in person provides.

- **Fellowship:** Providing a sense of communality between participants during the experience is a consequence of both the points presented in the *Nurture* and *Humor* categories. By encouraging users to interact with each other and be aware of their performance during the activity, we can encourage affection, sharing feedback, and team spirit between the elements of a group.

3.2 System

We developed “PlayHIIT”, which is a system designed to complement videoconference-based group HIIT sessions. This system is composed by a mobile and a desktop application to be used simultaneously as the videoconference software where users are engaging in physical activity with each other. The desktop application is a shared screen between all of the participating users, that displays both individual and group performance data to everyone, while providing relevant information through visual and audio that is connected to different events of the activity such as someone increasing their heart rate in a substantial way. The mobile application is used to connect to an Activity Tracking Band (ATB) that the users are wearing and gather the heart rate, as well as providing a repetition counter for users to wield, sending all this data to a cloud stored database where the desktop application gets its required information from. The design process of this system was conducted as an iterative process, with the prototypes being tested several times over the course of its development with a focus group that engaged in remote group exercise together.

Throughout the next subsection we will detail the architecture of “PlayHIIT”, including the technologies we used and its components. After that, two subsections will be dedicated to the design process and final prototype of both the mobile and desktop application components of our system, including the different iterations and design challenges that they went through over the course of its iterative user-centered development.

3.2.1 Architecture

As we mentioned, two main components comprise our system. The first one is a **mobile application** that each training participant uses on their smartphone. This component is responsible for handling the received heart rate and repetition input data. The second one is a **Unity desktop application** that shows the main display to all users who are participating in each exercise session. For a group to use our system during a videoconference exercise session, each user must have a Xiaomi Mi Band 3[1] **fitness band**, to which our mobile application will connect via Bluetooth Low Energy (BLE). This application is responsible for gathering the heart rate of the user by reading the corresponding Generic Attribute Profile (GATT) characteristic from the BLE Heart Rate service of the fitness band. Besides receiving

[1] https://www.mi.com/global/mi-band-3/

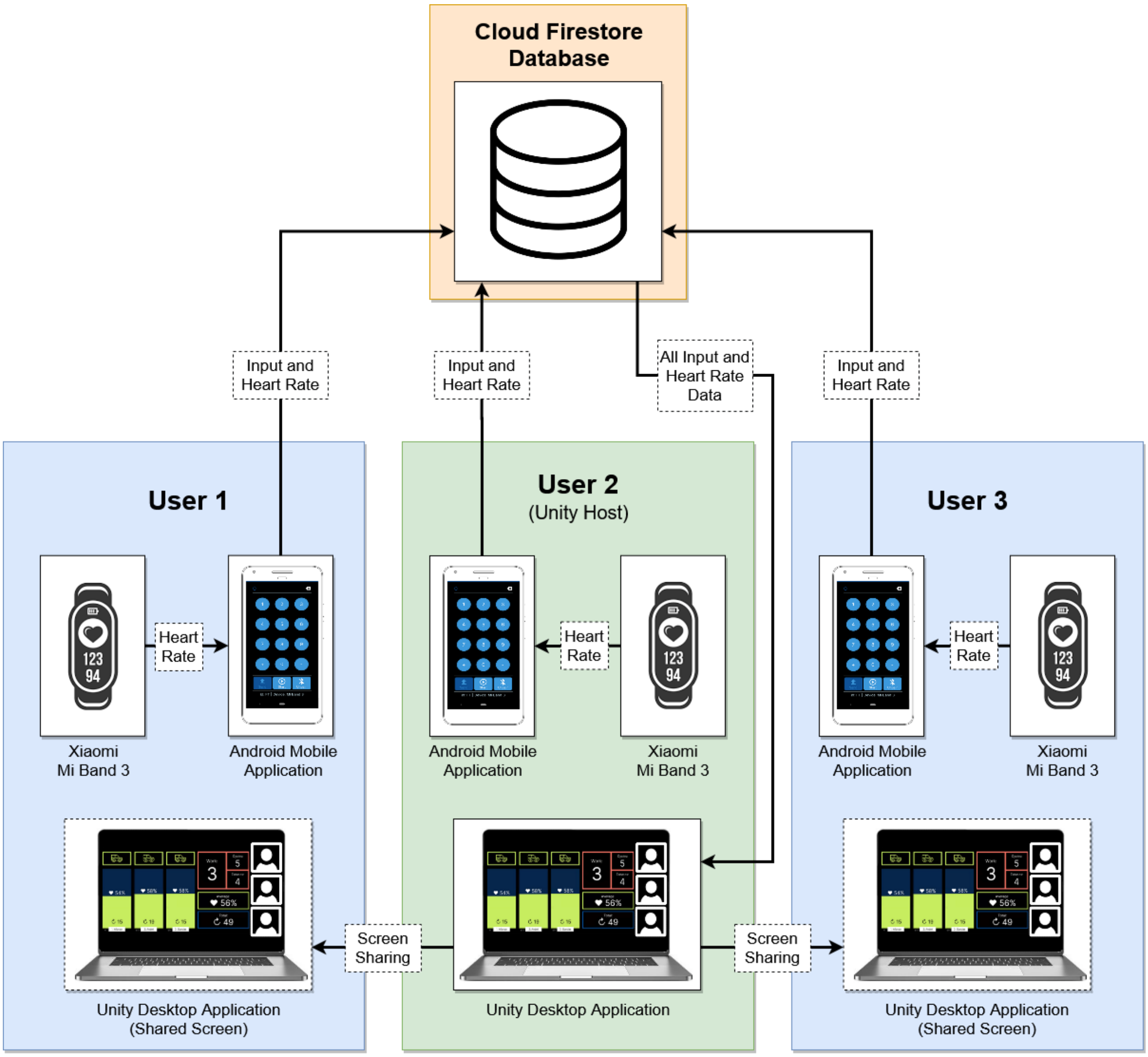

Figure 3.3: Diagram displaying the architecture of the "PlayHIIT" system.

inputs from the user through a numeric touchpad displayed on its main screen, the application also has the task of sending both these data types to a **cloud-stored database**, either through a wireless network or mobile data connection. This database is hosted through Google's Cloud Firestore service[2], a subsystem of the Firebase mobile development platform. During each training session, in this database, the live values of the inputs and heart rate of all users are registered, to be then used and displayed by the Unity desktop application, which accesses and retrieves these values via web requests to Firestore's Representational state transfer (REST) Application Program Interface (API) services. The combination of these different elements composes our entire system, which can be seen displayed in Figure 3.3. The final prototype we developed accommodates up to three simultaneous users, each connected through

[2] https://firebase.google.com/products/firestore

their own smartphone and fitness band. During each training session, only one of the users needs to host the Unity desktop application in their computer and share the displayed screen afterwards through the videoconference software of their choice.

The mobile application is developed in the Dart programming language 2.9.2 and makes substantial use of the Flutter development kit 1.20.3 version for its user interface. To perform the necessary read and write operations on the database, the application depends on the "firebase_core"[3] and the "cloud_firestore"[4] Flutter plugins, alongside "firebase_auth"[5] to provide authentication services. These plugins allow access to the required Firebase Core API, featuring all the tools for database update or read operations and anonymous authentication process for Flutter and Dart. Another plugin, "flutter_blue"[6] was used to provide the necessary tools for the BLE connection between the application and the ATB. The mobile application targets smartphones running Android versions 9.0 and above. The desktop application was developed in C# using Unity 2020.1, and resorted to an external plugin[7] dedicated to JSON processing, in order to read and filter the data gathered through the database REST API calls.

3.2.2 Mobile Application

The first step to accomplish our design foundation of sharing performance information between participants was to settle on what were the measures that we used for our system. We chose the heart rate of the users as the first and primary measure. The main reason that led to this decision was that it allows us to gauge the effort of users across several different exercises, in particular, aerobic ones, from which several variations do not require any home exercise equipment, lending themselves adequately to a video conference-based exercise session done at home. Having settled on the heart rate, we had to choose what type of sensor we were going to use to perform its measurement. Considering that electrical monitoring solutions require a complex transmitter setup process for users to do in their homes, we opted for an optical-based solution, through the Photoplethysmogram (PPG) sensors commonly available in commercial tracking bands. The model which we opted for (Xiaomi Mi Band 3) does not feature internet connection of any type, so communication has to be done through BLE connectivity. As this type of connection requires a peripheral dongle to connect to a personal computer directly, we opted for developing a simple mobile application that could handle the task of connecting to each of the bands that users wore throughout the exercise, and simultaneously share this data to a centralized localization which would be accessed by the main component of our system.

[3] https://pub.dev/packages/firebase_core
[4] https://pub.dev/packages/cloud_firestore
[5] https://pub.dev/packages/firebase_auth
[6] https://pub.dev/packages/flutter_blue
[7] https://github.com/Bunny83/SimpleJSON

3.2.2.A Initial Design

As an auxiliary system, the design goal of our mobile application was to be as functional and straightforward as possible, focusing only on accomplishing the three essential features that would be used by us, which are (i) connecting to the ATB through BLE, (ii) displaying the user's heart rate on the screen, and (iii) saving this same data in a remote database. The initial sketch for the application is illustrated in Figure 3.4. This sketch contains a possibility for the main screen before, and after connecting the application to the band and the button for establishing the BLE connection to a chosen device detected nearby. It also contains a button to start the activity, which would enable sending the data to the remote database in real-time during the activity.

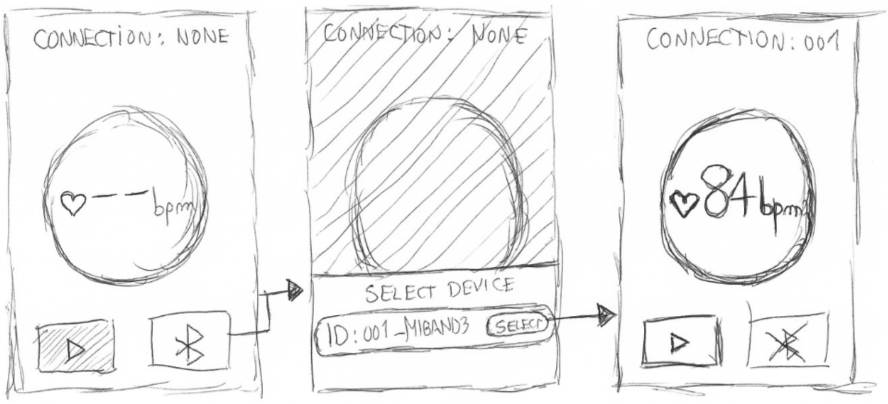

Figure 3.4: Initial sketch of the mobile application component of "PlayHIIT".

3.2.2.B First Iteration

Despite the general suitability of heart rate as a measure of effort during physical activity, there is still a factor that we need to consider. Different calisthenic exercise types affect heart rate in distinct ways. A cardio-training exercise such as jumping jacks will not have the same impact as an upper-body strength exercise such as a push-up, both due to the nature of the exercises themselves, but also due to the different physiques of users, that may find some exercises more strenuous than others. Considering that heart rate is more suitable to evaluate effort for cardiac training exercises, we also decided to add a measure that could ease the perception of effort in strength-training exercises. Taking into account how measuring muscle fatigue in specific muscles through methods such as Electromyography (EMG) would not be feasible using mainstream devices, we decided to take a proxy measure, through the addition of a repetition counter. Despite not providing absolute effort data, repetition numbers provide an intelligible metric, and suitable for comparisons between people doing the same shared exercises.

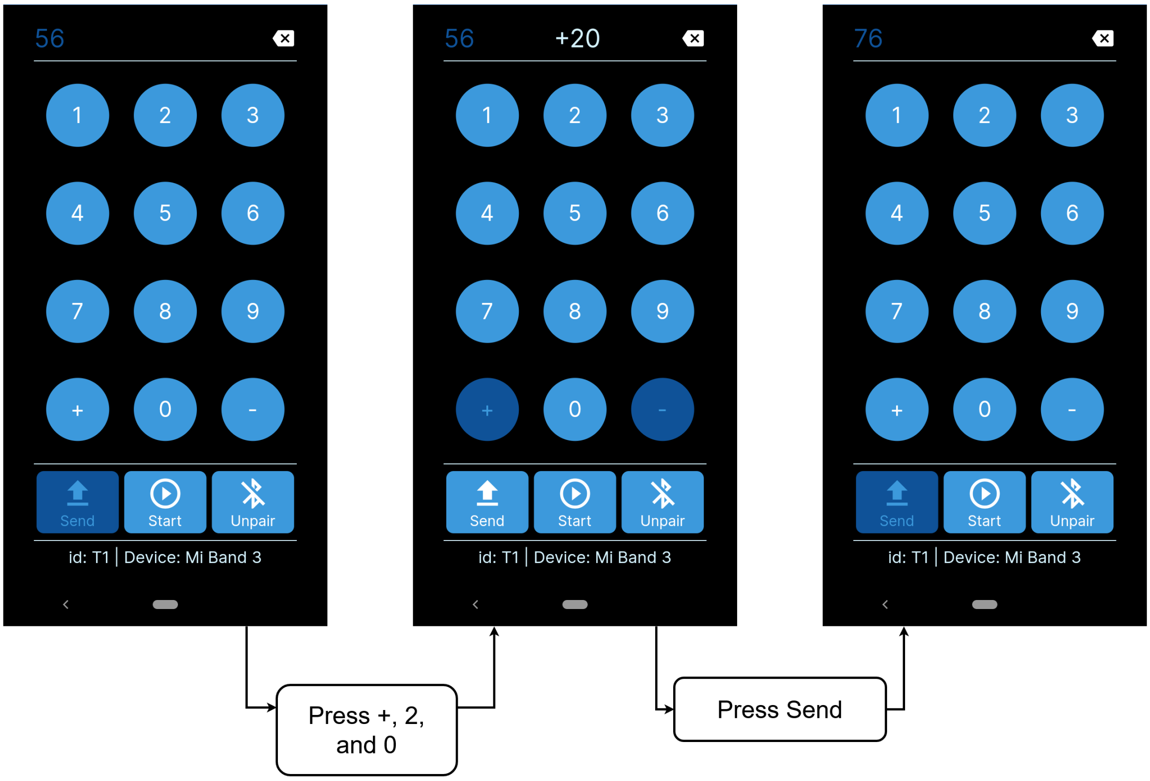

Figure 3.5: First prototype of mobile application interface.

After developing a prototype application that accomplishes our goals regarding treating heart rate data, we took avail of this existing component to also feature the interface that users would use to input their repetition counts during the activity. The primary user interface challenge comes from the fact that during physical exercise, in particular HIIT activities, resting times between sets can be as short as ten seconds, only allowing a very reduced time frame for users to input the number of repetitions they have done in the previous set. Our initial concept was exchanging the core display of the application for a numerical pad, reassigning the role of displaying the heart rate to the core desktop application instead, while still gathering and sending the data. An interaction example featuring this new numerical pad can be seen in Figure 3.5, alongside what was respectively displayed on the screen of the prototype. Through this feature, users could perform one of three options for inputting their repetitions during rest periods:

- **Input a single number and press "'Send"**, resulting in a direct attribution of that number to their registered repetitions count, overwriting the previous one (eg.: inserting "20" when the previous value is "41", results in the value "20");
- **Input a plus sign and a number, and press "'Send"**, summing it to the previous registered value (eg.: inserting "+20" when the previous value is "41", results in the value "61");

- **Input a minus sign and a number, and press "'Send"**, subtracting it to the previous registered value (eg.: inserting "-20" when the previous value is "41", results in the value "21").

3.2.2.C Final Prototype

Problems arose as soon as we tested the first iteration of our system with a focus group. After a session doing exercise while simultaneously using our application, users complaint about the interface still being rather complicated to use in short ten second intervals between sets, rendering it impractical. They also noted that if they made a mistake, they would not have time to fix it before the next set starting, making it stressful. To solve this issue, we attempted to reduce the complexity as much as possible in the following application iteration. After talking to the users who tested it, we realized that having a dedicated subtraction command would only be useful to fix mistakes and that in that case, a direct overwrite accomplishes the same task without requiring mental calculations. Having this in mind, instead of separating commands in attribution, sum, and subtraction, we simplified the system so that by default all numbers are added to the previous one, alongside an optional overwrite button. We also trimmed the required number of presses by making the system automatically sum any numbers that are in the input field if the user does not press anything else for three seconds. The possible interactions of this interface became the following:

- **Input a single number and wait three seconds**, summing it to the previous registered value (eg.: inserting "20" and waiting three seconds when the previous value is "41", results in the value "61");
- **Input a number and press "Overwrite"**, replacing the previous registered value (eg.: inserting "20" when the previous value is "41", results in the value "20");

The reception from our focus group was notably more positive with this prototype iteration, with the participants finding it a lot more feasible to quickly annotate their repetition counts in the application with only one to two clicks instead of three to four clicks, in the span of ten-second breaks. Having looked into how we idealized the application, how it tackled the different tasks that we assigned to it, and the interface challenges that composed its design process, we reach the final iteration of our mobile application prototype, displayed in detail in Figure 3.6.

The main screen contains the numerical pad, three additional buttons, and a text prompt displaying if there is any device connected underneath. When starting the application, the only available button is the "Pair" one which displays an overlay with all detected compatible devices scanned nearby. Pressing "Pair" pairs the application to the device, and starts listening for updates in the Heart Rate Service BLE characteristic of the connected band. After connecting, the numerical pad and the "Start" button become available, and a new display appears above the pad featuring a backspace button and the current repetition number registered. The "Start" button initializes the heart rate measuring, sending the

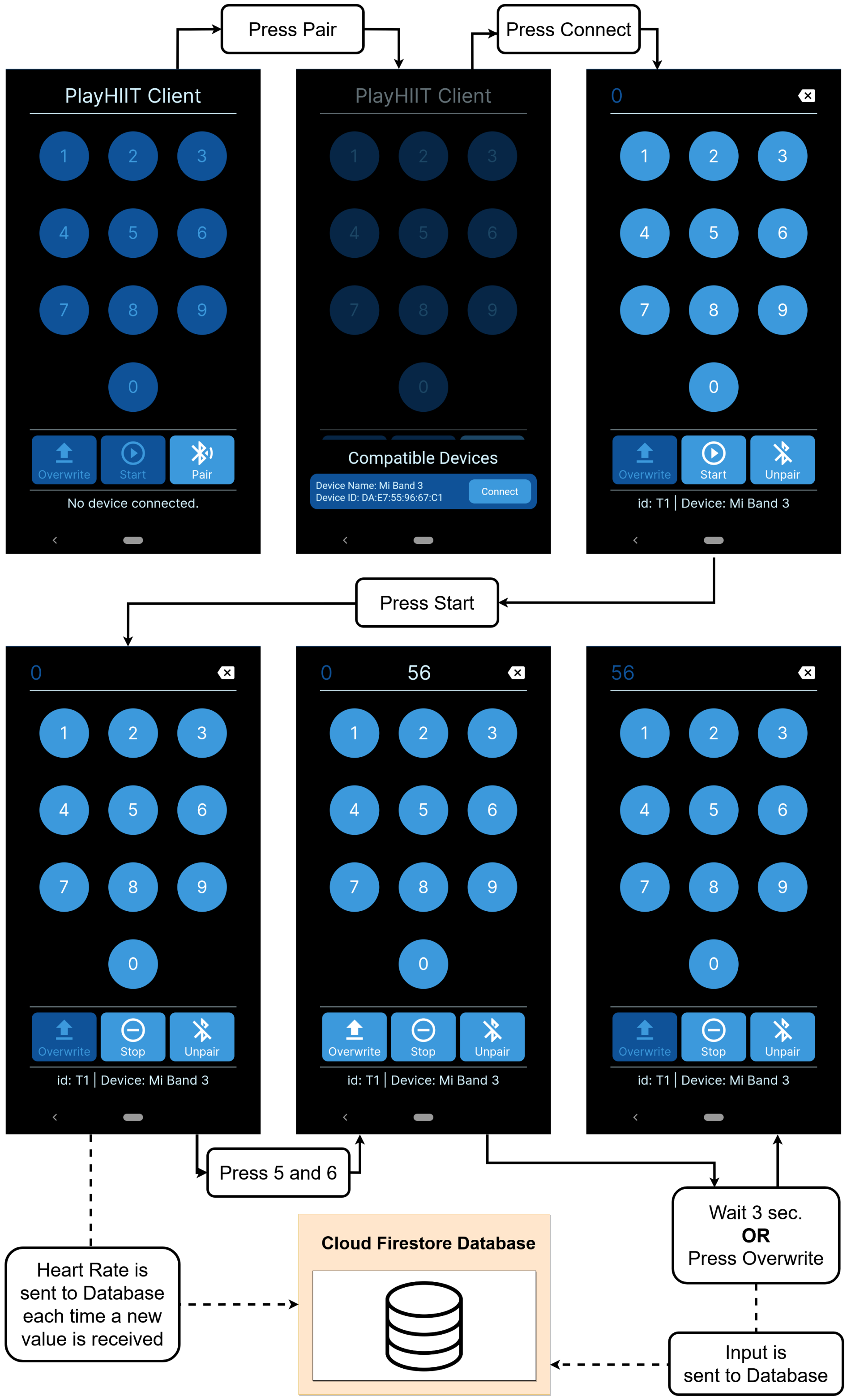

Figure 3.6: Complete diagram of usage example of our final Mobile application prototype.

data to the remote database through an internet connection. The numerical pad acts as an input for users to annotate their repetition counts throughout the physical exercise sessions and automatically consumes any input that is made after three seconds. We added an “Overwrite” button to allow quick corrections in case of mistakes during the possibly short rest periods of each session. Whenever the registered input value is updated, a request is also made to update that value on the online database.

3.2.3 Desktop Application

The first factor that we settled on regarding the main component of our system was that it would be a display shared by all users, meant to be used simultaneously as the videoconference software of their choice. To allow for an easy setup, only one person would need to initialise and set up the application, and then share their screen through to the others through the used Videoconferencing Software (VCS). Regarding its development, as we previously mentioned, the first metric that we decided to use as a measure of effort during the physical activity was the **heart rate**.

3.2.3.A Initial Concept & First Prototype

When conceptualising how we would share the information regarding the heart rate of their peers between the users of our system, we analysed two different core possibilities. The first option was using an auditory channel, through a sound representation or metaphor to transmit that information, and the second option was a visual channel, using an image or visualisation to display it on the computer screen while doing the activity. Each of these approaches presents different yet relevant advantages. Using sound to pass information allows for an immediate effect, as the type of exercise users perform and whether they are looking at their screen does not stop them from listening in any way. On the other hand, distinguishing different simultaneous information channels can be challenging, as with each layer of sound that is added, the more difficult it is to keep all channels intelligible. Opposingly, using visual channels to achieve this does not allow for an immediate effect, as users can only be aware of new information whenever they look at the screen, but they can understand a much greater variety of information. While we still conceptualised a design based on an auditory approach of presenting heart rate, which would rely on different instruments on a music track being highlighted or faded depending on the heart rate percentage of each user, we opted for a **visual approach** instead. As a visual approach can be checked on the display at the user’s will, it provides a more unobtrusive way of delivering the information. This way, users can have control over the frequency they check their and their peers’ heart rate during the activity.

Considering that heart rate as beats per minute on itself does not allow for a direct comparison between several people because individuals have different cardiac capabilities, we opted for a **simple balancing mechanism**, estimating the maximum heart rate of each user based on the Karvonen formula as featured in Stach et al. [25]. Through this we can present the heart rate of users not only as an absolute number but also as a percentage of their maximum heart rate, depending on their age, providing a normalised value and a more socially balanced experience as discussed in Chapter 2.

We chose to represent heart rate as **coloured bars set side by side** on the screen. The size of the bars was proportional to the percentage of individual maximum heart rate of each user, and we coloured them according to the interval in which they are inserted in, with gradually warmer colours until red, being the lowest interval up to 50%, and the highest from 90% to 100%. We picked this colour palette due to its common usage on graphs representing heart rate training zones in gym or sports contexts, which were a consequence of their prevalence in the heart rate monitor industry.[8] Having effort tiers distinguished by colour makes it easier for users to check on the status of their group with a glance while displaying different sized bars side by side allows for easy comparisons between users to facilitate competitive behaviour from those who enjoy it.

Figure 3.7: First prototype iteration of the "PlayHIIT" desktop application, featuring heart rate display for each user.

The first iteration of our system can be checked on Figure 3.7. We added a **training timer** allowing us to input the amount of time dedicated for set preparation and duration, resting intervals, and the number of sets and cycles per set, featuring provisional sound effects to signal the start of work and rest intervals. In order to fetch heart rate data from our cloud located database in real-time during its usage, the system uses REST API requests to access a JSON file of the document that contains the necessary data. For each registered MAC address, which correspond to the tracking bands used, an entry for maximum and current heart rate, and an identifier is kept and passed on to the desktop application.

[8] https://www.nytimes.com/2001/04/24/health/maximum-heart-rate-theory-is-challenged.html

3.2.3.B Repetition Counts & Second Prototype

The next step of the development phase was to settle on how to integrate the **repetition counts** into our system. Unlike heart rate, there is not a direct method to balance the repetition counts of different people and to attempt it would require previously evaluating the physical ability of each person, in order to establish a performance baseline. While we want to include a measure that allows users to have a more in-depth insight of the performance of their partners, we also want to aim for **social balance** as most as we can, so we opted to keep the heart rate as the primary measure through the size and colour of each bar, and present the input only as a number inside it.

Another factor to consider is that despite the system not providing direct incentives for users to compete such as rewards or a scoring system of some kind, providing the information in an easily comparable way will still implicitly suggest competitive behaviour, enhancing the *Competition* dimension of the PLEX framework. To counterbalance this and to provide a more enjoyable system for users who do not prefer competing with each other during physical exercise, we also displayed the **group average heart rate and total repetitions** between all users. The objective of this addition is providing more options to spark social interactions with a cooperative theme between users, such as commenting or cheering for each other to achieve a higher group average.

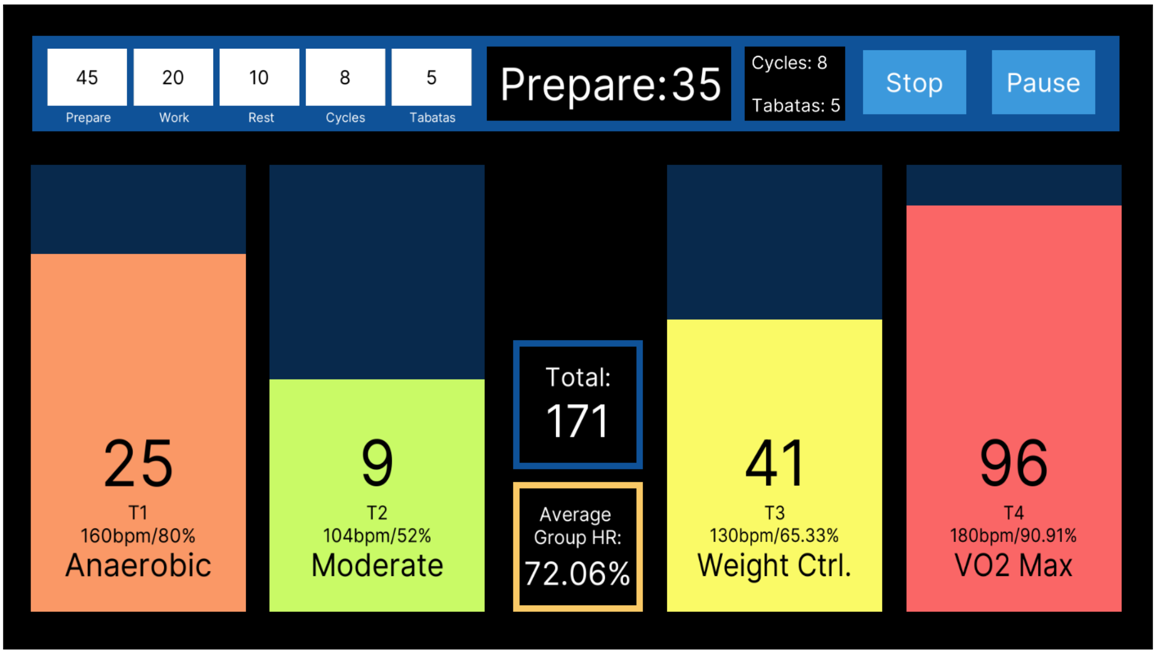

Figure 3.8: Second prototype iteration of the desktop application, with group heart rate, and repetition counts.

Figure 3.8 depicts the second iteration of our prototype, featuring the repetition counters for each user, the new group statistics, and a more contrasting **updated colour palette** to facilitate readability. This iteration was the first with which we performed user tests to obtain feedback from our focus group.

After using our prototype in a half an hour session with three participants, they praised the social side of exercise that it stimulated, as knowing how well others were performing allowed them to tease and cheer each other during the activity. Comments were made regarding the visibility of their heart rate, as despite the coloured bars being highlighted on the display, checking further details was challenging as the information was small on the screen and made it tough to check during different exercises.

3.2.3.C Final Layout & Third Prototype

We revised the layout of our system for our next iteration, which is displayed in Figure 3.9. Considering that the time of each different exercise is one of the most frequent things for participants to check while they are working out, either to know how much resting time they have left or how long until a set ends, we increased the size of the timer and provided it with different colour-coded borders that match with each different workout phase of a HIIT training. In this timer, a green border corresponds to resting periods, red to working out, and yellow to preparation time before a set.

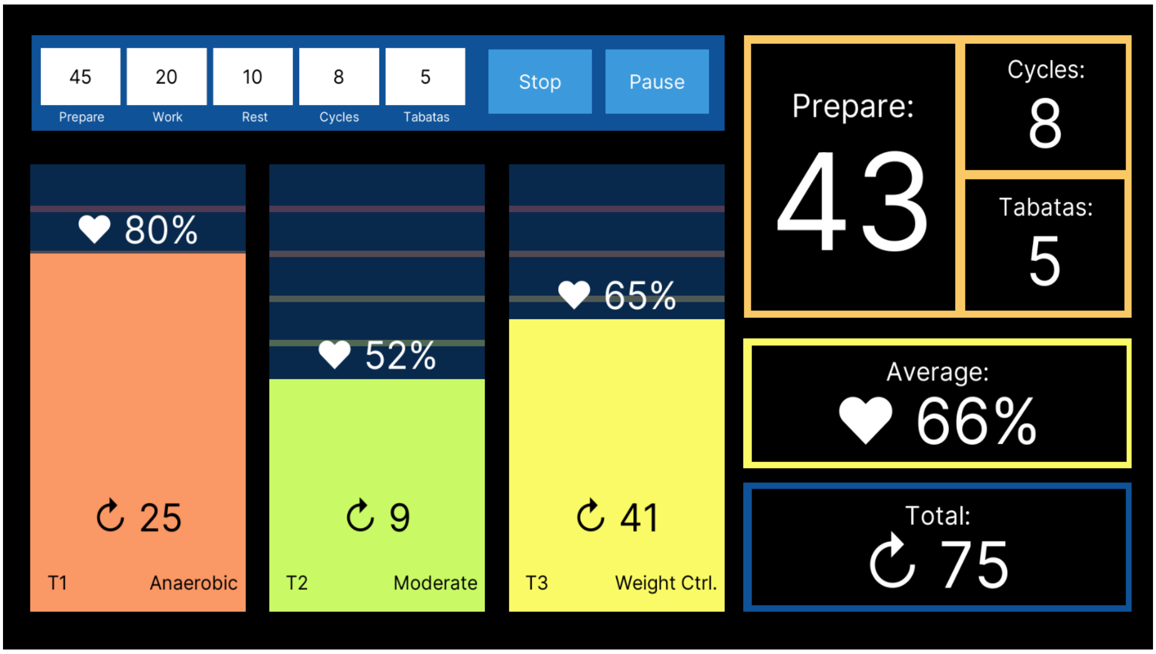

Figure 3.9: Third prototype iteration of the desktop application, with updated information emphasis.

We also increased the size of the group information and added visual markers for the different intervals corresponding to changes in the colour of the heart rate bars. We later removed these as participants of our focus group felt they contributed to the system feeling cluttered. The last significant change was regarding the layout of the different user values. We added the percentage of heart rate above each respective bar, both to make it easier to check, and to better mark the size of the bar as a representation of the heart rate itself. Small icons representative of a heart and a repeating action were also added to boost intelligibility further. All these changes have the collective goal of facilitating social awareness between group elements about their performances, affecting the *Nurture* dimension of the PLEX framework.

3.2.3.D Badges, Voice Lines & Final Prototype

The last two features that we added to our system were based on the remaining playfulness concepts that we wanted to stimulate. The first feature is a **set of badges** that provide a visual representation of the heart rate percentage of each user through a chosen metaphor. The addition of this feature was motivated by feedback received during the previous testing cycle of our application in which one of the participants suggested having discrete visual flairs to represent different heart rate intervals. We picked several vehicles of increasing speed to represent distinct intervals, alongside a warning sign to represent the highest interval, to provide a visual warning for overexertion. The main objective of this feature would be to stimulate and reward curiosity from users regarding our system, boosting the *Discovery* dimension, in terms of the PLEX framework. We want to provide an additional incentive for users to reach higher levels of effort, as well as an implicit indication of the objective of HIIT training itself, which is to reach higher heart rates for as long as you can without reaching overexertion. The different badges added along the intervals they correspond to can be checked in Table 3.1.

Table 3.1: Badge variations and corresponding heart rate intervals.

Displayed Image	Heart Rate Interval
	[0%; 50%[
	[50%; 60%[
	[60%; 70%[
	[70%; 80%[
	[80%; 90%[
	[90%; 100%]

The second feature is the inclusion of **voice lines** whenever a particular user raises or lowers his heart rate under or over a certain threshold. We added twenty-eight voice lines to the system, with three groups of seven dedicated to variations for each element of the group, ranging from “Number 1” to “Number 3”, and one group dedicated to variations of the group average heart rate. Whenever the heart rate of a participant crosses one of these thresholds, a voice line made using text-to-speech software is played, and a **speech balloon** is displayed above the relevant value in our system. To make sure that the voice lines do not continuously play if the heart rate of a user varies between nearby values of one of the thresholds, they only reset if the heart rate of a participant goes at least 5% above or below a certain threshold. (e.g., for the voice line corresponding to users going above 70% to play twice consecutively, it is required for them to reach 65% before the second time may play). Our objectives with this feature were both functional and social. The functional aspect of this feature is that it allows us to grab the attention of the remaining users for more relevant events such as a more considerable variation of the effort of one of the elements of the group. As we mentioned earlier, during the conceptual phase of development, using sound allows us to immediately transmit information to the user by not relying on them looking at the screen during the physical activity. The social aspect is to provide scaffolds for users to tease and cheer each other, by commenting on the interventions made by the system itself, in an attempt to stimulate the *Fellowship* and *Humor* dimensions of the PLEX framework. Inclusion of technological agents in playful role-taking, such as a virtual coach in this case, has been studied before as a possible trigger for social play [43]. The different voice line variants can be seen in Table 3.2.

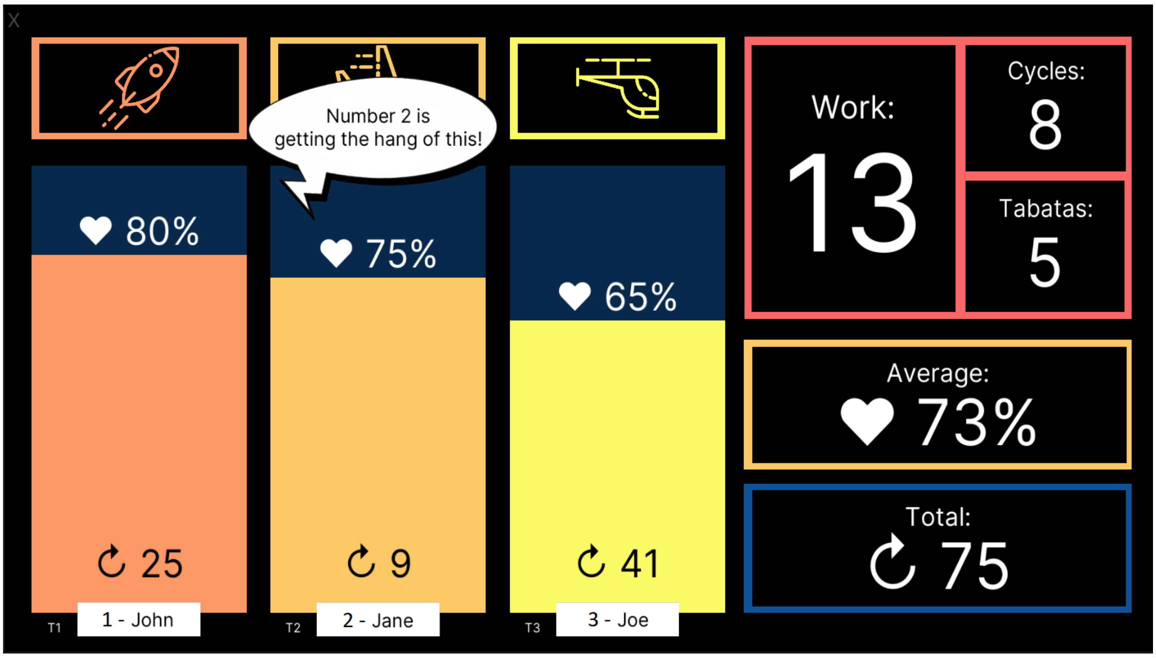

Figure 3.10: Final prototype of the desktop application, with the percentile badges and displaying an example of a voice line balloon.

Table 3.2: Voice line variants for both heart rate increase and decrease, and respective thresholds.

Threshold	Voice Line (Increase)	Voice Line (Decrease)
60%	”Number one is getting warmed up!”	”Number one is taking it easy.”
70%	”Number one is getting the hang of this!”	”Number one is slowing down.”
80%	”Number one is on fire! Keep going!”	”Number one is going a bit lighter.”
90%	”Number one, don’t push yourself too much!”	-

In Figure 3.10, we can see the final version of the “PlayHIIT” desktop application. By inputting an identifier corresponding to their band, users can visualize their heart rate as a percentage as both a colour coded vertical bar, and as a percentage, alongside the number of repetitions they are keeping track through their mobile application. On the right side, a timer is displayed, with differing border colours depending on the current training phase of the session. Below the timer, both the average group heart rate and the total sum of repetitions across all users are displayed. A badge with a different colour and vehicle depending on the heart rate of each user is presented above each one of their coloured bars, and an example speech balloon can be seen, in the same way, users see whenever one of them crosses one of several pre-defined thresholds.

4

Evaluation

Contents

In order to evaluate our system, we have designed and conducted an **experimental user study** over the course of three weeks, which we describe in thorough detail throughout this chapter, alongside its findings and a follow-up discussion. We start by describing the foundation that we had in mind while designing our study, through the form of the hypotheses that we proposed to test, and the research questions we intended to answer. Our study was approved by the Técnico-Lisboa Ethics Comission under the reference number 21/2020 (CE-IST).

4.1 Hypotheses & Research Questions

We first need to revisit the objectives of our study. We can divide the dimensions which we intended to influence in two major groups. The first group is the enjoyability of the physical activity itself, regarding whether our system and its social-oriented features do have an impact on how fun and how entertaining it is for the participating users. The second group is if our system is effective in increasing the effort of users, and whether this influence is significant or not. From both these dimensions, we can derive our two **hypotheses** that we intend to test through our study:

- **H1:** The integration of social-oriented playful features in group videoconference exercise increases the enjoyability of the activity.
- **H2:** The integration of social-oriented playful features in group videoconference exercise increases the effort of participants during the activity.

Furthermore, we also intend to provide a more in-depth analysis of the type of impact our system had on users. The inclusion of most features of our system was rooted in different playfulness components that we intended to stimulate and make more relevant during the activity. Considering this design choice, we found it worthwhile to provide a more profound analysis regarding how our system impacts playfulness facets. Additionally, we also want to observe whether users perceive their own effort to be different from regular video-conference exercise, and whether their engagement did make the activity seem less challenging to perform. Lastly, we also want to observe if the way groups interacted with each other changed while using our system. From these objectives, we can derive three additional **research questions** that we intend to answer through the results of our study:

- **RQ1:** What facets of playfulness does our system influence in a group videoconference exercise session?
- **RQ2:** Are users' perceptions of effort affected during physical activity? If so, how?
- **RQ3:** Does the system affect the social behaviours of users?

Having defined hypotheses and research questions, in the following subsection we provide clearer insights regarding on how we translated these goals to measurable dependant variables that we can analyse, and how we consequently designed our study around them.

4.2 Experimental Design

In order to test our hypotheses and answer our research questions, we designed an experimental user study to gather the necessary data. The independent variable of our study is the test condition, which has two possible values: (i) participating in a videoconference group physical exercise session while using our system, and (ii) in a control variant of the session that did not feature our system.

To avoid individual differences between users, we designed our study as being within-subjects, with all groups performing one training session each under both conditions, with one rest day in between. We recruited participants to perform the activity in groups of three people, to ensure that they already knew each other before the study occurred. In order to avoid order bias, we counter-balanced the conditions: half of the groups first trained while using our system, while the other half would do it without using our system. Each user was in their respective home, or any other place of their choice during each videoconference call.

The first step was to settle on what type of data we should gather during our study, to answer our research questions and test our hypotheses. To this effect, we decided on five different dimensions, that correspond to the objectives of the user study mentioned above. Our first hypothesis requires a measure that allows comparison of the enjoyment levels of each user after both conditions. The Physical Activity Enjoyment Scale (PACES) questionnaire [44] is the tool we chose for this, which is a multiple-item survey that evaluates the extent to which a person enjoys a particular physical activity. We settled on this questionnaire instead of other artefact-centred alternatives to focus on the enjoyment of the physical activity itself. The purpose of our system is to complement and make the preexisting activity more enjoyable to participants. Having this in mind, focusing on the system instead would not provide information on the matter that is most important to us, which is whether doing the proposed exercises was more enjoyable with our system in place. After each session, we then asked users to answer this questionnaire regarding the activity they had just done, providing us with data of their enjoyment levels. Our second hypothesis theorizes that our system has an effect on how much effort participants put in their physical activity. We opted for using heart rate as a measure of effort due to the easy setup required for measuring it in the homes of participating users when comparing it to other measures such as muscular effort.

Moving on to our research questions, the first one requires an adequate tool to analyse the different playfulness characteristics of our system. This requirement is so that we can verify if we met our intentions we during the design phase of our system or if we unintentionally emphasised any other playfulness concepts. The Playful Experiences Questionnaire (PLEXQ) [45] is the tool we found appropriate and chose to this effect. The objective of this questionnaire is to provide a lightweight research tool that can separate and identify the different playfulness facets that are more relevant in a given product or system. After each session, users were then also asked to answer the PLEXQ regarding the activity they participated in, providing us with the necessary data for this analysis.

A method for users to communicate how much effort they think that they are putting in their physical activity is needed to answer our second research question. One of the most commonly used self-assessment tools that accomplishes this requirement is the Borg Scale of Perceived Exertion (BSPE) [46]. The usage of this scale consists of asking users to rate how hard they are working. At fixed intervals during the training sessions included in our study, we asked each participant to rate their efforts and manually registered their answer. The order in which we inquired participants was different each time, in order to reduce anchoring bias with previous answers.

Finally, the last research question we proposed to answer with our study requires a less objective approach due to its open-ended nature. To analyse what changes occur in the way participants interact with each other during exercise, we first register the number of distinct social interactions that participants engaged in during the session. Afterwards, we interview them to find out their opinion on the way our system influenced their interactions. Through this methodology, we attempt to explore both the quantity and quality of the social interactions developed during our study. To further enhance this qualitative analysis, we will also have each participant answer the Inclusion of Other in the Self (IOS) single-item questionnaire [47]. The purpose of this tool is to take into account how close the elements from each group are to each other, which may be a relevant factor that influences their comfort level in socially interacting. To accomplish all this, we recorded for transcription the videoconferences containing the training sessions and subsequent interviews. We asked participants to answer a survey containing an IOS for each of their partners after the exercise sessions.

Regarding the physical activity aspect of our user study, we reached out to a professional sports technician to cooperate in the design of the training program that would be performed by participants in both conditions of our study. We arranged this cooperative effort to ensure two distinct factors. The first is that the exercises themselves should be suitable for both people that engage in physical activity frequently and people who are not used either to perform physical activity or HIIT sessions in particular. The second factor is that we can keep an adequate muscle effort distribution between all individual exercises. Additionally, we also wanted to choose exercises that do not require additional equipment or too much physical space so that they can be done independently of the size of the rooms where participants are. The resulting effort of this cooperation was a HIIT training session containing ten different exercises, divided between five different sets. The duration of the whole activity, including resting and preparation times, was 23 minutes and 45 seconds. One resting day between consecutive sessions was the suggested time to be applied to our study. The diagram displayed in Figure 4.1 shows all details regarding the composition of the training program. In summary, considering all information contained in this subsection, the structure of our user study for each group is the following:

- **Day 1:** Preparation videoconference call in which technical setup is done for each user.
- **Day 2:** First training session under one of the conditions, with both video output and heart rate being recorded, followed by a survey containing both the PLEXQ and the PACES questionnaires.
- **Day 3:** Resting day between sessions.
- **Day 4:** Second training session under the remaining condition, with both video output and heart rate being recorded, followed by a survey containing the PLEXQ, the PACES and the IOS questionnaires, ending with a simultaneous semi-structured interview with all participants of the group.

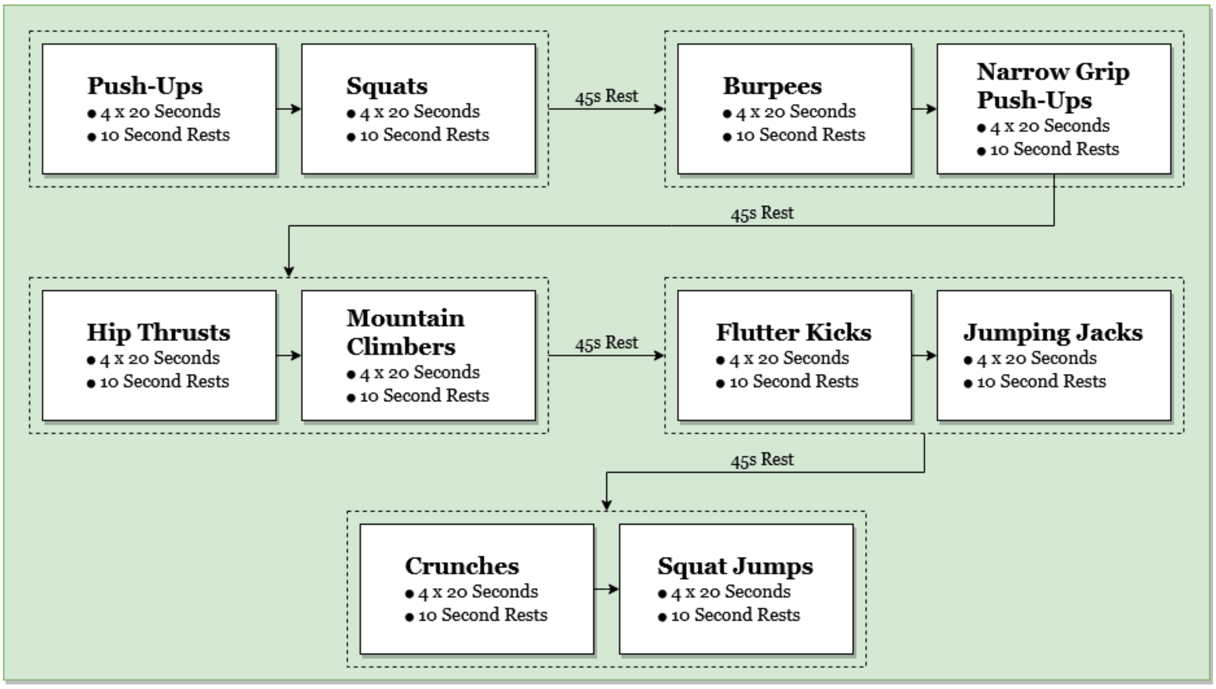

Figure 4.1: HIIT training program used in both conditions of our user study.

4.3 Participants

We recruited participants for our study as groups of three people who already knew each other beforehand. This recruitment process was performed through online college social network groups and word

Table 4.1: Characterization of the participants of our user study.

	ID	Age	Gender	Exercise Frequency	Done HIIT?	Used ATB?	Used VCS?	IOS
G1	P1	20	Male	0-1 times per week	No	No	Yes	37
	P2	21	Male	4-5 times per week	Yes	No	Yes	
	P3	21	Male	0-1 times per week	No	No	Yes	
G2	P4	20	Male	6+ times per week	No	No	Yes	18
	P5	20	Male	6+ times per week	No	No	Yes	
	P6	20	Male	0-1 times per week	Yes	No	Yes	
G3	P7	23	Male	0-1 times per week	No	No	Yes	32
	P8	20	Male	0-1 times per week	No	No	Yes	
	P9	22	Male	6+ times per week	No	No	Yes	
G4	P10	19	Male	0-1 times per week	Yes	Yes	Yes	24
	P11	19	Male	0-1 times per week	No	Yes	Yes	
	P12	19	Male	2-3 times per week	No	No	Yes	

of mouth. 15 participants responded to our requests, from which one of the groups was not able to perform the study due to incompatible availability from its members, resulting in twelve users, distributed between four groups, that performed our study as a whole. Additionally, all participants were required to sign a consent form. Participants did not receive any compensation.

All participants were male, with ages comprehended between 19 and 23 years old ($\overline{x} = 20.33, \sigma_x = 1.18$). From these, three of them performed physical exercise six or more times per week (25%). Only a single participant performed physical exercise either 2 to 3 times per week (8.33%) and another one 4 to 5 times per week (8.33%). 7 different participants answered that they engaged in physical activity one time per week or less (58.33%). From all users, only three had already performed a HIIT exercise session before (25%), two had already used an ATB at least once (16.67%), and all were familiar with VCS before our study (100%).

Regarding the degree of connection each element felt to their respective group, we requested participants to report it through the IOS Scale. The sum of the answers given for each group range from 6 to 42, which correspond to the least and greatest degree of connection, as each participant was asked to answer for each of their peers, resulting in six answers per group. These results alongside detailed information regarding the characteristics of the participants can be seen in Table 4.1.

4.4 Apparatus

The technical setup for our study differs slightly from the one described in the Architecture section of this thesis (Section 3.2.1). Users are still required to wear a Xiaomi Mi Band 3 activity tracker on their wrists, and to have a mobile phone each with Internet access, Android operating system updated to at least version 9.0, and the ability to perform BLE connection. Besides this each user also needs a device capable of running videoconference software, such as a tablet or a personal computer, equipped with microphone and camera. The main difference is that instead of having one of the users sharing the desktop application on their screen, the application instead runs and is shared from a desktop handled by the researcher supervising the study, which also requires microphone input for the videoconference.

Other relevant materials used include online forms shared to participants through the Google Forms platform, containing the PACES questionnaire [44], the PLEXQ [45], the IOS Scale [47], the BSPE [46], and a demographic survey containing age, frequency of physical exercise, and familiarity with HIIT training, activity tracking bands, and videoconferencing software.

Regarding the questionnaires we chose to use, the PACES questionnaire contains 18 Likert scale items ranging from 1 to 7 about the feelings of the user regarding the activity they have just done. Eleven of the composing items are presented with a reverse score, while the others presented regularly. Each of these items provides two different labels for both the minimum and maximum option of the scale (*i.e.: "I enjoy it. / I hate it."*). After correctly ordering each item, the sum of all scores provides us with a final result ranging from 18 to 126. The PLEXQ is a set of 51 different propositions to which the user must provide an answer ranging from "Totally Disagree" to "Totally Agree" in a 5-point Likert Scale. These 51 items are divided into 17 groups of three, each corresponding to the evaluation of one of the facets presented in the PLEX framework, which was discussed in Chapter 2. The BSPE is an exertion self-assessment scale, ranging from 6, which can be compared to reading a book or watching television, to 20 which corresponds to the last stretch of a race or any activity that cannot be maintained for long[1]. The IOS Scale is a single-item Likert scale which ranks how close someone feels to a given person or group of people from 1 to 7, with each rating corresponding to a different Venn diagram.

Besides these, example GIF files displaying the different exercises included in the training session were also shown at the same time to clarify any existing doubt from participants regarding their execution. The display that was shared to participants during the videoconference call, including the instructional GIF files and the camera displays, can be seen in Figure 4.2.

Since our system already supports heart rate measuring through several of its features, in order to record this data during the activity, we implemented an additional feature to our mobile and desktop application. When starting the training session, users will be prompted by the desktop application with a countdown going from 5 to 0, asking them to press a new "Start" button on their phone. The instant in which the button is pressed is then recorded as the starting time of the training session, and all subsequent heart rate values are registered in our cloud database, alongside the corresponding timestamp. When the timer finished on the desktop application, an Excel file containing all recorded values during the training session is extracted through an additional REST API request. Registering the local start time for each user instead of a simultaneous remote solution allows us to accommodate to the latency of the videoconference call in our data. Images displaying the additional prompt added to the desktop

[1] https://www.hsph.harvard.edu/nutritionsource/borg-scale/

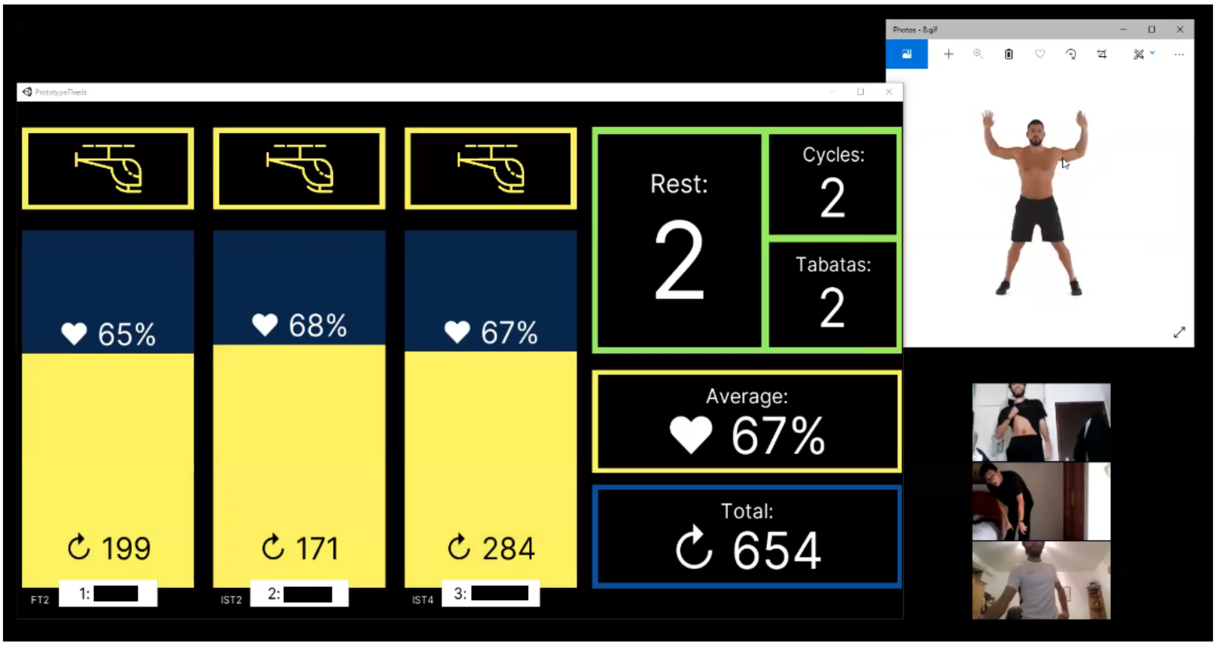

Figure 4.2: Display example of the screen shared to participants during our user study.

application, and the updated mobile application main screen can be seen on Figure 4.3.

In order to execute the sessions under the control condition, we also developed an additional variant to both our desktop and mobile applications that are solely focused on the previously described recording features. The desktop application only features the exercise timer for participants to be aware of the exercise set duration and progress, and the mobile application hides the input features, only displaying the heart rate of users to make sure its values match the ones presented in the ATB. Images displaying the final visuals of both these control modifications can be seen in figure 4.4.

4.5 Procedure

To better understand the procedure of our user study, we can divide it into two distinct stages. The first stage is the preparation of our study, which happened in the week before. The second stage is the core of our study and consists of both video conference sessions, which happened in three days for each group.

4.5.1 Preparation

The first step of the process was ensuring that each participant had the required material to engage in the online session. As soon as all participants were recruited, and their respective exercise sessions scheduled, a Xiaomi Mi Band 3 ATB was then lent to each of them, during the study. We also gave them

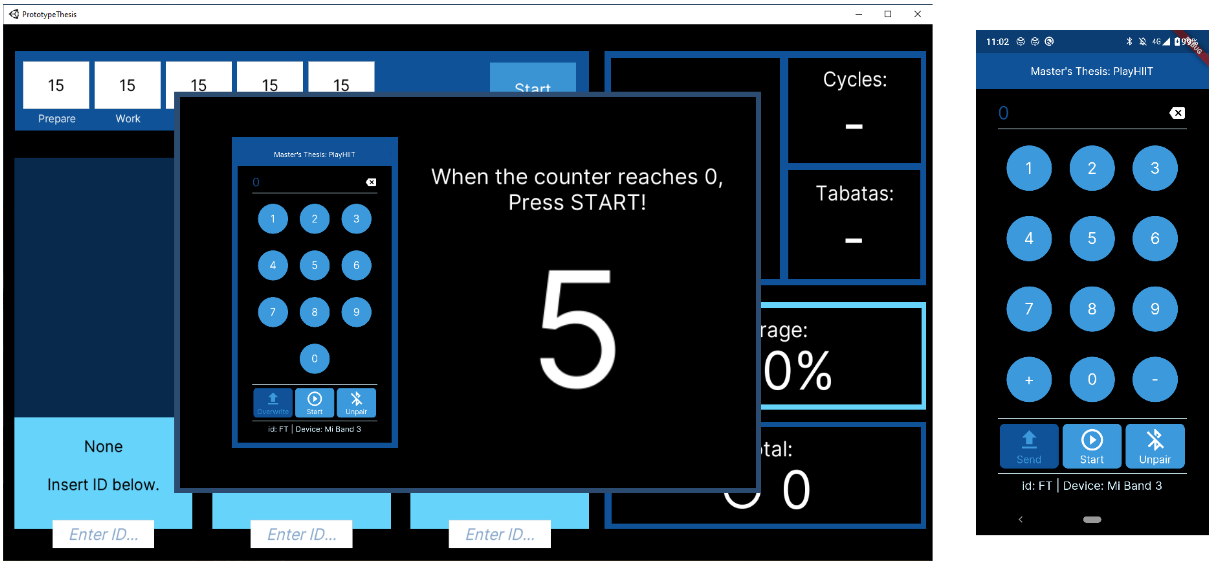

Figure 4.3: Updated version of our system featuring the recording features necessary for our user study.

a consent form to sign, providing them detailed information regarding privacy and the usage of their data in this study. Between the time we recruited them and the scheduled sessions, we asked participants to fill a survey regarding their demographic data, including age, exercise frequency, and familiarity with HIIT training, activity tracking bands and videoconferencing software.

On the day before the exercise sessions occurred, we held an introductory session with each group, in which we guided them through the technical setup for their fitness bands. Individual sessions were also held whenever availability issues arose. Participants were instructed to pair their bands to their mobile phones, followed by enabling the ability to pair third-party applications with the band and sharing heart rate data to other applications. This setup was manually done in each mobile phone to avoid potential pairing issues that occurred during the iterative testing phase of development.

4.5.2 Execution

At the beginning of the initial session, the first step was to explain to the whole group what a HIIT training session consists of, and the structure of the particular program that they will perform in each session. Its purpose is to guarantee that there are no doubts regarding the proper form of each exercise. We then inform participants that they are free to interact with each other during the session and that during the rest phase of each repetition set, they will be asked to self-evaluate their effort through the previously mentioned Borg Scale of Perceived Exertion. Afterwards, the standard protocol that participants were asked to follow in each session was the following:

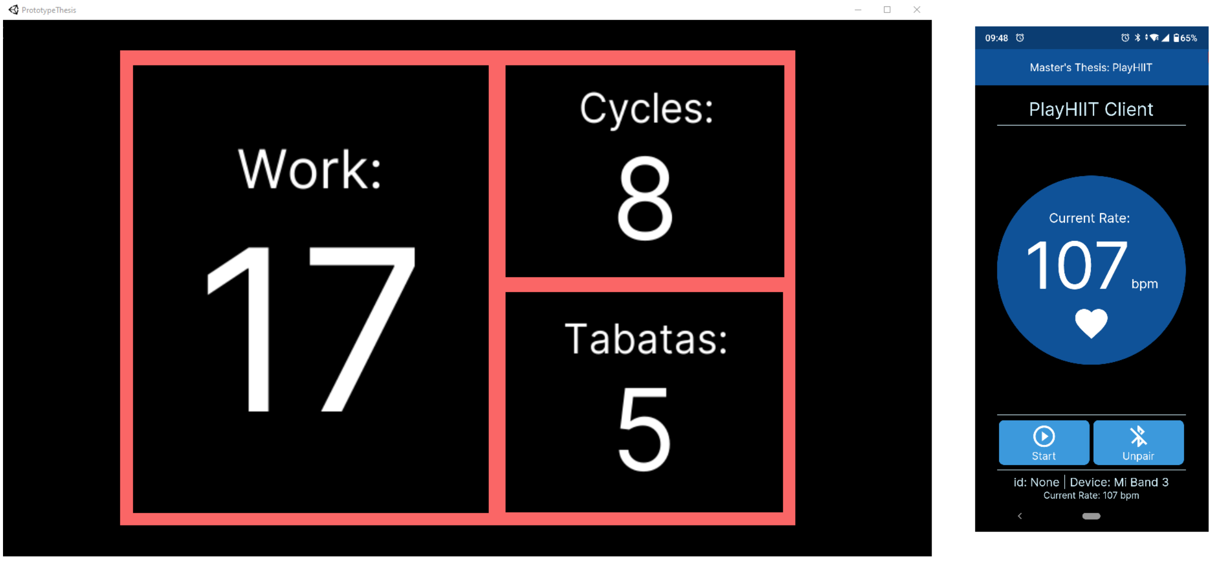

Figure 4.4: System variations used in the control condition tests of our study.

- **Step 1:** Turn on network connection, Bluetooth, and Location settings on their mobile phones.
- **Step 2:** Put their wristband approximately one centimeter above their wrist, according to the manufacturer's recommendation.
- **Step 3:** Turn on the *Exercise* mode on their wristbands, enabling BLE heart rate activity sharing.
- **Step 4:** Open the provided mobile application, and pair it with the wristband.
- **Step 5:** Check if the heart rate displayed in the wristband corresponds to the one displayed in the mobile application, ensuring the connection is functional.
- **Step 6:** When the counter on the desktop application reaches 0, press the Start button on their mobile phones in order to start heart rate recording.

There are some differences between the sessions with the control condition and the ones that included our system. In the second case, we explain the different visual elements that are present on the screen, type the names of participants in the respective input boxes and also explain the counter feature of our system, asking participants to try it. We then ask them to expose any doubts that they might have to ensure that they are familiar and capable of using it during the activity. As such, the additional steps for this particular condition are as follows:

- **Step 5.1:** Register a number above 0 in the counter input.
- **Step 5.2:** Register another number above 0 in the counter input to check how sum repetition numbers.

- **Step 5.3:** Register a number above 0 and click the overwrite button to check how to fix possible mistakes.

- **Step 5.4:** Register 0 in the counter input to reset the value back to zero.

After each training session, we provided a link, for each group to fill an online survey containing both the PLEXQ and PACES questionnaires. If the session in question was the last one, after the conducting researcher turned their camera back on, the semi-structured interview was held with all participant of the group simultaneously. After the interview is over, recording of the videoconference is turned off, ending the videoconference. Finally, we give participants a last online survey containing the IOS scale to evaluate the closeness of the social relations of each participating group.

4.6 Data Analysis

Regarding our chosen measure to evaluate enjoyment, the sum of all scores gathered through the PACES questionnaire [44], we started by analysing the histogram of the difference scores between conditions. These were concluded to be approximately symmetrically distributed, therefore, we conducted a Wilcoxon signed-rank test to the total scores of the questionnaires taken after a group videoconference exercise session that did not included our system, and one which did include it.

To analyse the heart rate data we gathered from participants during the exercise sessions, we first had to address the inconsistent time between each value, due to our lack of control on the sampling rate of the ATB we used. To solve this issue, we aggregated values through data binning, with each bin representing the average of each three second interval in our session. To handle missing values generated through this process, we performed linear interpolation between the closest two existing values to calculate these. Following this, we then checked for the assumptions to ascertain we could perform a paired-samples t-test between the average heart rates of each participant during the exercise session without using our system, and during the exercise session that did feature our system. Through inspection of the boxplot, no outliers were present in the data, and the differences between the average heart rate in the control session, and the session featuring our system were normally distributed, as assessed by Shapiro-Wilk's test ($p = 0.344$). Having these assumptions verified, we then performed a paired samples t-test to the average heart rates of participants.

Moving on to the answers to the PLEXQ survey, we analysed the difference scores between the 51 different items that compose the questionnaire. Considering that all answers were not approximately symmetrically distributed, we performed a Sign test between the answers of each item, comparing the answers given after the control exercise session, and the ones after the exercise session that was conducted while using the system we developed. A similar methodology was applied to the BSPE results gathered throughout the physical exercise sessions. An average value was calculated for each of the participants, in each of the conditions of our study, and a Sign test between these was performed, comparing both sets of data. The choice of the test was also due to the difference scores between conditions not being approximately symmetrically distributed. Finally a thematic analysis [48] was made to the transcripts of all four semi-structured interviews conducted after the last session of each group.

4.7 Results

From the twelve participants who joined our study, when analysing the results of the Wilcoxon signed-rank test made to the PACES questionnaire results, the usage of our system resulted in an increase of user enjoyment of the physical activity in seven participants, and a decrease of enjoyment levels in four participants. One participant did not report changes in the resulting score. Regarding the median PACES score, there was a statistically nonsignificant increase ($2.50\ pts.$) after subjects performed a physical exercise session while using our developed system ($96.00\ pts.$), when compared with the control condition ($92.50\ pts.$), $z = 0.490, p = 0.624$. Details regarding the scores of all users can be checked in Figure 4.5.

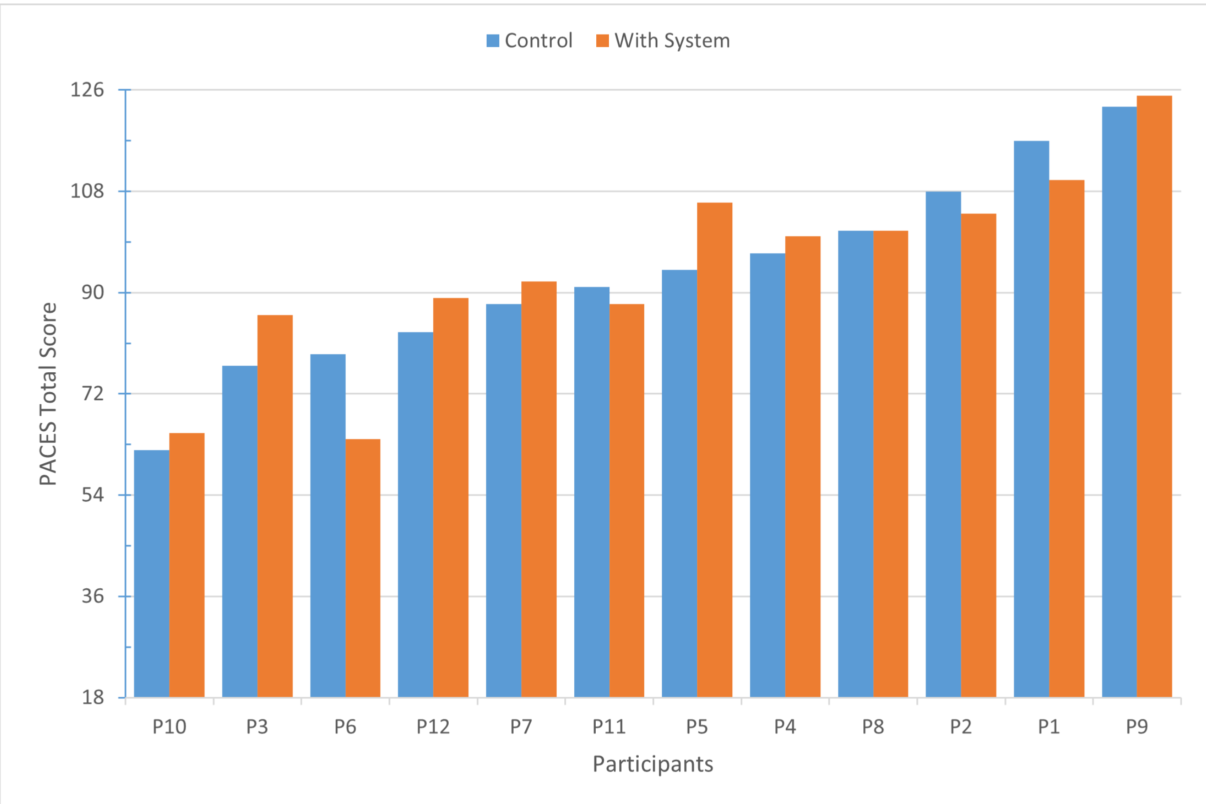

Figure 4.5: Difference between PACES scores in both conditions of our study.

Regarding the heart rate of participants during the proposed physical activities, the average rate throughout the whole session was higher while our system was being used ($\overline{x} = 114.06, \sigma_x = 6.29$) than during the session in which our system was not featured ($\overline{x} = 112.60, \sigma_x = 12.48$). Eight out of the twelve participants had a higher average heart rate with our system in place, while the remaining four reported a lower average heart rate. In terms of differences between conditions, usage of our system resulted in an increase of 1.47 (95% CI, -4.63 to 7.56) Beats per minute (BPM) in the average heart rate during a videoconference group exercise session. There was not a statistically significant mean increase in the average heart rate after exercising while using our system, $t(11) = 0.53,\ p = 0.61,\ d = 0.15$. The variation of the average heart rate of all participants for both conditions can be visualized in Figure 4.6. Additionally, Figure 4.7 displays the difference between the average heart rate while using our system and without using our system, over time.

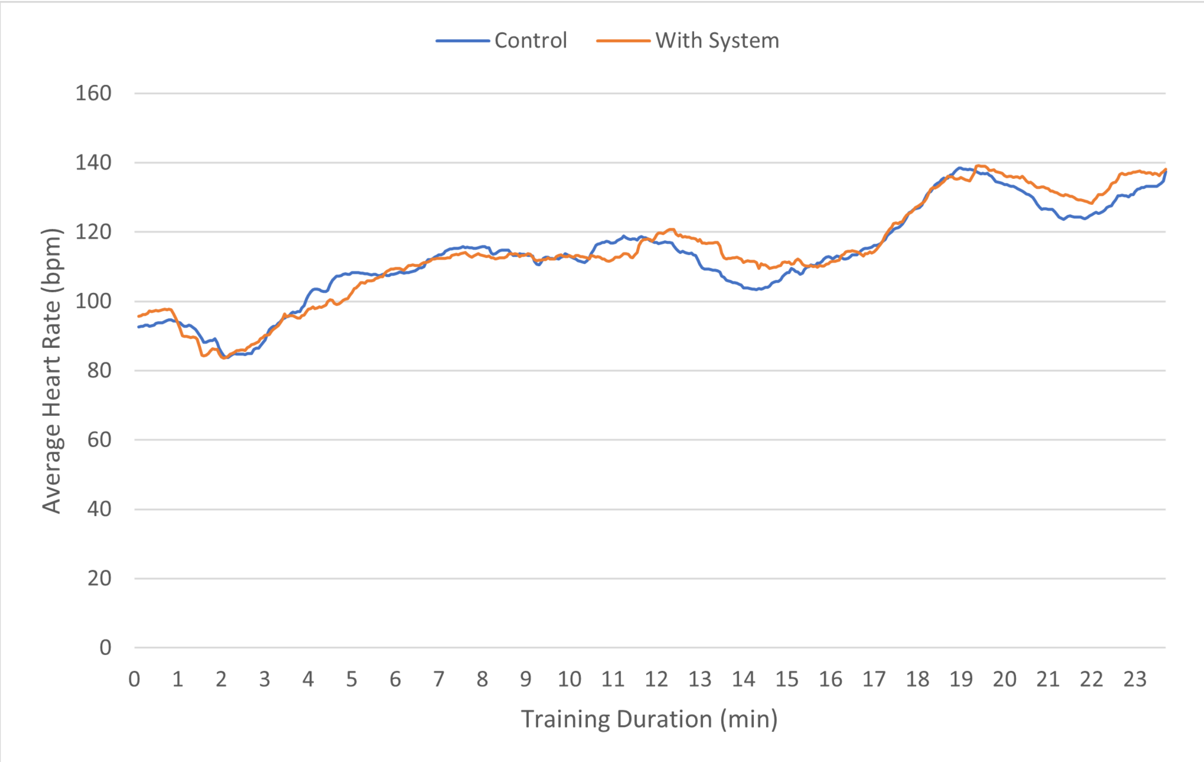

Figure 4.6: Average heart rate variation of all participants under both condition.

Moving on to the results of the PLEXQ, three out of the 51 items that compose the questionnaire registered a significant increase in their median score:

- **Competition:** Nine participants answered a higher score to the item “I felt competitive.”, while none registered a lower score. There was a statistical significant increase in the median score from the control condition ($3\ pts.$) to the one with our system ($4\ pts.$), $z = 2.667,\ p = 0.004$.

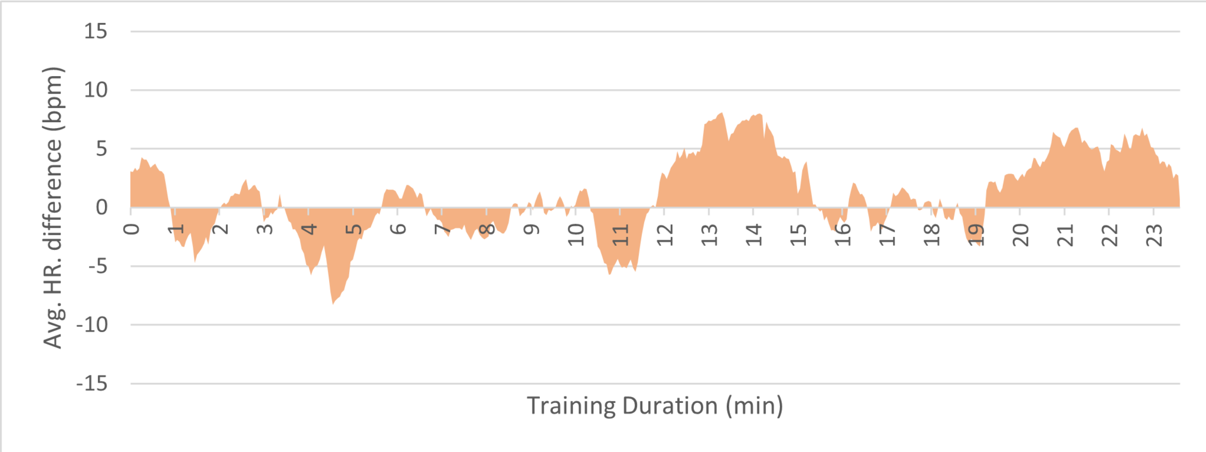

Figure 4.7: Difference between average heart rate while using our system and in control condition.

- **Sensation**: Seven participants answered a higher score to the item "I enjoyed the visuals.", while none registered a lower score. There was a statistical significant increase in the median score from the control condition ($3\ pts.$) to the one with our system ($4\ pts.$), $z = 2.268,\ p = 0.016$.

  Six participants answered a higher score to the item "I felt pleased by the quality of it.", while none registered a lower score. There was a statistical significant increase in the median score from the control condition ($3.5\ pts.$) to the one with our system ($4\ pts.$), $z = 2.041,\ p = 0.031$.

Regarding the remaining results, albeit not being statistically significant, some other noticeable trends in the answers gathered were:

- **Challenge**: No participant answered a higher score to the item "It was a true learning experience.", while five registered a lower score. There was a non-significant decrease in the median score from the control condition ($3\ pts.$) to the one with our system ($2\ pts.$), $z = -1.789,\ p = 0.063$.

- **Nurture**: Seven participants answered a higher score to the item "I enjoyed following its development.", while one registered a lower score. There was a non-significant increase in the median score from the control condition ($3\ pts.$) to the one with our system ($4\ pts.$), $z = 1.768,\ p = 0.070$.

- **Completion**: Five participants answered a higher score to the item "I managed to master a task.", while none registered a lower score. There was a non-significant increase in the median score from the control condition ($2\ pts.$) to the one with our system ($3\ pts.$), $z = 1.789,\ p = 0.062$.

- **Suffering**: Five participants answered a higher score to the item "I felt angry.", while none registered a lower score. There was a non-significant increase in the median score from the control condition ($1\ pt.$) to the one with our system ($1.5\ pts.$), $z = 1.789,\ p = 0.062$.

The complete results of the questionnaire including the number of increases and decreases in the answers given, the median scores for both conditions, and the results of the Sign test performed to each item are displayed in Appendix A.

Regarding the **perceived effort** of participants during exercise, after calculating the average rating for each user, in each condition, results to our Sign test show that six of the participants displayed an increase in their on their average ratings in the BSPE, while the other six showed a decrease in their ratings. There was no statistically significant median increase in their ratings from the control condition ($M = 14.5$) to the condition featuring our system ($M = 14.6$), $p \simeq 1.000$. The average rating for each participant under each condition can be checked in detail in Figure 4.8.

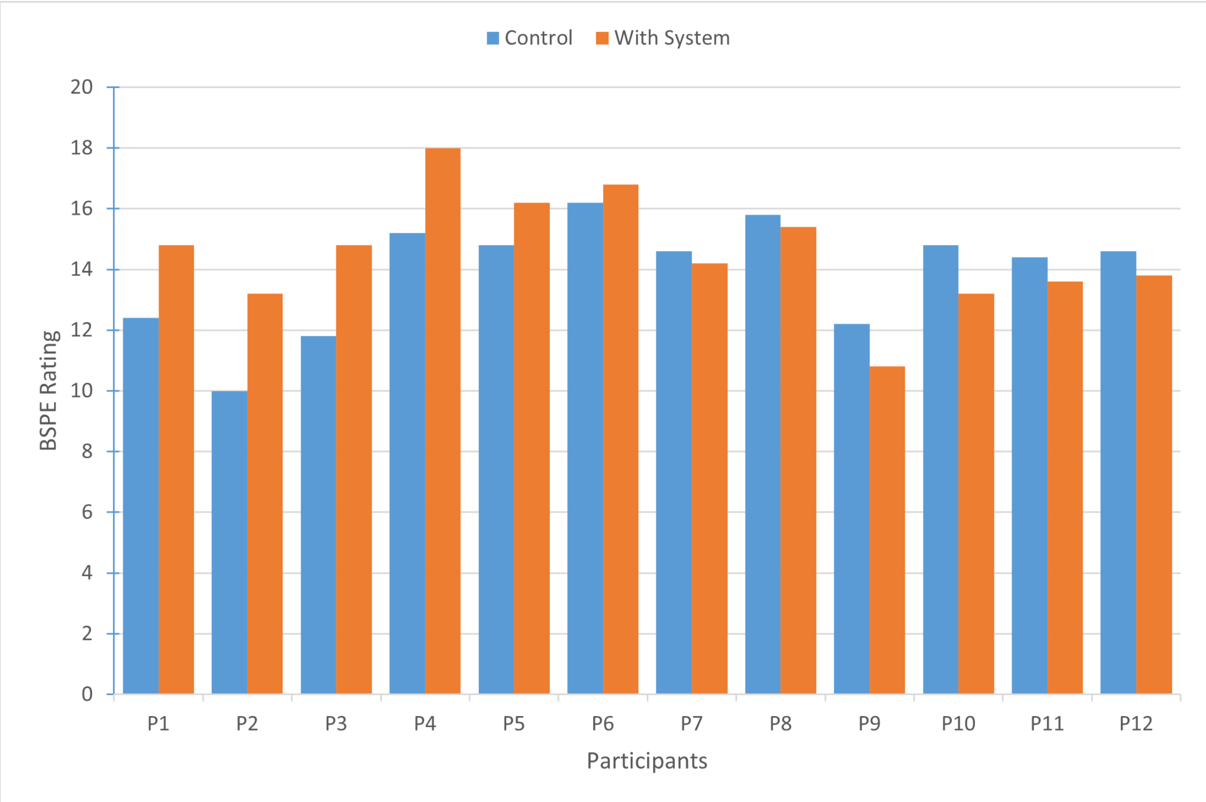

Figure 4.8: Difference between average BSPE ratings in both conditions of our study.

Finally, the results from the thematic analysis [48] done to the semi-structured interviews conducted to each different group were categorized in three different dominant themes that consist of **Motivation**, **Social Relationships**, and **Playfulness**, and a separate category featuring relevant comments regarding issues and limitations of our study design that were pointed by participants. The results for each of these are presented in the following subsections.

4.7.1 Motivation

Participants referred to the act of tracking their repetitions between exercise sets to be one of the most relevant aspects in an increase of motivation while using our system. Out of the twelve participants, nine of them directly referred or agreed with this. Quoting P2, *"Just the fact that I am saving my own reps gives me much more will to do the max I can, just because I am counting them"*. When asked which session was the most challenging to him, P11 replied the following, comparing both sessions: *"I think it was this one [with System]. Just because we are writing down our repetitions and comparing them with each other. On the previous one, I was like "Okay I'm just going to some reps of each exercise" while this one pushed me into giving my max"*.

Some participants framed this resulting motivation as a desire to compete with themselves. When asked what contributed to him being focused on competing with his partners, P6 answered: *"I think it was the number of repetitions. It was also [competing] with myself as I thought "Okay, if in this set I did this number of repetition, in the next one I'm going to try to do a number close to that"*. P11 further added to this awareness of comparing with oneself by saying: *"(...) The fact that we have to put the numbers ourselves also makes us want to keep up or increase that number in the following set".*

Although most participants noticed this as a positive feature, three of them shared that it had an impact on how relaxing physical exercise was for them. In the words of P7: *"There was a part of this session that was more competitive, which was kind of stimulating, but for me personally, took away a little bit of the relaxing part of doing exercise."*

Competition was also described as a motivation source for some participants, either due to the satisfaction inherent to surpassing the numbers of a peer or to the social pressure created by the registered values being exposed. Regarding one of their partners that had consistently higher repetition numbers than him, P3 said amidst laughter: *"Whenever I could do one more rep than P2 I got all pumped up! It happened twice in the last set!"*. When asked to comment regarding a previously referred feeling of social pressure during the session, P5 noted: *"I think that when you have people observing you, you intuitively want to show that you can perform a bit better than otherwise. With the repetition number shown, it's easier to notice how well other people are doing"*.

4.7.2 Social Relationships

When discussing what they felt had changed in the social interactions that occurred throughout the activity, some participants mentioned a change in the trending themes. When commenting differences in the way the group interacted, P3 mentioned: *"I think that in the first one [With System], our conversation was much more competitive. In this one it [Control] it was more normal stuff"* to which P2 added: *"Yeah, more like idle talk"*. All twelve participants identified the session featuring the system as being a more competitive experience at some point during their respective interviews.

Several participants also pointed out that some of the features of our system provided opportunities to comment and tease each other. While describing the communication in his group, P7 reported: *"I definitely noticed a difference, in this session [with System] we were commenting each others' results, which was something that you couldn't do in the other session [Control] because they simply didn't exist"*. When asked to comment on the voice lines, P2 cited them as being a cause for interactions in the group: *"(The voice lines) allowed us to mess and tease with each other. Usually when the woman spoke were the times I took the chance to tease someone like "You're almost dying, man!" and stuff like that".*

Regarding social awareness, becoming aware of the effort of their partners became a lot easier, as P3 mentions: *"If we were all exercising in the same room instead of through videoconference, maybe I could compare myself with the others without writing down my reps by looking at them and seeing that they are working more than me. In this case, I wouldn't be able to understand very well"*.

P7 referred to the voice lines as also being an important agent in improving social awareness: *"Besides finding them a bit funny, I think they were cool because they pointed us to specific things amid all visual information available, you see?"*.

Even though this factor was mostly seen as a positive characteristic of our system, P7 further added: *"There was a bit of social pressure, and I personally felt a bit guilty for being out of shape, although honestly, I don't think that made a big difference. I think the pros of having the information available to stimulate participation ends up compensating that pressure, but only because I'm doing this with people I already knew"*.

4.7.3 Playfulness

Regarding the badge icons above each participant's heart rate, two users in different groups went ahead and exposed their curiosity. As soon as he was asked what he thought regarding the badges, P10 replied: *"Which was the last one? I just really want to know what was the last one. The plane was like around 70%".* P7 also added: *"I thought it was cute. At the beginning I was a bit confused on why was there a car and bikes on the screen but when it started to change I was like "Oooooh!". *laughs* I'm curious though, what did come after the plane?"*. On the other hand, four participants mentioned that they had not noticed the badges until a later stage of the activity, while one of them did not notice them at all. When asked to comment on the feature P8 replied: *"I just noticed them in the end! I thought they were funny, but I didn't pay much attention, In the end, I was just busy being tired!"* to which P9 added: *"Yeah I just noticed them in the end as well, I didn't even know there was a bike until now!"*.

When commenting on the voice lines feature, four different users referred to them as a positive addition that made them more excited to work more. This feeling was not shared by all participants, as two of them mentioned that they used them to check if they could slow down the pace of the exercise.

Quoting P5, *"I noticed that whenever I got positive feedback, my heart rate started to slow down, maybe it's because I started to relax."*. When asked on his opinion regarding the voice lines he head, P10 said: *"Whenever I heard "You are increasing your rhythm" I thought like "Alright, now I need to keep up, so he doesn't say anything else!""*.

Overall, ten out of the twelve replied that they found the session featuring the system more enjoyable. Being that competition making the activity more fun was the most frequent occurring justification for this. When asked about what made them unanimously choose the session with the system as being the one they preferred, the participants of the first group P2 and P3 said: *"P3: Fun, the amount of exercise I think I did, and how happy I am with my efforts. I felt much more accomplished than in the first one [Control], and I had a lot more fun. - P2: I think the only factor for me was motivation, and that is the source for all others, I feel motivated, then I train more, and I feel better about it. - P3: And then you can poke fun at the others, which makes it more fun. - P2: Yeah, It's like a snowball effect."*

4.7.4 Limitations

Two participants from different groups shared displeasure regarding the feedback the heart rate values were providing them, as they felt it did not match the effort they were putting in. Regarding this, P5 said: *"There was one time when I was giving all that I had, I was super tired, and it started saying that I was slowing down, and I was slightly annoyed cause I knew that wasn't true".* One participant also mentioned that unlike the repetitions, heart rate was harder to understand as a measure of effort. P1 said: *"From the three of us I was the one with the lowest [heart rate] value, but on the scale that you asked us, I was the one that kept saying the highest values. I couldn't understand the relation between them and why was my heart rate so low."*.

When asked about which of the sessions felt more challenging, all participants replied that their respective first session felt more challenging, due to them not knowing beforehand what they were going to do, making it difficult to compare. When asked which was the most challenging condition, P6 stated: *"I think it was the first one, both due to both not being used to exercise for a while and because in the second one I already knew what I was expecting. I already knew how to manage the course of the exercises."* P9 shared a similar feeling: *"I think I have to say the first one, due to the impact of the surprise factor. You don't know what you're going to do so it ends up being more difficult. When I was going to do the second one, I was already mentally prepared to do it."*

4.8 Discussion

When analysing the results of our system regarding its primary objective, which is **providing a more enjoyable experience** to people who want to engage in group exercise through videoconferencing, despite there being a slight positive trend, results were nevertheless heterogeneous, having achieved a nonsignificant higher median score ($96.00pts.$ vs 92.00, $z = 0.490, p = 0.624$). These results lead us to not accept the first hypothesis (H1) we proposed. The main reason we identified for results not being generally more positive was that unlike what we intended, the experience became heavily more competitive to not only participants who are fond of this type of interaction but also the ones who are not. Many participants cited that this competitive aspect was mainly brought by the inclusion of the repetition numbers in the display, as they very often compared themselves to each other. Even though it was not the most highlighted feature of the screen, it is possible that being bundled with the highly contrasted heart rate coloured bars was enough so that it took over the group-centred information displayed at its side, as only one participant referred that feature without being previously asked to comment on it. Nevertheless, when interviewed, ten out of the twelve participating users still found the system providing a more enjoyable experience to them, making us believe that the pending issue is linked to the visual balancing of the chosen features and not to limitations of the concept itself.

Regarding the **effort** participants put into the activity, results were mixed, with a low nonsignificant increase of heart rate ($1.47\ bpm$) with a large confidence interval. These results lead us to also not accept the second hypothesis (H2) we proposed. Despite this, closer inspection of the difference between average heart rates in each condition, as displayed in Figure 4.7 shows that the second half of the planned activity displayed a more notable increase in heart rate than the first half. We identified two possible motives for this. The first is the possibility of some exercise activities being more prone to competition and comparison between participants than others, which would require a study changing the training structure between conditions to evaluate the effects of our system. The second possible motive is that the time participants took to get used to the system had an effect on making them more focused in understanding how the system works in the early stage of the activity, and only later on its social aspect. In this case, a more comprehensive study in which users could use the system multiple times would be relevant to dispel existing doubts. The significant competitive role that the activity took while featuring our system also might have negatively impacted the performance of participants who are not prone to competing with each other, rendering more polarized results as we observed.

Moving on to our research questions, in order to answer the first of the three questions (RQ1) we intended to answer, we performed an analysis of the **different playfulness facets of the activity**. We observed the most notable effect in two different categories. The first is the Competition dimension, with both an item that had a significant increase (*"I felt competitive."*) and an item that had a positive trend (*"I enjoyed competing against it."*). As previously referred, the active engagement of having users counting their repetitions and displaying them was unanimously referred by all during the interviews as being the dominant reason for this. The second is the Sensation dimension, with two different items that displayed a significant increase in the answers of participants (*"I enjoyed the visuals."* and *"I felt* *pleased by the quality of it."*). Users found the system to be visually pleasing, which is consistent with the referrals that were made to the visuals during the interview, having accomplished the objective of balancing the display of information while maintaining a simple and contrasting image to make it easy for users to check what they want in a short period. Also within the theme of easing the transmitting information, we found the voice lines feature to have accomplished its objective of highlighting relevant events within the activity, being praised and mentioned by several users as helpful to this regard during the interview stage of our study. Generally, users also found the system to be a pleasant addition to the activity according to the corresponding PLEXQ item, not contradicting the positive trend of the answers given to PACES questionnaire featured above.

Other trends in the answers gathered through the questionnaire are worth taking a more in-depth look. Participants were keen to keeping track of their repetitions, and checking how they were performing regarding the heart rate over time, observing their evolving performance during the activity. The positive trend noticed in one of the Nurture dimension items (*"I enjoyed following its development."*) reflects this detail. One of the items in the Completion category (*"I managed to master a task."*) also displayed such trend, in line with the generally reported feel of greater satisfaction with the amount of work participants put into the activity. The Challenge dimension featured an item with, unlike the others, a negative trend ("It was a true learning experience."), unlike what we intended, as we wanted participants to be more informed and better understand both their and their peers' performance during the activity. This outcome may be a negative consequence of the competitive focus of our system, moving the focus of users to the competitive dimension instead. Moving on to dimensions related to negative experiences, we observed an increase trend in an item from the Suffering group (*"I felt angry."*). We can interpret this item as related to the feeling of dissatisfaction for lagging behind in terms of repetitions or heart rate of a partner. This reaction is a consequence of the competitive tone of the activity. A wider participant pool would be required to study further whether these trends would be significant or not, as our low participant count impacts the ability to provide a more assertive evaluation of these parameters. This may also be the reason for no significant changes or trends being observed regarding the *Humor* and *Fellowship* dimensions, despite the positive comments regarding social interactions.

We were not able to answer our second research question (RQ2) due to the results of our evaluation of the **way users perceive their effort** being mostly inconclusive. A case-by-case inspection allows us to observe that all participants perceived their effort being a lesser amount in the second sessions that they participated in, independently from the corresponding condition. This factor was also mentioned in the conducted interviews. Some participants referred that already knowing the difficulty of the task in the second session allowed them to prepare themselves for the activity better, both mentally and physically.

Lastly, concerning **the social aspect of our system** and our third research question (RQ3), participants noted that despite some of them not being fond of the competitive format the experience took, almost all of them still preferred the session with our system to the control one, mainly due to the comfort that doing the activity as a group that already knew each other provided. One notable aspect of our study was that participants who mostly referred the opportunity to comment and tease each other as an advantage of using our system belonged to the groups with the higher closeness between elements (G1 and G3). A possible endeavour for a future study can be analysing the impact on a larger number of groups with varied closeness levels to identify if the enjoyability impacts are stronger on groups whose elements are closer to each other beforehand.

4.9 Design Implications

We can summarize what we have learnt regarding the design space of video conference group exercise interfaces in the six following lessons:

- **Using Sound for Immediate Feedback:** When choosing how information is shared, the large number of different exercises that do not allow users to look at a screen or other visual display are an issue. If the information immediately delivered to the user is an essential element of an interactive experience, using sound cues, voice lines, or similar methods is an appropriate option to solve this issue.
- **Using Visuals for Continuous Feedback:** On the other hand, visual feedback allows for the display of continuous information throughout time, making the user free to check it at their will. Whenever something should be shown to the user only as much as they want to monitor it, using a display on a desktop, in a smart band, or any other non-intrusive method allows this to happen.
- **Using Individual Measures for Competition:** Providing users with individual measures regarding their performance in an easily comparable way facilitates competitive behaviour. By providing them with the necessary tools, users that enjoy this type of social dynamic can have a more enjoyable experience even without established objectives for an activity.
- **Balance Individual and Global Measures:** Striking a balance between the relevance given to individual comparable measures and aggregated ones for the whole group is an essential factor in guaranteeing that the experience may not alienate users who dislike either competition or cooperation.
- **Provide Easily Explorable Elements:** If the system is designed to appeal to the playfulness of its users, the limited possible ways to interact while performing different exercises can be an issue. Despite this, revealing hidden contents or visual treats depending on something as simple as the effort of users promotes their curiosity, without needing additional movements or interactions.

- **Use Events as the Foundation of Social Interactions:** Highlighting particular events that users may overlook in a video conference environment, such as someone significantly increasing or decreasing their physical effort in an activity, may create opportunities for users to comment upon the funny, awkward, or perhaps intentionally unfair judgment provided by the system. This, in turn, can encourage users to tease, comment, and cheer on their peers whose actions were highlighted.

4.10 Limitations

The main limitation of our study is its limited participant amount. Although still providing useful analysis of several trends on our results, a larger participant amount would be useful in better understanding the strength of its impacts on the different aforementioned research topics. The lack of more sessions per group also reduced our ability to deal with the learning bias inherent to performing the physical exercises for the second time, which may have been exacerbated by our demographic being composed by people who do not perform physical exercise frequently. Regarding technical aspects, the inability to control the sampling rate of the tracking bands, alongside its reliance on optical heart rate sensors instead of more precise alternatives such as electrical-based ones also may affect the quality of the gathered data, as some participants questioned its precision during the activity.

5

Conclusions and Future Work

This dissertation attempts to turn group video conference-based physical exercise into a more enjoyable and fun experience. In order to accomplish this, we developed a composite application for desktop and mobile devices simultaneously that aims to provide a social augmentation to this activity. This application shares performance information regarding HIIT to the elements of a group, while providing social opportunities for groups to interact, tease, and cheer each other through several included playful-oriented elements.

The main contribution of our study is our system, dedicated to augmenting HIIT training sessions that are held in a video conference environment. We also provided an experimental study that aimed to analyse the different effects of this system in the user experience of group video conference exercise, regarding how much effort users put into the activity, their level of enjoyment, and the different playful interactions that our system allows users to take part during the activity, through the formulation of two different hypotheses and three research questions. Results of this study showed nonsignificant positive trends for both the level of enjoyment and the average heart rate of participants. Regarding playfulness, both the *Sensation* and *Competition* dimensions of the PLEX framework had a significant increase in some of their items, while nonsignificant positive trends were seen in items of the *Challenge*, *Nurture*, *Completion*, and *Suffering* dimensions. This in-depth analysis provides a thorough understanding of the effects of our system regarding playful interactions.

In the end, even though the comments of our participants demonstrated a preference to our system, we did not accomplish our objective of significantly improving the experience for its users. Despite existing positive trends for both enjoyment and effort, and having stimulated different types of playful interaction, the inability to provide a balanced dynamic between cooperation and competition depending on different preferences remains as the core issue in our work. Nevertheless through our efforts we explored and learnt about the design space of video conference group exercise interfaces. Further research would be needed to improve on the current issues in order to reevaluate its effects on remote exercise groups.

For future work, a possible option to solve the unbalanced social dynamic is the analysis of different customisable displays for users of this type of system, providing details tailored to their individual preferences instead of a single global view. Further analysis with larger samples would also need to be done to understand better the effects of our system on the amount and type of social interactions that are held throughout the activity. Regarding recruited participants, including more people who are used to practising regular physical exercise would also provide for a more appropriate representation of the possible target audience for this category of systems.

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A

PLEXQ Results

Table A.1: Sign test results for the PLEXQ.

		Inc.	Dec.	Med. (C)	Med. (S)	Sign Test	
						Z	p
A) Stimulation							
Challenge	It stimulated me to learn new things.	1	4	3	2.5	-0.894	0.375
	It was a true learning experience.	0	5	3	2	-1.789	0.063
	I enjoyed learning new things.	3	2	3	3	0.000	1.000
Discovery	I enjoyed discovering new things.	2	3	3	3	0.000	1.000
	I enjoyed finding useful new ways of using it.	4	1	3	3	0.894	0.375
	I enjoyed finding something unexpected.	5	3	3	4	0.354	0.727
Exploration	I felt curious.	5	4	3.5	4	0.000	1.000
	I enjoyed experimenting.	6	2	4	4	1.061	0.289
	I enjoyed trying out new things.	3	2	4	4	0.000	1.000
Expression	It supported my identity.	4	3	2	3	0.000	1.000
	I felt special.	4	5	3	2.5	0.000	1.000
	I enjoyed creating things.	5	3	2	2	0.354	0.727
Fellowship	I enjoyed sharing my experience with others.	1	3	4	4	-0.500	0.625
	I felt a great need to share my experience with my friends.	3	4	3	3	0.000	1.000
	It felt like friendship.	1	1	4	4	0.000	1.000
Nurture	I enjoyed nurturing it.	4	3	3	3	0.000	1.000
	I felt it was taking care of me.	2	5	3	2	-0.756	0.453
	I enjoyed following its development.	7	1	3	4	1.768	0.070
B) Pragmatic							
Competition	**I felt competitive.**	**9**	**0**	**3**	**4**	**2.667**	**0.004***
	I enjoyed competing against it.	7	2	3	4	1.333	0.180
	I enjoyed competing with myself.	4	3	4	4	0.000	1.000
Completion	I managed to master a task.	5	0	2	3	1.789	0.062
	I got rid of a burden.	5	3	2	2	0.354	0.727
	I enjoyed succeeding.	3	2	4	4	0.000	1.000
Control	I had the capability to influence what was happening.	5	3	4	4	0.354	0.727
	I felt powerful.	4	2	2	3	0.408	0.688
	I enjoyed being in control.	2	4	3	3	-0.408	0.688
Sensation	I felt pleased by its aesthetics.	3	1	3	3.5	0.500	0.625
	I enjoyed the visuals.	**7**	**0**	**3**	**4**	**2.268**	**0.016***
	I felt pleased by the quality of it.	**6**	**0**	**3.5**	**4**	**2.041**	**0.031***
Thrill	I enjoyed the suspense.	4	0	2	3	1.500	0.125
	I had an adrenaline rush.	4	1	3.5	3.5	0.894	0.375
	I felt excited.	2	1	3.5	3.5	0.000	1.000
C) Momentary							
Captivation	I forgot about my surroundings.	4	3	3.5	4	0.000	1.000
	I felt completely absorbed.	5	2	3	4	0.756	0.453
	I lost track of time and space.	3	4	3	3	0.000	1.000
Humor	It made me laugh.	3	1	3.5	4	0.500	0.625
	I had fun.	1	1	4	4	0.000	1.000
	I experienced funny situations.	2	5	4	3	-0.756	0.453
Relaxation	I felt relaxed.	2	5	3	2	-0.756	0.453
	I enjoyed passing time with it.	3	2	4	4	0.000	1.000
	I felt relieved from stress.	2	3	4	4	0.000	1.000
D) Negative Experiences							
Cruelty	I felt satisfied as if beating an opponent.	6	1	2.5	3.5	1.512	0.125
	I felt malicious towards others.	2	0	1	1	0.707	0.500
	I enjoyed manipulating others.	1	1	1	1	0.000	1.000
Subversion	I enjoyed doing things with it that others might disapprove of.	3	4	2	2	0.000	1.000
	I enjoyed breaking the rules.	2	3	1.5	1	0.000	1.000
	I enjoyed doing socially unacceptable things.	1	2	1	1	0.000	1.000
Suffering	I was wasting my time.	1	3	1	1	-0.500	0.625
	I felt angry.	5	0	1	1.5	1.789	0.062
	I felt stressed.	2	3	2	1.5	0.000	1.000

* **Bold text** marks significant p values.