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SMART INSOLES SUPPORTING THE EXECUTION OF PIROUETTES THROUGH A MOBILE APPLICATION

Dissertation in the context of the Master Degree in Design and Multimedia, with guidance provided by Prof. Paula Alexandra Silva and presented to the Faculty of Sciences and Technology / Department of Informatics Engineering

January 2022

Acknowledgements

To my parents, who made it possible for me to be here, who always provided me with all the necessary tools so that I could achieve success. Who showed me that great work takes a great deal of time to be done and who have always encouraged me to follow my dreams no matter how difficult and challenging they might seem.

To my supervisor, Prof. Paula Alexandra Silva for all the guidance and will, for believing in the potential of my proposal and for reassuring me whenever a problem arose during the course of the project.

To Prof. Mahmoud Tavakoli, who explained me the QGait insoles project, allowed me to use it and put me in contact with the QGait Insoles team, who made the development of this project possible.

To João, for accompanying me throughout this phase, for encouraging me to continue, for understanding and for being always there to help and comfort me.

To both of my grandmothers, for believing and always reminding me that I am a great person and for all the help provided during the project.

To Sérgio Soldado, for all the help and support provided during the dissertation whenever problems with the implementation arose.

To all,

Muito Obrigada!

Abstract

Pirouettes are one of the most complex and difficult exercises in rhythmic gymnastics. To date, and to our knowledge, there is still no technological support to assist in the learning and performance improvement of pirouettes. However, such technologies could afford gymnasts the opportunity to train and improve their pirouettes autonomously and efficiently. This work contributes to filling that gap and reports on the design, development, and evaluation of a proof of concept of a mobile application – Turning Point – that aims to support gymnasts in the training of pirouettes. Combined with the QGait smart insoles, Turning Point leverages the data collected by pressure sensors, a magnetometer, an accelerometer and a gyroscope to analyse the movements performed, correct errors, and provide feedback to gymnasts in real time. In developing this work, a series of training sessions, involving 11 gymnasts, were observed and interviews with 12 gymnasts and four coaches were conducted. We then carried out co-design workshops to create and iterate the prototype of the solution. Finally, we validated the solution with 10 gymnasts, who have reported a high level of satisfaction in using the application and good results during tasks execution. This project will benefit rhythmic gymnasts in the process of learning and improvement of pirouettes, rhythmic gymnastic coaches who wish to elevate movement analysis to better assist their athletes in the training session and ballet dancers who also perform pirouettes. This work equally contributes with knowledge to the areas of sports analysis and technology for sports.

Keywords

Pirouettes, Feedback, Smart Insoles, Learning, Performance Improvement, Exercises Analysis.

Resumo

As piruetas são um dos exercícios mais complexos e difíceis da ginástica rítmica. Até à data, e segundo os nossos conhecimentos, ainda não existe qualquer apoio tecnológico para ajudar na aprendizagem e na melhoria do desempenho das piruetas. Contudo, estas tecnologias poderiam proporcionar às ginastas a oportunidade de treinar e melhorar as suas piruetas de forma autónoma e eficiente. Este trabalho pretende colmatar essa lacuna com relatórios sobre a criação, desenvolvimento e avaliação de uma prova de conceito de uma aplicação móvel - Turning Point - que visa ajudar as ginastas no treino de piruetas. Com ligação às palmilhas inteligentes QGait, Turning Point usa os dados recolhidos por uma série de sensores de pressão, um magnetómetro, um acelerómetro e um giroscópio para analisar os movimentos realizados, corrigir erros e fornecer feedback em tempo real às ginastas. No desenvolvimento deste trabalho, foram observadas uma série de treinos, envolvendo 11 ginastas e foram realizadas entrevistas com 12 ginastas e quatro treinadores. Em seguida, foram realizados workshops de co-design para criar e iterar o protótipo da solução. Finalmente, a solução foi validada com 10 ginastas, que manifestaram uma elevada satisfação ao utilizarem a aplicação e bons resultados durante a execução das tarefas. Este projecto irá beneficiar ginastas de rítmica na aprendizagem e aperfeiçoamento de piruetas, treinadoras de ginástica rítmica que desejam elevar a sua análise de movimentos e assistir melhor as suas atletas durante o treino e bailarinos que também executam piruetas. Este trabalho contribui igualmente com conhecimento para as áreas de análise desportiva e tecnologia para o desporto.

Palavras-Chave

Piruetas, Feedback, Palmilhas Inteligentes, Aprendizagem, Melhoria do Desempenho, Análise de Exercicios.

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Chapter 1

Introduction

Even after 12 years since I stopped practising Rhythmic Gymnastics, I still feel a passion for this sport. Nowadays I have a new passion - dance - and all I can say is Rhythmic Gymnastics (RG) and Dance complement each other 100%. However, I did not expect to find the same obstacles in dance as I had found in gymnastics. I am referring to the way coaches provide feedback for improvement, where there is no solution besides the same old method. The coach's corrections are based on what she has just seen and her empirical knowledge that she communicates verbally, sometimes by exemplifying, and the gymnast just goes on from there. With current technological breakthroughs, it would be expected that some kind of tool could support the practice of gymnasts and the work of coaches; however, as far as I am aware, this is not the case. With such complex movements, there are so many issues to take into consideration that I felt the need to, at least, attempt to create a bridge between technology and gymnastics training, and this way, contribute to fill in the giant gap that exists. As soon as I become aware that, in the context of my dissertation, I could use a pair of smart insoles (details in the next section), I instantly felt compelled to use them to improve gymnastics practice. In particular, I proposed to create a mobile application, that could use the data collected by the smart insoles, to support the execution of pirouettes. And, in this way, I hope to contribute with a tool that could complement current methods for both gymnasts and coaches. My goals with this work and how I intend to proceed, will be detailed later in this chapter, but first I will introduce the smart insoles system that my work will leverage to create the proof-of-concept of my application, Turning Point.

1.1 The QGAIT Smart Insoles

The QGAIT set of smart insoles is a compact, 2 millimetres thick, pressure mapping insole system, with an integrated battery with up to 20 hours of autonomy and an 8 gigabytes micro SD card with up to 100 hours of storage (Figure 1.1). The smart insoles include capacitive sensing technology of up to 200 sensors per foot, with values ranging from 0 to 400 kilopascal (kPa), and an electronic box attached containing an integrated *Inertial Measurement Unit* (IMU), which has an accelerometer, a gyroscope and a magnetometer. Through its optimised Bluetooth hardware, with a range of up to 20 meters, the insoles support real-time communication, compatible with *Matlab*, *Unity* and *C*.

During use, the smart insoles allow for the collection and analysis of data that produces information about the foot pressure map, centre of pressure, balance, and motion. A chain of nine-axis IMU further enables the analysis of step size, step frequency, and lower limb

Figure 1.1: QGAIT Smart Insoles (*QGait*, 2019)

gait analysis. If coupled with a chain of wearable Electromyography (EMG) systems, the insoles also allow for muscular analysis (*QGait*, 2019).

At present, the QGAIT set of smart insoles communicates only with a Windows computer via Bluetooth through a dongle connected to the regular COM ports. It is also possible to connect the smart insoles to a smartphone by Bluetooth, but this functionality has not yet been fully developed. Once connected, the insoles send binary data (Listing 1.1) which is then decoded and analysed by a QGAIT dedicated application or the code developed for the application.

Listing 1.1: Insoles String Code

```
1 TIMESTAMP (milliseconds); Sensor[0]; Sensor[1]; Sensor[2]; Sensor[3];
      Sensor[4]; Sensor[5]; ... ; Sensor[207]; CoPx; CoPy; Raw; Pitch; Yaw
      ; AccelX; AccelY; AccelZ; Quaternion W; Quaternion X; Quaternion Y;
      Quaternion Z; TOTALSUM; BalancePercentage;
```

So far, the QGAIT smart insoles have been used for post-stroke rehabilitation (*SwitHome MOOC*, n.d.), for which a number of games have been developed (*Insole games*, n.d.; QGait, 2019). However, the insoles can also be used for sports analysis and even as a corrective insole. **In this dissertation, the smart insoles will be used to collect data from gymnasts balance positions and pirouette movements**. For this purpose, the **pressure sensors**, **accelerometer** and the **gyroscope** of the QGAIT system will be key.

The **pressure sensors** allow for the analysis of pressure maps (Figure 1.2a) and the centre of pressure of each foot (Figure 1.2b). By having access to this information, it will be possible to study the position of the foot and the distribution of the gymnast's pressure point during her performance. Once a gymnast starts training a balance in the *attitude* position, the smart insoles will allow her to see whether she is applying the centre of pressure at the point of equilibrium or if her balance is skewed towards one side. This way, it is possible to analyse the deviation applied and generate corrective feedback highlighting the identified balance deviation. If the gymnast's centre of pressure is too much to the right, feedback will be generated directing her to shift her weight towards the left. In addition, if the centre of pressure is near to her heels rather than her toes, the gymnast will made aware that her *relevé* is low, producing feedback compelling the gymnasts to rise it up.

The **gyroscope** allows for the measurement of the number of complete turns performed. Knowing how many turns were performed, it is possible to inform the gymnast whether she needs to hold her turns a little bit longer in order to be able to complete a 360 degree turn or if she is still far from achieving that goal.

The **accelerometer** enables the measurement of the speed achieved during the exercise, and knowing by the laws of physics that without enough speed, it is not possible to complete many turns in one performance, we will be able thereby, to inform the gymnast that she needs to apply more force in the beginning in order to reach the desired speed.

(a) Pressure Map

(b) Centre Pressure

Figure 1.2: QGAIT Data Analysis (*QGait*, 2019)

1.2 Goals and Contribution

The overarching goal of this dissertation is to design, develop, and evaluate a proof of concept of a mobile application, which leverages the data gathered by the QGAIT smart insoles, to support the learning and practice of pirouettes by rhythmic gymnasts. In particular, the application will receive data from the QGAIT insoles during the performance and will analyse it, returning the performance feedback. With the data, important information about correct performance will be highlighted and provided to the gymnast.

In order to successfully address the goal of this dissertation, and create a product that will fit the context and needs of rhythmic gymnasts, we will need to:

- Develop an understanding of the various aspects related to RG and pirouettes training, from coaches' and gymnasts' perspectives, to training characteristics and dynamics;
- Study how feedback is usually provided in RG practice and how it can be adapted to the present project;
- Identify the main features for the application, and, together with gymnasts, determine the key design characteristics of the proof of concept to be created;
- Develop the proof of concept of the application and evaluate it with its end-users, gymnasts.

This work will benefit rhythmic gymnasts who are in the process of learning pirouettes or who wish to improve their performance. The results of this study will hopefully also contribute to raise interest in the topic and to promote the development of the area of sports analysis and the design of technology for sports to some extent.

1.3 Methodology

The methodology chosen for this dissertation, which will be further detailed in chapter 3, combines different nuances from user-centred design, contextual design, and participatory design approaches. In short, the work follows through a user-centred design approach, in which continuous (re)design, prototyping and evaluation iterations take place, while seeking to get a rich understanding of the context of the end-user's life and activities, in order to create an artefact that serves real needs and fits smoothly into users' routines.

The work followed a number of steps, the first being a background and literature review search to gain knowledge of the context and essential information about dissertation topics and existent projects and technologies. The work then proceeded to conduct observations of training sessions and interviews with both gymnasts and coaches to complement the information gathered in the review of the literature phase, and in the observations, in the case of the interviews. A preliminary design proposal as well as an initial application flow were created, after which we conducted co-design sessions with end-users using the PICTIVE method. A final application design was defined and the implementation process begun, eventually leading to usability and user experience tests, which were conducted with the end-users, rhythmic gymnasts.

1.4 Document Structure

This document is organised in eight chapters: Introduction, Background and Literature Review, Methodology and Work Plan, User and Context Understanding, Early Prototyping and Co-design, Final Application Design Elements and Implementation, Usability and User Experience Evaluation, and Conclusions and Future Work.

- This first chapter, **Introduction**, provided an overview of the project, with a brief presentation of the QGAIT smart insoles, the project's goals and contributions, a brief overview of the methodology as well as this document structure.
- Chapter 2, dedicated to the **Background and Literature Review**, serves to bring the reader up to speed on the relevant themes and key concepts necessary to the understanding of the problem at hand, as well as projects and technologies that have been used to support training.
- Chapter 3 presents the **Methodology and Work Plan** laid out to undertake the activities in which this work will unfold.
- Chapter 4, **User and Context Understanding**, describes the stages carried out during the study that allowed for an in-depth understanding of the user and the context in which gymnastics training activities take place.
- Chapter 5, **Early Prototyping and Co-design**, describes the first design proposal developed and the initial application features as well as the co-design sessions, and all its related issues, such as data analysis and results.
- Chapter 6, **Final Application Design Elements and Implementation** describes the decisions taken while developing the proof-of-concept that was implemented, from design elements to the architecture, components as well as databases. Implementation key code excerpts are also included and explained.

- Chapter 7, **Usability and User Experience Evaluation**, is the chapter where the matters related with usability and user experience were addressed and reports on the tests and evaluations that were made.
- Chapter 8, **Conclusions and Future Work**, provides an overview of the project for its whole duration and a reflection on the difficulties experienced and the prospects for future work.

To complement the work, at the end of this document, it is possible to find the **Appendices** section that includes a series of documents and information that were produced along with this project and which were essential for its development.

Chapter 2

Background and Literature Review

This chapter briefly contextualises rhythmic gymnastic, presenting the perspectives on training of both gymnasts and coaches, along with the challenges faced by gymnasts when training autonomously or with other gymnasts, in the studio or not. This chapter also provides insight into training as a means to improve performance, where aspects such as the coach - gymnast relationship and the means to giving and receiving feedback are highlighted. This chapter then looks into the specific action of performing pirouettes, covering issues such as static and dynamic balance, proprioception, foot anatomy, and the importance of injury prevention. It is important to note, that due to the scarcity of resources and the lack of scientific studies, which specifically focused on Rhythmic Gymnastics (RG), this research resorts to ballet-based articles to help understand problems and find solutions to RG.

2.1 Brief Contextualisation of Rhythmic Gymnastics

Rhythmic Gymnastics (RG) is an Olympic sport that finds its roots in the former Gymnastics of the Ancient Greeks (*FIG - Discipline*, n.d.). However, it was only in the early 1800s that an activity resembling Rhythmic Gymnastics started to emerge, when Pehr Henrik Ling begin encouraging his gymnastics to express their feelings and emotions through fluid movements (Palmer, 2003). Then, in 1929, in the Medau School of Berlin, a new type of gymnastics took shape and began to incorporate apparatus such as balls, clubs, ropes and tambourines. Eventually, the sport evolved to include a competitive focus and went from Modern Gymnastics to RG (Palmer, 2003).

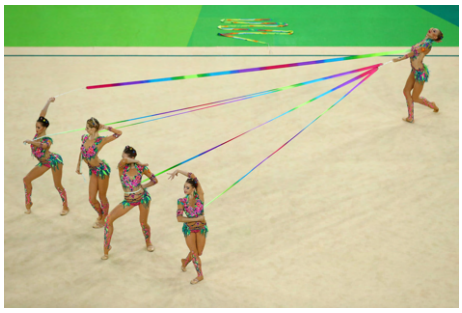
The official rules that govern the RG sport were established in 1962, when the *FIG* (*Fédération Internationale de Gymnastique*) set up the first World Championships, held in 1963, and gave official recognition to the various RG apparatus exercises, the rope, hoop, and ball. The clubs and ribbon exercises were only included later (Bott, 1989). It was in 1984, in Los Angeles, that RG became an Olympic Sport (Berra, 1997). With a strong influence from Ballet and Modern Dance, RG is a blend of sports and art (Botti & Nascimento, 2011). Routines are performed with music, individually (Figure 2.1a) or in groups of five gymnasts (Figure 2.1b), within the limits of a carpet 13 x 13 meter, especially designed to the practice of the sport. Rhythmic gymnasts have astonishing body skills and execute enormously difficult manoeuvres, while operating hand-held apparatus: hoop, ball, clubs, ribbon and rope.

In a RG routine, flexibility and musical interpretation are important elements, however,

what distinguishes an outstanding from an ordinary routine is the amount of risk that the gymnast takes during the exercises (Figure 2.1a). Gymnasts are often seen throwing the apparatus several meters into the air and losing sight of it, while at the same time performing leaps, turns or acrobatic manoeuvres before catching it, often in impossible-seeming catches (*FIG - Discipline*, n.d.).

Gymnasts are scored on: jumps and leaps, throws, balances, turnouts, flexibility and body and apparatus difficulty. Further to those elements, the judges look for originality, artistry, finesse and personal style. There are two different scores, the difficulty score and the execution score. The difficulty score has no limit, starts with 0 and every time a gymnast performs an exercise correctly, the correspondent number of points are added to her score. Contrariwise, the execution score has a maximum of 10 points, and every time a gymnast performs an exercise incorrectly, points are taken out from the total. The final score is the result of the difficulty score and the execution score, and, in the end, the gymnast with the highest combined score of the four apparatus wins the competition (FIG Channel, 2018).

(a) Yana Kudryavtseva - Individual Competition



(b) Russian team - Group Competition

Figure 2.1: Olympic Games - Rio 2016 (*Russia continue golden streak in rhythmic gymnastics*, 2020)

This dissertation focuses on two of the elements on which rhythmic gymnasts are scored: balances and pivots (or, as we refer to then in this document, pirouettes). Pirouettes are particularly challenging for a gymnast to learn and perform, and, when gymnasts are able to finally grasp how they work, there is a huge leap forward in their practice. Gymnastics training is considered similar to dance (Smitt & Bird, 2013) and at the core of gymnastics training one finds ballet, in particular the *ballet barre*. In ballet, exercises are designed to give flexibility and strength to the muscle, and enable ballet dancers to jump, turn, be on time with music, and all with grace, balance and control. These are also essential skills for a rhythmic gymnast. Both RG and Ballet training are dedicated to technical exercises with similar aspects, like *pliés* (Figure 2.2). Like in RG, one of the most important aspects in ballet is the turnout (Beaumont & Idzikowski, 2003). Due to the little scientific information existent in this area, and knowing that detailed information, which is specifically directed at end-users, it is needed to project appropriate design solutions, throughout this dissertation a close interaction with users will be kept in order to ensure that any issues are clarified, specially with regards to the needs of the different users and contexts involved.

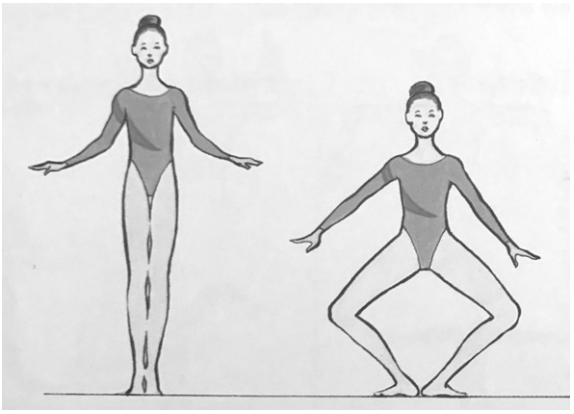


Figure 2.2: *Plié Relevé* Exercise (Berra, 1997)

2.2 Training to Become a Rhythmic Gymnast

2.2.1 The Structure and Challenges of Rhythmic Gymnastics Practice

The way a person should act and the way others act towards that person is represented by the social role that each represents (Bronfenbrenner, 1979). In gymnastics, the roles that exist within training obey a hierarchical relationship, where coaches have full control over the training, especially in the choice and selection of the exercises that will be executed, while on the other edge, gymnasts obey and perform the suggested exercises consistently from the beginning to the end, with no other option (Botti & Nascimento, 2011; Stefanello, 2000). There are also interpersonal hierarchical relations between the gymnasts, which are determined by their technical level. As so, gymnasts who are more advanced attract the attention of others serving as an example (Botti & Nascimento, 2011).

In RG there is a strong relationship between the gymnasts - in the role of learners - and the coaches - in the role of teachers - and also between gymnasts - as role models - which is reflected during the training and in the way it is conducted (Mesquita, 2000). These relationships are crucial in the development process (Botti & Nascimento, 2011; Bronfenbrenner, 1979). To experience a full commitment and a successful development of the gymnasts, it is essential that coaches understand and use these relationships to the gymnasts benefit (Botti & Nascimento, 2011). This is an important issue, since an extreme disorganisation or stiffness in the functioning structure of these relationships, may cause various problems at psychological and development levels in gymnasts, whereas stable and flexible relations represent the ideal conditions for their good development as human beings (Bronfenbrenner, 1992).

Coaching RG is a process that takes time and dedication and only with systematic and continuous training is it possible to achieve goals and improve performance (Raheb, Stergiou, Katifori, & Ioannidis, 2019). RG training follows a routine that is repetitive, monotonous and disciplinarian (Botti & Nascimento, 2011). Given the complexity of the sports, coaches wish to have the full engagement of their gymnasts. It is essential that gymnasts are aware that the gym is a workplace and their attitude towards training must meet this reality (Vianna, 2005).

Classes with different **gymnasts capacities and skills** and **providing useful and timely feedback** are two main challenges coaches face (Trajkova et al., 2019). Similarly to other skill-based activities, RG has various levels of expertise and there are always

differences among gymnasts (Botti & Nascimento, 2011). The challenge is to figure out to whom should the class be addressed, to the most advanced gymnasts making the others run to keep up, or to the less advanced gymnasts stalling the more advanced ones (Trajkova et al., 2019).

While delivering post response information after every trial is the ideal method for fostering efficient learning (Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997) this is also a difficult task to fulfil in a room full of gymnasts. The coaches' feedback capacity is limited and it is not possible to reach every gymnast at the same time. It is also important to understand the amount of feedback needed by each gymnast, as feedback has to be sufficient to enhance performance without overloading them. When gymnasts are exposed to too much new information, they get lost and it is more difficult to implement corrections and make connections with prior knowledge (Trajkova et al., 2019). These are the aspects that need to be taken into account in the development of projects in this area. It is important that coaches can promote skill-levelled exercises adapted to the gymnasts and can give feedback in customised quantity and quality, on time.

Gymnasts need to reach a high level of strength and endurance to maximise their capabilities and keep up with the increasing competition level (Trinidad, 2019). Because of this, gymnasts spend a great amount of hours inside the gym training, rehearsing and improving performances, where at least a coach is present directing the training, teaching a variety of exercises, helping maintaining its structure and giving feedback on the performances, assisting on anything needed. In most cases, training does not stop outside the gym, as there are gymnasts who keep training at home, outdoors or even in their own gyms (Trinidad, 2019). Still, training outside the gym implies a lack of structures and appropriate conditions, making it harder to achieve the equivalent goals. It also means training alone, having no coach preparing exercises, easing off logistics and learning, and providing motivational corrections (Trajkova et al., 2019), while, at the same time, feeling obliged to discipline themselves, beware of their bodies and their limitations but keep pushing it out of their comfort zone, otherwise they will not improve and get a better performance.

It is important that the extra training outside the gym is adapted to each gymnast and takes into consideration their needs and problems (Trinidad, 2019). As there is no such technology capable of assisting gymnasts in autonomous training, it is not possible to regulate it and reassure it is adequate to the gymnast, preventing bad technique and injuries. As so, the development of an application capable of measure various foot related issues during performance is an asset to the gymnasts community and a big improvement in the autonomous training sessions.

2.2.2 Key Elements in Learning Rhythmic Gymnastics

Rhythmic Gymnastics (RG) is a sport that requires a lot of technical expertise from gymnasts due to the complexity of rules and movements (Botti & Nascimento, 2011), hence the need for gymnasts to be focused and ready to learn, right from the start of the training. It is also important that gymnasts are happy and in agreement with the training system their coach uses (Trajkova et al., 2019).

In a training context, for gymnasts, learning by **listening** or learning by **trying** are two distinct realities. **Demonstration** can be used to explain the core ideas, whilst corrections to positioning must be done by **speaking** and **touching** the part of the body that needs attention (Hallam et al., 2014). It is known that learning by experiencing is the most effective way to get good results and to achieve the desired goal (Anderson et al., 2013).

With RG training, the same happens, where tangible corrections are received to then be applied during the exercise training.

According to (Trajkova et al., 2019), three aspects need to be taken into consideration by gymnasts during a practice in order for it to be efficient and beneficial:

- gymnasts must understand their own body;
- receive personalised corrections and attention from engaged coaches;
- remember and incorporate all feedback provided.

There are two key aspects to the understanding of the own body - **embodiment** and **proprioception**. Embodiment refers to the recognition of the movement as being part of the self (Hallam et al., 2014) and the awareness and subjective sense of the body (Peng & Tanaka, 2019). Proprioception refers to the sense of position and action of the limbs (Hillier, Immink, & Thewlis, 2015).

Newbies and beginners find embodiment challenging because they have no idea what it feels to do the movements and how to perform it correctly (Hallam et al., 2014). According to Hallam et al (2014), **chunking** and **mirroring** may offer substantial help to improve and develop it. Chunking, a key element of visual-motor sequencing, is the ability to take individual movements and string them together into a sequence, resulting in a full exercise. Mirroring, as the word implies, is the act of mimicking other's movements symmetrically, which is somewhat natural to everyone, once humans are born with a phenomenological sense of embodiment, responsible for the ability to move relatively to another person (Hallam et al., 2014).

By promoting the understanding of one's own body we are changing gymnasts way of absorbing technique and of feeling things (Trajkova et al., 2019). That understanding allows them to acknowledge the absolute positioning of their body and supports them in executing embodied movements (Hallam et al., 2014). Furthermore, the understanding of the body enables them to successfully implement corrections.

To acknowledge the issue of **personalised corrections**, Trajkova et al (2019) performed semi-structured interviews with seven experienced ballet teachers and six pre-professional dancers at a large dance conservatory in Maryland, United States. Dancers related a bad technique class to teachers not providing enough personalised corrections and their **engagement** and **attention** being compromised.

Receiving personalised corrections and having attention from coaches can be hard, as there are more gymnasts seeking their attention, however personalised corrections are essential to keep gymnasts **actively engaged** and **motivated**, and to promote effective learning (Anderson et al., 2013). Gymnasts cannot realise they are doing something wrong if there are no corrections, and most of the time looking at the mirror is not enough to understand the error by themselves (Trajkova et al., 2019).

Remembering and incorporating all feedback can be challenging since a lot of corrections are given in a short period of time, which adds to the fact that a significant amount of this is provided verbally and thus easily forgotten (Trajkova et al., 2019). Trajkova et al. (2019) suggests that, in addition to verbal cues, physically helping gymnasts to reach the correction, will make it easier for them to remember, leading to performance improvement. Written feedback can also be a solution, since it is possible to get back to it as often as necessary.

To sum up, in order to successfully create a project to help gymnasts, designers must keep in mind that corrections must be provided by different modes of communications, verbal, written and physical (kinesthetic) (Trajkova et al., 2019). It is also mandatory to keep in mind the importance of promoting an easier body understanding, by presenting chunked exercises and allowing learning by mirroring, and the importance of providing personalised feedback.

2.2.3 Feedback in Gymnastics Practice

This section introduces the main types and means of providing feedback to a gymnast. Feedback can be provided before, during, and after an exercise (Figure 2.3) (Trajkova et al., 2019). The mirror is the primary visual feedback any gymnast has **during** an exercise, but unlike coaches, mirrors do not have the ability to provide tips for correcting the error (Trajkova, 2016). Feedback is the information, judgement or correction given to someone about the performance (Gibbons, 2004, pg.38) as well as a means to guide performers's actions (Janelle et al., 1997). Feedback is also a key factor in successful and efficient skill acquisition (Gibbons, 2004; Chan, Leung, Tang, & Komura, 2011, pg.38). In gymnastics, feedback can be provided by the coach to an individual gymnast or to the whole class, it can be provided by a gymnast to another gymnast following coaches criteria; alternatively, a gymnast can learn how to analyse their own movement and self-correct (Gibbons, 2004, pg.38).

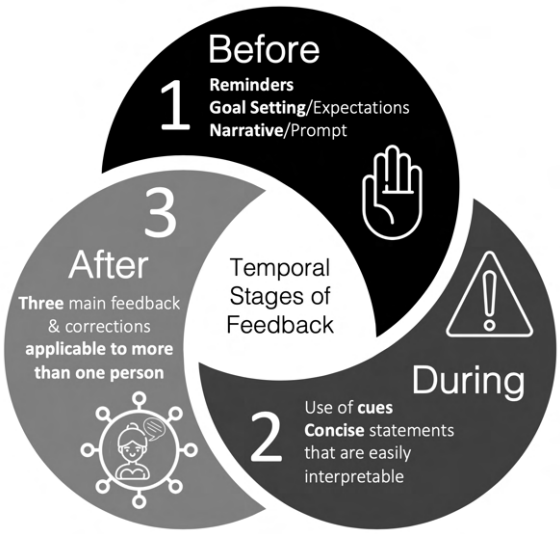


Figure 2.3: Feedback Structure (Trajkova et al., 2019)

Initial feedback needs to be **direct** and **simple** in order to immediately illustrate how the performance is being made (Trajkova & Cafaro, 2016) and has to correspond to the authentic nature of the activity (Trajkova et al., 2019).

Feedback has three functions, to provide: **information to direct error correction**, **reinforcement** and **motivation** (Trajkova & Cafaro, 2016). Feedback to direct error correction must be **prompt** and **specific**. **Prompt feedback** enables gymnasts to correct errors before embodying it; this prevents bad habits and stimulates effective and quick learning (Gibbons, 2004, pg.38). Specific feedback, enables gymnasts to identify the source of the error and knowing how to correct it (Trajkova & Cafaro, 2016).

In addition, when something is being correctly done, feedback serves as reinforcement of

good performance and behaviour. Positive feedback provides powerful motivation, as it allows gymnasts to know they are evolving and that they are valued (Gibbons, 2004, pg.38).

Gibbons' feedback framework (Figure 2.4) is a combination of "mode of communication" and "type of communication" (Trajkova & Cafaro, 2018), feedback can be given by three different types: **verbal**, **visual** or **kinesthetic** behaviour (Gibbons, 2004, pg.39).

- **Verbal behaviour** is feedback provided through the use of vocalisations or verbal statements (Trajkova & Cafaro, 2018) such as *"Bring your arm a little higher"*, or *"DUM de de, Dum de de, dum DAAAH d'dum"* as Gibbons (2004, p. 40) mention.
- **Visual behaviour** includes feedback through facial expressions such as smiles or frowns, hand movements mimicking the actions of the feet, and even full demonstrations of the movement (Trajkova & Cafaro, 2018). It also includes symbols such as a written analysis or photographs, portrayed for example, when gymnasts watch them videotaped (Gibbons, 2004, pg.40). This also offers visual guidance to reach corrections instead of just identifying the error (Trajkova & Cafaro, 2016).
- **Kinesthetic feedback** enables gymnasts to feel the corrections, it's a hands-on feedback essential for this art form that uses the human body. This type of feedback includes turning out the gymnast's leg or correcting spine alignment (Gibbons, 2004, pg.40).

As with a mobile application it is not possible to create kinesthetic feedback, this one will be disposed.

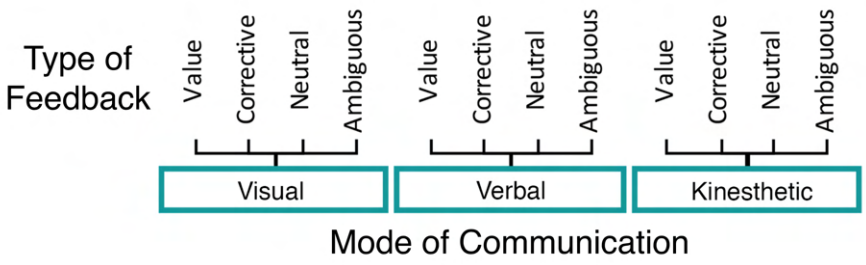


Figure 2.4: Gibbon's Feedback Model (Trajkova & Cafaro, 2018)

Feedback undertakes one of four forms, regardless of the mode of communication: **value**, **corrective**, **neutral** or **ambiguous** (Trajkova & Cafaro, 2018).

- **Value feedback** reveals a judgement through a specific word *"Great footwork!"* or nonspecific words *"Your jetés look great today"*.
- **Corrective feedback** focuses on a specific error and includes a statement that identifies the error and a statement about how to correct it, like *"Your leap should take off from the right foot, not the left"*.
- **Neutral feedback** is descriptive and factual, it acknowledges what has been done by describing factual statements, avoiding judgement or corrections.
- **Ambiguous feedback** includes verbal phrases such as *"Not bad!"*, it does not convey to the gymnast precise information about the performance and can be misinterpreted (Gibbons, 2004, pg.40,41).

- **Ambiguous** form, according to Gibbons, do not aid the learning process and for this reason it will be discharged from this project. **Neutral** form is also not good to deliver corrections but really useful to explain exercises or statements.

This study will use this feedback framework as a guide and adapt it into feedback provided by a mobile application and a pair of smart insoles.

It is also important to keep in mind the difference between gymnast types. **Novices** and **experts** need different approaches in terms of feedback and communication so they can perform their best (Trajkova et al., 2019; Trajkova & Cafaro, 2016). Trajkova et al. (2019) identified three temporal stages of generating feedback (Figure 2.3) from coach to gymnasts and created a structure.

This process is based on reminders **before the movement**, anticipating probable mistakes, keywords and concise phrases **during the movement**, triggering immediate pictures of what needs corrections, followed by **terminal feedback**, where it's provided advice of things that need improvement or correction (Trajkova et al., 2019). Despite the research in this area, designing effective technological interventions to benefit both gymnasts and coaches still remains an open challenge (Trajkova et al., 2019).

2.3 Performing Pirouettes

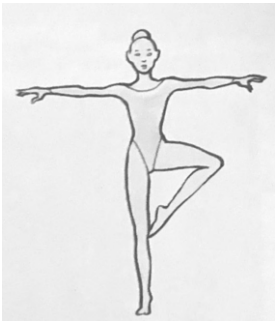
2.3.1 Static and Dynamic Movement

Balances

The most important factor in both Balances and in Pirouettes is **stability**. To achieve stability, the whole weight of the body has to be directly above the point of balance, which, in Rhythmic Gymnastics (RG) is most usually the foot (Bott, 1989, pg.25). It requires a great deal of concentration (Berra, 1997, pg.42) and the body has to show tension, any incorrect movement, especially of the limbs, may cause a wobble and pull the body out of balance. The body line must be **exact** and the body shape **held**, without the shoulders hunching up (Bott, 1989, pg.25).

A balance has three phases: **preparation**, **maintenance** of balance and **finalisation**. During preparation it is necessary to apply a double action: the **impulse on the ground** and the **stretching upwards** for the realisation of the equilibrium (Berra, 1997, pg.42).

(a) *Relevé*



(b) *Passé*

Figure 2.5: Ballet Positions (Berra, 1997)

A balance is considered properly executed if it is **clearly maintained** for at least two seconds and if the shape is **clearly defined**. The exercise may be executed or not in ***relevé*** - on the tip of the toes - and the ***cou-de-pied*** - the arch of the foot - should rise above the vertical (Figure 2.5a). Bearing in mind that doing it without *relevé* is worth fewer points in competitions (Berra, 1997, pg.42-44).

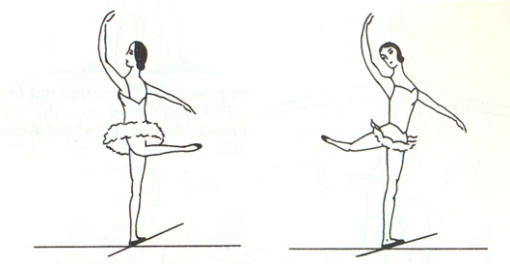


Figure 2.6: *Attitude* (of Ballet, 2015)

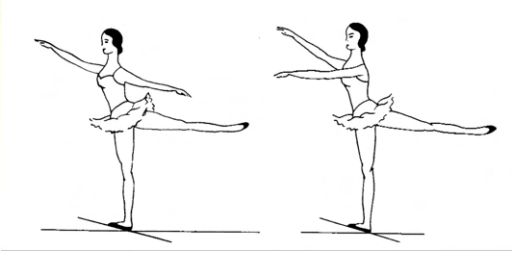


Figure 2.7: *Arabesque* (Classroom, n.d.)

It is possible to identify some main balance positions like a ***passé*** (Figure 2.5b), the most important one, **Arabesque** (Figure 2.7), in which the leg is extended high behind, **Attitude** (Figure 2.6), or even a **Developpé** (Figure 2.8) (Berra, 1997; Bott, 1989, pg.25). This positions will be studied with gymnasts and will be perceived which are viable and will be part of the mobile application.

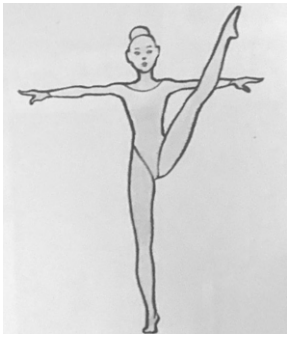


Figure 2.8: *Developpé* Position (Berra, 1997)

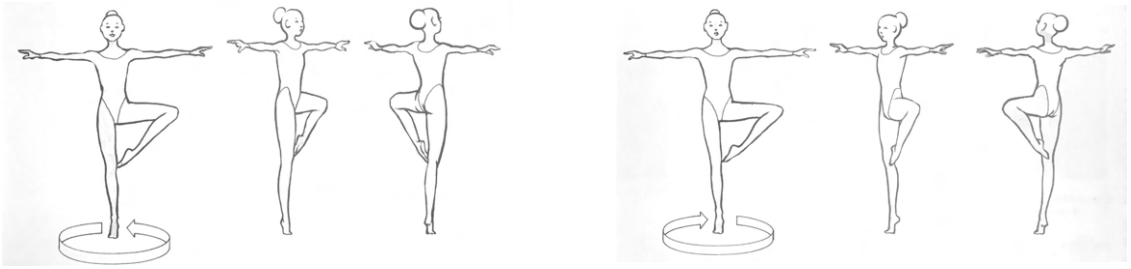
Pirouettes

Without a gradual and consistent training of **balance** and **body positioning** during the turn, gymnasts may easily acquire a poor technique and not be able to perform pirouettes properly (Vaganova, 1969). Also the *spot* is an important aspect to keep in mind. ***Spotting*** is a technique that keeps gymnasts from getting dizzy while performing pirouettes. Correctly spotting involves choosing something ahead in the eye line to look at. While performing the turn, the eyes must keep looking at it, until it is no longer physically possible, then quickly snapping the head around until it reaches again the spot, losing sight of it for only a fraction of a second (Moss & Leopold, 1999, pg.186).

Performing a pirouette correctly requires **tension and leg strength** plus **good balance** and is only considered correct if it is performed a fully complete turn (360^{o}). The turn must be performed high on the toes and the body has to stay upright with the weight over the supporting leg, otherwise the balance will not be maintained throughout the full turns.

Pirouettes can be performed both *En Dehors*, turning to the side of the support leg (Figure 2.9a), or *En Dedans*, turning to the opposite side of the support leg (Figure 2.9b) (Berra, 1997, pg.47). The start of the rotation must be **smooth** but **strong** and the ending must

be balanced and confident, more correct and complete turns equals to a more valuable exercise in competition (Berra, 1997, pg.46-48). Practising the ***relevé*** on one foot will not only help the balance position, but will also improve leg strength (Bott, 1989, pg.23).



(a) Pirouette *En Dehors*

(b) Pirouette *En Dedans*

Figure 2.9: *Passé* Pirouette (Berra, 1997)

2.3.2 Proprioception in the Performance of Pirouettes

Sir Charles Bell, around the 1830s, described the **sixth sense** as the sense of position and action of the limbs (McCloskey, 1978). The word proprioception is derived from the combination of Latin *proprius* which means "one's own" and **perception**, thus, the literal translation is **perceiving one's own self** (Hillier et al., 2015). This notion of **self-perception** reflects one's ability to detect subconsciously the position of a joint at any time, body movement and orientation as well as sense limbs motion, like moving an arm (Figure 2.10), sense of tension and force, and sense of **balance** (Hillier et al., 2015; Martínez-Amat et al., 2013; Proske & Gandevia, 2012; Smitt & Bird, 2013, pg.12).

Figure 2.10: Bending the Arm (Proske & Gandevia, 2012)

The mysteriousness of proprioceptive sensations lays in the fact that people are largely **unaware** of them. They are distinguished from exteroceptores (sensory receptors located on the external surface of the body - eyes or ears), because they are associated with none of the specific and recognisable sensations. Proprioception can be considered one of the subsystems within the somatosensory system, along with pain, touch, thermal sensations. Given that the sensory information is derived from changes within internal structures it is then considered **interoceptive** (Hillier et al., 2015).

Although proprioceptive information from all over the body can contribute and play a

role in the balance control (Han, Anson, Waddington, Adams, & Liu, 2015), some proprioceptive information of particular parts are crucial (Han et al., 2015), that is the case of **ankle proprioception**. In most sports, as with Rhythmic Gymnastics (RG), most of the time the foot-ankle set is the only part of the body in contact with the ground. For this reason, essential proprioception information is provided and allows the adjustment of ankle position and movement of the upper body, so that the exercises are well performed. Ankle proprioception can be improved by general and sport-specific **training**, and can be diminished by **injuries** and **fatigue** (Di Giulio, Maganaris, Baltzopoulos, & Loram, 2009; Han et al., 2015; Sasagawa, Ushiyama, Masani, Kouzaki, & Kanehisa, 2009).

Smitt (2013) states that proprioception training and improvement would be beneficial to gymnasts once it would reduce the amount of time invested in training and would enhance the quality of the movements performed. The relationship between poor balance control and heightened injury risk was proven by Tropp et al. (1984), so both **balance control** and **ankle proprioception** are negatively associated with **ankle injuries** (Han et al., 2015; Hrysomallis, 2007; Witchalls, Blanch, Waddington, & Adams, 2012; Tropp, Ekstrand, & Gillquist, 1984). Gymnasts with poorer ankle proprioception after injury demonstrated worse performance in both static and dynamic postural and balance control tasks (Forkin, Koczur, Battle, & Newton, 1996; Han et al., 2015; Leanderson, Eriksson, Nilsson, & Wykman, 1996). It is therefore important to study the anatomy of the foot and how to prevent injuries, so losses in proprioception can be avoided.

2.3.3 Preventing Pirouette-related Foot Injuries

The human foot has a complex anatomy and function, with both passive and active structures working as a single component. The foot segments act as an interactive unit to not only be a firm support configuration and propel the body, but also become sufficiently compliant to adapt to contact with the surface and dissipate ground reaction forces (Gwani, Asari, & Ismail, 2017; Holowka, O'Neill, Thompson, & Demes, 2017; McKeon, Hertel, Bramble, & Davis, 2015; Williams, Tierney, & Butler, 2014). The foot is divided into anatomical spaces containing different **muscular** and **neurovascular** structures, surrounded by fascia or bones (DiFelice, Seiler, & Whitesides, 1998; Reach et al., 2007).

Each foot includes 26 bones in addition to the tibia and fibula and are constructed and aligned to form a series of arches. Of these 26 bones, seven are tarsal, five are metatarsals and fourteen are phalanges (Cl, 1988; Clemente, 1985, pg.408-422). The formation of the foot arches allows the support of the body weight without wear out anatomical material and it also provides protection for the nerves and vascular supply on the plantar aspect of the foot (Clemente, 1985; Hoppenfeld, 1976, pg.422-424).

Injuries such as anterior cruciate ligament ruptures (ACLR) and **lateral ankle sprains** (LAS) can be minimised with prophylactic programs, that commonly include physical training, such as balance plyometric, strength, coordination (Van Der Merwe, Shultz, Colborne, & Fink, 2020). Not only the **stability** and **orientation** of the foot play a significant role in the position of the centre of pressure under it, influencing the moments and forces acting on the lower limb (Kelly, Cresswell, Racinais, Whiteley, & Lichtwark, 2014; McKeon et al., 2015; Williams et al., 2014), but also **intrinsic and extrinsic muscles** of the foot have a significant role in risk factors associated with lower limb injuries (Van Der Merwe et al., 2020).

Injuries in gymnasts are commonly caused by **hypermobility** - extreme flexibility - that compromises the level of stability and can increase the probability of injury. Hypermobile

joints demonstrate a lower level of tendon reflex forces and muscle spindle and mechanoreceptor output, which results in decreased proprioceptive acuity (Smitt & Bird, 2013). If **rehabilitation** is not adequate, the chance of recurrence is higher.

During application use, in order to prevent and even help on the rehabilitation process, every time the foot is badly positioned on the floor and hazardous extremes are reached, warnings must be sent to the gymnasts alerting that and warn that a injury may occur if the positioning is not corrected, explaining how to do it and how to prevent it.

2.4 Technologies and Related Projects

Having contextualised Rhythmic Gymnastics and the aspects of it which are relevant to this dissertation, this section discusses the potential of technology to support gymnastics training. It highlights projects that have contributed to this context and provides examples of technologies that have been used in adjacent areas. They have contributed with findings and successful systems, that will support and inform the development of this project.

Technology in sports is constantly changing in today's era and it is making a big impact, creating advantages to both coaches and gymnasts (Ramesh, 2016). Areas such as biomechanics, physiology, and behavioural neuroscience have been studied, leading to the development of systems and methods to evaluate sports performance (Bideau et al., 2010).

As detailed in Figure 2.3 feedback timing is essential and a key concept to motor learning (Sigrist, Rauter, Riener, & Wolf, 2013). In this context it is specially important to look at technologies which can provide augmented feedback. **Augmented feedback** - feedback provided by an external source - not only is believed to effectively enhance learning but also can make it possible for coaches to extract more than visual information from gymnasts performances and to retrieve the feedback at a rapid rate (Sigrist et al., 2013). Augmented feedback then hold the potential to mitigate one of the biggest problems of slow progress in sports, bad feedback. Technologies as Kinect-based Systems, Augmented and Mixed Reality, Mobile Games and Applications, Wearables, Video Recordings, Motion Capture Systems (MOCAPs), can be useful technologies and solutions to keep in mind while designing systems to help and assist sports activities. Examples of such solutions will be provided in the next section.

Wearables are miniature embedded computing systems worn by people (Williamson et al., n.d.). Their small size, most of the times, allow constant daily use without interfering with routines, yet delivering a big set of data information (Williamson et al., n.d.). The concept of wearable technology arose back in the 1980s when people started wearing electronic watches (Williamson et al., n.d.). An astonishing growth on technology development and market success has been experienced since the late 2000, when several technology drivers began to invest in this technology (Williamson et al., n.d.). Although there is still room for improvement, wearables are becoming mainstream technology, in the everyday use of people. In today's quotidian, most people are likely to be using wearable technologies, that if thoughtfully designed, can powerfully change ones life (Isbister, 2016). However, wearables also face several challenges, such as, short battery life and large energy consumption. Another challenge relates to the expectation that wearable devices will function 24/7, without the need for human intervention or maintenance (Williamson et al., n.d.).

The QGait smart insoles used in this project are an example of a wearable technology. They will be worn by users while performing exercises and transmit real time data to a receiver, for example a computer. The next section presents a series of examples were

wearable technologies are proposed as solutions for contexts adjacent to ours.

2.4.1 Super Mirror

The Super Mirror project is a Kinect-based system that combines the functionality of studio mirrors with prescriptive images to provide the user with instructional **feedback** in real-time. The user places her/himself in front of the kinect system and performs the exercises asked. A motion-capture is performed with a joint skeleton tracking through the Kinect camera and the transferring of input from the camera to the processor is mediated by a specific application, Synapse. The system compares the angles of the knee and hip joints of the user while performing in real-time with pre-recorder motion data, indicating whether there is a correspondence or not with the previously established pose.

In Figure 2.11 the two skeleton models in grey and blue demonstrate the correct final position and the movement that leads to this position, in this case a *plié*. While the grey figure with yellow joints is a real-time skeleton tracking of a dancer performing the movement ((Marquardt, Beira, Em, Paiva, & Kox, 2012)).

Figure 2.11: Super Mirror (Marquardt et al., 2012)

Although in this project feedback is given instantly, it is necessary to be properly positioned in front of the kinect system for it to work properly. It is also a fragile and fixed in place apparatus that should not be constantly moved in order to preserve its good functioning. Apart from the fact that it presents a huge error rate detected during the tests (Figure 2.12), were blue indicates the accurate hits and red indicates the inaccurate, the obligation of a fixed kinect system spot and as rhythmic gymnastics exercises are performed in constant movement this project does not attend the dissertation and the gymnast's needs.

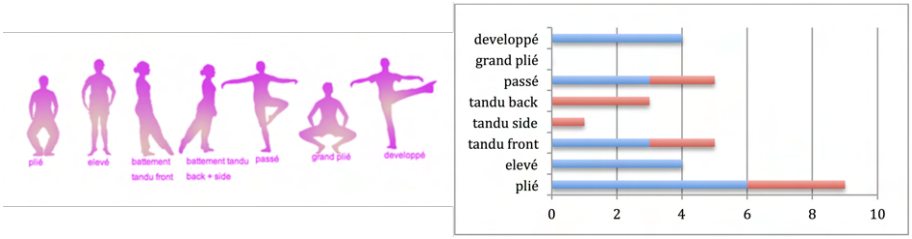


Figure 2.12: Super Mirror (Marquardt et al., 2012)

2.4.2 Ballet Hero

Ballet Hero is a project that uses wearable technology that consists of a garment for mimetic *embodiment* in dance learning. It incorporates *visual feedback* (Figure 2.13b) inspired by animation techniques that more directly convey the essential movements of ballet, thus was idealised to aid adult beginners to start learning ballet (Hallam et al., 2014). The teacher wears the garment seen on Figure 2.13a while performing the exercises simultaneously with the student. Different colour lights correspond to different timings. While the teacher is performing the exercise, the in motion light is on and when the final position is achieved, the stop lights light up. The student is supposed to follow the teacher's movement by mirroring and understanding the timings relying on the lights. An assistant is watching and if the student is out of sync with the teacher, a flash a corrective error message is sent and the garment lights deliver it.

(a) Garment

(b) Feedback

Figure 2.13: Ballet Hero (Hallam et al., 2014)

This application mirrors synchronous movements and establishes a natural embodied connection between student and teacher (Figure 2.14), and effectively manages chunking to decrease the initial complexity of the visuomotor sequencing (Hallam et al., 2014). Unfortunately, in order for this technology to work, this system requires the constant presence of a person who knows how to perform the exercise. In addition, an assistant must always be present, in order to deliver the feedback on the right time, which may be challenging for the more difficult exercises, as there could be the case that no one besides the teacher knows how to perform them.

Figure 2.14: Ballet Hero Storyboard (Hallam et al., 2014)

Furthermore, this garment is a complex set of circuits intertwined and connected to led strips (Figure 2.15) that can be damaged with more abrupt exercise. It also will not fully work on faster paced exercises, as the student does not have enough time to properly mirror all steps. Due to the issues above mentioned, this technology does not answer the proposed problem either.

Figure 2.15: Ballet Hero Circuits (Hallam et al., 2014)

2.4.3 Dance! Don't Fall

Dance! Don't Fall is a game-like mobile application that enables users to both monitor their own risk of falling and actively reduce it through fun and easy exercises (Kerwin et al., 2012). The application gives users *feedback* on dance performance and risk of falling, based on the analysis of their movement, as they perform choreographed moves along with audio or video dance instructions (Figure 2.16). It presents three modes: learn, perform, and also a competition mode that allows users to challenge their friends to a group dance contest. The phone is placed in the lumbar region secured with a rope around the belly and its sensor will do the measures and send it to the application (Kerwin et al., 2012).

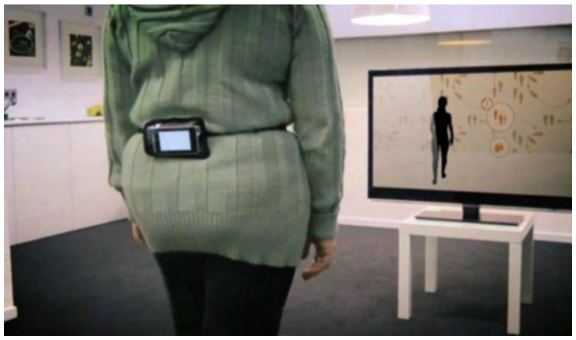


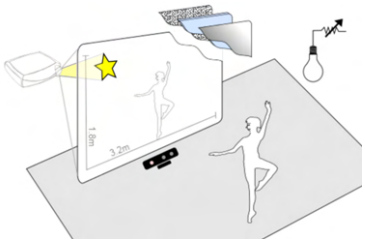
Figure 2.16: Dance!Don't Fall (Kerwin et al., 2012)

With this project, the smartphone is used as a sort of wearable technology that is handled in such way that provides a hands-free dance interaction. This project also measures questions related with balance and rhythm but does not analyse real time data that allows the error correction in terms of foot supports and positioning, two major issues in the good performance and execution of pirouettes, and so not a solution to the problem found and mentioned.

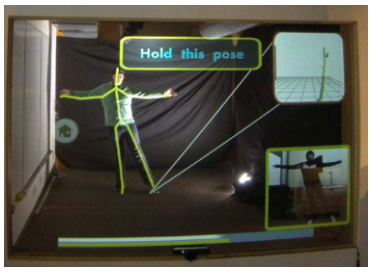
2.4.4 YouMove

YouMove is an Augmented Reality Mirror system that allows users to create and share training content, and learn physical movement sequences (Figures 2.19). It uses recorded data to train the user, using a large-scale augmented reality mirror and a series of stages that gradually reduce the user's reliance on *guidance* and *feedback* (Figures 2.18) (Anderson et al., 2013). The user must place her/himself inside the mirror range area during performance in order to be detected by the kinect system. For movement analysis, the user must perform the exact same exercise displayed on screen, from a database list of existent exercises.

Like other projects using kinect, a permanent spot for the whole installation system is necessary, which results in a fixed technology requiring to practice always in the same



(a) YouMove



(b) YouMove

Figure 2.17: YouMove System (Anderson et al., 2013)

spot. It also requires the user to be properly placed in the kinect range and the joint skeleton to correctly track the movement. As pirouettes are quick exercises and this type of technologies do not have the accuracy to analyse it, this system is a no go to solve the proposed problem.

(a) Movement Gallery

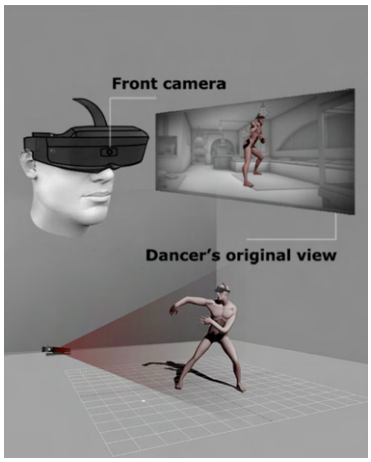
(b) Post-Stage Feedback screen

Figure 2.18: YouMove (Anderson et al., 2013)

2.4.5 Outside Me

Outside Me is a mixed reality and wearable system that consists of a head-mounted display (HMD) (Figure 2.19a) and that offers four different working modes: self-practising, training with a virtual leading dancer, rehearsing with an extra dancer and video feedback (Yan et al., 2015). The dancer's posture is captured and blended in with scenes from their surroundings in real time, providing an external self-image without distracting dancers' *performance* (Figure 2.19b). A virtual character is presented to dancers to support *self-training* and *cooperative rehearsal* (Yan et al., 2015). The user wears the HMD and places her/himself inside the range of the kinect system, a screen reproduces exactly what user is seeing as the dancer's posture is captured and blended in with scenes from their surroundings in an interactive frame rate, providing an external self-image without distracting dancers' *performance* (Figure 2.19b). A virtual character is presented to dancers to support *self-training* and *cooperative rehearsal* (Yan et al., 2015). This system promotes self-practising, as the user corrects her/himself seeing in real time the movements being performed. It also promotes learning by mirroring a virtual assistant, allowing for third party feedback, training with other dancers, and the delivery of video feedback that can later be analysed.

Once again and because of the whole kinect system, this project it is not ideal to help gymnasts to learn and improve pirouettes performance. They have to keep themselves within the system range and perform slower movements for the kinect properly map everything and have to keep the facility always in the same spot.



(a) System

(b) In use

Figure 2.19: Outside Me (Yan et al., 2015)

2.5 Summary

Rhythmic Gymnastics (RG) is a complex and challenging sport that requires a lot of training from gymnasts. Due to the similarities with ballet, and since there is very little scientific information on RG, it was decided to use in this chapter and in the context of this dissertation, articles and projects addressed to ballet and further, verify the conclusions.

We understood that the training session should be adapted to the gymnast level and coaches should deliver useful and timely feedback. The training structures and conditions should also be maintained, even outside the gym, as well as exercises dynamics and organisation. Promoting training through trying, using demonstrations and with carefully explanation of the exercises will support the gymnast in performance improvement. A good sense of embodiment and proprioception also play a major role in the correct execution of balances and pirouettes, as well as in the prevention of pirouette-related foot injuries.

The projects chosen and analysed presented great proposals in the field of autonomous training. Nevertheless, none presented a solution to the problem of this project, as their ideas were based on the use of kinect - which requires a fixed setup and errors in the detection of movements - the use of a garment with a built-in LED circuit - that can be damaged, especially with vigorous and powerful exercises like pirouettes and the obligatory presence of a person exemplifying - and a game-like mobile application - does not measure relevant data to this project. The upcoming chapter will present the research approach and stages developed throughout the duration of this project.

Chapter 3

Methodology and Work Plan

This chapter introduces the research approach and work-plan of this dissertation. In doing so, and to justify the methodology chosen, it starts by reviewing key concepts and approaches in the field of Human-Computer Interaction. Afterwards, the chapter introduces and explains the steps involved in the development of the project, in a way that readers are able to understand the project and how the final goal will met. Finally, the chapter presents a timeline that elucidates on deadlines, milestones and the specific tasks undertaken.

3.1 Research Approach

Designing artefacts can be difficult. Artefacts that are not designed properly can leave users frustrated and render them unable to complete even a simple task (Chadia Abras, 2004). One of the ways to prevent this is through the involvement of users throughout the entire project. The involvement of end-users is crucial and, in involving them, designers and developers gain a better understanding of their needs and goals, leading to a more appropriate product (Jenny Preece, Yvonne Rogers, Helen Sharp, 2002, pg. 279, 280).

User-Centred Design (UCD) is a design process highly influenced by end-users (Chadia Abras, 2004), and evolves towards satisfying the users needs (Sanders, 2002). This method involves finding out as much as possible about users and their tasks and take advantage of this information to improve the design (Jenny Preece, Yvonne Rogers, Helen Sharp, 2002, pg.279). This process is done in cycles of "design, test, measure and redesign" repeated as many times as needed (Keinonen, 2008). The researcher and the designers' roles are distinct, yet interdependent, and the user is not part of the team (Sanders, 2002). This method helps managing user's expectations since users can see, from an early stage, what the product is capable of (Chadia Abras, 2004), and if they have contributed to product's development, this contribution may lead to a sense of "ownership" resulting in higher customer satisfaction (Jenny Preece, Yvonne Rogers, Helen Sharp, 2002, pg.281). A downside of using UCD is the amount of time it takes to organise, manage and control user's involvement and also the monetary costs associated (Jenny Preece, Yvonne Rogers, Helen Sharp, 2002, pg. 282).

Having introduced UCD, the discussion now focuses on two other approaches, participatory design (PD) and contextual design (CD), which will be essential in our work. PD has its own articulated methodological orientation, methods and validity (Spinuzzi, 2005), in which designers have access to a pool of representative users (Nielsen, 1994, pg.88).

Users are co-designers (Chadia Abras, 2004), express themselves and actively participate in the process, so designers and users' roles may be blurred (Sanders, 2002). To take full advantage of users' involvement, designers must present users with understandable ideas, since users are good at reacting to concrete designs (Nielsen, 1994, pg.88,89). PD implementations' present a commitment to sustained and methodical investigation according to reasoned methodological principles. Several research methods, act as a basis for participatory design, but are only used to iteratively produce emerging designs (Spinuzzi, 2005). In this dissertation, we had privileged access to a large pool of rhythmic gymnasts, and leveraging on that, we conducted co-design sessions with them. Specifically for this purpose, we followed the PICTIVE method (Muller, 1992).

Contextual design (CD) is an approach that gathers field data and uses it to drive design through a series of steps (Holtzblatt & Beyer, 1999). CD is known as a scaffolding for user-centred front-end design, whose techniques can be changed if not suitable (Beyer & Holtzblatt, 1997, pg.21). It is based on the principle that the product is always part of a bigger practice (Holtzblatt & Beyer, 2016, pg.2) which goal is to enhance the user's existing way of working (Wixon, Holtzblatt, & Knox, 1990). A successful system offers customers a way of work that they will want to adopt (Beyer & Holtzblatt, 1999, pg.33). In brief, CD externalises good design practice for a team (Beyer & Holtzblatt, 1997, pg.22) and goals to reach a high level of comprehension about users in their surroundings, allowing the development of knowledge to apply into the design problem (Holtzblatt & Beyer, 2016, pg.2). There is a continuous contact between participant parts and a constant immersion into users' lives that prevents products designed with solutions for the developers, instead of products designed with solutions for the end-users (Holtzblatt & Beyer, 2016, pg.3). As Beyer & Holtzblatt (1999) state, great product ideas come from the marriage of a designer's detailed understanding of a customer's need and their in-depth understanding of the possibilities introduced by technology. Bearing this in mind, a CD approach will be adopted for the development of this project, complemented by PD activities. Without a strong and rich context of the end-user's life and activities, it is not possible to understand key design aspects and issues (Holtzblatt & Beyer, 2016).

3.2 Research Phases

The goal of this dissertation is to design and develop a proof-of-concept of an artefact that can assist gymnasts in the practice and learning process of pirouettes.

Starting by **analysing the problem**, its context was studied and essential information and articles reviewed to understand the subject matter and its fundamental aspects (Holtzblatt, Wendell, & Wood, 2005, pg.39); this allowed for a thorough and informative literature review to be be written. Next, we sought to identify **existing projects** in similar and adjacent fields, so we could learn from them. Those projects were then analysed, as well as their methods and tasks; we reused suitable knowledge in this project (Holtzblatt et al., 2005, pg.39).

Going into the second phase, the first task lead was the **contextual inquiry**, in which a researcher investigates how the tasks are done, to unveil details and motivations implicit in the work, materialise real needs and setting customers data as basis for the decisions (Beyer & Holtzblatt, 1999). In our work, we carried out a series of **observations of the training sessions**, to validate the knowledge acquired before and adjust requirements accordingly. Further to that, we conducted a number of **interviews** with both gymnasts and coaches. Afterwards, **model data** captured was interpreted, filtered and analysed,

and notes made to provide a context and define essential aspects to be featured in the proof of concept application to address the dissertation goals (Holtzblatt et al., 2005, pg.39).

The next stage was dedicated to the **consolidation and visioning** stages, in which collected data is convened together, issues and needs addressed, data and sequence models consolidated and reviewed (Beyer & Holtzblatt, 1999). After carrying out these steps, a preliminary design proposal was created, which embedded the idea and the specific aspects to appear in the artefact and could provide a high-level view of how people will interact with it (Beyer & Holtzblatt, 1997; Holtzblatt et al., 2005, pg.39,40).

With these activities, we expected to uncover extra information that users might not be externalising, or were not even aware of. We also aimed to get end-users point of view on the design of our preliminary prototype proposals, as suggested by (Graham, Rouncefield, Gibbs, Vetere, & Cheverst, 2007). Co-design sessions, following the PICTIVE method were led (Muller, 1992), aiming to reach a design that could better suit the target audience, providing users with a non software-based "rapid prototyping" environment (Turmo Vidal, Márquez Segura, Parrilla Bel, & Waern, 2020).

For the **development and implementation** of the project, a **continuous iterative cycle** with constant alternations amongst **(re)design**, **prototyping** and **evaluation** was used, which led to prototypes of evolving fidelity, from low to high fidelity prototypes, in order to implement the solutions developed in previous stages.

As a more stable version of the prototype was available, a **Usability and user experience (UX) evaluation** was conducted to understand what was working and what needed improvements, lastly and whenever need, changes and corrections were applied to the project. Both tests with the smart insoles and the mobile application were conducted.

3.3 Work Plan and Timeline

3.3.1 Early Planning

A work plan was carefully prepared for the entire duration of dissertation, in order to organise tasks and make sure that the planned steps were fulfilled in due time. Tasks were organised following a logical sequence, based on the steps that needed to be accomplished, since the initial review and contextual design phases, until the later development and testing phases.

The work started in September 2020 and was first planned to end in June 2021 (Figure 3.1). However, as we will explain in section 3.3.2, the work of this dissertation was only concluded in February 2022. A timeline of the revised version of the work plan can be seen in Figure 3.2.

In both work plans, tasks were also organised and grouped into five large categories, according to their purpose:

1. Task 1: Background and literature review
2. Task 2: Contextual inquiry
3. Task 3: Early prototyping and co-design
4. Task 4: Iterative (re)design, prototyping and evaluation

5. Task 5: Writing and Dissemination

Task 1 consisted in the first step of dissertation, the written document was prepared and important decisions were made. Research information was gathered and documentation selection and analysis made, were identified existing projects and insoles exploration was done in order to understand its potential.

Task 2 hosts the contextual inquiry structure. A compilation of context information was collected, the hows and whens, were carried out through gymnastics training observation sessions, interviews with gymnasts and coaches. It was also initially planned to hold a podiatrist interview at this stage.

Task 3 covered the early prototyping and co-design workshops, conceptualisation and ideation were done and the data gathered was analysed to achieve design solutions. Originally in this task, technology probes were going to be used to assist in the search.

Task 4 consisted of continuous cycles of iterative (re)design, prototyping and evaluation, where low, mid, and high fidelity prototypes were created to test features before implementation. It was also in this phase that we started to develop the design solution. Usability and UX tests were made and carried out throughout the process; changes and corrections were applied, as a result of those tests, whenever required and were felt appropriated.

At last, task 5 that refers to the writing and dissemination of the work, included from the background and literature review writing, to the corrections to the written intermediate defence document, and the writing and review of the final document as well as the preparation for the intermediate and final defences.

3.3.2 Revised Planning

As we will explain in this section, the original timeline could not be met and the deadline for final submission was extended until January 2022, with its defence being in February 2022. The initial plan therefore underwent some amendments (Figure 3.2).

The changes to the initial planing were due to three types of reasons: excessive complexity of the initial plan, adaptations imposed by the undergoing COVID-19 pandemic, and severe health problems experienced by the student. Considering the complexity of the first proposal and the effective time to project development, we decided to simplify some tasks and eliminate or replace others. It was decided to abandon the interview with the podiatrist, as extensive injury prevention would be a secondary part of the project, a new project in itself, and because the coaches, who are already equipped with the essential knowledge on injury prevention, could provide us with the guidance we needed. Using technology probes requires an intensive and time consuming process that the project did not have, so it was also decided to remove this step from the timeline. As the project was going to have a strong and active participation of the end users, it was decided to drop the storyboard task, as weaknesses and improvements would be perceived in the numerous interactions we would carry out with the gymnasts, relieving some of the heavy workload.

Then some changes resulted from adaptations that were necessary due to COVID-19. Training observations were planned for January and February, but because the COVID-19 pandemic was at its peak at the time, remote training was then made mandatory. As the gymnasts took some time to adapt to this type of training, it was decided to postpone the observations to the beginning of March, so that we could draw conclusions from training sessions, as close as possible to normal.

The gaps in the schedule where no work was developed are justified by periods when it was not possible due to the declining health. From the end of April to the beginning of August, the project was put on hold due to a series of serious health issues which compromised the normal course of the tasks. The task 3, 4 and 5 were postponed until August. Preparation and execution of the co-design sessions with PICTIVE method, low fidelity prototypes and subsequent data analysis and interpretations were developed until mid-September, when due to a major surgical intervention, the project suffered another halt. In December, and still with some limitations, work was resumed and tasks were developed up to the final submission date of the project, in January 2022.

3.4 Summary

After an in-depth study on key concepts and Human-Computer Interaction research approaches, a contextual design approach, complemented by participatory design activities, was adopted for the development of the project, not only to ensure a rich understanding of the context of the end-user's life and activities, but also to actively include their contribution to the design produced.

The initial ideas for the project were too ambitious considering its useful development time, so changes and adaptations were made in order to make it more viable and achievable. Despite the deviations in the timeline due to force *majeure* problems, all tasks proposed in the revised plan were accomplished with success and the project was fully developed.

1. Background and Literature Review

1.1. Research and information gathering
1.2. Selection and analysis of documents
1.3. Identification of similar existing solutions/projects
1.4. Insole exploration and experimentation

2. Contextual inquiry

2.1. Observation of gym training sessions
2.2. Interview with podiatrist
2.3. Interview with gymnasts
2.4. Interview with coaches
2.5. Interview coding and analysis
2.6. Final project goals

3. Early prototyping and co-design

3.1. Technology probes
3.2. Co-Design workshops
3.3. Conceptualization and ideation
3.4. Storyboarding
3.5. Research and information gathering (II)

4. Iterative (re)design, prototyping and evaluation

4.1. Low fidelity prototyping
4.2. High fidelity prototyping
4.4. Solution development & implementation
4.5. Usability and UX evaluation
4.6. Changes and corrections to the project

5. Writing and Dissemination

5.1. Literature review writing
5.2. State of the art writing
5.3. Review of the written intermediate defense document
5.4. Preparation of the intermediate defense
5.5. Prototyping and implementation writing
5.6. Review of the final document
5.6. Review of the final document

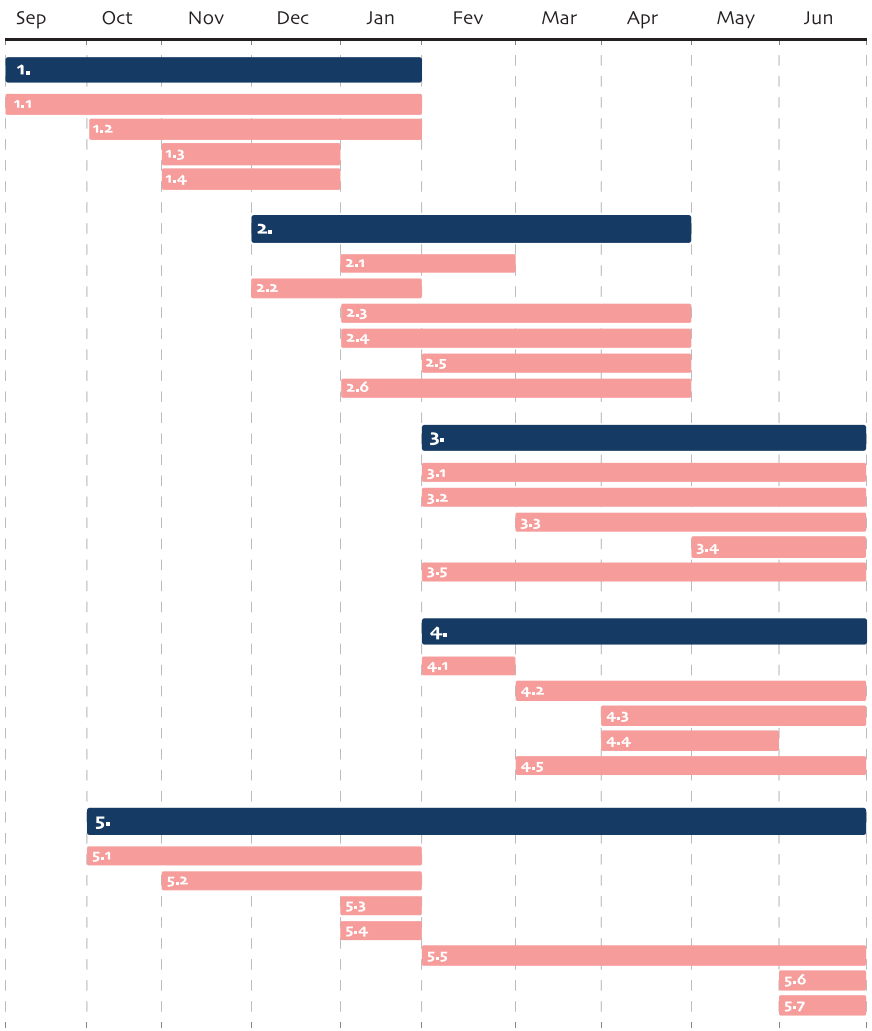


Figure 3.1: Early Planning Timeline

1. Background and Literature Review

1.1. Research and information gathering
1.2. Selection and analysis of documents
1.3. Identification of similar existing solutions/projects
1.4. Insole exploration and experimentation

2. Contextual inquiry

2.1. Observation of gym training sessions
2.2. Interview with gymnasts
2.3. Interview with coaches
2.4. Interview coding and analysis
2.5. Final project goals

3. Early prototyping and co-design

3.1. Preparation of co-design workshops - PICTIVE
3.2. Co-Design workshops - PICTIVE
3.3. Conceptualization and ideation

4. Iterative (re)design, prototyping and evaluation

4.1. Low fidelity prototyping
4.2. Mid to high fidelity prototyping
4.4. Solution development & implementation
4.5. Usability and UX evaluation
4.6. Changes and corrections to the project

5. Writing and Dissemination

5.1. Writing and review of the intermediate defense document
5.2. Preparation of the intermediate defense
5.3. Writing and review of the final document
5.4. Preparation of the final defense

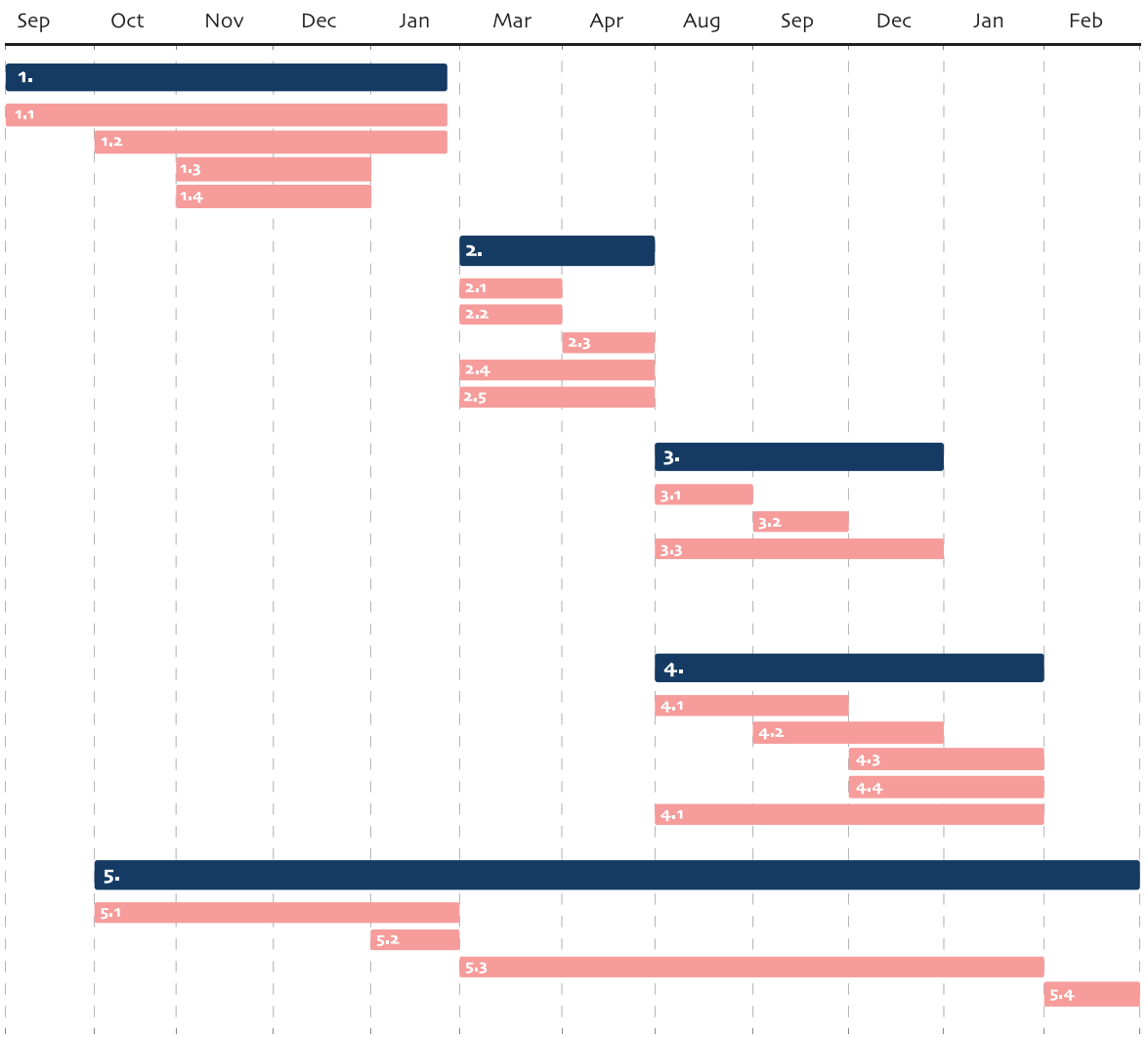


Figure 3.2: Revised Timeline

Chapter 4

User and Context Understanding

This chapter reports on the activities that were carried out to develop an understanding of the users and their contexts. Two main types of activities took place: an observation of training sessions and interviews with gymnasts and coaches. A series of observation of training sessions were conducted in the early stages, which were then analysed and results were drawn from. Despite all the enlightening information gathered from the observations, other queries also arose. To bring out the necessary answers to those questions, we carried out interviews with both gymnasts and coaches. The results of those interviews were again analysed and conclusions extracted.

4.1 Observation of training sessions

The literature review provided an overall view on the different perspectives in the practice, the importance of coach-gymnast relationships, the importance and the feedback timing delivery, and the organisation of pirouette training.

However, due to the lack of resources focusing on RG specifically, the majority of sources were more oriented towards ballet and some questions still needed a more in-depth investigation. For this reason, a series of observations of gym training sessions were conducted, in order to validate the previous knowledge and gain a more comprehensive understanding, and make any required adaptations. The observations were initially planned to take place in the gym, but due to the ongoing COVID-19 pandemic they took place online, as explained below.

To structure the observations we used the AEIOU framework. Developed by Rick Robinson, Ilya Prokopoff, John Cain, and Julie Pokorny, at the Doblin Group in 1991 (*AEIOU*, n.d.), AEIOU is a heuristic method to assist on observation interpretations (*AEIOU*, n.d.) as well as a coding framework mnemonic (Figure 4.1) that enables the information gathered to be organised under five categories: **Activities**, **Environments**, **Interactions**, **Objects** and **Users** (*AEIOU*, n.d.).

Table 4.1: AEIOU Framework

A ACTIVITIES	E ENVIRONMENTS	I INTERACTIONS	O OBJECTS	U USERS
How is the practice organised? How is the pirouettes practice organised? Level of difficulty of the training? How long is the average duration of the practice?	Where do gymnasts train? How much space do they need for practice? What is the training environment like?	How is the feedback given? How does the coach analyse the movement and notice the mistakes? How many corrections are given to one gymnast? How many corrections does the gymnast apply? How many times do gymnasts repeat the exercise before and after corrections? Do the gymnasts train alone or only when the coach is watching? Do they restart after encouragement?	Which objects are used in the training? Is there any specific object used in the training of pirouettes?	How many gymnasts? And how many coaches? Does the gymnast react to all coaches the same way? The level of concentration of the gymnast during training (high, medium, low) Is the gymnast successful in the implementation of corrections? After how many repetitions can the gymnast implement the corrections and improve performance? After how many repetitions does the gymnast get tired? Is there improvement over time?

Activities, are a group of goal-directed actions and its processes (*AEIOU*, n.d.). For this study, and bearing in mind the AEIOU framework should be customised and adapted into each case (*AEIOU*, n.d.), the key aspects taken into account were, as synthesised in Figure 4.1:

- A1 - "How is the practice organised?"
- A2 - "How is the pirouettes practice organised?"
- A3 - "Level of difficulty of the training?"
- A4 - "How long is the average duration of the practice?"

Environments refer the context where the activities take place (Bose, n.d.) and provide details about the background and characteristics of the surrounding environment. As training was taking place online, the questions about the environment had to be adapted to this reality and aimed to answer how the gymnasts adapted to the new situation,

- E1 - "Where do gymnasts train?"
- E2 - "How much space do they need for practice?"
- E3 - "What is the training environment like?"

Interactions include both interpersonal and person-artefact interactions and are like the building blocks of activities (*AEIOU*, n.d.).

- I1 - "How is the feedback given?"
- I2 - "How does the coach analyse the movement and notice the mistakes?"

- I3 - "How many corrections are given to one gymnast?"
- I4 - "How many corrections does the gymnast apply?"
- I5 - "How many times do gymnasts repeat the exercise before and after corrections?"
- I6 - "Do the gymnasts train alone or only when the coach is watching?"
- I7 - "Do they restart after encouragement?"

Objects refer to the items found within the environment (*AEIOU*, n.d.). They are building blocks, key elements, objects and devices people use and how they are related to their activities.

- O1 - "Which objects are used in the training?"
- O2 - "Is there any specific object used in the training of pirouettes?"

Users refer to the people being observed within the environment (*AEIOU*, n.d.). It sums up the behaviours, the preferences, the roles, the relationships, and their needs (Bose, n.d.).

- U1 - "How many gymnasts? And how many coaches?"
- U2 - "Does the gymnast react to all coaches the same way?"
- U3 - "The level of concentration of the gymnast during training (high, medium, low)"
- U4 - "Is the gymnast successful in the implementation of corrections?"
- U5 - "After how many repetitions can the gymnast implement the corrections and improve performance?"
- U6 - "After how many repetitions does the gymnast get tired?"
- U7 - "Is there improvement over time?"

4.1.1 Observation of Training Sessions Participants

Table 4.2 provides an overview of the characteristics of participants involved in observation phase. 11 female gymnasts, aged from 9 to 17 (Mean = 12.27), voluntarily participated in this study, and agreed to be recorded while doing so. The selection of participants was of an opportunistic nature - they were recruited from a rhythmic gymnastics academy in Aveiro - Aveirogym - where the researchers were based and with whom a good working relationship was maintained. Aveirogym promptly made themselves available to participate in all phases of the study. Participants were all young rhythmic gymnasts, who competed regularly presenting a great demand for improvement, participants were considered adequate participants. No gymnasts below the *initiation* age group were involved, because at that age, gymnasts still do not present the physical and psychological capacity to follow an autonomous training without the presence of the coach. No information was collected that directly allows the gymnasts identification.

The age group presented in the table represents the group where each gymnast is included in competitions and is in accordance with their age and year of birth: Benjamin - 6 years; Infant 7 - 8 years; Initiation 9 - 10 years; Juvenile 11 - 12 years; Junior 13 - 15 years; and Senior $>$ 16 years.

Table 4.2: Observation of Training Sessions Participants Characteristics

Participant	Age	Gender	Competition	Age Group
P01	17	Female	Yes	Senior
P02	11	Female	Yes	Juvenile
P03	16	Female	Yes	Senior
P04	11	Female	Yes	Juvenile
P05	12	Female	Yes	Junior
P06	09	Female	Yes	Initiation
P07	11	Female	Yes	Juvenile
P08	13	Female	Yes	Junior
P09	10	Female	Yes	Juvenile
P10	14	Female	Yes	Junior
P11	11	Female	Yes	Juvenile

4.1.2 Gathering consent

In order to get consent and since all gymnasts were underage, an informed consent form was addressed to their legal tutors, explaining the tasks that would be performed and the conditions of the study. The informed consent form included details about the researcher, the purpose of study, and confidentiality aspects. Deadlines for the first tests were mentioned and contacts for extra clarification were made available. The first declaration was delivered by email and required the tutors to print it, to sign and resend it to us. Due to the few responses received at this point and due to due to the increasing challenges posed by the COVID-19 pandemic, a decision was made to produce a new and easier declaration where tutors only had to fill out one online form that would be used for the entire duration of the study, rather than having new consent forms signed at each stage. Both of consent forms can be consulted in Appendix A: Informed Consent Forms.

4.1.3 Procedures

The study was conducted online, via zoom, as all training sessions took place during the COVID-19 pandemic. Five practices were observed, from March 04 to March 10, where each sessions lasted between 1h45 and 2h15. During the first practice session the researcher's webcam was off, so that gymnasts would not feel inhibited and had time to adapt. For the next four sessions, the researcher's webcam was on the whole time (Appendix B: Screens Shots of Observation of Training Sessions). The microphone was turned on just for the study presentation and turned off the rest of the time, so it would not interfere with the training session. The researchers took notes of main aspects noticed during the sessions, without having any kind of interaction with any of the participants. When the OTS ended, researchers reviewed the videos recorded in order to fully analyse and interpret all data according to the AEIOU framework, as described before.

The computer used to login in zoom was a MacBook Pro (Retina 13-inch, early 2015), 3.1 GHz Intel Core i7 dual-core processor. In order to record the sessions a LUMIX DC-GH5 DSLM Camera, Digital Single Lens Mirrorless Camera, was used. The computer was positioned on a large table, completely framed within the camera, which was strategically placed, so that the gymnasts could not see it. Since there were only 11 participants in class simultaneously, they all fit in the first window of the zoom meeting and so sliding between windows during the training was not needed.

4.1.4 Results and Interpretations

Observation data coding and analysis

Data coding and analysis is what forms the outcomes of the research. Data collection is limited to recording and documenting the sessions while the qualitative research is concentrated on analysing such recordings (Flick, 2014, pg.3). Qualitative data analysis often combines approaches of rough analysis of the material, like overviews and summaries, with approaches of a detailed analysis, elaboration of categories, hermeneutic interpretations or identified structures. The ultimate goal is often to arrive at generalise statements by comparing several materials (Flick, 2014, pg.4).

To code and analyse the observations of the training sessions, we decided to use a combination of two major strategies, **reducing complexity and big sets of data**, and **expanding the material by producing one or more interpretations** (Flick, 2014, pg.5). So, to start reducing data complexity, sessions were re-observed looking to individually answer each question proposed in the AEIOU method, starting with **activities** and continuing throughout the mnemonic (Figure 4.1). After answering all questions, we moved on to expanding the material, where the results were analysed and interpretations about them were made. Tables with the information gathered, handled and analysed can be found in Appendix C: Observations of Training Sessions Results. Next, we present a summary of the results obtained, which follow the organisation of the AEIOU framework and each of the questions included it main elements.

Activities

A1 - "How is the practice organised?"

All the five training sessions were structured with a sequence of activities. Although the exercises were not always the exact same, their nature and purpose were. They all started with a stretching and warm-up session, followed by a flexibility practice, balance training and pirouettes training (Table i).

By analysing the evidences collected and crossing information, it was concluded that it is important to follow a sequence of logical and well thought out exercises in order to prepare the gymnasts body. Coaches have to study a lot to be able to prevent injuries in gymnasts and to help to promote a good training method, so that gymnasts have good technical basis to properly execute every exercise (Palmer, 2003).

A2 - "How is the pirouettes practice organised?"

As in the previous result, also the pirouettes training was structured and followed a logic of exercises to prepare the gymnasts to perform pirouettes correctly. The practice started with balances, where the pirouette body position was repeated and maintained for as long as possible, with both legs and also trained to improve strength with *pliés* and *relevés*. For the less advanced gymnasts, it was suggested that they used the back of a chair as support (like a *ballet barre*) and for the more advanced gymnasts, the use of a gymnastics ball under the heel in the *relevé*, in order to create instability in the balance.

The second part of the training was dedicated to the promenades, where gymnasts had to complete at least one full turn, with no more than a 1/4 rotation at every impulse. They did the exact same body position as in the balances, to prepare the pirouettes. Finally they start practising pirouettes, where they were asked to implement all the techniques learned previously and repeat as many times as possible (Table ii).

A3 - "Level of difficulty of the training?"

The difficulty level changed throughout the training depending on the exercises. The stretching exercises were intermediate, but since gymnasts had been doing them for several months, they were all successfully adapted to them and thus executed them with few errors. The warm-ups with rope and music were a new exercise being introduced to the training at the time of the interviews. They were simple repetitive exercises, easily performed, but the younger and less advanced gymnasts had some troubles remembering the sequences, so in the first two training sessions they all remembered it together before performing with the music. In the flexibility session, the exercises were the same since the beginning of the season, so all gymnasts could perform them, leaving the success depending only on their physical capabilities. On one training session, more difficult flexibility exercises with rope were proposed, which led the less advanced gymnasts not being able to keep up. The balance training was accessible to all gymnasts, as it was slow and repetitive. The differences between levels were noticed in the perfection of execution - the more advanced gymnasts performed the balances for longer and with better execution, while the others presented several errors and stayed little time in the correct position. The pirouette training was the same for all gymnasts, but the ones who showed poor balancing skills, could not keep up with these exercises (Table iii).

Due to the different gymnasts levels, it was impossible to create one single workout that suited them all. So coaches tried to find a balance between the more advanced exercises and the more initiation, leading to the more advanced gymnasts to wait for the others to catch up, and least advanced gymnasts could not keep up with the training, inhibiting their improvement or even causing injuries, as they did not know how to perform correctly.

A4 - "How long is the average duration of the practice?"

On March 04, the practice was divided into four blocks, Stretching (10min), Flexibility (47min), Ball technique (20min) and Ballet (45min), making a total of 2h02 out of 2h15.

On March 05, there were six blocks, Stretching (10min), Warm up (15min), Flexibility (35min), Balance training (10min), Pirouettes training (5min) and Stretching (10min), making a total of 1h25 out of 1h45.

On March 09, there were only 3 blocks, Warm up (30min), Flexibility (60min) and Balance Training with and without ball (20min), giving a total of 1h50 out of 2h00.

In the first training, on March 10, there were seven blocks, Warm up (15min), Warm up feedback (7min), Flexibility (45min), Balances with ball plus with a step (25min), Pirouettes training (20min), Feedback and corrections (10min) and Ball technique (11min), making a total of 2h13 out of 2h15.

In the second training on March 10, there were six blocks, Warm up with rope and music (12min), Warm up feedback (12min), Flexibility (40min), Balances with ball plus with a chair (20min), Pirouettes training (8min) and Ball technique (8min), making a total of 1h40 out of 2h00.

All training sessions had almost the same duration (1h30 - 2h30) and the balance/pirouette training came at the end of the session lasting 20/30min (Table iv). It is important not to overtrain as gymnasts start to become tired and less productive and it is also very important to take breaks during the different exercises to rest and drink water.

Environment

E1 - "Where do gymnasts train?"

Throughout the sessions, four different training spaces were used, the living room, the hall, the bedroom and the playroom (Table v). The most used room was the living room, presenting the other rooms equivalent use. The majority of gymnasts always trained in the same room throughout the sessions. There were two pairs of sisters among the participants and sometimes they trained together in the same division. In the first observation session, P01 and P02 trained together in the living room, as well as in the session of March 10. The participants P08 and P09 also trained together in the first session in the playroom.

The gymnasts probably chose their training space taking into account maximisation of the free space so they could practice gymnastics safely. Since in the pavilion the training takes place in a fairly large space, they had to try to replicate the same space as much as possible at home, hence the large amount of gymnasts training in the living room, which is usually the largest space in the house.

E2 - "How much space do they need for practice?"

The training rooms varied from a minimum of 1.5m x 1.5m to a maximum of 3m x 3m of free space and the average of free space was close to 2m x 2m (Table vi). It was possible to see that the gymnasts with more free space were able to train better and more securely than the others, who sometimes had to dodge objects during the movements or even interrupt the exercises due to lack of space. Although for general gymnastics training it's needed a large and unoccupied space, for balance and pirouette training a space of about 3m x 3m is more than enough for good practice. Even if the space was bigger it could not be used because the zoom camera could not pick up more space and the gymnasts got out of sight.

E3 - "What is the training environment like?"

Most gymnasts tried to create an open space, moving furniture away and creating free space. In the rooms with less furniture it was possible for them to achieve it, but in the rooms fully furnished it was a hard task. Despite that all gymnasts presented themselves with a room with some considerable space to train (Table vii). With the sisters exception and the gymnasts living with the coach, all gymnasts were completely alone in the room, in order to be focused and to train without distractions.

Interactions

I1 - "How is the feedback given?"

During flexibility training, kinesthetic, verbal and visual feedback were presented. **Kinesthetic feedback** was only possible to achieve with the gymnasts who trained in the same physical room as the coach, as she had to touch and move the gymnast to apply the correction. Kinesthetic feedback was always supported by verbal complements reinforcing what was being done kinesthetically. **Verbal feedback** was given in 3 moments of the exercise: before, during and after. Before the exercise, where it was explained how to execute it and main issues to pay attention to, they served as reminders and goal and expectation setters and were present as narratives. During the exercise, as gymnasts did it, they were simple and specific words known by both gymnasts and coaches, that allowed easy and instant communication. Afterwards, the most obvious and biggest mistakes were pointed out, as well as what needed to be improved. **Visual corrections** were used to supplement verbal feedback, the coach used one of the more advanced gymnasts to follow the explanation and to follow the corrections as they were given, promoting first the chunking as they were dividing one exercise in multiple little steps, and after the mirroring as the other gymnasts

copied what they were seeing.

Balance training followed the same logic as flexibility training, since both were slow exercises where coaches could deliver various types of feedback in the different phases. Visual feedback was used in the beginning of these exercises to explain what was supposed to be done, usually with the help of a gymnast who did the exercise as coach explains it (chunking and mirroring). Kinesthetic corrections, only possible if both stakeholders were in the same physical space, were used to reinforce verbal corrections, so gymnast could feel what was supposed to be done, and sometimes unable to be done alone. The verbal feedback was used throughout the whole exercise, **before** to explain and remind the main issues to pay attention, **during** to correct instant mistakes and as motivational reinforcement to strive to the end, and **after** to correct what was done wrong, to explain how to improve it and as a form of encouragement to continue.

In pirouettes training, the feedback was also given through kinesthetic corrections, verbal and visual feedback. But as these exercises were really fast, the corrections differed from its predecessors in some aspects. The visual feedback, used to exemplify the correct execution and shown by one of the more advanced gymnasts (chunking and mirroring), also accompanied by verbal feedback, was given in two moments. **Before**, used to explain the correct execution and some issues to pay attention to. And **after** the exercise, to correct what was done wrong, to explain how to improve it and as a form of encouragement to continue. Exceptionally, it may be presented **during** the execution if the gymnast already knows what to do and as a quick reminder.

The four forms of feedback were presented to gymnasts during training sessions being **corrective** and **value** the most common ones. They allowed gymnasts to understand their errors and correct them, and motivated them as they could see that they were doing something right. Coach also delivered **neutral** and **ambiguous** feedback to gymnasts. This last was used when she was frustrated after correcting an error multiple times and gymnast not corresponding. Having in mind this is not the best approach because, especially younger gymnasts, did not understand its purpose and became confused. The neutral feedback was factual and descriptive and was used when an exercise was being explained at the same time as a gymnast performed it, making it easier to understand what was being done.

The feedback was **clear** and **simple**, and coach used key-words or key-phrases seemingly meaningless, but known by the gymnasts, making communication and corrections easier and faster (Table viii).

Due to the online training sessions, coaches felt the need to motivate gymnasts, they use a lot of positive reinforcement and even in corrections a motivational phrase was delivered. This way corrections served to directly correct the error and served as incentive and motivation.

I2 - "How does the coach analyse the movement and notice the mistakes?"

There was no difference in the observations of the training sessions conducted. In all sessions, the correction methodology used was the same - gymnasts executed the exercises while coach observed and analysed each movement narrowing their corrections to what they could see. The corrections were given based on empirical knowledge and without any support of technology or scientific data. This could lead to generic feedback that may not suit every gymnast, becoming useless (Table ix).

Coach also used kinesthetic practices to realise that the gymnast was already at her physical limit and from there give feedback appropriate to her difficulties. This situation was only possible with P01 and P02, because they were the only ones in the same room as coach.

I3 - "How many corrections are given to one gymnast?"

When gymnast could not perform the first exercise good enough, they would not get corrections on the second one, as happened with P06 and P09. If the practice would have been addressed to their level, they would probably not even change to the new exercise, staying in the first until they could get it right, receiving few and simple corrections (Table x).

The most advanced gymnasts - P01, P03, P05, P10 - received about three to four corrections during performance, with few exceptions. It was more direct feedback and in the easiest exercises received more congratulatory feedback. The remaining ones received reasonable feedback on both exercises, nearly always more than four. Gymnast P04 was the example that there were not enough coaches to the number of gymnasts, because she was doing the balance exercise too, but did not receive any feedback.

I4 - "How many corrections does the gymnast apply?"

The more advanced gymnasts - P01, P03, P05, P10 - were able to implement all the feedback received, as they understood what to do, but also the amount of feedback received was low.

The other gymnasts, even receiving a larger amount of feedback, did not manage to implement more than two corrections (four in the case of P11) (Table xi). Once they were still learning, they had split their attention and remember a lot of things at the same time.

I5 - "How many times do gymnasts repeat the exercise before and after corrections?"

Gymnasts did not repeat because they though it was important, but repeated until they felt they succeed at the exercise or coach said they did it well. The most of them get tired after three or four repetitions. Once they felt they accomplished their goal, they stopped doing it. Also P06 did not repeat bearing in mind how many times had done it, but until she got tired of the exercise (almost instantly) (Table xii).

I6 - "Do the gymnasts train alone or only when the coach is watching?"

All gymnasts had the same reaction during the two different parts of the training session. When they were practising alone, they stopped a lot and took long breaks in between repetitions, otherwise when the coach was leading the practice and imposing a training rhythm, all gymnasts, more or less successfully, were following the counts and training a lot more and more consistently (Table xiii). It is difficult to keep a high training pace without any external input and it was probably for this reason that gymnasts were more disciplined when the coach was making counts. They also trained harder when coaches were watching because they did not want them to be upset.

I7 - "Do they restart after encouragement?"

Again, all gymnasts had the same reactions. Each time they got complimented, they would smile and for the next two or three repetitions they would try their best again. Everytime they got complimented, they felt proud of themselves and felt they were doing a good job (Table xiv). Since they knew all eyes were on them in that moment, they wanted to show others that they could perform it well multiple times.

Objects

O1 - "Which objects are used in the training sessions?"

The objects used during the sessions were almost always the same: a **gym rope** for warm

up, a **wall** for flexibility, an **elastic band** also for flexibility, a **chair** to support the balances, a **gym ball** to promote instability in the *relevé* and **Music** (Table xv). In some training sessions a **step** was also used during the balance training and, on March 04, a **ballet barre** was also used.

It was perceived that a mirror was an important object to use during the training because gymnast could correct better themselves if they could see what they were doing, but because of the online training, just two gymnasts had access to mirrors during the sessions.

The rope was used during warm up because it promoted cardio training while doing the exercises and as it was a difficult it apparatus also improved motor coordination and technique. Both the wall and the elastic band were used during flexibility, which allowed gymnasts to go beyond their limit as they could apply counter-force and go further, the elastic band also stimulated strength training and body explosion. The chair, the step and the gym ball were used in the balance and pirouettes exercises (8.2, Table xvi).

The music was used in different moments making the training more rhythmical and pleasant. When the music was cheerful, the gymnasts were in a good mood and active, when the music was slower, some gymnasts stayed more concentrated, others got bored and stop working hard and the training stopped being productive.

O2 - "Is there any specific object used in the training of pirouettes?"

In every pirouette session was used an elastic band, a chair, a gym ball, and in addition in two of them was also used a step (Table xvi). The **elastic band**, with one point tied to each foot of the gymnast, was used to improve flexibility and help to define the position during balancing, helping the gymnast to reach a more extreme position while minimising the strength she had to exert. The **chair**, used to replace the *ballet barre*, supported the gymnasts when in balance, so they could hold the position for longer. The **step** created a higher level for gymnasts to climb and hold balance position, this enhanced the focus of gymnasts as they were holding a balance position far away from the ground and did not wanted to fall. Also climbing and holding being repeated multiple times, improved strength and agility. The **ball** was placed under the heel on *revelé*, creating instability and preventing the gymnast from lowering her heel during the exercise. This way they could understand how to regain and maintain balance, also strengthening foot and ankle muscles. The ball was also used as a rhythmic gymnastics apparatus, which was added to the exercise, increasing the difficulty level and preparing it for the competitions.

In these sessions only the ball was used as an apparatus due to the online training, as it's one of the smallest and the one that does less damage if hits something, but all the other apparatus can be used with the same purpose.

Users

U1 - "How many gymnasts? And how many coaches?"

In the first practice, there were between 17 and 25 gymnasts for two coaches, while in the second session there were 13 gymnasts for two coaches. On March 09 there were only 10 gymnasts and still two coaches, while in the last two practices there were 11 gymnasts to only one coach and five gymnasts to one coach, respectively (Table xvii).

It was really difficult for the coach to give corrections to all gymnasts in the correct timing, once there was only one coach for multiple gymnasts and she could not see everyone at the same time. Gymnasts had to train by themselves until their moment with the coach came and they could be corrected.

U2 - "Does the gymnast react to all coaches the same way?"

All gymnasts presented the same reaction to the different coaches (Table xviii). The differences existing were related to the kind of exercise being executed, seen with P02 and P07, who during fun and active exercises were making an effort and when it came to ballet training, turned off the camera or left the zoom session. They were also related to the way coaches presented feedback and instructions, seen with P06, that did not pay attention to anything coaches said unless they screamed and get mad with her.

The oldest and more advanced gymnasts tried their best regardless of the coach and the exercise being done. In general all gymnasts accepted the corrections and tried to implement them the best they could.

U3 - "The level of concentration of the gymnast during training (high, medium, low)"

The more advanced gymnasts - P01, P03, P05, P10 - presented a high level of concentration during all different training moments and the gymnast P11, even though was not the most advanced nor the oldest, also presented a high level of concentration in the sessions.

The gymnasts P02, P04, P07, P08, P09 presented an inconstant degree of concentration, at the beginning of the exercises they were concentrated, but as the training progressed the concentration decreased substantially. Only gymnast P06 did not show any degree of concentration throughout the whole training, maybe because she was very young and still did not understand its importance. It was also perceptible that ballet, being a very slow and physically demanding training, was the moment when some of the gymnasts found it most difficult to concentrate (Table xix).

U4 - "Is the gymnast successful in the implementation of corrections?"

It was possible to split gymnasts in two groups, the more advanced and older gymnasts and the less advanced ones. The more advanced group - P01, P03, P05 and P10 - understood the importance of feedback and tried to implement corrections received, being successful in the majority of times. The rest - P02, P04, P06, P07, P08, P09 and P11 - found it harder implementing corrections, either because they did not have the physical skills needed to do it, or because they did not understand or know how to do it, either because they did not understand the importance of corrections and they did not care (Table xx).

U5 - "After how many repetitions can the gymnast implement the corrections and improve performance?"

The most advanced group - P01, P03, P05 and P10 - could quickly understand and implement corrections, one feedback or maximum two, just to reinforce the first. This was true for both balances and pirouettes.

The remaining gymnasts needed two or three emphasis to implement corrections and it was necessary to explain and remind them about preview mistakes, in order for them to not repeat. Gymnasts P06 and P07 reacted better when the coach was upset and they implemented feedback quickly, maybe because they got afraid of being punished, the remaining times they almost never implemented any corrections. P02, as seen above, did not have any major difficulties but also did not show much will to improve, and perhaps this was why she only implemented corrections when she felt like it (Table xxi).

U6 - "After how many repetitions does the gymnast get tired?"

When the training session had an imposed rhythm, as a coach making counts or leading the exercises, all gymnasts trained at the same time, at a good pace and without long

unnecessary breaks.

Whereas, when the train was autonomous, no gymnast could maintain a good training rhythm (Table xxii). They repeated once or twice and stopped for long periods, only P11 got off to a good start on pirouette training repeating eight times the same exercise, but right after she took a break and got into the pace of the others.

It was easier to keep a good rate if an external party was controlling it, imposing a rhythm, otherwise gymnasts became unproductive.

U7 - "Is there improvement over time?"

Because the exercises were hard and take time to improve, it was not possible to see improvement in the gymnasts during these observation sessions (Table xxiii). But since all of them could do it, with or without some mistakes, it was assumed an evolution since the beginning of the training of these exercises.

4.1.5 Findings and Implications for Design

OTS data coding and analysis resulted in a series of tables of evidences and interpretations responding to the questions proposed initially. To understand the design implications these data were again analysed to understand in which way they would influence the application implementation and functioning. These implications influenced issues such as feedback, organisation of information, exercises presented, duration and intensity of training, among others, in the final application.

A1 - "How is the practice organised?"

Training organisation	The training session is organised in such way that every exercise had a specific intention and purpose in the preparation for the more advanced and more difficult exercises. For these manners, the application should be organised by **categories** and **difficulty levels**, with a section with **locked exercises** that only unlock if the previous one is already successfully accomplished.

A2 - "How is the pirouettes practice organised?"

Pirouettes practice organisation	Pirouettes training specifically is a very complex series of different exercises that if done successfully, lead to a good performance. For this manner, alongside with the previous implications, the application should have the exact same exercise sequence that was seen in OTS. Starting with a **Warm up**, followed by **Balance exercises**, **Promenade exercises** and finally **Pirouette exercises**. Since the smart insoles were made to analyse only the feet and weight distribution, we can only replicate *plié* and *relevé* exercises and analyse them. So for the warm up exercises, where it is needed to train flexibility and cardio, the application can **remind gymnasts that it is important to warm up** the whole body before using the application, in order to be ready to train without the risk of getting injured.

A3 - "Level of difficulty of the training?"

Difficulty level	Bearing in mind that each gymnast has her own level and that all gymnasts progress at different times, the application should adapt each exercise to the gymnast executing it. When the gymnast enters the application for the first time, a **level analysis** should be executed to integrate her in the proper level of difficulty. Once gymnast shows improvement and good results in the training sessions, a **level re-analysis** can be done to upgrade the current level in case it is needed. This way every gymnast should have exercises adapted to their difficult level and can evolve and progress at their own pace, preventing injuries and promoting a healthier evolution and learning.

A4 - "How long is the average duration of the practice?"

Training duration	More than training hard, it is important to train consciously and correctly. For this to be possible it is necessary to respect both training periods and breaks, bearing in mind that a full pirouette training should not last longer than 30 minutes, the **application should advise the gymnasts that 30 minutes is the maximum period** in which their bodies are fit for training and within they will get results, also that from then on it is **advisable to take breaks** to avoid injury and overtraining.

E1 - "Where do gymnasts train?" and **E2 - "How much space do they need for practice?"**

Space	When a gymnast uses the application, it is important to **advise her about the precautions and the needs** for the use. Issue an **alert with the specification of a 3m x 3m free space** for the application good use and gymnast security.

E3 - "What is the training environment like?"

Environment	Adding to the space defined previously, application should also **advise gymnasts that the space they choose shall not have furniture** in order not to hit anything accidentally and hurt themselves. And as one learns better when it is focused, application should also emit an **alert advising gymnast to train alone** and without any distractions.

I1 - "How is the feedback given?"

Feedback	Application should follow the training feedback format, **replicating timings**, **keywords**, **intentions** and **interactions**, in order to gymnasts notice little differences and easily adapt to these new system. The application should present different forms of feedback accordingly to the type of exercise performed. All feedback shall be presented in two modes, **visual**, either with images, written text or videos, and **verbal**, a description of what is visually presented or hearing complements. Knowing about the impossibility of applying kinesthetic feedback through the application, the other forms have to be so enlightening that gymnast understands what she has to feel during the exercise. In **balances** and **promenades**, feedback will be delivered in three phases, before, during and after the exercise. **Before** the exercise, with a set of instructions explaining the exercise (neutral feedback) and some common mistakes to watch out (corrective feedback). **During** the exercise, with key words and graphics, indicating mistakes being committed (corrective feedback). **After** the exercise is over, most obvious and biggest mistakes and what needs to be improved, as well as encouragement and motivation to continue. In the case of pirouettes and realising how fast and instantaneous is the movement, feedback should to fit its characteristics, so it will be delivered **before** and **after**, with exactly the same functions as in the previous exercises. Feedback should be **explicit** and **clear**, so that there are no misinterpretations.

I2 - "How does the coach analyse the movement and notice the mistakes?"

Movement analyse	The smart insoles give exact values of the movement being executed, these data will allow us to **inform gymnasts exactly what is being wrongly done** during performance and give the **appropriate feedback**.

I3 - "How many corrections are given to one gymnast?" and **I4 - "How many corrections does the gymnast apply?"**

Feedback quantity	The more **advanced** gymnasts can receive as **many corrections as needed** since they can implement almost all, although they generally do not need more than one or two. Communication should be done through **scientific language** and a **correct use of words**. The **intermediates** should **not receive more than three** different feedback in one exercise, as they can not implement more than this, and should be used a **normal language** with a **scientific explanation**. The gymnasts still in **initiation** shall **not receive more than two** different corrections in one exercise, and they should be presented with **normal language** and an **easy explanation**.

I5 - "How many times do gymnasts repeat the exercise before and after corrections?"

Repetitions	Although it is not constant, gymnasts tend to repeat three to four times before breaks. Application should **encourage gymnasts to do multiple repetitions** of the same exercise.

I6 - "Do the gymnasts train alone or only when the coach is watching?"

Training incentive	A rhythmical and accompanied training session is more efficient than gymnasts training alone, for this matter, exercises shall present an **incentive or an audible accompaniment to the exercise**, which gives the gymnast an indication of when to start and preventing unnecessary breaks. Also deliver **alerts if gymnasts take too long between exercises**.

I7 - "Do they restart after encouragement?"

Encouragement	Overly positive feedback does no good during training sessions. Although it is important to motivate gymnast to continue, it should be done consciously. **Motivation shall be occasionally** unless, in advanced gymnasts there is more than four corrections, in intermediates there is more than three corrections (even though only three are shown) and initiation if there is more than two corrections.

O1 - "Which objects are used in the training?" and **O2 - "Is there any specific object used in the training of pirouettes?"**

Objects	Once it is not possible to confirm if gymnasts are using the object correctly or even using it at all, application should only give **tips with exercises with objects** used during training (rope, ball, wall, chair, step, elastic band), for them to train and improve performance. Also allow gymnasts to **play music** during the use of the application.

U1 - "How many gymnasts? And how many coaches?"

Insoles purpose	The application will play the role of 2 coaches at the same time. It will **explain how to do the exercises**, **how to correct mistakes** and **give advice on how to improve and correct** what is needed. It will act as a **private coach**, analysing only one gymnast, capturing her mistakes and analysing during the whole duration of the performance.

U2 - "Does the gymnast react to all coaches the same way?" and **U3 - "The level of concentration of the gymnast during training (high, medium, low)"**

Reactions	The reactions do not depend on coaches but on the type of exercise being done, slow and long exercises have less acceptance by the gymnasts (especially younger ones). Application shall present **different forms for training the same exercise** and allow gymnasts to **choose what they want to train** in that moment.

U4 - "Is the gymnast successful in the implementation of corrections?"

Feedback implementation	Depending on the level, gymnasts implement a different number of correction, despite that, the application should **present a "special help" button** to give a more extensive and descriptive **instructions** to the exercise.

4.1.6 Summary and Discussion of Observation of Training Sessions

OTS data analysis and interpretations allowed the clarification and definition of some important design implications to the application. Questions related with feedback timings, training space and environment, difficult levels and training organisation were the main issues to keep in mind during this stage. It was noticed that feedback assumes very similar

patterns to those found in literature reviews whether in relation to timing, intentions and form. Training organisation and different levels of capacities led us to conclude that if the level is not customised to each gymnast, they will not be able to fully take advantage and benefit from the application. Keeping in mind that training at home is not common, it was tried to soak up as much information as possible from the OTS, in order to understand needs and obligations and later on, try to understand the differences felt by both coaches and gymnasts. Training organisation was also an important matter, as literature review better focused on ballet training instead of rhythmic gymnastics training, and was necessary to understand it to plan a correct application flow.

During this process, more questions came up, to which answers were not clear and for this purpose a series of interviews with gymnasts and coaches were prepared, hoping to gain a more in-depth and detailed knowledge. These interviews will be discussed in the following section.

4.2 Interviews

After the OTS there were still some questions left to answer and new ones came up, that raised the researchers' interest, given their potential for the project. In order to further study and deepen our knowledge, two sets of interviews were conducted, one with gymnasts and other with coaches.

Interviews are a method of data collection that involves two or more people exchanging information through a series of questions and answers (DeCarlo, n.d.). Although interviews may afford an easy and quick way to collect information, good preparation is required in order to have a successful outcome. While preparing the interviews, it is important to set a final goal, to arrange the scene and make users as comfortable as possible. Having some questions prepared and some follow-up ones to redirect the conversation to the research topic in case it is lost is a fundamental aspect for a good outcome (Pernice, 2018).

There are three types of users interviews, structured, semi-structured, and unstructured (NNgroup, 2019). We decided to conduct semi-structured interviews, whereby interviewers have some questions prepared - an interview/discussion guide - usually open ended that allow the participant to talk freely and the interviewer the freedom to ask probe in-follow questions and to change the order of the questions and spend longer time in specific questions, if getting good information from the participant (NNgroup, 2019). The interview guides used can be consulted in Appendix D: Interview Guides.

4.2.1 Interviews with Gymnasts

Interviews with gymnasts were conducted in order to understand some important aspects during training sessions from the learning perspective. These interviews have dealt with issues such as training dynamics and preferences, differences felt between home and the gym, feedback ways and timings, and some attitudes noticed in the OTS. The goals were to understand the best way to communicate with gymnasts, and how and why they react differently in certain moments during training sessions. The interview guide used for the interview with gymnasts can be consulted in Appendix D: Interview Guides.

Participants of the Interviews with Gymnasts

12 gymnasts (all female) aged from 9 to 17 (Mean = 12.42) voluntarily participated in this study, and agreed to be recorded while doing so. The selection of participants was the same as in previous OTS study, since we were interested in understanding attitudes and issues based on what we had observed. One gymnast joined the study at this moment, as she was unable to participate in the previous phase. All characteristics and ages remain the same as Observation of training sessions chapter, with the admission of the new gymnast (Table 4.3).

Table 4.3: Gymnast Interviews Participants

Participant	Age	Gender	Class	Competition	Age Group
P01	17	Female	Elite	Yes	Senior
P02	11	Female	Elite	Yes	Juvenile
P03	16	Female	Elite	Yes	Senior
P04	11	Female	Elite	Yes	Juvenile
P05	12	Female	Elite	Yes	Junior
P06	09	Female	Elite	Yes	Initiation
P07	11	Female	Elite	Yes	Juvenile
P08	13	Female	Elite	Yes	Junior
P09	10	Female	Elite	Yes	Juvenile
P10	14	Female	Elite	Yes	Junior
P11	11	Female	Elite	Yes	Juvenile
P12	14	Female	Elite	Yes	Junior

Procedures

The interviews, like to the OTS, were conducted via zoom, in a one-to-one conversation between one participant and the researcher. For this purpose, a zoom room was prepared to held the interviews with each gymnast. The interviews took place during the normal training schedule, where one by one the gymnasts would interrupt their training to enrol in the interview room. A researcher was waiting and as soon as the gymnast entered the room and settled in, she introduced herself and briefly explain the purpose of the interview, keeping in mind that it was important to leave the gymnast as comfortable as possible. Each interview lasted between 15 and 35 min each. During all interviews both users and researcher microphones were on the whole time, as well as their webcams. Interviews were recorded in order to researchers to be able to review the conversations at the end of the sessions, exhaustively analyse it and draw relevant findings. At this point consent was not gathered, as the participants had previously agreed to voluntarily participate in all stages of the study.

Results of the Interviews with Gymnasts

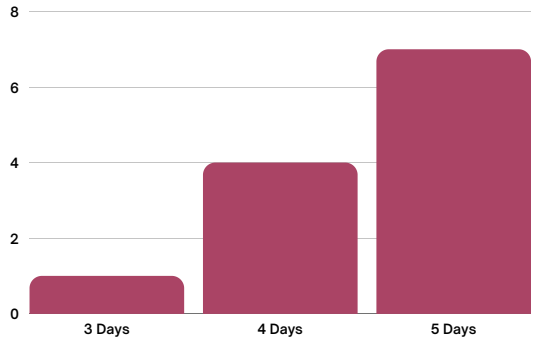
One of the main steps after conducting the interviews is the data analysis and interpretation. Firstly, the transcriptions of all 12 interviews were made to ensure that nuances of the interviews were captured. Since this project phase was designed to better understand what was seen on the OTS, we decided to use the interview results mainly to inform and complement the OTS results rather than to do an in-deep and comprehensive analysis.

As the interviews conducted were semi-structured with open and closed questions (Appendix D: Interview Guides, Gymnasts Interviews Guide), we decided to section the data analysis in two parts. We first analysed the closed questions and the most direct and factual information was organised, followed by the analysis of the more thematic and open ones, where the qualitative data was reviewed and interpreted more carefully.

The first four questions "What's your name?", "How old are you?", "How long have you been doing gymnastics?" and "What class are you in?" were made to make gymnast more comfortable, since all personal information needed to the study had already been collected in the previous research phase. Moving to the closed questions (CQ):

CQ1. How often do you train a week?

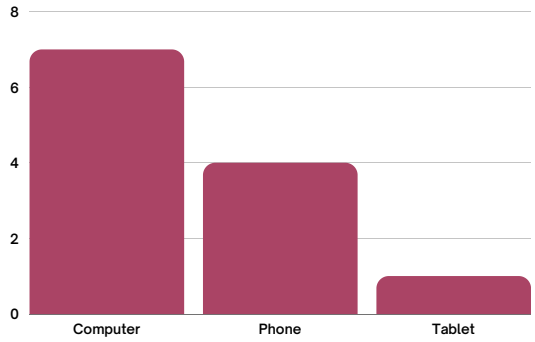
Table 4.4: Training frequency



Of the 12 gymnasts interviewed, seven train five days a week, four train four days a week and only one trains three days a week. All of them train between three to four hours per training session.

CQ2. Which electronic device do you use to attend zoom?

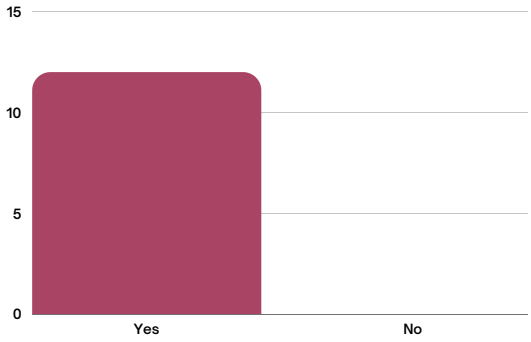
Table 4.5: Electronic device used



Regarding electronic devices used do attend zoom training sessions seven gymnasts use a computer, four use a phone and one uses a tablet. Although some gymnasts change electronic devices from one training session to the next, here are represented the most used one.

CQ3. Do you feel any difference training at home or training at the gym?

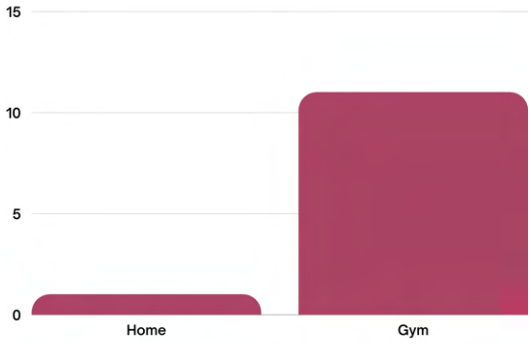
Table 4.6: Home/gym differences



When asked if they felt any difference training at home or training in the gym, all gymnasts answered yes. They said it is easier to train at the gym because they have friends with them, the circumstances are better and it is easier understand the exercises and have a better performance.

CQ4. And in which would you rather train?

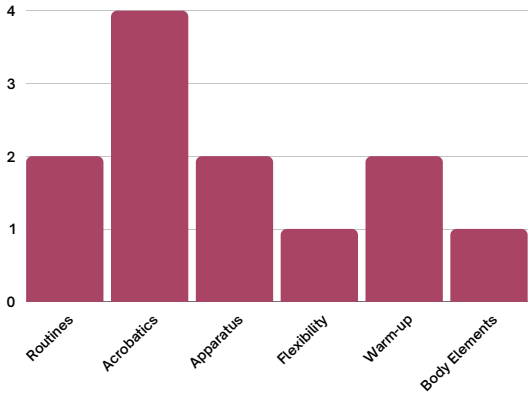
Table 4.7: Preferred training location



Only one gymnast answered that she preferred training in her house instead of training at the gym, like all the other gymnasts. She said it was because she lived far away from the gym and training at home allowed her to spend more time with her family, but she also stated that if she lived near the gym, she would prefer to train there and not at home.

CQ5. Which part of the training do you enjoy the most?

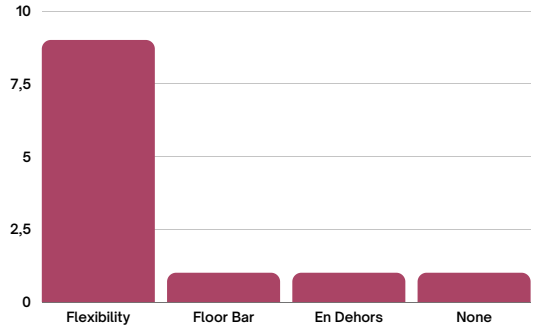
Table 4.8: Favourite training part



Although a wide variety of responses have been received, almost all are related to dynamic and active exercises, which require more physical condition and exigency but which in the end offer more fun.

CQ6. Which part of the training do you enjoy the least?

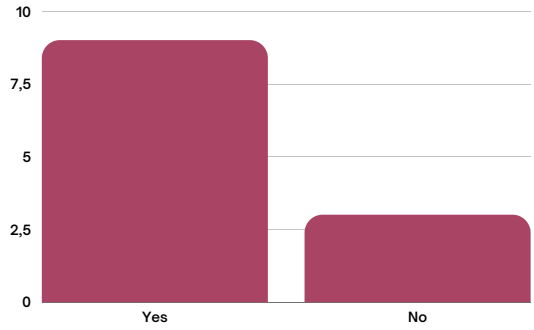
Table 4.9: Least favourite training part



Again, and although there are different answers, the exercises indicated are slow and long, which require a great degree of concentration and the ability to endure pain, ending up not being as fun and cheerful. The flexibility is by far the least liked exercise.

CQ7. Do you like balances training?

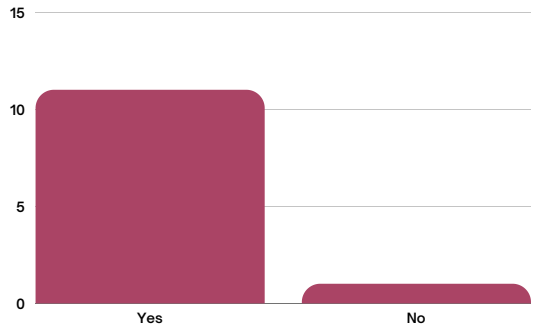
Table 4.10: Balance training opinion



Regarding balances training, nine gymnasts answered they like training them, whereas three answered they do not like it. Those who answered that they do not like training balances are three of the younger gymnasts and said they were very slow and boring exercises. The rest said that although being slow exercises, they were also challenging because gymnasts had to balance all their weight in one leg, maintaining a perfect body figure. As they can easily perceive if they are doing it correctly, it is also easy to feel proud when they outdo themselves.

CQ8. Do you like pirouettes training?

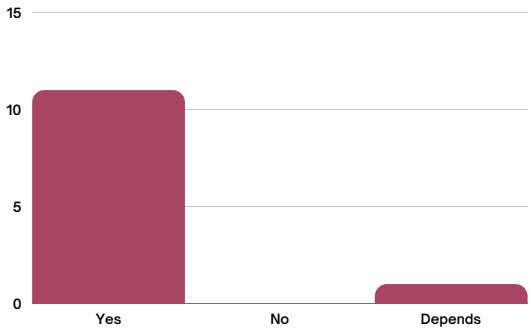
Table 4.11: Pirouette training opinion



Only one gymnast said that she did not like to train pirouettes, quickly justifying that it was because she did not know how to do them well. All the others gymnasts stated that they like to practise pirouettes, and with great enthusiasm. To the more advanced ones, because it is a more challenging exercise, the rest like it because they are spinning and moving really fast like a "roller coaster".

CQ9. Do you like to receive corrections or do you prefer to train without them?

Table 4.12: Training with/without corrections

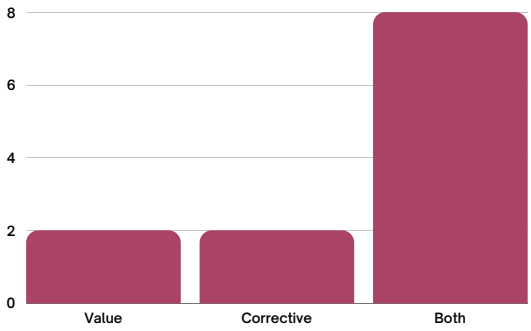


The same gymnast who did not like to practice pirouettes also answered differently from the other gymnasts to this question. She prefers to train with or without corrections depending on the coaches mood, if the coaches are nice, she prefers with corrections, otherwise she prefers without corrections.

All the other gymnasts answered they preferred a training session with corrections because they can understand what is being wrongly done and correct it in order to improve performance.

CQ10. Do you prefer value or corrective feedback?

Table 4.13: Value or corrective feedback

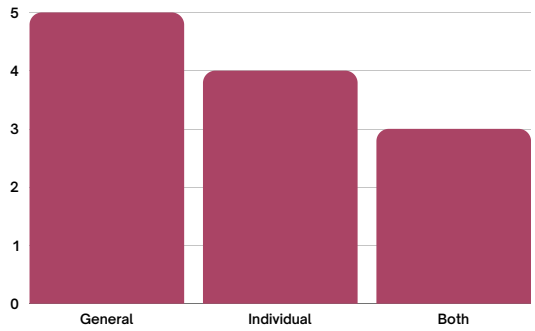


The two older and more advanced gymnasts, although understanding the importance of corrective feedback, prefer only value corrections when training in group so the younger gymnasts, who look up at them, do not realise their errors. Bearing in mind that older gymnasts nearly always understand their errors and know how to correct them. Whereas the two younger gymnasts prefer only corrective feedback, so that way they really understand what is supposed to be done and do not get confused.

All the rest prefer both value and corrective feedback, so they know what is supposed to be corrected, improve performance and also to be able to feel proud and motivated once they are improving and learning new skills.

CQ11. Do you prefer general or individual feedback?

Table 4.14: General or individual feedback

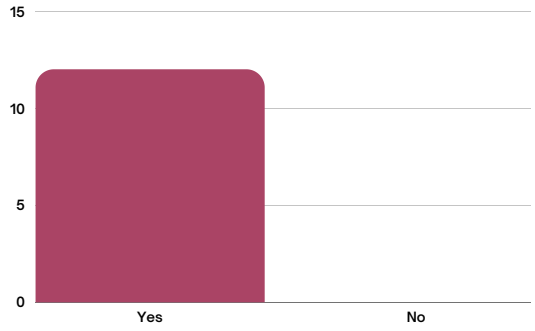


The responses were very mixed, five gymnasts prefer general feedback, four wish for individual feedback and three like both types of feedback. Gymnasts who answered general feedback justified it with being ashamed of doing something wrong in front of others and this way corrections were to everybody and not exclusive to them, whilst the ones who answered individual feedback said that they can not understand if general feedback applies to them, so they can not improve over time. The ones who have chosen both gave a justification covering the previous two: some individual feedback so they know it is for them and easily correct important errors, mixed with general and more vague feedback so they do not get embarrassed of doing a lot of wrong things.

When they were asked to think of an ideal scenario where in a room full of gymnasts only the person herself would listen to the corrections, they all replied that they would prefer individual feedback.

CQ12. Do you feel feedback helps you improve performance?

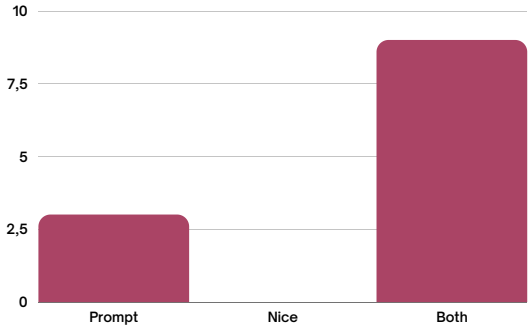
Table 4.15: Improving through feedback



All gymnasts replied affirmatively, letting us to realise they understand the importance of feedback and the importance of properly implement it, wishing to improve performance and correct significant errors.

CQ13. Do you prefer more prompt or more nice feedback?

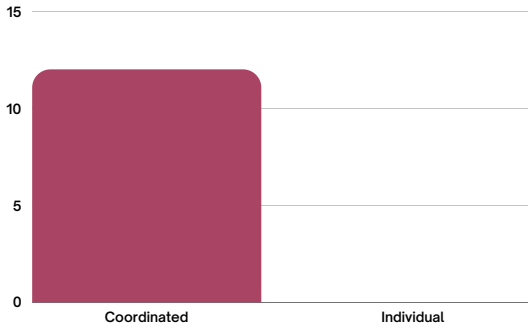
Table 4.16: Feedback prompt or nice



The older gymnasts would rather receive more prompt and direct feedback since they are grown up and have a certain maturity that allows them to understand the importance of feedback even if it is not delivered in a nice way, solely focusing on the goal. While the younger gymnasts get anxious when they are shouted at or when they are spoken to in a more abrupt manner, so they prefer to exactly know what they are doing wrong but in a softer mood.

CQ14. Do you prefer coordinated or individual training?

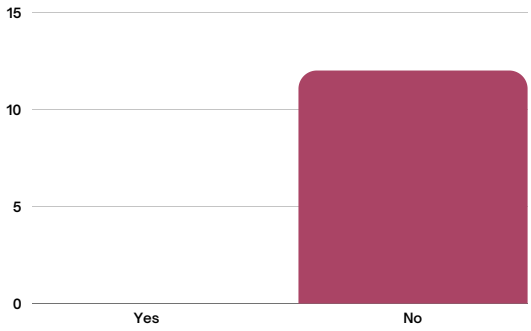
Table 4.17: Coordinated or individual training



All gymnasts replied they prefer a coordinated training session, where the coach is imposing a rhythm and training pace. This way they feel obligated to comply with that pace and hence taking fewer and shorter breaks, getting a more productive training.

CQ15. Do you train at home out of training hours?

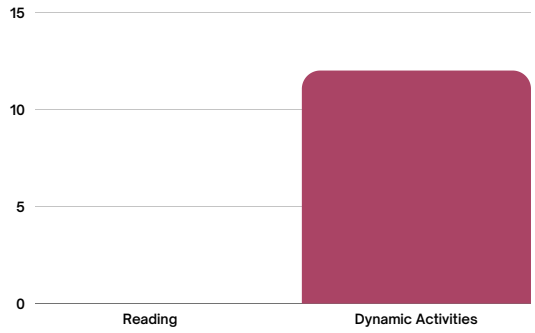
Table 4.18: Independent training



None of the interviewees trained regularly at home out of the training hours because they do not get motivated to train alone and it involves a great deal of logistics to set up everything and also prepare the body to work properly.

CQ16. Do you prefer to learn by reading or through dynamic games and activities?

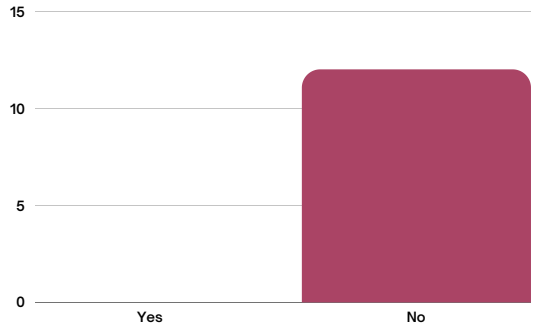
Table 4.19: Reading or dynamic activities



Another question that all gymnasts answered the same. They all prefer to learn with fun and dynamic activities instead of just reading and remembering subjects. They all said that learning while having fun is a lot easier and faster than normal education, and they also said that being able to compare results with other participants would be more exciting and challenging as they are gymnasts and really enjoy the competitive nature of the sport.

CQ17. Do you remember all feedback received throughout training sessions?

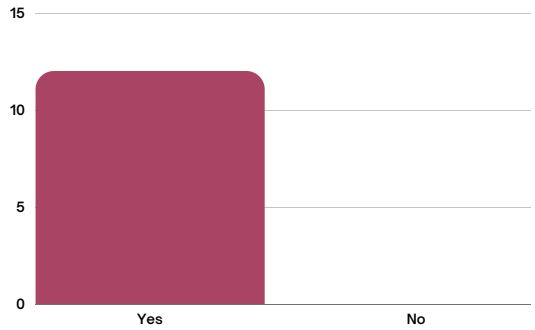
Table 4.20: Remembering feedback



According to gymnasts, it is almost impossible to remember all feedback received during a week without writing it down or save it somewhere, due to the big amount of corrections and opinions on the different exercises practised.

CQ18. Would you like an application to help you improve pirouettes performance?

Table 4.21: Help of an application



Not only did all the gymnasts say yes, but they were very enthusiastic about the idea and this project, saying it would be a great add to what is available right now, and an excellent support and working tool for the development of gymnasts.

The CQ are here presented in a formal and prompt way. During the interviews they were delivered along the conversation and in a manner adapted to the age of each gymnast. The open questions (OQ) appeared during the conversations and whenever was felt necessary to complement what was being discovered with the CQ. The OQ were not the same to all gymnasts, since it depended on the information researchers were getting. This questions were all transcribed and analysed, crossed with previously gathered information and summarised to easily reach conclusions.

Now on the open questions (OP):

OQ1. Why did you choose that spot to train?

Regardless of the type of spot chosen, the explanation was always the same. They all said they choose it bearing in mind the maximisation of free space and conditions to train. They valued big and open spaces as much as they valued mild temperature and more comfortable floor, so when choosing between two big rooms, they would go with the more comfortable one. For those participants who changed divisions across different training sessions, was also asked why they did it so, and they replied it was due to the presence of other people in the room and that they preferred to train by themselves not to get distracted.

OQ2. Why did you choose that electronic device?

The gymnasts who answered computer said that they preferred a big screen so they could understand what was being shown and could also see other girls. When they were asked if they would change to a phone if the images displayed were big enough, all of them said yes, and got excited because they would be able to take the device to other places more easily.

The four gymnasts who said phone stated that it is easier to use, more manoeuvrable and it does not take up as much space as the computer. And also the majority of them did not have their own computer, and the one they have home is not always available for them to use.

The girl who answered table said that she did not had a computer to use and the zoom application does not work on her phone. But if she could choose, she would pick the phone.

OQ3. How is the pirouette training session structured?

Despite some nuances, with more or less detail, all gymnasts responded in the same way and presented the same exercise sequence. Briefly the pirouette practice starts with some warm-up to prepare the body, followed by balance training, promenade training and finally pirouette training.

A lot of gymnasts also mentioned flexibility training and some phases with the use of external equipment to the basic exercises, such as the use of an elastic band or a ball. These extra workouts are really good to assist on the pirouette practice but are not part of the original training, so they can be mentioned and explained on the application, but not really present as actual exercises.

OQ4. Are you always able to implement corrections? If not what do you think the problem is?

The older and more advanced gymnasts have a better body proprioception and can understand when they are doing an exercise well or not, therefore making it more easy to implement corrections. They said that when they can not implement corrections it is because of a lack of physical ability and not a lack of understanding.

As for the younger ones it is harder to always implement corrections, since all of them stated that sometimes they do not understand what is supposed to be done and therefore can not correct what is wrong. They prefer simple and easy language and smaller corrections so they can understand what to do.

OQ5. How do you feel when you receive different types of feedback?

The answer was common to all. When the feedback is value and positive they get really proud and happy because they realise they are doing it right and the effort is worth it. And when they get more corrective and harsh feedback, they get really attentive and endeavour to implement it so coaches do not get mad at them.

They also replied that regardless of the type of feedback received they really enjoy to receive it because they feel monitored and feel there is someone who worries about them, watching what they are doing.

OQ6. Do you spend a lot of hours a day on your mobile phone? If yes, doing what?

All the answers were promptly delivered as positive, they all stated they spent hours on the phone, on school breaks, even at home. The younger ones spend more time playing games and watching videos, while the older ones do not like to play games anymore and rather spend time on social media and talking to friends.

OQ7. Why do you turn off the camera/leave the room during training sessions?

This question was asked to the two gymnasts who turn off the camera on several moments of the training sessions and left the zoom room before it was supposed to. First they got embarrassed and then said it was due to the type of exercise being done, or they were hard exercises that hurt a lot and they did not want to do them or was the ballet class and it was really boring and slow and they left so they did not have to do it.

OQ8. Why wont you pay attention to feedback and do not try to implement it?

The last question was specifically asked to the younger gymnast because she was the one who did not care about feedback and did not implement any in OTS. Analysing now by the interviews, she understands the importance of the feedback and knows it is important for the improvement, but when putting into practice she said that it is really hard to remember and understand it, so she gives up and does not make any effort to implement it.

Implications for Design of the Interviews with Gymnasts

After cross-referencing the data from the OTS with the results from the interviews it was possible to clarify some doubts and uncertainties that arose after the analysis. The electronic device chosen to design and build the application took us time to decide due to the feedback received during the interviews, as the opinions were divided between phone and computer. After carefully deliberating, it was decided to build an application for mobile so that users could use it anywhere and anytime and also because the projects target audience is mostly composed of young girls who do not have a personal computer to use as they wish. It was also perceived that even though a phone was being used to build the application. It is important to keep the images big, so gymnasts can easily see them during application use. Once gymnasts prefer to train in the gym, the application should replicate its strengths, keep gymnasts interconnected and deliver simple explanations. The

application should be dynamic and catchy as gymnasts enjoy the most when exercises have these characteristics and have a harder time with slow and demanding on pain level exercises.

At this stage of the investigation, it was possible to realise that all gymnasts understand the importance of feedback and like to receive it, but are not so fond of others knowing their mistakes too. For these matter, the application shall always give written feedback and allow gymnasts to choose if they also want to hear feedback or enable them to turn it off. The feedback should be straightforward but also be delivered in a nice way. They are also aware of the importance of a structured training session and as previously seen the application will have to maintain that structure and exercise sequences.

The training rhythm and pace should be controlled by the application in order to keep it constant and worthwhile. A spot will have to be present in the application where gymnasts can consult previous feedback whenever necessary.

Having analysed the results of the interviews with gymnasts as well as the implication for design of those interviews, the next section focus on the interviews with coaches.

4.2.2 Interviews with Coaches

Interviews with coaches were also conducted to learn more about the coaching perspective. Although the application is not completely targeted at coaches, it is important to perceive their job/role during the training session, since the application will somehow take the role of the coach during its use. Therefore to understand how to interact with gymnasts, how to gain their attention and how to analyse and correct an exercise, are essential concerns to review and scrutinise, so that the application resembles as much as possible the real training experience. The interview guide used for the interview with coaches can be consulted in (Appendix D: Interview Guides, 8.2).

Participants of the Interviews with Coaches

Four female coaches aged from 24 to 43 (Mean = 32.5) voluntarily participated in this study, and agreed to be recorded while doing so. Since we were working with a rhythmic gymnastics academy in Aveiro - Aveirogym, the participants involved in this stage of the interviews were also from the existing group. Since it is a relatively small academy, they only have four active coaches, so we could only carry out four different interviews to assist the study.

Table 4.22: Coaches Interviews Participants

Participant	Age	Gender	Years as a Coach	Competition Coach
C01	43	Female	23	Yes
C02	30	Female	11	Yes
C03	33	Female	13	No
C04	24	Female	04	Yes

Procedures

Following the example of the gymnasts interviews, and since our goal is also learn more about coaches topic and opinions, it was decided again to conduct semi-structured inter-

views, having some prepared questions in an interview/discussion guide. With a set of open-ended questions and a few closed sections, our goal was for coaches to be able to express their ideas in this topics and receive direct and objective answers to key aspects. Once again interviewers had the freedom to change the order of the questions in the guide and use more time whenever it would be beneficial.

A zoom room was again prepared to held the interviews with each coach. This interviews have taken place outside the training time, so that it would not interfere with the proper functioning of the training sessions, since without a coach, the training does not run smoothly. When the coach entered the zoom room, a researcher was waiting, and as soon as she was settled in, a quick introduction was made and the purpose of the interview was briefly explained, trying always to leave the coach as comfortable and pleasant as possible.

Results of the Interviews with Coaches

After the interviews, a transcriptions of all four interviews was made to understand the discourse and not to miss details. As a continuation of previous interviews, these ones were also designed to better understand what was seen on the OTS and so it was not needed to go much deeper into analysis, keeping it simple and enlightening.

The first four questions "What's your name?", "How old are you?", "Do you train a competition class?" and "How many years have you been a coach?", were made to make coach more comfortable. Now on to the questions for coaches (QC:):

QC1. What gymnastics qualifications do you have?

Table 4.23: Formation

COACH	QUALIFICATIONS
C01	*FIG* grade III coach
C02	*FIG* grade II coach *FIG* grade international judge
C03	*FIG* grade II coach *FIG* grade national judge
C04	*FIG* grade national judge

All coaches have an official *Fédération Internationale de Gymnastique* (FIG) course. Whether as a coach or a judge, or both. We can confidently vouch the information collected with this interviews, despite the small sample size group, is trustworthy and reliable.

QC2. How long you think is adequate for the duration of a training session?

Table 4.24: Training duration

COACH	TRAINING DURATION
C01	<8 years - 2h - 3x a week <12 years - 2h30m - 4/5x a week +13 years - 3h/4h - 5/6x a week
C02	It depends on the gymnasts, but never < 1h for younger gymanasts and never <2h for oldest gymnasts
C03	3h/3h30
C04	3h

It was clear the duration of the training sessions is not consistent and varies according to the gymnasts age, time of year and technical level. The younger gymnasts are, the quicker practice should be, increasing in duration with their progression. Practices should not linger less than one hour in the formation classes and less than two hours in the competitions classes. In any case, practices should not over four consecutive hours.

QC3. And a balance or pirouette practice?

Table 4.25: Balance/Pirouette training duration

COACH	SPECIFIC TRAINING DURATION
C01	15/20m
C02	20m
C03	15/20m
C04	15/20m

As these are more specific exercises and require a lot of repetitions of the same position, coaches explained one should not train for more than 20 min, since from then on it is no longer recommended.

QC4. How do you organise your training session? How do you decide on the exercises and know which ones to choose?

Table 4.26: Training structure

COACH	TRAINING ORGANISATION
C01	Stretching the main muscle groups and warm-up. Feet strengthening, impulsion, balance and active flexibility.
C02	Stretching, Physical exercises, Strength, Flexibility, Competition Exercises.
C03	Stretching/Warming up, Specific physical preparation, Flexibility, Body elements, Competition Coreographies.
C04	Warm up, Physical preparation, Flexibility, Specific Training, Competition Coreographies.

Depending on the phases and periods in which the gymnasts are (pre-season, pre-competitive period, competitive period), the selection of the exercises is based on what coaches consider important in relation to the current phase and which will help to work on future exercises. Exercises are evaluated on their effectiveness in training and chosen based on that. For the general training session, coaches answers have all covered the same aspects of the training. Starting with a warm-up and a stretching session, moving to a more physical and specific exercises and body elements. Closing with competition exercises and choreographies.

QC5. And what does good balance/pirouettes training consist of?

Table 4.27: Balance/pirouette training

COACH	BALANCE & PIROUETTE TRAINING
C01	Static and dynamic balance, active flexibility, promenades, correct positioning
C02	Give priority to the support foot, the shape and flexibility of the exercise
C03	Isometric positions, correct body placement, muscle activation. Dynamism and movement exercises
C04	Flexibility, promenades, overall balance, static and dynamic exercises

A good balance and pirouette training, should firstly have a floor *barre* or *ballet barre* where the support foot is privileged. The shape and positioning of the balance and pirouette should be also worked on and flexibility exercises executed, directed towards that same element. Static and dynamic balances, muscle preparation and a correct execution technique were also addressed as important complements.

QC6. Difficulties experienced during training?

Table 4.28: Difficulties during practices

COACH	DIFFICULTIES ENCOUNTERED
C01	The inability of being with a gymnast from the beginning to the end of the training.
C02	Divide the attention among many gymnasts
C03	Maintain the gymnasts' focus over a long period.
C04	Keeping an eye on all gymnasts and without them getting distracted

The biggest difficulties outlined were related to not being able to accompany the gymnasts from the beginning to the end of the training. Gymnasts have a lot of work that they have to develop independently. Also maintain the gymnasts' focus over a long period of time was pointed out. As help, strategies can be applied to suit the technical level, age group and individual characteristics.

QC7. How do you analyse the exercises/on what basis? And how do you know what is right or wrong and what corrections to give?

Table 4.29: Exercises analysis and correction

COACH	EXERCISES ANALYSIS
C01	Based on observation on the training and filming footage
C02	Watching gymnasts as they perform the exercise. Previous knowledge and experiences)
C03	Relies on observation of the exercises
C04	Seeing the exercise performance and its outcome

All four coaches analysis are based on observation of the performance of the exercises and on previous experiences. They stated the alignments, the preparations and the receptions are fundamental. The execution shall be harmonious from preparation to final phase. They find the corrections with the analysis of these points, and they are also decided according to what they have been learning and gathering through the years. Coaches mentioned they still rely a lot on the help of those who have been in the area for longer to help them to evolve.

QC8. How are these zoom training sessions going? What differences do you feel? Positive and negative points?

Table 4.30: Zoom training sessions

COACH	ZOOM TRAINING
C01	Positive - train more body control and flexibility. Negative - corrections without the coach's touch and they generally train looking down.
C02	Positive - a greater interaction with the gymnasts' families Negative - less motivation and no possibility to go and help
C03	The greater difficulty in having the gymnasts attention, greater heterogeneity of the classes reorganised, the difficulty felt in correcting the exercises.
C04	Positive - Helped on maintaining the trainings Negative - Gymnasts get distracted more often and do not understand exercises

Contrary to expectations, there were presented positive and negative points. The positive were related to the help in maintain a routine and allowing trains to continue, and the obligation on more simple and specific training sessions that enabled gymnasts to evolve a lot on technique. There was also a greater interaction with the gymnasts' families, since at these times they had to rely a lot on the help of the parents. But also the training at zoom has proved to be very challenging, having a greater difficulty in having the gymnasts attention, classes with different levels mixed and difficulties in correcting the exercises. There is always less motivation when the training is online. Once gymnasts can not be corrected with the coach's touch, they often do not understand the error. Another big point has to do with the fact that gymnasts train looking down, since the computer/phone is on the ground, developing a poor technique.

QC9. How did you adapt to this new reality and what strategies did you have to adopt to be as effective as possible?

Table 4.31: Adaptation and strategies

COACH	STRATEGIES USED
C01	Different contents and different areas classes: ball technique class, ballet class, contemporary class, choreography class...
C02	Using different stimuli. Give challenges and set goals.
C03	More playful moments during training time.
C04	Being more positive and alternate exercises between workouts to create new dynamics.

For coaches, to adapt to the zoom training was not an option, it had to happen for the benefit of gymnasts. It was necessary to look for exercises that they could do themselves without risk. Activities had to be dynamic, it was important to promote different training and different activities so that a monotonous routine would not become unmotivated for gymnasts. Challenges were implemented, goals set and objectives defined every week for gymnast to felt it was important to continue to work with the same dedication and to have the will to overcome themselves.

QC10. Do you feel a difference in the gymnasts, from pavilion to zoom? In what aspects?

Table 4.32: Differences felt in the gymnast

COACH	DIFFERENCES FELT
C01	There are differences, but the zoom was a lesser evil.
C02	Gymnasts more absent and can not focus for a long time
C03	In the gym are less distracting elements and there is a physical presence of the coach
C04	The communication between both coach and gymnasts is harder

Despite of the zoom being the lesser evil in all this situation, differences are still felt. Gymnasts are less involved and absent, they end up not being able to focus for a long time. Communication between both coach and gymnast is harder to be performed. It is very different for coaches to be on a screen trying to look at various squares, and it's very different for gymnasts to see coaches in a square and doing the same exercises and not feeling the touch and the help. The physical presence of the coach ends up involving them more actively in the training.

QC11. How do you motivate them?

Table 4.33: Motivation

COACH	HOW TO MOTIVATE
C01	Different classes, games, challenges
C02	Corrections, incentives and compare evolution
C03	New or playful activities, asking them to exemplify exercises
C04	More ludic activities, delivering motivating words and with challenges

By creating different exercises each train and promoting ludic and playful activities. Motivation is done daily with all the corrections, with incentives, and evaluating the progress and how far gymnasts have reached. Setting challenges, goals and planning activities in which they show their evolution and are really working towards a goal, increases their motivation and training sessions became more productive. Motivation is also increase with compliments and congratulations on the performance of good exercises, gymnasts feel proud and strive to continue.

QC12. What do you think works better, "less nice" and more direct corrections, or corrections that are more encouraging and more "sweet"?

Table 4.34: Type of corrections

COACH	CORRECTIONS TYPE
C01	I am all for empathy and encouragement in correction
C02	Corrections must be direct, objective and clear, but also "sweet"
C03	Depends on the sport season, level of the gymnast, the age group and individual characteristics. There should be a balance between the two forms of correction.
C04	Although prefering "nicer" corrections, sometimes they respond better to others

A little bit of both. Corrections can be and should be direct, objective and clear, but also "sweet". The clearer and more succinct the information is, the better gymnasts will understand it. If coaches can exemplify or show examples, the better. With no need to be rigid about it once gymnasts can became reticent or afraid of reprisals and its purpose is not fulfilled. Usually coaches adopt a more rigid posture when it a gymnasts has effectively been corrected many times and when it is felt that the gymnast needs such a posture to react.

QC13. General or individual corrections? Why? Does it depend on the gymnasts?

Table 4.35: Deliver general or individual corrections

COACH	GERAL OR INDIVIDUAL CORRECTIONS
C01	Both are important, depends on context and gymnast.
C02	Depends on both gymansts and type of mistake.
C03	It depends on the gymnast and what is to be corrected.
C04	It will depend on the type of correction and the gymnast in question.

General corrections allow all the gymnasts present to listen and assimilate them. Individual corrections allow to refine issues. It depends on the gymnasts, but it also depends on the error. If it is something that is common to all gymnasts and that has been repeated a few times, coaches do it in a general way. If it is something very specific, that has already been corrected in the same gymnast and it is something that already causes her some aversion, it is better to do it in particular. On the other hand, there are gymnasts who do not like to be corrected, if corrections are given to the group, they are better accepted.

QC14. What feedback do you use during training?

Table 4.36: Feedback used

COACH	TYPE OF FEEDBACK
C01	Talking, showing and by applying feedback on them
C02	Correcting their positions, visually providing help and through verbal complements
C03	Visually, Audibly and through touch
C04	Visually demonstrating, verbally explaining and physically correcting

The four coaches use the same three methods. Visual feedback to show what is supposed to be done, with or without a gymnasts help. Verbal feedback in order to explain what is needed to or the give audible guides. And although explained without the correct term, they also use kinesthetic feedback, to assist gymnasts and help them achieve the desired result. They also explained the opt for positive reinforcement most of the times. They try to make sure there is something positive to say and try not to correct everything that did not go so well at the same time to avoid them feeling demotivated.

QC15. How do you know how many corrections a gymnast can implement and what her limit is?

Table 4.37: Corrections quantity

COACH	FEEDBACK QUANTITY
C01	Is related to the age and technical level, but it preferable to give one or two corrections at a time
C02	Depends on the gymnast but too many corrections at a time are not learnt
C03	Depends on multiple aspects, but especially depends on the ambitions of the gymnast
C04	Younger gymnasts can not take more than 2, while the more advanced ones can manage a higher number

Once again, it depends on the phase of the sport season, the technical level of the gymnast, the age group and individual characteristics. It is important to understand what the gymnast wants, aspires to or is willing to give, because if the coach ambitions more than the gymnast, it is not worth insisting. Younger gymnasts do not have the capacity to acknowledge more than two corrections at a time, while the more advanced gymnasts usually manage well four corrections at a time, although most of the time they do not receive as many, since it is not needed.

QC16. Do you feel they are motivated by the corrections or does it make them give up training?

Table 4.38: Motivation through corrections

COACH	DO CORRECTIONS MOTIVATE?
C01	I believe the correction stimulates the pursuit of success.
C02	When gymnasts understand what to do and see results, they feel more motivated
C03	They are usually motivated, when that do not happen it is important to talk with them.
C04	They feel happy and train harder

When gymnasts really understand and can see the result of the corrections, they became very motivated. Corrections instil a positive feeling and an extra drive to train because gymnasts feel that someone is supervising them. It is also important to be alert and understand the signs, if so, talk to the gymnast about what is worrying her and the existent problems, not letting her give up.

QC17. When to give corrections to an exercise and why?

Table 4.39: Corrections Timing

COACH	WHEN TO DELIVER CORRECTIONS?
C01	When gymnast is doing something wrong. The first time trying an exercise is mandatory.
C02	On multiple errors without improvement and on new exercises
C03	On new exercises and there are several failed attempts at execution.
C04	When they are doing an error multiple times.

When it is a new exercise, when it is perceived that there are several failed attempts at execution on the part of the gymnast. It is possible to call attention to the focus, exemplify corrections, film and analyse the exercise with her.

QC18. What do you have to pay attention to when teaching balances? What about pirouettes?

Table 4.40: Focus of attention on training

COACH	BALANCES & PIROUETTES IMPORTANT ISSUES
C01	A good vertical body position, knowing how to used muscles, the support foot and the spotting.
C02	The supporting foot positioning, the correct alignment and the spotting.
C03	Activation of the support leg, correct placement of the body and vertical body position.
C04	The supporting foot, the spotting and the positioning.

In both balances and pirouettes, the focus is the same. The activation of the support leg. It is important to explain and make gymnasts understand the importance of the support leg, it is this leg that will support the weight of the body and therefore has the main task. The shape of the element is also important and should be worked on.

QC19. Would it be pertinent to have scientific technological support during training sessions? Would it allow to have more exact and certain information about the execution of the exercises of each gymnast?

Table 4.41: Scientific technological support

COACH	TECHNOLOGICAL SUPPORT
C01	Absolutely. Sport is science and the more we know about it, the more we can improve.
C02	Yes. To exactly detect the error and easily correct it.
C03	Yes, in particular to perfect the rotations/pirouettes technique.
C04	Of course. It would allow to really undertand the positionings and possible errors

It would be a great opportunity to exactly detect the problems and correct them, it would be something really useful. It would probably be even quicker to solve errors, increasing the motivating of the gymnasts, being something exact, it would allow coaches to save time and concentrate on other issues that may also arise.

QC20. Important aspects about the training or the gymnasts which have not been mentioned?

Table 4.42: Gymnasts/Training important aspects

COACH	FURTHER QUESTIONS
C01	The gymnasts learning process varies throughout the year.
C02	Keep in mind gymnasts mental availability depends on several external factors and influences your training performance
C03	Nothing to add
C04	Nothing to add

There are no recipes to the success, learning is a continuous and open process. There are moments and times of the year when gymnasts learn faster and better, coaches have to know how to take advantage of it and not get frustrated when at other times it is more complicated. Often, the effectiveness of a training or a correction, depends on the timing. The success rate depends on different factors, for example if there will be time to explain it in detail, if the gymnast is mentally available to learn a new exercise or if it is a very overloaded phase.

Implications for Design of the Interviews with Coaches

At the end of the interviews analysis, questions collected in the survey and in the observations of the training sessions were corroborated and others were clarified.

It is important that the application keeps track of the time gymnasts is training in order to prevent an overtraining period or to alert that it was not long enough. It should to promote a structured training and enable gymnasts to correctly prepare their body.

As gymnasts get distracted and bored really fast during autonomous training sessions, the application should regularly promote challenges and goals to be fulfilled in order to maintain a routine, as well as also delivering motivational complements during its use.

An advise should be lodged urging gymnasts to place the phone at the eye level rather than close to the ground, to keep the correct body positioning while performing the exercises. A

variety of exercises and modes should also be made available to encourage use and dissuade boredom. Feedback should be delivered visually and verbally in a prompt, direct and nice way. It shall be adapted to the gymnast using it and the first time an exercise is performed, feedback is obligatorily buried.

4.3 Summary

The observations of training sessions (OTS) afforded us the opportunity to understand the characteristics of training environment and how gymnasts react to different stimulus. As observations were made during the online home training context, it provided a great opportunity to understand how the gymnasts train without the physical presence of a coach, and thus bring the observations closer to the real use of the application. With the gymnasts interviews, it was possible to clarify questions that arose during the OTS related with gymnasts attitudes and decisions. The interviews with coaches have provided an excellent opportunity to understand the teaching perspective, how to manage relationships with gymnasts, organise and conduct a training session.

Chapter 5

Early Prototyping and Co-design

This chapter presents the primary design proposals for the application, developed in the early stages of the project and its purpose. Afterwards, the co-design sessions will be presented, where the method stages will be explained as well as results and interpretations. As part of the design process, low, mid, and high fidelity prototypes were created; the latter are described and presented in the last section of the chapter. In is important to note that, although the information in this chapter is presented sequentially, there was a lot of inter-twinning between the phases here described.

5.1 Preliminary Design Proposal

The first preliminary design proposal (Figure 5.1) developed during the study was created and used after the OTS, with the sole purpose of allow the designer to brainstorm and tidy up ideas. The first prototypes were paper and pen prototypes, with basic information and few features, with the results of study developments. With these preliminary proposals errors and unstructured ideas were understood and worked on. It was an essential task before moving on to the next phase, as it served to correct problems before they were presented to the users and before they were implemented, facilitating the work. To analyse the remaining preliminary design proposal see Appendix E: Preliminary Design Proposal, First Design Proposal.

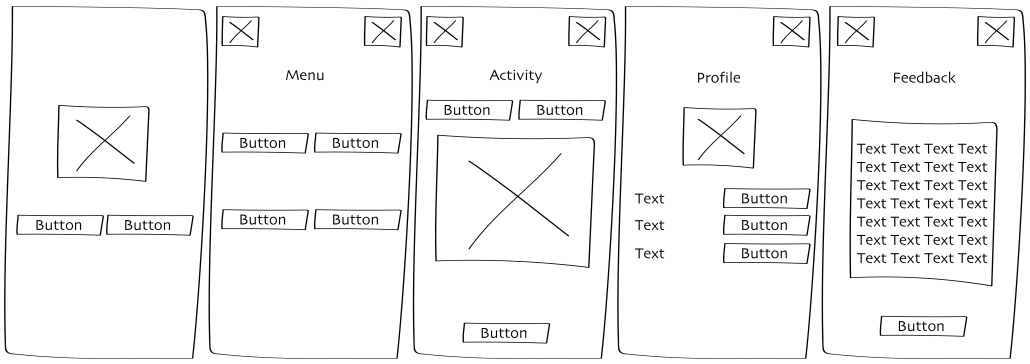
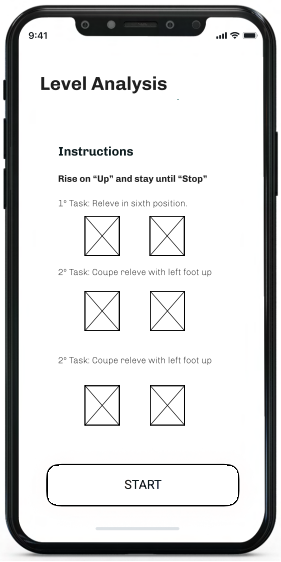


Figure 5.1: First preliminary design proposal

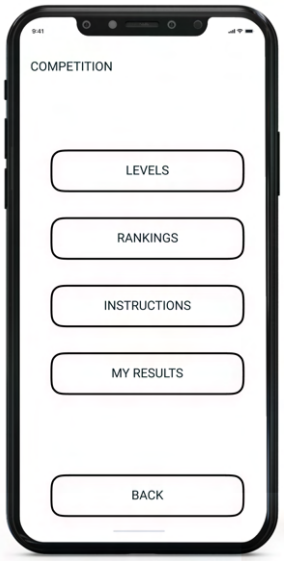
Later on and before PICTIVE method was conducted, researchers felt the need to create a new design proposal, more complex than the first one but still non-binding. These

prototypes consisted of a basic representation of the application screens initially defined, as login/register, menu, profile, instructions, activities (Figure 5.2). These screens assisted in the preparation of the PICTIVE method, where the main elements to be made available were defined and prepared to be used in the co-design sessions. Elements such as titles, buttons, boards, images and graphic elements were designed and an application flow chart developed to reassure that key elements were not forgotten or incorrect. On Appendix E: Preliminary Design Proposal, Section Second Design Proposal, can be found the complete set of screens developed.

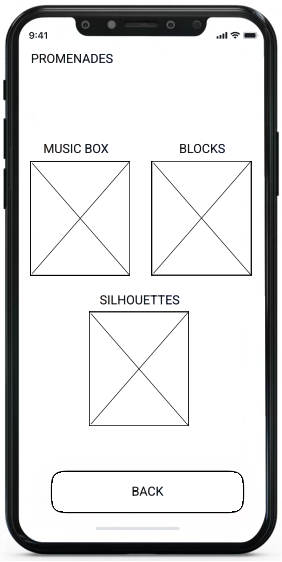
(a) HomeScreen



(b) Level Analysis Screen



(c) Menu Screen



(d) Activities Screen

Figure 5.2: Second Preliminary Design Proposal

5.2 Co-design Sessions with PICTIVE

Moving to the next project phase and with the information on training, methods, preferences and communication gathered, it was time to start defining design issues. To design

solutions with better results and better acceptance from the users, we decided to use a co-design approach, in particular the PICTIVE method, developed at Bell Communications Laboratory (Bellcore) in 1990 (Muller, 1992; Farrell, Farrell, Mouzakis, Pilgrim, & Byrt, 2006).

PICTIVE is an experimental participatory design technique that intends to enhance user participation in the design process, used in the initial stages of creation of a design (Farrell et al., 2006). This technique employs a series of consciously low-tech design components, such as paper, pencils, coloured pens, sticky notes, with high(er)-technology video recording facilities, to simplify the social dynamics of the design session. Creating a non software-based "rapid prototyping" environment, provides all stakeholders an equal participation on the design process, since any expertise or experience in computing is minimised (Muller, 1991, 1992).

The PICTIVE method is thereby an implementation of a user-centred approach which incorporates three principles that leads to a successful product, early focus on users and tasks, observation and measurement of user responses and iteration (Farrell et al., 2006).

In order for the researchers to be prepared to lead this technique, a temporary and superficial workflow of the application and some low fidelity prototypes were developed with the information gathered in the investigation until the moment. This way, critical graphic elements and information required for the proper functioning of the application were delivered directly to the participants instead of them having to create them.

5.2.1 Participants of the PICTIVE Sessions

Seven gymnasts (all female) aged from 10 to 17 years (Mean = 13) voluntarily participated in this study, and agreed to be recorded while doing so. Participants involvement method was the same as previous stages, since the interest was to continue the study with the same gymnasts group. Four of the gymnast who participated in previous activities were not available in these stage so the study continued with the seven gymnasts described in Table 5.1.

Table 5.1: Characteristics of the Participants involved in the PICTIVE Sessions

Participant	Age	Gender	Competition	Age Group
P01	17	Female	Yes	Senior
P02	13	Female	Yes	Junior
P03	14	Female	Yes	Junior
P04	13	Female	Yes	Junior
P05	10	Female	Yes	Juvenile
P06	13	Female	Yes	Initiation
P07	11	Female	Yes	Juvenile

5.2.2 PICTIVE Sessions Procedures

A collection of graphic elements was created to be manipulated on a design surface. The kit that was prepared by the designer included various elements designed on the computer, printed and plasticised so that they would last throughout the study without disadvantaging the last participants. The components of the kit included:

- 4 different colour palettes,
- 5 sets of typography,
- 6 collections of icons and images,
- several buttons with various functions,
- numbers from 0 to 9,
- descriptive elements to accompany the icons

And simple office materials:

- coloured pens, high-lighters, Post-It notes of various sizes and blank paper sheets so that participants could add whatever they thought was missing.

The kit also included a plasticised phone paper prototype, significantly bigger than normal, so that participants could arrange, place and move the design elements with no problems or added difficulties. On figure 5.3 are presented some of the graphic elements created, being possible to analyse the full kit on Appendix F: PICTIVE Kit and Results, Figure iii.

When participants arrived, the kit was on display and participants would be asked to think of a job/task in which an application could be useful in the context of their gymnastics practice and then invited to create an application flow making use of the different objects that were available in the kit (Appendix F: PICTIVE Kit and Results, Figure 8.2).

Each PICTIVE session took between 12 and 35 minutes, a video camera, Panasonic Lumix GH5, was used to record the whole process. The video camera should be positioned on the side of the table used for the method, in order to frame both elements participating in the study, focusing on the design objects and recording the voices during all process. Bearing in mind the familiar space where the process took place, Aveirogym Pavilion, and the close relationship between the participants and the design team, there seemed to be no requirement that the camera should be hidden or even unobtrusive.

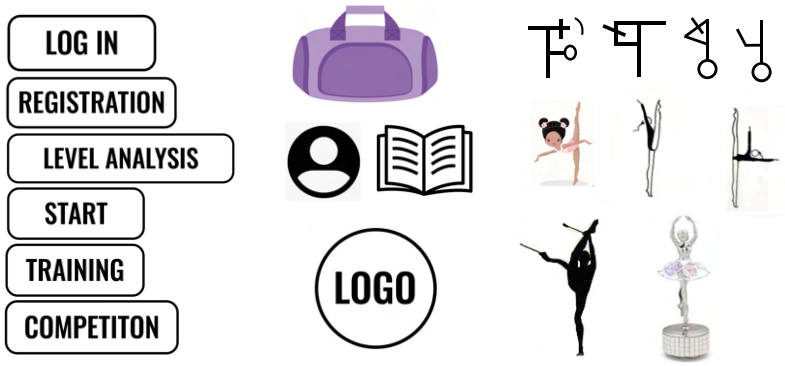


Figure 5.3: PICTIVE Graphic Material Sample

5.2.3 Results of the PICTIVE Sessions

Before the real hands-on work started, each participant was asked to think of job/task that they would like the application to do for them (Table 5.2).

Table 5.2: PICTIVE - Job/Tasks Scenarios

PARTICIPANT	JOB/TASKS SCENARIOS
P01	Tips to improve performance Activities/Challenges Share results with a score table Evolution over time Other gymnasts' experiences
P02	Help when gymnast does something wrong Teaching new pirouettes and balances Videos of other gymnasts for inspiration
P03	"Outstretched arms" "Stretch your feet" "Legs stretched out" Ballet foot positions
P04	Correcting feet position Analyse torso and arms position Tips to improve speed and balance
P05	Help in balances and pirouette preparation Many different gymnastics pirouettes Explain how to do exercises the right way
P06	Feedback Specific training (balances, pirouettes, etc) Clear and direct corrections Appropriate level training
P07	Weight Videos Instructions

Gymnasts were then asked to create an application flow, where the participants should present the most important phases of the application and sort them as they wish to appear in it. But it was quickly realised this task would not be used to the analysis, since all gymnasts had little knowledge and notions of how an application operates. The results were only used to compare with the jobs and tasks previously defined and see if they could complement each other.

The majority of task suggested by the participants were already included in the designer notes, outlined in the previous stages of the study. It was noted, in more than one response, that participants would like to have contact with other gymnasts either with experiences shared by them or with videos to serve as inspiration. Participants also requested the application to measure different body parts as arms or torso positions, but since the smart insoles are only able to measure foot-related aspects, this goal can not be achieved in this stage of the project, it will thus be proposed for future work. The weight suggestion will also not be taken into considerations as there are several weight problems and eating disorders related with these kind of sports and as an educational project we do not want to promote or encourage any kind of problem related to this.

PICTIVE:

Choosing the Colour Pallete:

Participants were presented with four different colour palettes (Figure 5.4), created based on the interviews conducted earlier. They were asked, after giving an overall look, to

choose the one they liked best.

PARTICIPANT	COLOUR PALETTE
P01	PALETTE 3
P02	PALETTE 4
P03	PALETTE 4
P04	PALETTE 4
P05	PALETTE 2
P06	PALETTE 4
P07	PALETTE 2

Figure 5.4: Colour Palette Selection

From the results obtained and validating the greater number of responses for palette 4, the colour to be implemented in the application contemplates a combination of cold colours and warmer ones, 2 blues and 3 pinks. Next was palette 2 followed by palette 3 and lastly palette 1, which did not get any votes.

Choosing the typography:

Participants were then asked to make another choice between the different typography combinations (Figure 5.5). These combinations went through a selection process to be created, the title was intended to have strong and big font, to make reading easier even by far. The next two fonts in each combination were randomly generated in an online programme for font pairing, that uses deep learning to select fonts which share an overarching theme and yet have a pleasing contrast. [1]

PARTICIPANT	TYPOGRAPHY SET
P01	TYPOGRAPHY 3
P02	TYPOGRAPHY 4
P03	TYPOGRAPHY 1
P04	TYPOGRAPHY 4
P05	TYPOGRAPHY 4
P06	TYPOGRAPHY 1
P07	TYPOGRAPHY 2

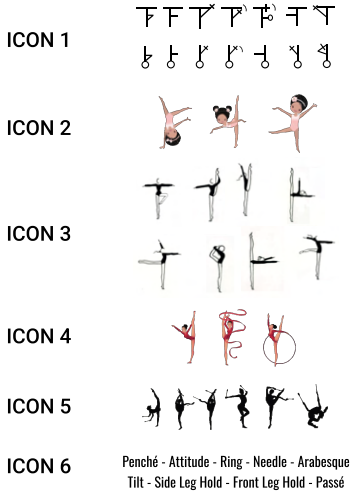
Figure 5.5: Typography Selection

For the application typography, the participants choices were more evenly distributed, possibly because none of them had any previous graphic studies background and they chose purely for personal taste. In any case, the combination with the highest number of votes was typography 4 and was therefore chosen to integrate the application.

[1] (Fonts randomly generated on https://fontjoy.com/)

Choosing graphic elements and icons:

The third and last task was to pick the graphic elements and icons to be used in the application design (Figure 5.6). Participants were presented with 6 different icons. Within these elements were two sets of images which are present in the official rhythmic gymnastics code of points manual and as researchers we wanted to know if gymnasts would find it important to be featured in the application or not. It was also present a set of words with the exercises names instead of images, and three more image collections, with two different dolls as basis and one silhouette collection.



PARTICIPANT	ICON SET
P01	ICON 5 & 6
P02	ICON 5 & 6
P03	ICON 3 & 6
P04	ICON 3 & 5
P05	ICON 4 & 6
P06	ICON 1, 5 & 6
P07	ICON 2 & 5

Figure 5.6: Icons Selection

The results obtained allowed us to conclude that the gymnasts need both images and words for the application to work in their best interest, one of them said "This way we can better understand what is supposed to be done". It was also a big request that silhouettes were present in the application rather than a more doll-like version, only chosen by the two younger gymnasts. They said the silhouettes were more beautiful and more professional than the dolls, which made us realise that they do not see training as a playful moment but rather as a serious and important task.

Assembly the Application Screens:

The graphic elements created by the designer prior to the session were presented to the participants as well as some time for them to become familiar with them. As soon as they felt prepared, the designer would start the process.

Since the first participant was one of the oldest gymnasts in the study and she was having some difficulties going forward independently, seeking for researchers approval, it was presumed that younger gymnasts would find it even harder. Thus, the designer relied on the workflow created previously to lead gymnasts throughout the process. With simple instructions and non leading assistance, researchers conducted the sessions, posing questions like "What do you think it would appear as soon as the application opens" or "What do you think it would be the next page of the application" every time a participant was stuck.

After the sessions, the PICTIVE videos were watched and analysed, faithfully recreating on the computer the screens created by the participants. On a handwritten typography red are represented the elements created and added by gymnasts with the papers and pens available. This screens can be accessed on Appendix F: PICTIVE Kit and Results, Section PICTIVE Records and Results.

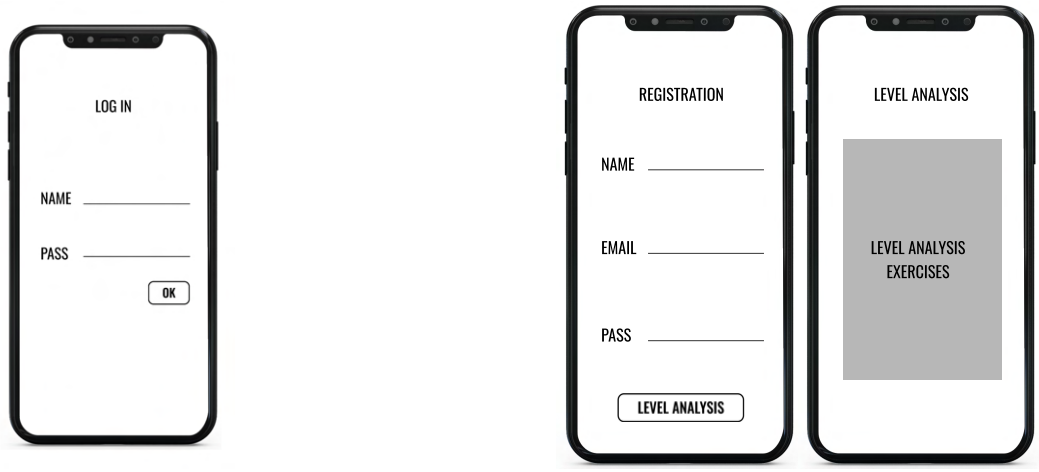
After an extensive results examination and realising very similar results as well as a far more comprehensive response from P05 than any other. It was decided to have the P05 design set as basis and compare all the remaining ones, to see if there were any contradictions or if any participant proposed further functions.

5.2.4 Implications for Design of the PICTIVE Sessions

Based on the results of the PICTIVE method, low fidelity prototypes were developed, the first page presented a logo that transitioned to the login/registration page (Figure 5.7).

Figure 5.7: Home Screen Prototype

The login button led to the respective page where there was a login form to fill in and a validation button (Figure 5.8a). The registration button also led to its respective page with a sign-up form and level analysis button. Following this were the instructions page and a mandatory level analysis page for all users upon registration on the application (Figure 5.8b).



(a) Login (b) Registration

Figure 5.8: Login and Registration Screen Prototypes

Moving to the centre page of the application, the menu page was first designed like participants proposed, but soon after some analysis it was realised that having a constant change

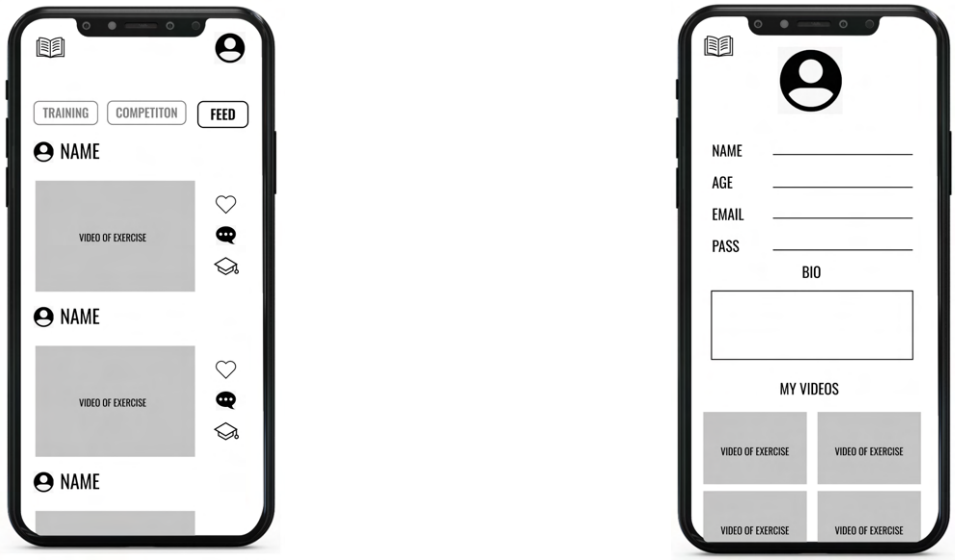
of pages between choices and having to go backwards whenever a change was to be made, was not a good feature. Thus it was decided to keep the order in what options appeared the same as participants defined, but keep all buttons on the same menu page.

The final menu page presented different groups of buttons, the first set Training-Competition-Feed, the second set Music Box-Blocks-Silhouettes, the third set Balances-Promenades-Pirouettes, the fourth set that contained the principal exercises available on rhythmic gymnastics. Initially both training and competition sections had the same components and organisation, differing only on the feedback. After analysing, it was acknowledged that it would not appear visual feedback in the competition section and for that reason, it was pointless to have 3 kinds of activities, when they would all behave likewise. The Music Box and the Blocks activities where then removed from the competition tab, leaving the silhouettes as it is the activity that most resembles a real competition (Figure 5.9).

Figure 5.9: Menu Screen Prototype

The remaining section of the menu had the feed, where gymnasts would be able to post their own videos, search and see other gymnasts videos too. It would works like a regular social media network, where users could like, comment or send messages among them, with the addiction of a special top hat button, so that gymnasts could learn and practice the exercise shown in the video (Figure 5.10a).

The profile page was also addressed during this study and participants built a page containing user information, a possibility to level re-analysis and their own videos published in the feed (Figure 5.10b).



(a) Feed Screen Prototype

(b) Profile Screen Prototype

Figure 5.10: PICTIVE - Feed and Profile Page

The notebook page where all feedback received was stored and presented by order of recurrence as well as a classification board where users could see their scores and places (Figure 5.11).

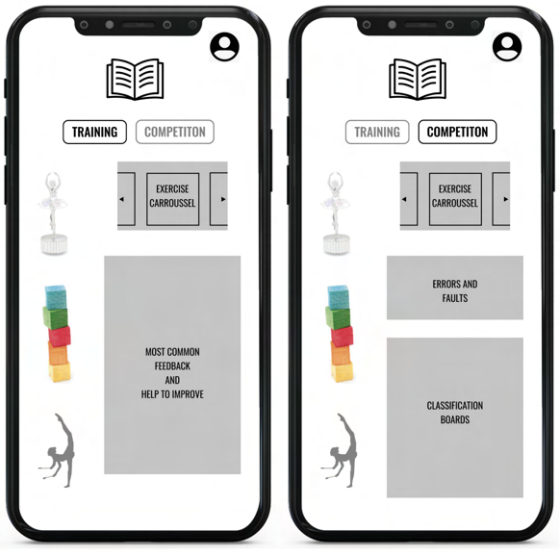


Figure 5.11: Notebook Screen Prototype

On the activities themselves, participants came up with 3 screens, the first had the pre exercise info, like instructions, help, previous corrections and the option to record or not. The second page had a countdown to start the exercise and the activities being performed. Last screen had the info after exercise, as corrections, score, a back button, a repeat button and an option to share the performance on feed (Figure 5.12).

Figure 5.12: Activity Screen Prototype

Discussion

At the end of this milestone and with the experience gained, it is possible to assert how powerful the PICTIVE method is, not only did researches get excellent design results but also the participants showed great commitment and enthusiasm for participating in the study, which was not so evident in the previous phases. As it is a hands-on method, using images and graphic elements, it is also a playful moment with immediate visual results, encouraging the participants as they could see and understand the outcomes.

With this method the design basis and organisation was defined, next the screens need to be adapted to the colours, typography and icons chosen by participants and also the final design had to be improved and made more professional. It was also needed to test this arrangements to check for possible errors or assignments made by participants that may not result or need improvements.

Further ahead will be presented the application design chapter where aspects related to interfaces, graphic elements, feedback manipulation and essential database will be addressed.

5.3 High-Fidelity Prototype

After the definition of the main graphic design elements and before implementation, high fidelity prototypes were created. To develop this screens, we used Figma [2], a primarily web browser-based vector graphics editor and prototyping design programme. For the design, a Samsung Galaxy A32 5G dimensions was chosen - 6.5-inch of screen measured diagonally [3] - since it was the phone available within our researchers possibilities. The screens appearance defined in Figma corresponded mostly to the final screens looks of the application.

Maintaining the graphic coherence previously defined, we tried to keep the application simple and straightforward, as some of its users were not very experienced with mobile

[2]https://www.figma.com/
[3]https://www.samsungmobilepress.com/mediaresources/galaxy_a32_5g/techspecs

devices. The buttons follow the same graphic logic, keeping its consistency and making it easier to use.

The screens related to the home, the login and registration, and level analysis, presented in the low fidelity prototypes, did not suffer any changes, having only been developed and finalised (Figure 5.13). Moving to the menu page, the top elements still remained the same, the activities and exercises to peak appear all at the same time avoiding delays and making choices easier, as it was possible see all the options at once. It was also agreed to add welcoming words, personalised with the user name, to make the application more personal and welcoming (Figure 5.14).

The feed page also kept the same structure as above (Figure 5.15). The profile page had undergone some minor changes in the user information (Figure 5.15). In the notebook page, it was decided not to include the activity type for the feedback storage as it was not important to the corrections, being only essential which exercise was performed (Figure 5.16), the remaining stayed the same.

Lastly, the activities pages also underwent minor amendments, related only to the arrangements and organisation of some elements. They still presented instructions, extra help, record button, countdown to start performance, corrections, score points, corrections, possibility to share on feed, and a back button (Figure 5.17).

For screen orientation of the application, only one option, vertical blocked, was made available. Since gymnasts need to see the entirety of of the information that is being presented, if the screen could turn horizontally the images would get too small or would be cut off the screen, leading to errors or poor understandings.

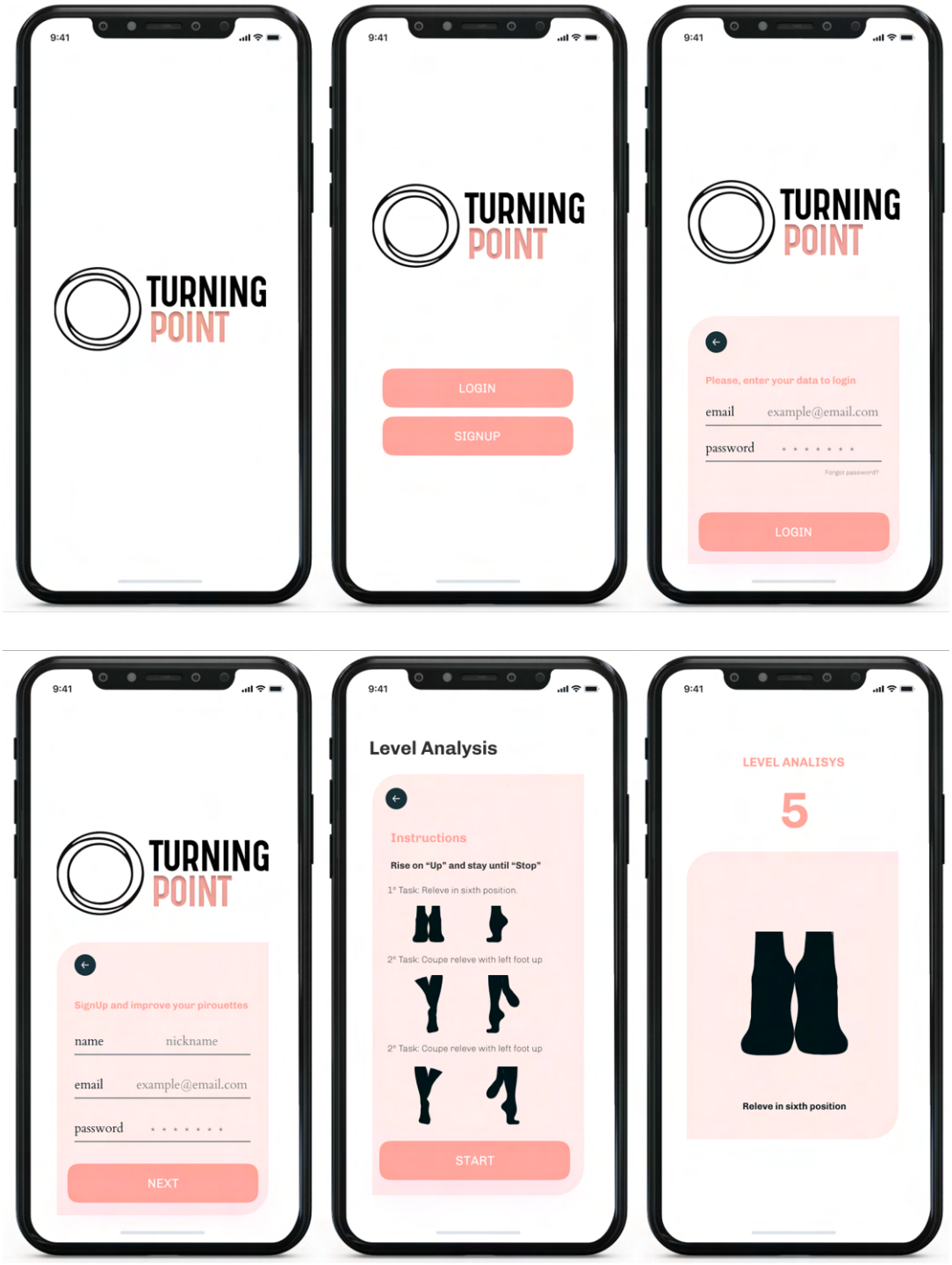


Figure 5.13: Home Screen/Login/Registration Screens

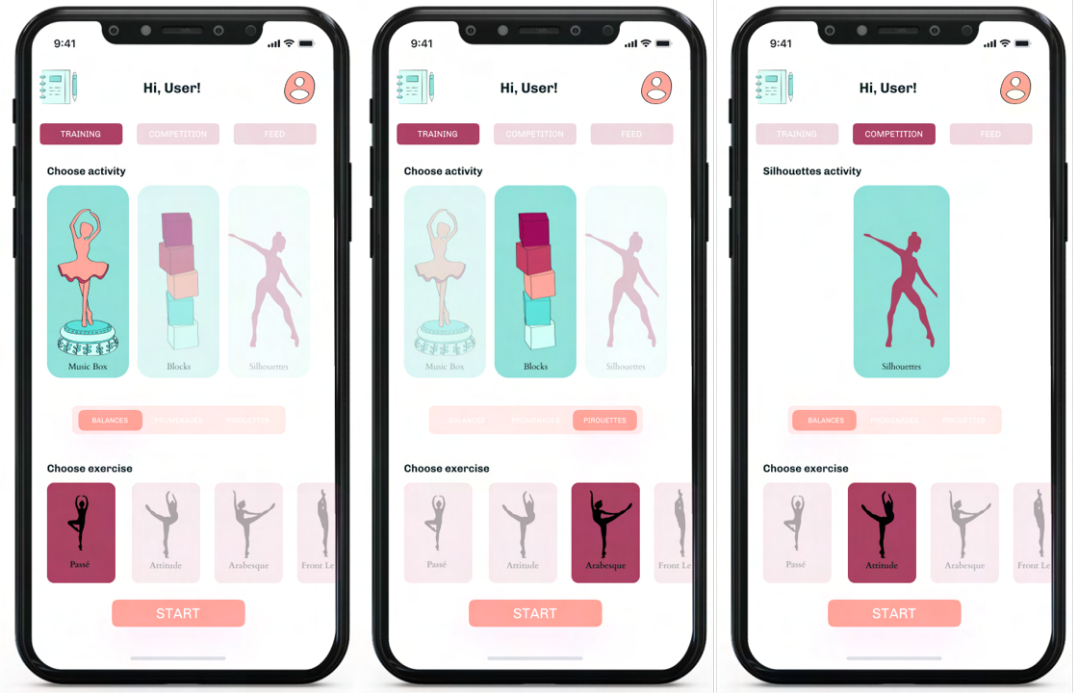


Figure 5.14: Menu Screen

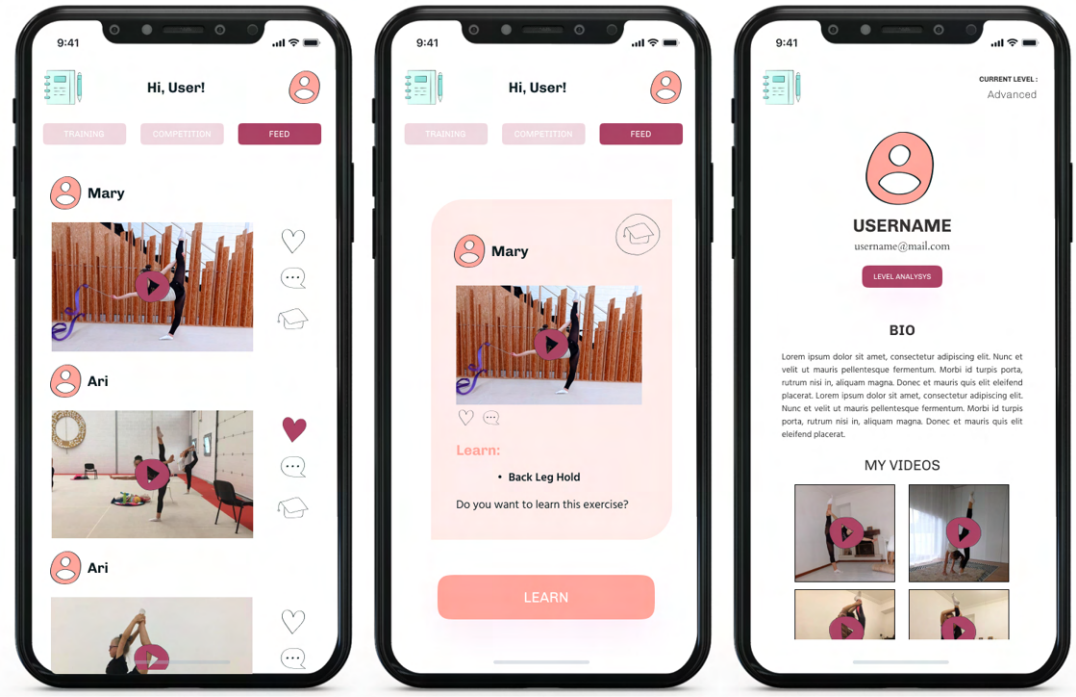


Figure 5.15: Feed and Profile Screens

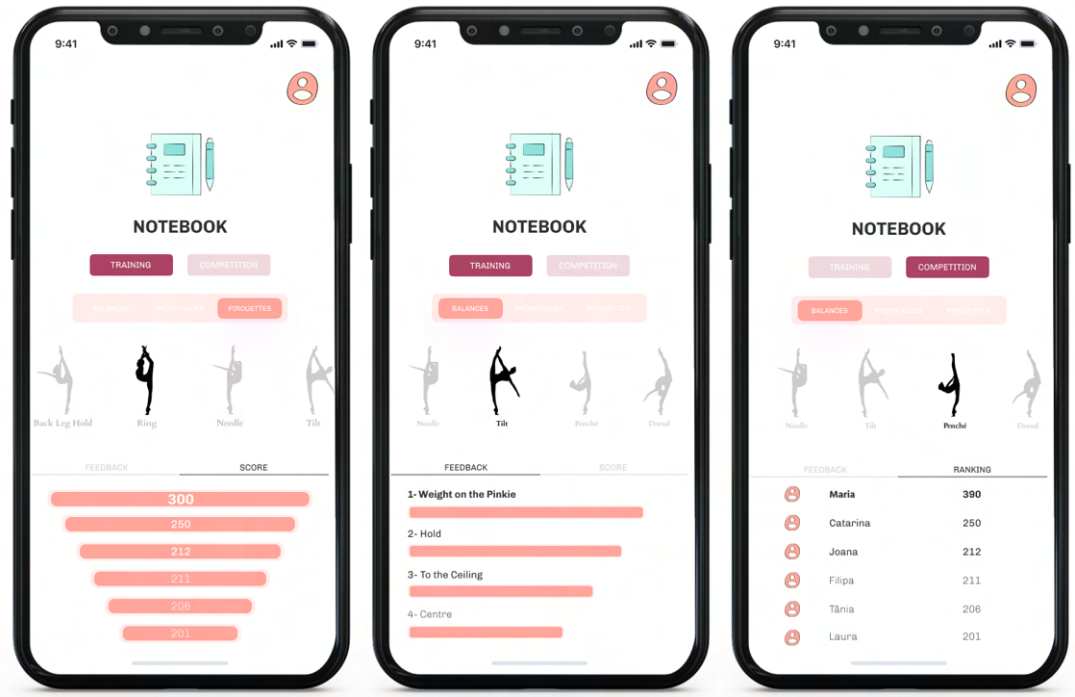


Figure 5.16: Notebook Screens

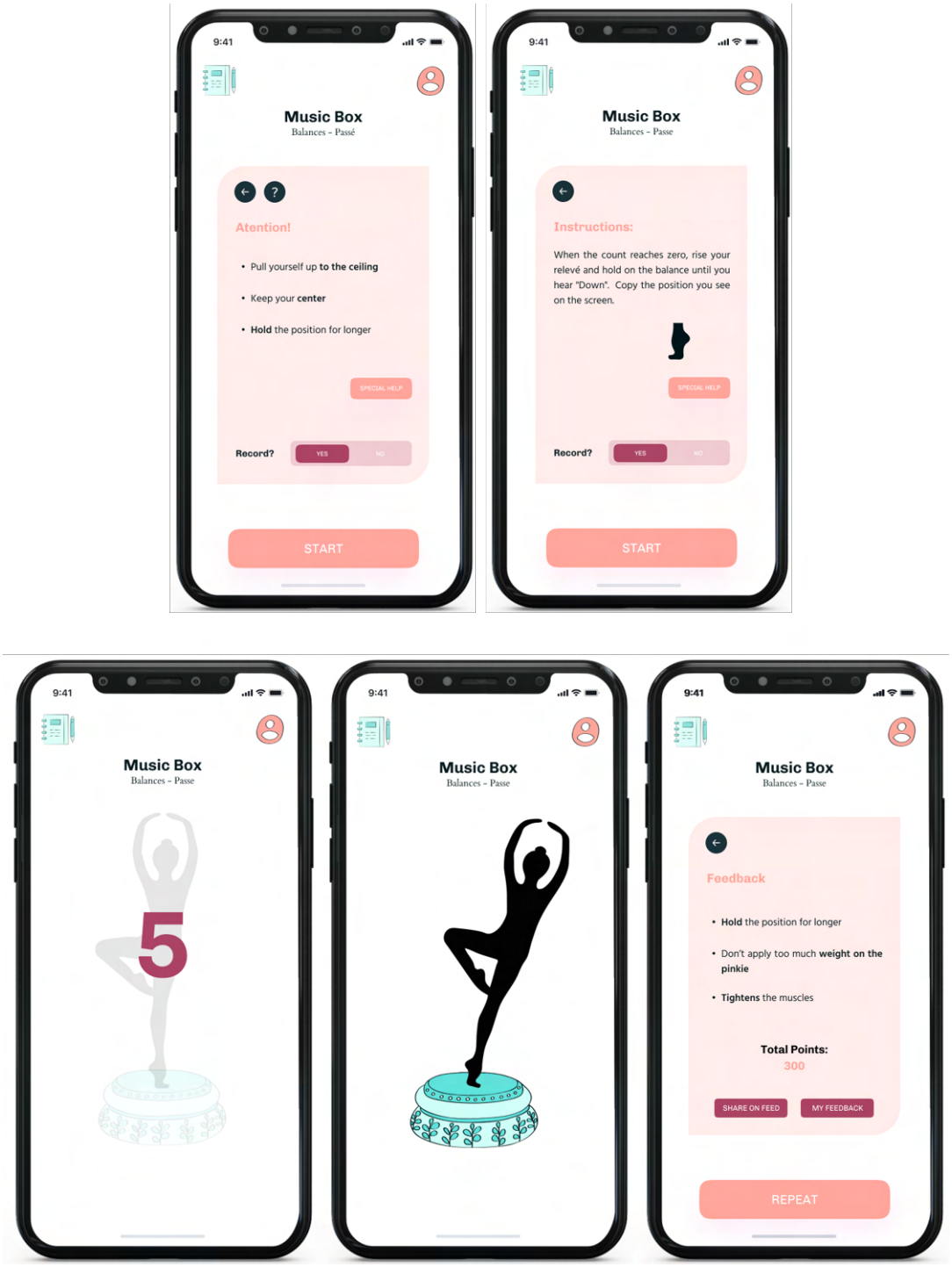


Figure 5.17: Activities Screens

Discussion

Being the high fidelity prototypes ready, issues resolved and elements developed, it was possible to understand how important was all the stages of the project until this point. The designer came up with a cohesive and consistent application, who matches users needs and fulfils their expectations. Participants expressed a big sense of pride as they know they also participated in the development of the project and see their suggestions applied and functioning. The participants excitement over the application could also barely be controlled and researchers even got asked when would the application be available for them to download and use.

5.4 Summary

The results obtained deviated a bit from our initial proposal, which was then adapted to the results to meet the ones suggested by the participants. In the end of this stage, the high fidelity prototypes were developed and the final design proposal started to be developed.

The use of the PICTIVE method turned out to be very effective to all participants, but in particular it was of great assistance with younger gymnasts, that although having contact with technologies, were not autonomous enough to participate in the process without affecting the results. As the PICTIVE sessions were composed of hands-on activities, that included visual tangible elements, and provided an immediate idea of the result, participants were fully committed to deliver a good work and got really excited about the opportunity.

Chapter 6

Final Application Design Elements and Implementation

This chapter covers aspects such as the final application design, structure and navigation, databases, and users. It also includes aspects related to the implementation, where key sections of code and the most important functions will be presented and explained.

6.1 Final Application Design Elements

The purpose of the tasks so far was to gather as much information as possible, analyse and compare what was compiled, learn with both gymnasts and coaches, in order to better define the application to serve the target audience. Having completed the research that led to the creation of the application, at this stage, the application design will be steered and the main issues will be tackled. Questions related to the design elements will be presented and defined and the ways in which feedback will be managed and delivered during application use will be sorted out. Also two databases were created in order to provide the application with the right exercises and typical expressions used in training sessions, to faster and better reach users.

6.1.1 Interface Elements of the Application

The set of graphic choices presented below resulted from the studies made previously with the participants in the co-design workshops. Since the ideas for the application identity were already dated back to the beginning of the project it was decided to develop it without participants intervention, whilst still allowing for adaptations and changes to better serve the choices made by them.

Colours

For the colours, the majority of participants' choices rested on palette 4, a range of five pastel colours between blue and pink (Figure 6.1). This palette, as all others presented earlier, were randomly generated with the input of one specific colour in the *ColorSpace* website [1].

[1] https://mycolor.space/

Palette 4 was generated through the input of a salmon colour #FFA69E named **Melon**, which was then used in main buttons, profile identification icon and in the boxes background with a lower opacity. The **Irresistible** pink was used to smaller and secondary buttons. The **Middle Blue Green** was used to the activity choice buttons (as they needed some emphasis on the menu) and in the notebook icon. And lastly the two far-ranging colours **Pansy Purple** and **Light Cyan** were used to details. It was felt the need to add a blackish colour to be used in the texts, on details and images complements, and the use of pure white to the application background.

Figure 6.1: Colour Palette

Typography

The fonts used for the application arose again from choices made by the participants in the study previously seen; they are a set of three different fonts, **Chivo** for the titles and some text info with weight variation, **Cardo** for the subtitles and important information and **Hind Vadodara** for the texts (Figure 6.2). They are three typefaces from google fonts and hence optimised and ready to work with.

Chivo was created by Omnibus-Type, that is a collective typefoundry based in Buenos Aires, meaning "goat". It is a new Omnibus-Type grotesque Sans Serif typeface family and its strength makes it ideal for highlights and headlines [2].

Cardo, created by David Perry, is a large Unicode font who works really good with chivo font. Its large character set supports many modern languages making it easier to use in many cases [3].

Hind Vadodara is a family of five Gujarati fonts, created by Indian Type Foundry (ITF), it was developed explicitly for use in User Interface design that has a humanist-style construction, paired with seemingly mono linear strokes. The entire family feels very legible when used to set text [4].

[2]https://fonts.google.com/specimen/Chivo?query=chivo
[3]https://fonts.google.com/specimen/Cardo?query=cardo
[4]https://fonts.google.com/specimen/Hind+Vadodara?query=Hind+Vadodara

Figure 6.2: Application Typography - Chivo, Cardo, Hind Vadodara

Icons and Graphic Elements

During the project, the designer needed to create and adapt icons for the application and customise them to match the identity. During the sessions, gymnasts have chosen types of icons and elements, silhouettes for the images and plain words to support them, serving as a description, as well as some hand made like icons to the rest of the application (Figure 6.3).

Icons were created for the different menu options, activities and exercises figured in the application. Icons were also created for the email, the profile, the saved feedback, the application instructions, the messages and feed reaction buttons. As regarding the graphic elements and every time some instruction is delivered to the user, a visual supplement is provided, which was also created based on the proposed silhouettes of the participants.

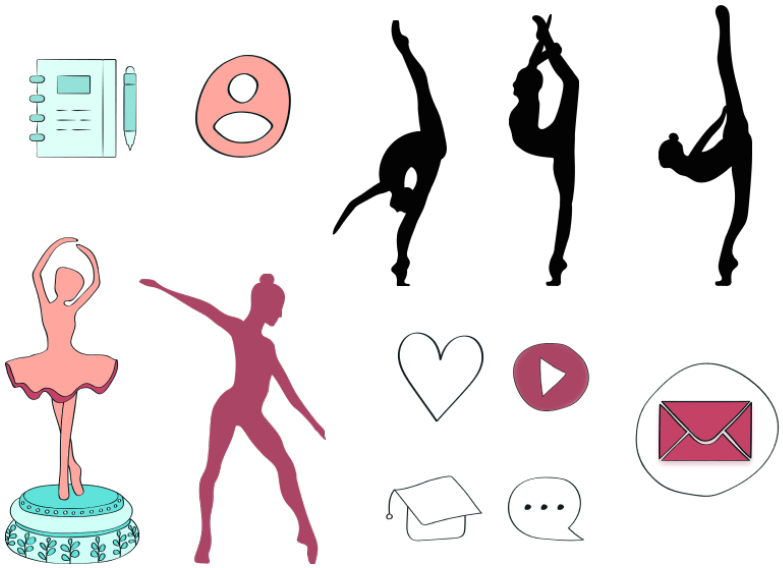


Figure 6.3: Icons Available

The development process of the icons was entirely carried out on the computer, as most of them were created based on photos of real gymnasts performing that exact same exercise, to help users better understand the exercise proposal. The icons were made playful and eye-catching to better capture the users' attention taking into account the target audience age range and preferences.

Some doubts arose during the decision of the feedback notebook icon, so we conducted a short study with the gymnasts to understand which was the best feedback icon to integrate the application. Before the session, eight icons were designed and displayed on a white

page (Figure 6.4), after being printed they were cut out individually and presented to one participant at a time, to whom it was asked which icon represented better the place where they would write down their feedback. The first test resulted in a tie between icon 3 and icon 6 with three answers to each one, and two answers to icon 4 and icon 8 (Table 6.1). Since an impasse had been reached, it was decided to repeat the test but only with the two most voted icons, so it was possible to break the tie. From this last test the icon with a higher number of votes was icon 3 (Table 6.2) and therefore the icon chosen was the notebook.

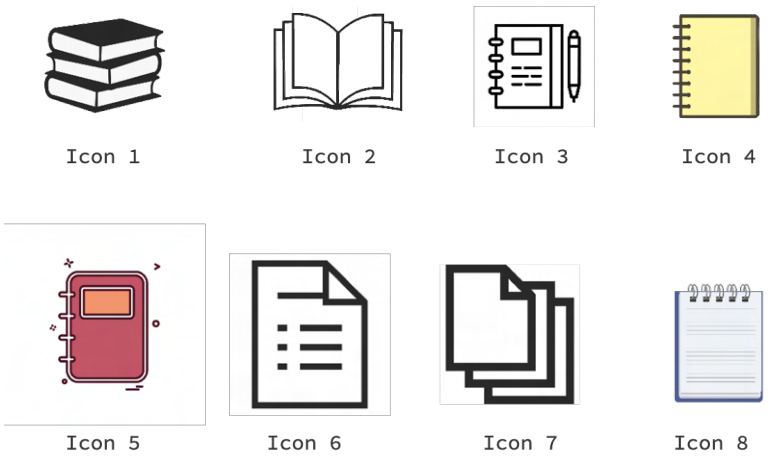


Figure 6.4: Icons Available

EN_LATEX_template/images/NotebookIcon1i.pdf

Table 6.1: Test with 8 Icons

EN_LATEX_template/images/NotebookIcon2i.pdf

Table 6.2: Final Notebook Icons Test

Identity

As for the application name, the designer wanted something meaningful, that really went along with the project and, after some deliberations, the designer came up with the name "Turning Point". The designer decided to keep this name for two reasons: first, because when doing pirouettes correctly, gymnasts turn on a point of balance also called the turning point, and second, because of the expression itself - turning point also means a time at which a decisive and beneficial change occurs, leading to better results. This is exactly the goal of the application: to help gymnasts to learn pirouettes properly, to improve

performance and be a better gymnast. With a double meaning, this name was the right one for the project.

Moving to the logo itself, the designer wanted a mixed logo with both text and image, with a symbol that carried a meaning that would reinforce the concept of the name. After some studies on the consistency of circumferences it was determined that the logo would be an assembly of a couple of circumferences representing the actual point of turn, with other two circumferences offset from the centre, creating the sensation of rotation and movement (Figure 6.5).

Figure 6.5: Turning Point

For the application icon to be featured in the phone menu, android developers icon design specifications were followed. As applications on Google Play are adopting a new icon system to better fit diverse developer artwork and the ambition of this project is to make it there, it was decided to leave it ready and already set. To fulfil the Google Play requirements it is important to ensure it conforms to the final size 512px x 512px, format 32-bit PNG, color space sRGB, max file size 1024KB, shape full square and with no shadows [5].

Most devices already have Android 8.0, having the option to choose different shapes for the icons, so the icon has been created in order to be adapted to different shapes.

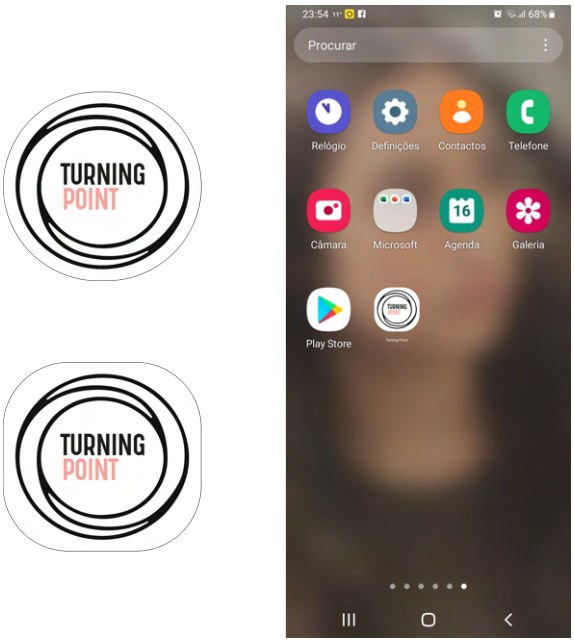


Figure 6.6: Application Icon

[5]https://developer.android.com/distribute/google-play/resources/icon-design-specifications

6.2 Information Architecture Organisation and Components

6.2.1 Feedback Information Organisation

Feedback has been a central role throughout this study. Evidences started in the searches for literature review, where studies in similar areas had a great focus on how to analyse and deliver feedback. When it came to the practical component of this study, with OTS and interviews, there was a clear focus on feedback and how it influenced the training and its participants, since it is trough feedback that both parties involved communicate and understand each other.

With the information collected, a diagram was made in order to summarise and simplify the way feedback will behave in the Turning Point application. We starter by splitting the application functioning in two major modes, the training and the competition. The **training mode** replicates the actual training environment where corrections are delivered before, during and after the exercises, being everything carefully explained so gymnast understands the goal and how to reach it (Figure 6.7). The **competition mode** mimics the competition environment where corrections are only delivered at the end of the exercise. During both modes, instructions and guide feedback are equally delivered before, during and after performance (Figure 6.8).

There is also a difference in between exercises. During balances and promenades, as they are slower and more static exercises, visual and audible feedback is delivered, so gymnasts can rely on both to improve performance. In pirouettes, as it is an instant and faster exercise, only audible feedback will be delivered, to help situate the performance timing. Another difference in the feedback concerns the level of expertise of the gymnasts. Depending on their capacity of performing the exercise, different ways of delivering feedback should be adopted. The number of corrections, the type of language and motivation factors should differ (Figure 6.9).

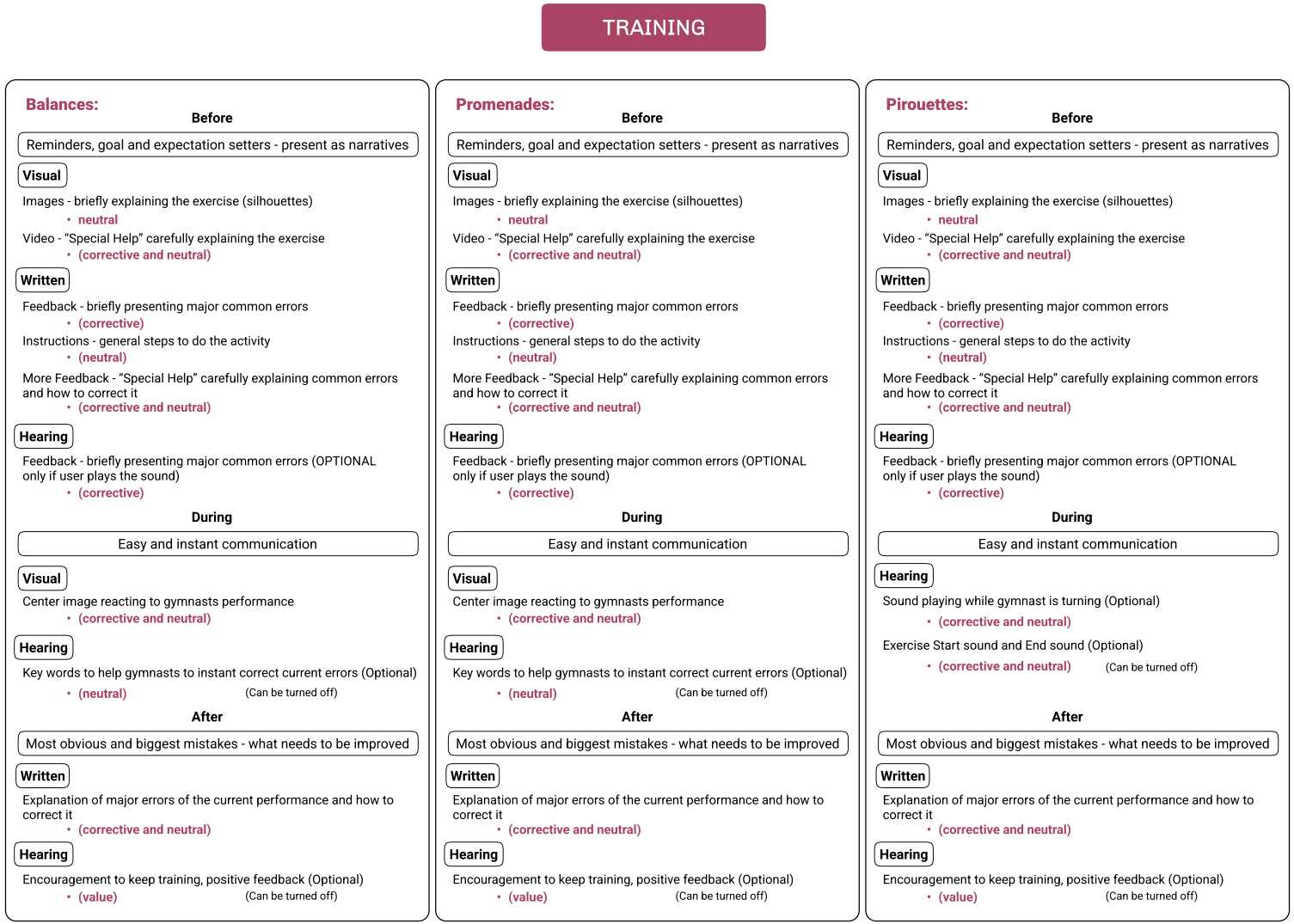


Figure 6.7: Training Feedback

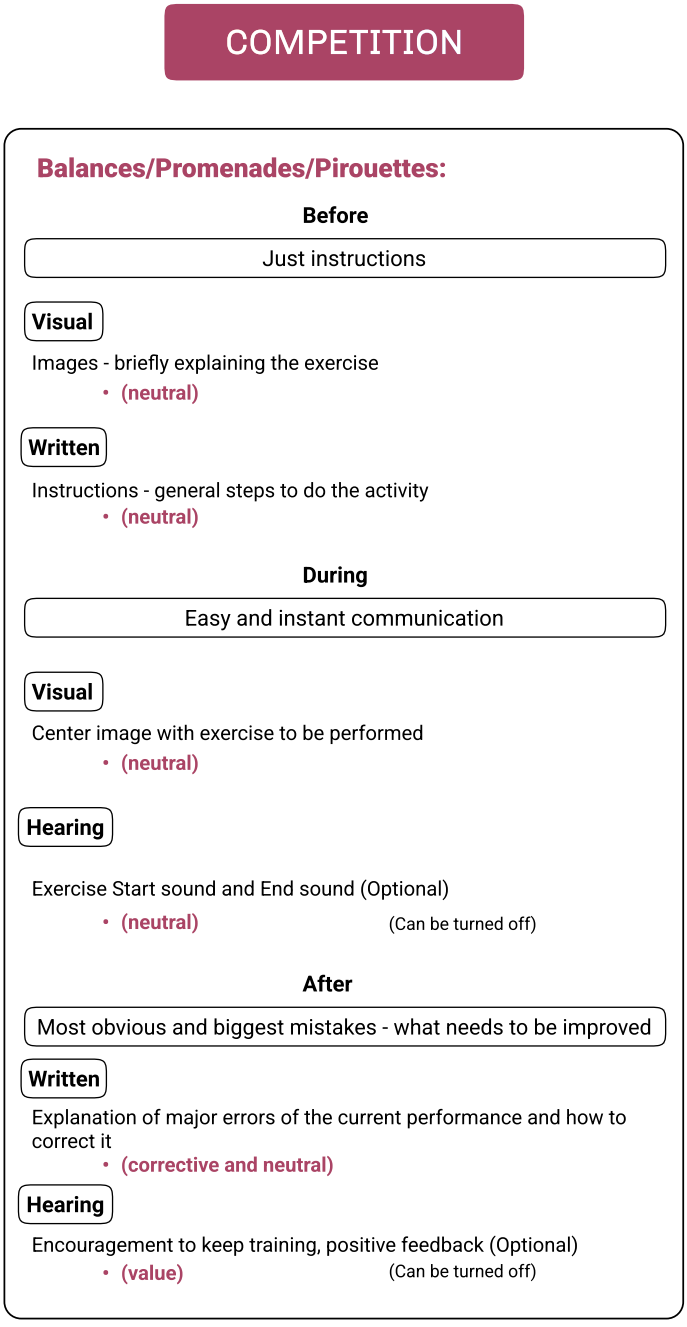


Figure 6.8: Competition Feedback

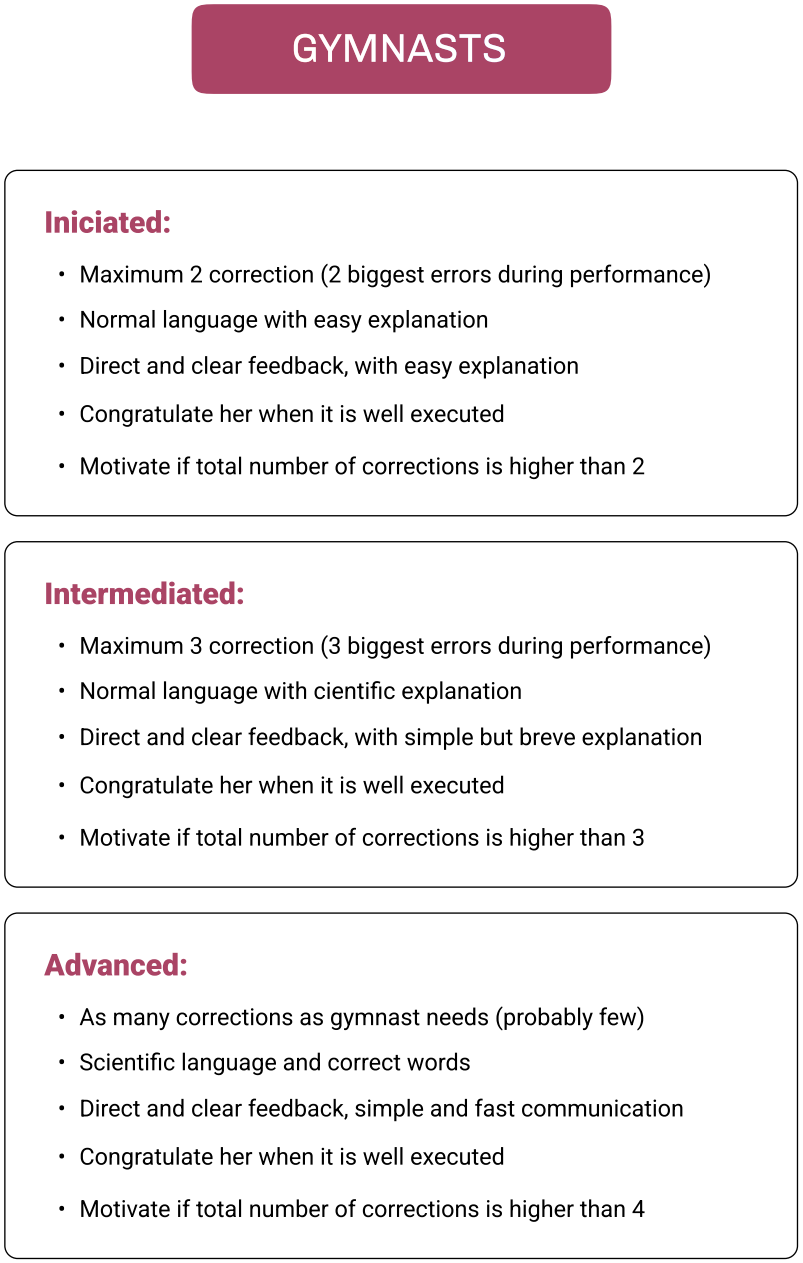


Figure 6.9: Feedback for Different Levels

6.2.2 Databases

For the application to present real and personalised choices and user interactions, databases needed to be created where options were stored. Databases are collections of information that is structured and organised.

Exercises

In order to fulfil the criteria of many different exercises for gymnasts to choose as they will, a database with the most common exercises was created (Figure 6.10). The exercises were picked from the code book of rhythmic gymnastics and with the help of a coach were picked the most important ones for this stage of the project.

Thus, the following were chosen and organised in ascending order according to their difficulty degree and consequently, their value in the score book.

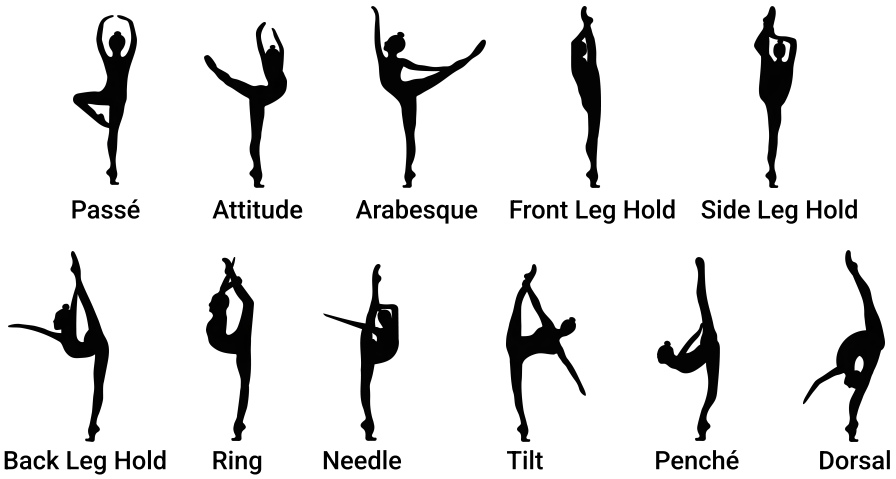


Figure 6.10: Application Exercises

Expressions

For corrective feedback with keywords to work out, the application needs to be used expressions known by the users and that they are familiar with. It was decided to conduct a quick observation session on a balance and pirouette training to gather the expressions used by the coaches to correct errors during performance. The following expressions were collected and added to the list associated with the specific error it intents to correct.

TO THE CEILING	When gymnast has a lower *relevé* and it is meant for her to rise her heal. When saying up "to the ceiling", coach is using a hyperbole for the gymnast to really try to reach as high as possible.
CENTRE	By saying "centre" gymnast knows that she has to keep her weight in the centre of balance and it is used when gymnast is very unstable.

TO RIGHT	With "right" gymnast knows she is supposed to transit slightly her weight to the right and it is used when she is leftward decompensated.
TO LEFT	With "left" gymnast knows she is supposed to transit slightly her weight to the left and it is used when she is rightward decompensated.
TIGHTENS	"Tightens" is used when gymnast is off balance and constantly diverting her balance point, this way she knows it is important to tense the muscles of the body to keep the balance.
HOLD	When gymnasts is constantly lowering and raising the *relevé* and does not hold the balance position, she knows right away she is supposed to fix a point and distribute the weight of the body on the support surface.
DIRECTIONS	To advert gymnasts that directions during rotation are not being respected, and that they need to turn only 1/4 turn at a time.
WEIGHT ON PINKY	Warn that too much weight is being applied on the pinkie toe and weight must be shifted to the centre.
WEIGHT ON BIG TOE	Warn that too much weight is being applied on the big toe and weight must be shifted to the centre.

Table 6.3: Expressions Database

6.3 Implementation

This section focuses on the implementation process of the Turning Point application, and presents technologies choices, its structure and some functionalities.

6.3.1 Application Structure and Navigation Model

The application implementation was made in the Unity platform. The Unity platform is available free of charge and offers a wide range of documentation support, both in terms of code and interface development. Besides the official Unity website, pages such as Stack Overflow, Github, Quora and Medium were also used to solve problems and to deepen the knowledge. To ensure the proper communication of the insoles, was imperative the platform chosen would allow such connection. Previous studies and projects with the smart insoles resulted in a unity platform code that connects the two parties and allows their interaction. This code has been made available and used for the implementation. The project has so also been developed in the same platform.

Figure 6.11 shows the sequence of actions available for a user to navigate through the application, which represents the workflow. This flowchart was developed to help to plan and understand the process. It is a complex diagram where all connections between pages are represented, as well as possible options and choices.

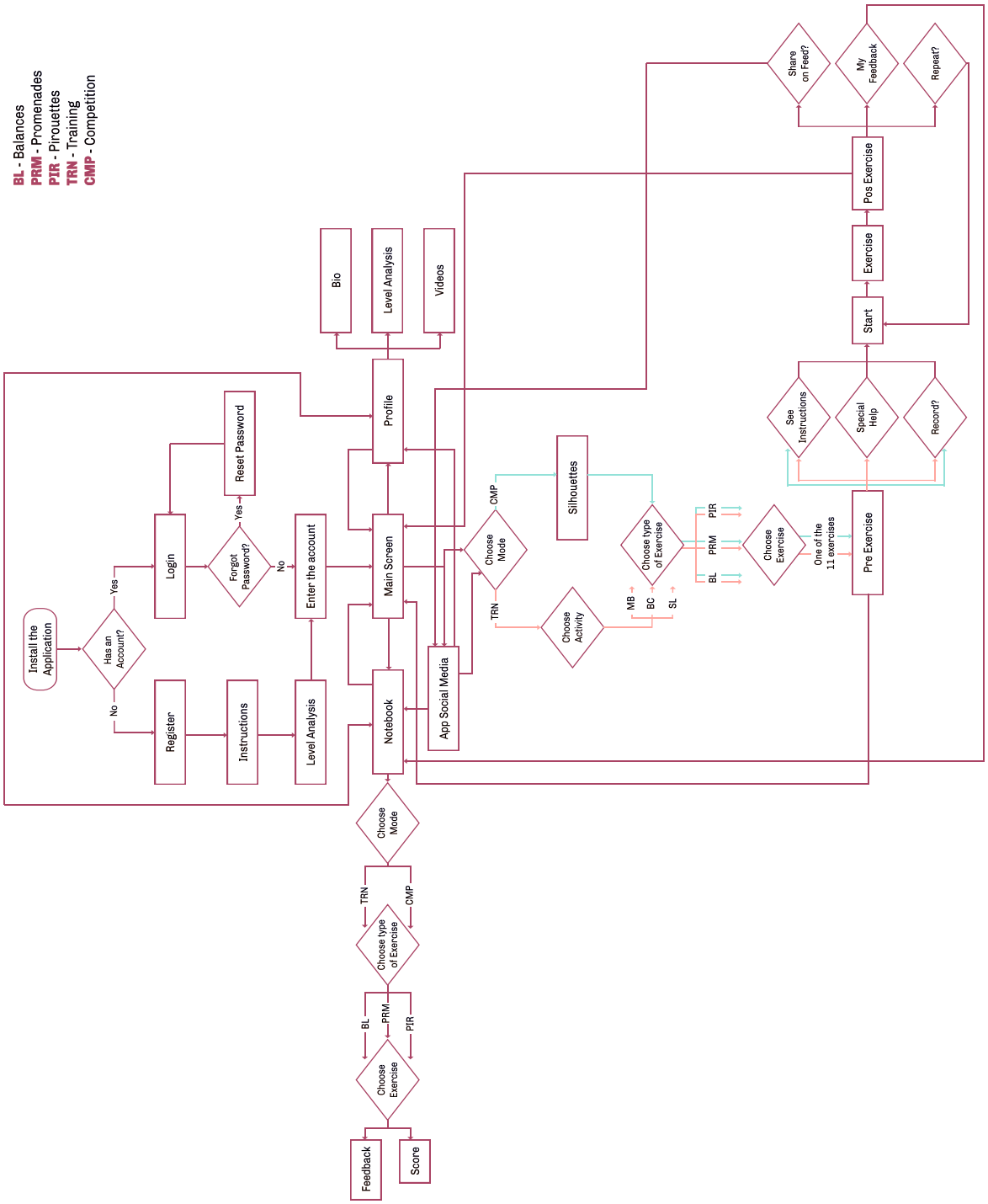


Figure 6.11: Application flowchart

6.3.2 Users Management

To manage users accounts and to be able to save one's data in their respective account, we decided to use Microsoft Azure PlayFab. PlayFab is a backend platform that enables developers to use the intelligent cloud to build and operate, analyse data and improve overall experiences (Figure 6.12). It also offers cost-effective development solutions and helps to engage, retain and monetise users. The crossing-network identity and data allows the user authentication and user data management, sharing information across devices. It also makes leader boards and statistics matters easier and is fully compatible with Unity platform (Sebgrink, n.d.).

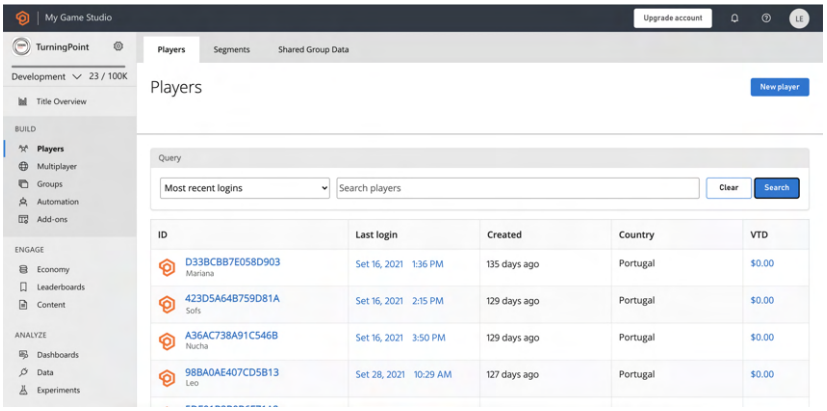


Figure 6.12: PlayFab Website for Turning Point

On the PlayFab website, inside the teams account, a studio with the project name "Turning Point" was created where user info would be stored and accessed whenever required. The next step was to import and install the PlayFab Unity Editor Extensions Asset Package and to configure the project. After importation, a PlayFab unity editor extensions panel appeared (Figure 6.13), a login was made and a PlayFab SDK was imported to the project connecting to the studio created online.

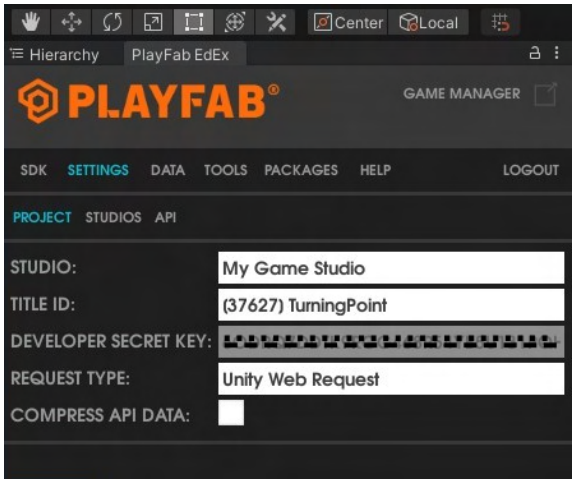


Figure 6.13: PlayFab Interface in Unity

Listing 6.1, shows the code used for the registration of a new user and Listing 6.2, the login. The registration saves new users data into the online data base, checks if the email is properly entered and alerts in case of the passwords not being good enough. The login

part checks if there is a user with the data entered and has the option to reset the password in the event of forgetting. More features implemented such as, reset password can be found in Appendix G: Application Features Implemented, Section Reset Password Code.

Listing 6.1: Register Code

```
public void ButtonLevelAnalysis() {
    if (passwordInput.text.Length < 6) {
        messageText.text = "Password too short, minimum 6 characters!";
        return;
    }

    var request = new RegisterPlayFabUserRequest {
        Username = nameInput.text,
        Email = emailInput.text,
        Password = passwordInput.text, RequireBothUsernameAndEmail =
            false
    };
    PlayFabClientAPI.RegisterPlayFabUser(request, OnRegisterSuccess,
        OnRegisterError);
}
    void OnRegisterSuccess(RegisterPlayFabUserResult result) {
        Debug.Log("Register");
    }
    void OnRegisterError(PlayFabError error) {
        Debug.Log(error.GenerateErrorReport());
        messageText.text = error.ErrorMessage;
    }
```

Listing 6.2: Login Code

```
public void ButtonLogin() {
    var request = new LoginWithEmailAddressRequest {
    Email = emailInput.text,
    Password = passwordInput.text
    };
    PlayFabClientAPI.LoginWithEmailAddress(request, OnLoginSuccess,
        OnLoginError);
}
void OnLoginSuccess(LoginResult result) {
    Debug.Log("LogIn Successful");
}
void OnLoginError(PlayFabError error) {
    Debug.Log(error.GenerateErrorReport());
    messageText.text = error.ErrorMessage;
}
```

After the registration data is introduced, a level analysis is performed in order to examine the current user level and save it to later personalise feedback. For this analysis, it was used the Big Toe/Pinky Toe Code, the High/Low *Relevé* Code, and the Right Foot/Left Foot Code, in order to check if gymnasts weight was being applied on the centre, if the *relevé* was high enough and if they were not also applying pressure on the other foot during *coupé*.

6.3.3 Insoles Data Analysis During Exercises

To connect the insoles to the unity and take advantage of it during the use of the application, we relied on the code that was previously available to start the process. Sooner

realised the code was outdated and that changes had to be made to make it work. With some updates on Daniel Wilches SerialCommUnity (Serial Communication for Unity) series of codes [6], communication between insoles and unity were established. Below, some of the comments Daniel Wilches has left on the code are presented, explaining its functions, helping in the understanding. The class **SerialController** allows the Unity program to continually check for messages from a serial device, creating a Thread that communicates with the serial port, where the insoles dongle is connected, and continually polls the messages on the wire. That Thread puts all the messages inside a Queue, and the SerialController class polls that queue by means of invoking SerialThread.GetSerialMessage().

The SerialController only allows reading/sending text data that is terminated by new-lines, while **SerialControllerCustomDelimiter** class allows reading/sending messages using a binary protocol where each message is separated from the next by a 1-char delimiter.

On the **AbstractSerialThread**, **SerialThread**, **SerialThreadBinaryDelimited** and **SerialThreadLines** classes are the methods that must be run from inside a thread and the ones that must be invoked from Unity.

A small piece of code was included in the class in order to do a calibration before analysis (Listing 6.3), to adjust details to the current user and make it personalised to her values. It was used the difference between the mean of both insoles.

Listing 6.3: Calibration Code

```
1 private int cali = 0;
2 cali = (int)LeftData.insole_sum - (int)RightData.insole_sum;
```

On **balances**, to analyse whether gymnasts weight is placed on the pinkie toe, on centre or on the big toe, centre of mass was used on X-axis. Accessing the values sent by the insoles and getting the mean of centre of mass of each one, it was possible then to use an if clause to compare values. By doing tests with the gymnasts about the weight distribution between pinkie toe and big toe, it was noticed that the average centre of balance values varied between 30 and 40 without them losing balance (8.2, Table Balance Values). The values collected from the two younger gymnasts were not used to this study, once their foot was too small to the insoles, number 36/37. If the mean is equal or higher than 40, the weight is being put on the pinkie toe, if the mean is lower than 30, the weight is being applied on the big toe, if the weight is in the middle, the weight is also in the middle (Listing 6.4).

Listing 6.4: Big Toe/Pinky Toe Code

```
1 float ry = 40 - (RightData.CMy - 40);
2 float x_mean_right = (LeftData.CMx + RightData.CMx) / 2;
3 float y_mean_right = (LeftData.CMy + ry) / 2;
4 x_mean_right = RightData.CMx;
5 y_mean_right = RightData.CMy;
6 //Right Insole
7 if ((x_mean_right < 180 && x_mean_right > 120) && (y_mean_right >= 40)
      && y_mean_right > 0) {
8     Debug.Log("Weight on Pinkie");
9 } else if ((x_mean_right < 180 && x_mean_right > 120) && (y_mean_right
      <= 30) && y_mean_right > 0) {
10    Debug.Log("Weight on Big Toe");
11 } else {
12    Debug.Log("Weight on Point");
13 }
```

[6] https://github.com/dwilches/Ardity/tree/master/UnityProject/Assets/Ardity/Scripts

To measure the difference of weight from the right foot to the left foot the pressure presented in each foot was used. After checking values with the gymnasts, if the difference is negative, the right foot has more weight on, else the weight is being applied more on left foot (Listing 6.5).

Listing 6.5: Right Foot/Left Foot Code

```
int diff = (int)LeftData.insole_sum - (int)RightData.insole_sum - cali;
//Difference between Left and Right Foot
if ((RightData.insole_sum > 500 && LeftData.insole_sum > 500) && (-diff
    > pressure_threshold) && y_mean_right > 0){
    Debug.Log("Right Foot");
} else if ((RightData.insole_sum > 500 && LeftData.insole_sum > 500) &&
    (diff > pressure_threshold) && y_mean_right > 0) {
    Debug.Log("Left Foot");
}
```

To analyse if the *relevé* was high, on the toes, or lower, near the heels, the mean of the Y-axis values of the insoles was used. Reviewing and analysing values of high *relevés* with gymnasts (8.2, Table *Relevé* Values), once again the values collected from the two gymansts with smaller feet were disposed. It was understood that if the value is bigger than 145 the weight is on the toes and the *relevé* is correct, else if the value is smaller the *relevé* is not high enough (Listing 6.6).

Listing 6.6: High/Low *Relevé* Code

```
if (x_mean_right > center_x + threshhold_x && x_mean_right > 0) {
    Debug.Log("Toes");
} else if (x_mean_right < center_x + threshhold_x && x_mean_right > 0) {
    Debug.Log("Heels");
}
```

For the **pirouettes**, and in addition to the commonalities with the balances, the application also needed to measure how many full turns were performed by the gymnast. For that purpose, the data collected by the gyroscope was used. As this data was being received as quaternions, we converted it to euler to manipulate them more easily (Listing 6.7).

Listing 6.7: Conversion from Quaternions to Euler Code

```
float gir_many, gir_many_2, gir_many_3, gir_many_4;
gir_many = RightData.QuatWIn;
gir_many_2 = RightData.QuatXIn;
gir_many_3 = RightData.QuatYIn;
gir_many_4 = RightData.QuatZIn;

float siny_cosp = 2 * (gir_many * gir_many_4 + gir_many_2 * gir_many_3);
float cosy_cosp = 1 - 2 * (gir_many_3 * gir_many_3 + gir_many_4 *
    gir_many_4);
double degrees = (180 / Math.PI) * (math.atan2(siny_cosp, cosy_cosp));
float normalizedValue = Mathf.InverseLerp(-180, 180, (float)degrees);
float resultnew = Mathf.Lerp(0, 360, normalizedValue);
manypoints.GetComponent<LevelAnalysis>().Rotations(resultnew);
```

It was then defined when the rotation would begin and two booleans to check whether gymnasts were spinning and whether rotation was being stored. After some tests with the gymnasts, it was decided to leave a margin of error of 15 degrees, adding or subtracting to the initial rotation position. This decision was made because, if the gymnast was spinning too fast, the insoles would not be able to check the initial position and would not be able

to count the number of turns completed. This way, even with faster turns, every time the gyroscope passed through the initial position (with the margin of error of 15 degrees), one turn was added to the count (Listing 6.8).

Listing 6.8: Quantification of Pirouettes Code

```
1  //pirouettes
2  if (piruettesRotInitial == 0) {
3      piruettesRotInitial = piruettesCurrentRot;
4      piruettesStartSpinning = true;
5  }
6  if(piruettesStartSpinning){
7      if(Math.Round(piruettesRotInitial, 0.0f)<315){
8          if(Math.Round(piruettesCurrentRot, 0.0f) > Math.Round(
               piruettesRotInitial, 0.0f)+45){
9              piruettesSpinning = true;
10             piruetteRotationAdded = false;
11         }
12     } else if ((Math.Round(piruettesRotInitial, 0.0f)>=315)){
13         if(Math.Round(piruettesCurrentRot, 0.0f) > 45 - Math.Round(
               piruettesRotInitial, 0.0f) && Math.Round(piruettesCurrentRot
               , 0.0f) < (90-(360-Math.Round(piruettesRotInitial, 0.0f)))){
14             piruettesSpinning = true;
15             piruetteRotationAdded = false;
16         }
17     }
18 }
19 if(piruettesSpinning && !piruetteRotationAdded)
20     if(Math.Round(piruettesRotInitial, 0.0f)<=345 && Math.Round(
           piruettesRotInitial, 0.0f) >= 15){
21         if(piruettesCurrentRot >= piruettesRotInitial-15 &&
               piruettesCurrentRot <= piruettesRotInitial+15){
22             for (int i = 0; i < 1; i++){
23                 piruettesFullTurns++;
24                 i++;
25             }
26         piruetteRotationAdded = true;
27         piruettesSpinning = false;
28         }
29     } else if(Math.Round(piruettesRotInitial, 0.0f) < 15){
30         if(piruettesCurrentRot > 345 + piruettesRotInitial ||
               piruettesCurrentRot < piruettesRotInitial + 15){
31             for (int i = 0; i < 1; i++){
32                 piruettesFullTurns++;
33                 i++;
34             }
35         piruetteRotationAdded = true;
36         piruettesSpinning = false;
37         }
38     } else if (Math.Round(piruettesRotInitial, 0.0f) > 345){
39         if(piruettesCurrentRot > piruettesRotInitial-15 ||
               piruettesCurrentRot < 15-(360-piruettesRotInitial)){
40             for (int i = 0; i < 1; i++){
41                 piruettesFullTurns++;
42                 i++;
43             }
44         piruetteRotationAdded = true;
45         piruettesSpinning = false;
46         }
47     }
48 }
```

For the **promenades**, no additional data received by the insoles had to be analysed.

Using balances foot supports evaluations and pirouettes spinning positions, it was possible to check whether the gymnast was doing a quarter of a turn each time and analyse other questions as supports and positioning (Listing 6.9).

Listing 6.9: Quantification of Promenades Code

```
1  //promenades
2  if (promenadeSpinning) {
3  //   1/4 of a turn
4      if (promenadeRotInitial < 255){
5          if (promenadeCurrentRot > promenadeRotInitial + 75 &&
               promenadeCurrentRot < promenadeRotInitial + 105) {
6          tre = false;
7          }
8      } else if (promenadeRotInitial >= 255 && promenadeRotInitial <= 285)
           {
9          if (promenadeCurrentRot >= promenadeRotInitial + 75 ||
               promenadeCurrentRot <= 105 - (360 - promenadeRotInitial)) {
10         tre = false;
11         }
12     } else if (promenadeRotInitial > 285) {
13         if (promenadeCurrentRot > 75 - (360 - promenadeRotInitial) &&
               promenadeCurrentRot < 105 - (360 - promenadeRotInitial)) {
14         tre = false;
15         }
16     }
17 //   2/4 of a turn
18     if (promenadeRotInitial < 165) {
19         if (promenadeCurrentRot > promenadeRotInitial + 165 &&
               promenadeCurrentRot < promenadeRotInitial + 195 ) {
20         tre = false;
21         }
22     } else if (promenadeRotInitial >= 165 && promenadeRotInitial <= 195)
           {
23         if ( promenadeCurrentRot >= promenadeRotInitial + 165 ||
               promenadeCurrentRot <= 195 - (360 - promenadeRotInitial)) {
24         tre = false;
25         }
26     } else if (promenadeRotInitial > 195) {
27         if ( promenadeCurrentRot < 195 - (360 - promenadeRotInitial) &&
               promenadeCurrentRot > 165 - (360 - promenadeRotInitial)) {
28         tre = false;
29         }
30     }
31 //   3/4 of a turn
32     if (promenadeRotInitial < 75) {
33         if ( promenadeCurrentRot < promenadeRotInitial + 285 &&
               promenadeCurrentRot > promenadeRotInitial + 255) {
34         tre = true;
35         }
36     }  else if (promenadeRotInitial >= 75 && promenadeRotInitial <= 105)
           {
37         if (promenadeCurrentRot <= 285 - (360 - promenadeRotInitial) ||
               promenadeCurrentRot >= promenadeRotInitial + 255 ) {
38         tre = true;
39         }
40     } else if (promenadeRotInitial > 105) {
41         if ( promenadeCurrentRot < Math.Abs(285 - (360 -
               promenadeRotInitial)) && promenadeCurrentRot > Math.Abs(255
               - (360 - promenadeRotInitial))) {
42         tre = true;
43         }
44     }
45 //   4/4 of a turn
```

```
46      if (tre && promenadeRotInitial < 15) {
47          if ( promenadeCurrentRot > 345 + promenadeRotInitial ||
                promenadeCurrentRot < promenadeRotInitial + 15) {
48          tre = false;
49          }
50      } else if ( tre && promenadeRotInitial >= 15 && promenadeRotInitial
            <= 345 ) {
51          if ( promenadeCurrentRot >= promenadeRotInitial - 15 &&
                promenadeCurrentRot <= promenadeRotInitial + 15 ) {
52          tre = false;
53          }
54      } else if (tre && promenadeRotInitial > 345) {
55          if ( promenadeCurrentRot > promenadeRotInitial - 15 ||
                promenadeCurrentRot > 15 - (360 - promenadeRotInitial)) {
56          tre = false;
57          }
58      }
59  }
```

6.3.4 Profile

In the profile page, main user aspects are displayed. To make it personalised to current user and show the real data, once again was used the PlayFab account for the project. To show users info, a database is accessed and values are consulted. For example, username and email (Listing 6.10).

Listing 6.10: Username and Email Code

```
1 PlayerName = result.InfoResultPayload.PlayerProfile.DisplayName;
2 PlayerEmail = result.InfoResultPayload.PlayerProfile.
      ContactEmailAddresses.ToString();
3
4 Username.text = PlayFabManager.PlayerName;
5 Email.text = PlayFabManager.PlayerEmail;
```

6.3.5 Activities

The Turning Point application offers three different activities to practice the exercises, the music box, the blocks and the silhouettes. They all measure the same values and the same exercises, but have a distinct graphic interface to offer choice to gymnasts.

Music Box

In this activity there is a music box ballerina, performing the exercise chosen by user. In the **balance** case, the ballerina only oscillates between left and right (Figure 6.14), according to the users movement collected by the smart insoles - if the gymnast if is unbalanced to the right, the ballerina will also oscillate to the right, and if the gymnast corrects the position, the ballerina accompanies.

In the **promenades** case, the ballerina turns 1/a of a turn matching gymnast movement, analysing also the balance distribution, *relevé* altitude and one foot support during the movement (Figure 6.14).

On the **pirouettes** case, as seen previously, there is no need for visual feedback once it is a

quick movement and gymnasts can not see it. Therefore the ballerina does not move during gymnast movement, demonstrating solely the position that the gymnast must maintain throughout the rotation, while the insoles are measuring the data related to the pirouette (Figure 6.14).

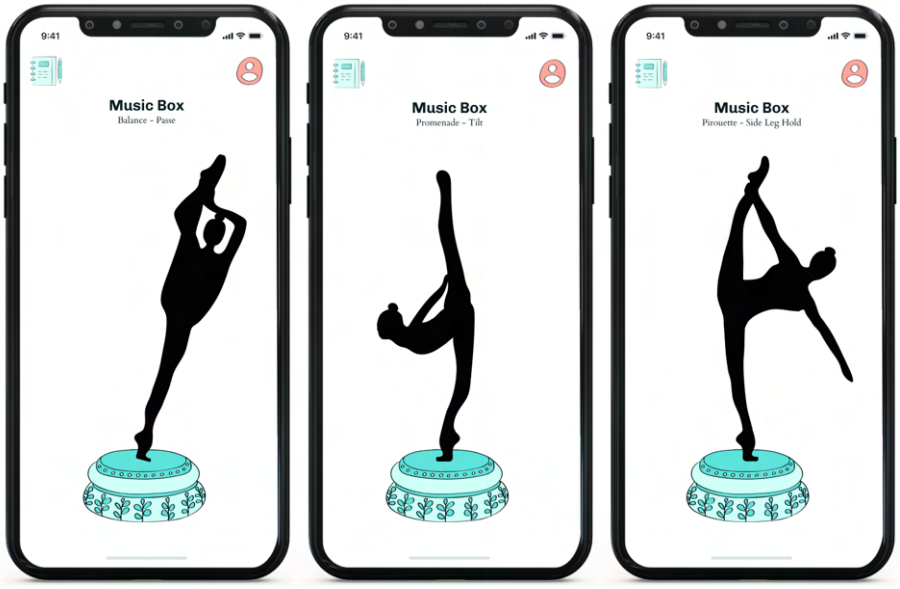


Figure 6.14: Music Box Exercises

Blocks

In the blocks activity, five blocks are dropped one at a time from the top of the screen during the performance of the exercise.

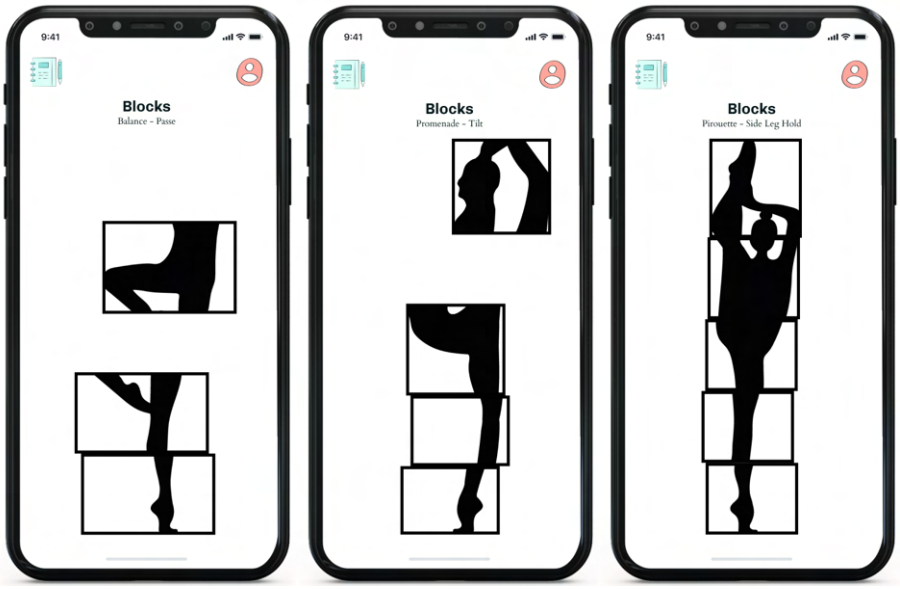


Figure 6.15: Blocks Exercises

In the **balance** case, each block falls at intervals of two seconds, of a total of ten seconds (Figure 6.15). The position of the block to be dropped varies according to the position of

the centre of balance of the gymnast during the performance.

In the **promenades** case, each block is consecutively dropped as soon as 1/4 turn is complete, again varying its position accordingly to the gymnast centre of balance(Figure 6.15). In the **pirouettes** case, the blocks are all piled up, without motion, as in the music box, leaving the analysis solely to the smart insoles(Figure 6.15).

Silhouettes

The silhouettes option, replicates the competition scene in all exercises. Both in balances, promenades and pirouettes, does not exist any motion throughout the performance, it appears only on the screen the figure of the silhouette of the exercise to be performed (Figure 6.16).

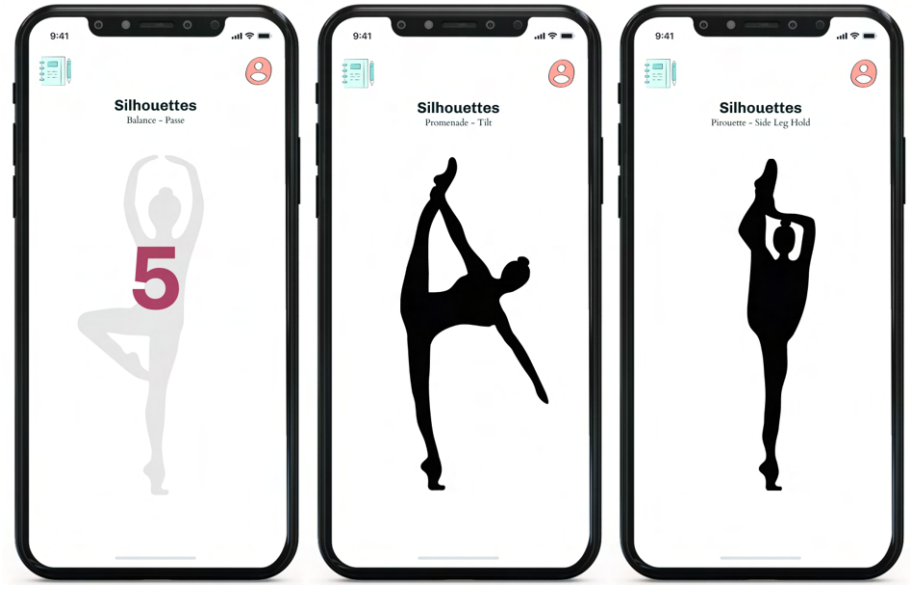


Figure 6.16: Silhouettes Exercises

6.3.6 Feed

From the research phase, the need for communication between users was outlined, in which they would be able to share their videos and achievements, search and see other users videos, like, comment, learn from and send messages between them. These identified aspects are the characteristics of a common social network as those participants are accustomed to navigate every day.

After an extensive search in various forums we have reached the conclusion that developing a social network in Unity platform was not appropriate, once it would not need any 3D component, any augmented reality and any heavy animations in the social application (Khan, n.d.). Unity is geared towards games and a social network application is geared towards GUI experience and, while it is possible to develop it in Unity, it will drain battery faster and practicalities that the Android brings, would be missing out . (Volkov, n.d.). The solution for the problem rests in the cross-platform option, using unity + native (android/iOS), getting the best of both world (Khan, n.d.). But as this milestone goes beyond the proposed goal of this dissertation and time is scarce, it was decided to leave it for a further and future phase of the project, developing now the design screens and

leaving everything ready for the moment of implementation. The screens developed are presented below on figure 6.17.

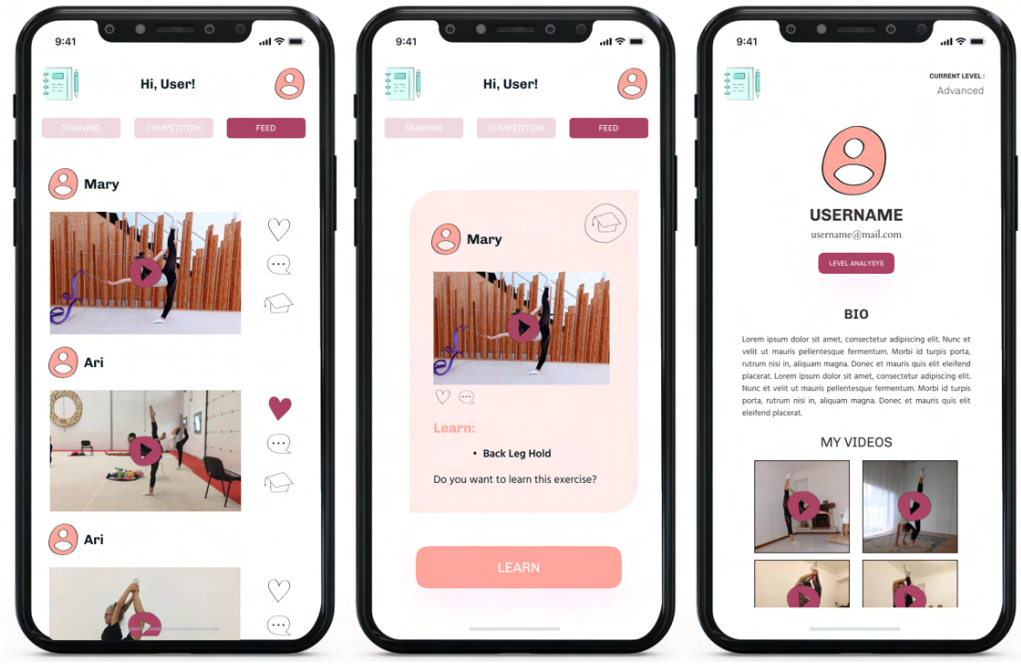


Figure 6.17: Final Feed Screens

6.4 Summary

The graphic elements present in the application, such as colour palette, typography and icons, were set and developed based on the choices made by the participants during the PICTIVE method. The Turning Point identity was designed with an idea based on its intended purpose and was adapted to the Android requirements. Aspects related with the feedback information organisation were defined and the distinction between the training and competition mode; advanced, intermediated and iniciated gymnasts clarified. A database with exercises and expressions used during the training sessions was developed to bring the structure of the app as close as possible to actual training session.

The implementation phase was also carried out with the development of as application structure and navigation model. A backend platform, Microsoft Azure PlayFab, was used to deal with user management, logins and registers, and the connection between the smart insoles and the Turning Point application was set. The analysis of the exercises with the help of the smart insoles was developed for the different activities and the final feed screens were designed.

Chapter 7

Usability and User Experience Evaluation

This chapter is dedicated to the usability tests and user experience evaluations. Multiple usability definitions share three common issues: first, it is that a user is involved, second, is that the user is doing something, and third, is that the user is doing something with a product or system (Tullis & Albert, 2008). Whilst usability refers to the ability of a user to do a task or use a product, experience takes a wider view by taking into consideration one's entire interaction with the product, as well as the thoughts, feelings, and perceptions that result from that interaction (Tullis & Albert, 2008).

Questions like effectiveness, the ability to complete a task, efficiency, the amount of effort required to complete the task and satisfaction, the degree of happiness with the experience while performing the task, will be analysed. To prepare the evaluation, issues like the number of participants, types and tasks to be performed had to be thought through, as suggested by (Tullis & Albert, 2008).

Two evaluations were performed. The first tests were conducted with the smart insoles to understand how the gymnasts would adapt to the smart insoles and whether it would hinder the exercises. As previous projects used the smart insoles inside the sneakers, the team also wanted to understand if it was feasible to wear them with socks and which option would best suit gymnasts. The second ones, with a functional prototype of the Turning Point application, were intended to how gymnast would interact with the Turning Point Application, to ensure the options were clear and the tasks could be completed with ease. Lastly, one wanted to uncover errors to upgrade the project.

The tests will be described and the methods used presented in this chapter. Results obtained will be presented and analysed and any resulting amendments will be also described and explained. These tests were conducted during the project development and focus on usability and user experience.

7.1 Smart Insoles Testing

With the smart insoles testing, our main goal was to understand how gymnasts would adapt to the insoles and if they would feel comfortable using them. As gymnasts train in socks or in gymnastics toe shoes, we intended to understand whether the smart insoles could be used in the gymnastics context or if it was better to use the insoles while wearing

sneakers (Figure 7.1).

Figure 7.1: Smart Insoles + Socks | Smart Insoles + Sneakers

7.1.1 Smart Insoles Testing Procedures

To prepare the test, and based on the OTS notes, a sequence of exercises were created (Figure 7.2) for the gymnasts to perform, ones with the smart insoles and sneakers and others with the smart insoles and socks. Also a couple of questions were created in order to assess the gymnasts feeling about the two insoles possibilities and how those two options would influence their training. Furthermore, we decided to use counterbalancing, which involves changing the order in which different tasks are performed, once participants may learn the product as their experience with it grows (Tullis & Albert, 2008). The tests order starting with the socks or starting with the sneakers was alternated among the participants, to try to make the results as unbiased as possible.

- 6th Position Releve
- Coupé Releve Right
- Coupé Releve Left
- 10 Jumps 6th Position
- Retiré Balance
- Ring Balance
- Retiré Pirouette
- Ring Pirouette

Figure 7.2: Smart Insoles Tests

The activities with both socks and sneakers were the same, so no matter which shoe type they started with, the exercises were the same (Figure 7.2). Gymnasts were placed standing facing a wall, so they could be focused and would perform the listed exercises following the researches voices (Appendix I: Smart Insoles Tests, Smart Insoles Testes Records).

For the analysis of these first tests, the focus was on the gymnasts impressions on the experience with the insoles, during performance. Since participants were young, and some of them were still in the first years of school, we decided to show them a visual questionnaire to catch their attention and encourage them to answer the questions correctly (Figure 7.3). For the main analysis, a set of smiling faces were disposed in front of each

Figure 7.3: Smart Insoles Tests Setup

exercised performed (Figure 7.5). Participants were asked answer accordingly to the way they felt the insoles have influenced the performance. They were also presented with five different crayons with which they were asked to paint the smile (Figure 7.4), dark green for "felt really good", light green for "felt good", yellow for "nor good nor bad", orange for "disliked it" and red for "hated it" (Appendix I: Smart Insoles Tests, Insoles Testes Questionnaire Answers). For a side analysis, researchers were attentive to participants comments, pointing them out and making a list to subsequently examine and draw conclusions. The smiley faces tests were composed of ordinal data, meaning they were ordered by groups with intervals between the measurements, which were not meaningful (Tullis & Albert, 2008).

Figure 7.4: Coloured faces

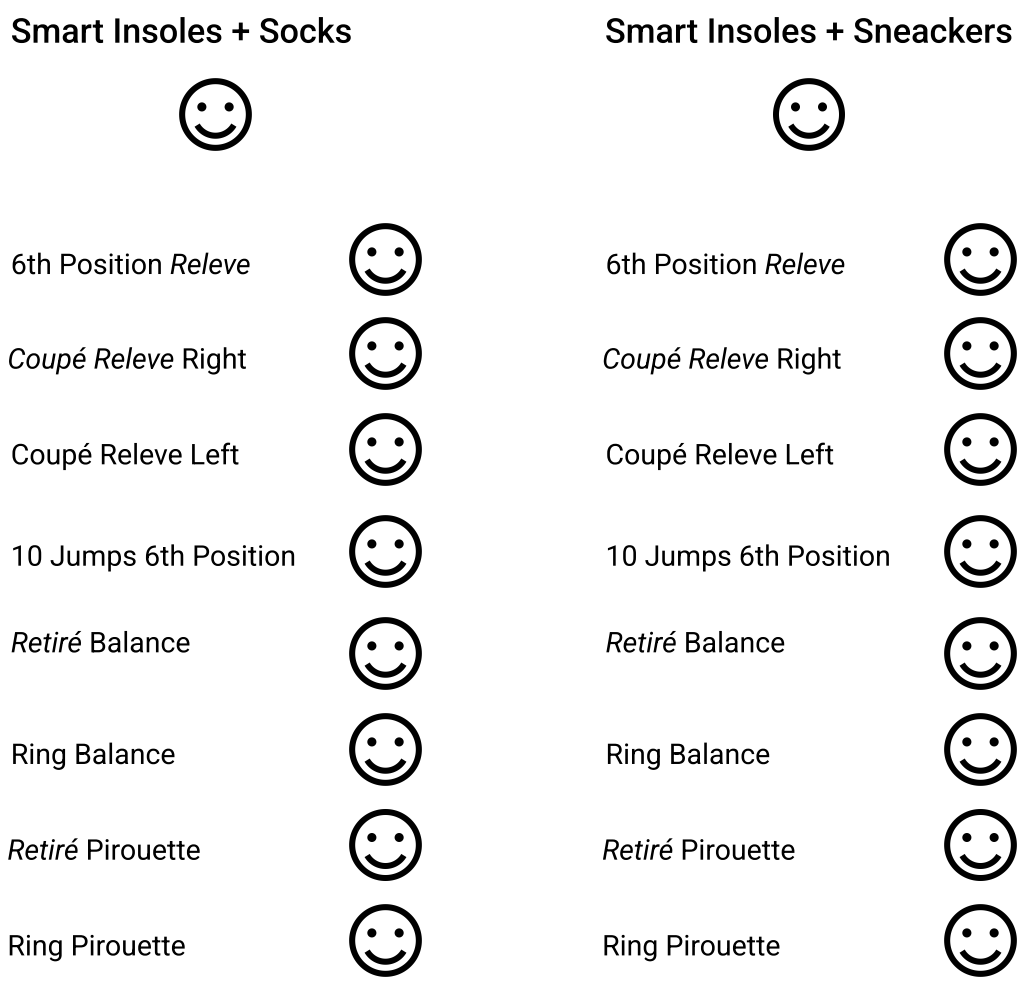


Figure 7.5: Feeling Opinions

7.1.2 Insoles Testing Participants

Participants were once again recruited from Aveirogym. Ten female gymnasts, aged from 9 to 18 (Mean = 12.4), voluntarily participated in this study, and agreed to be recorded while doing so. We tried to gather a wide range of ages within the available participants to understand whether there was any interference related to age or gymnast skill level.

Table 7.1: Smart Insoles User Experience Tests

Participant	Age	Shoe Size	Age Group	First with
P01	09	34	Initiation	Socks
P02	09	32	Initiation	Socks
P03	18	39	Senior	Sneakers
P04	11	36/37	Juvenile	Socks
P05	11	37	Juvenile	Sneakers
P06	12	37	Junior	Socks
P07	13	38	Junior	Sneakers
P08	10	36/37	Juvenile	Socks
P09	17	38	Senior	Sneakers
P10	14	36	Junior	Socks

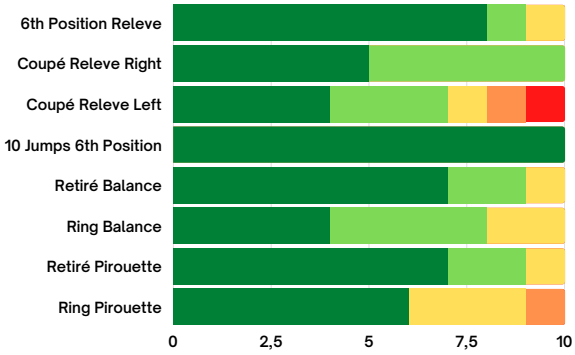
7.1.3 Results and Analysis of the Smart Insoles Testing

Moving to the analysis and referring first to the the smart insoles with the socks. Questions were individually analysed and participants were asked to sum up the experience with the smart insoles and the socks in one colour (Figure 7.6).

Starting with the **socks and smart insoles set of exercises**, in the first exercise, ***Relevé* in sixth position**, eight gymnasts felt it was really good, one felt it was good and one felt it was nor good nor bad. For the second question, ***Coupé Relevé* Right**, the answers were equally split between the two most positive feelings. As for the third exercise, ***Coupé Relevé* Left**, all possible answers were mentioned at least once, four gymnasts felt it was really good, four felt it was good, one thought it was nor good nor bad, one has disliked it and one hated it. The difference reported between the feeling of the same exercise, same shoe, just with a different leg, hang on the fact that they were predominantly better with the first leg and did a better exercise, thus gaining more confidence and feeling better. On the **10 Jumps in Sixth Position**, as they were so excited and the smart insoles interfered a little with the exercise, and all the 10 results were the best possible. Moving to the ***Passé* Balance** and the **Ring Balance**, answers were similar, but slightly more positive on the first foot, once again because it is an easier balance and more gymnasts could get it right. Finally, in the pirouettes, in the ***Passé* Pirouette**, replies were really positive, but as with the balances, the **Ring Pirouette** caused worse feelings than *passé* pirouette, as it is a way more difficult exercise. In particularly, some of the gymnasts were not able to do it properly.

When asked about the whole socks and smart insoles experience feeling, nine gymnasts answered they have felt really good in general and only one has answered she felt good throughout the exercises (Figure 7.6). It should be noted that one of the participants presented far more negatives in the overall answers than the rest, possibly due to personality factors. Also, although they have been warned not to take into consideration their performance and only focus on the how the smart insoles felt, it was a hard task for the

younger gymnasts, concerned also with their performance.



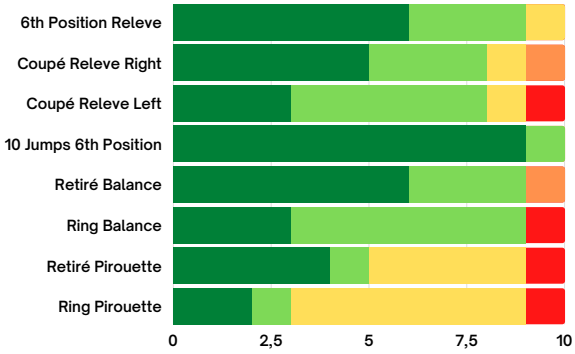
(a) Exercises

(b) Overall

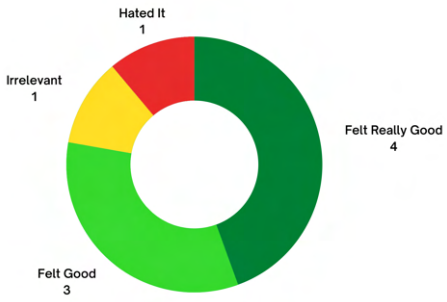
Figure 7.6: Socks and Smart Insoles Tests

For the **sneakers and smart insoles set of exercises**, less positive responses were received (Figure 7.7). In the ***Relevé* in sixth position**, six gymnasts felt it was really good, three felt it was good and one thought it was nor good nor bad. In the second exercise, ***Coupé Relevé* Right**, the answers were the same with the exception of minus one really good and plus one on disliked it. For the ***Coupé Relevé* Left**, only three gymnasts felt it was really good, five felt it was good, to one it was nor good nor bad and one hated it, exhibiting again that they were also taking into consideration how they were performing. On the **10 Jumps in Sixth Position**, responses were again really good and only one gymnast did not give the most positive response. Once again, insoles and sneakers had little interference in the exercise. With the ***Passé* Balance** and the **Ring Balance**, responses were worse than with the socks, with responses ranging from less good and really good, disliked it, and hated it. For the ***Passé* Pirouette** and the **Ring Pirouette**, an overall negative result was received, with little responses to really good and good, a lot of responses for nor good nor bad and one response in each with hated it.

For the overall experience (Figure 7.7), four felt really good, three felt good, two thought it was nor good nor bad and one hated it.



(a) Exercises



(b) Overall

Figure 7.7: Sneakers and Smart Insoles Tests

During the tests, expressions by gymnasts were written down to be analysed. With the socks and smart insoles, there were a lot of giggles and gymnasts were enthusiastic with the experience. Onto the sneakers, a lot of different comments started to came out, a lot of *"ai"*, *"fogo"*, and frustrated faces have been noticed, gymnasts had a lot less balance than before and had to be constantly restarting the exercises because they were falling. The worst exercises were the pirouettes because they could barely turn and none of the gymnasts managed more than one turn, unlike with the socks, where their performance was very similar to training. This was possibly due to the rubber creating attrition with the floor, thus preventing any fluid turns.

When asked why they did not like the sneakers combination as much as the socks combinations, answers like "I can not turn and rise my *relevé*", "It does not do any good", "I can not stretch my foot" and "They are too hard, I rather use the socks" were received. Also one gymnast said there were things which were better with the socks and things which were better with the insoles, like jumping and foot stability, but regardless of that, she still preferred the socks combination.

After the whole analysis, it was established that the insoles would be used with the socks and not with the sneakers, as the latter impeded movement and there was no impediments with the use of the sock.

7.2 Usability and User Experience Tests

7.2.1 Usability and User Experience Procedures

Firstly, high fidelity prototypes were developed in Figma for the usability test. But since the application was already implemented with the interactions and screens ready, usability tests ended up being conducted with it, as the designer thought it more appropriate. The goal was to understand how gymnasts would react to the application and understand if the main tasks were easily understood and executed. A list of assignments was drawn up (Figure 7.8), like a historical dialogue in such way that the participant would be guided through the whole application unconsciously and perform the more important tasks which would be accessed.

The application was delivered to each participant at a time in a cellphone, Samsung Galaxy A32 5G, and a brief explanation of what was going to happen handed out. As the application was being built in English and some of the younger participants were not fluent in the English language, researchers made themselves available to translate every word participants could possible not know the meaning, always exempt and without interfering with the tests results (Appendix J: Usability and User Experience Tests, Link to Video of the Application Running). Younger participants also had difficulties understanding the task, so researchers noticed that reading the tasks alongside with them would solve the problem and would enable them to continue the tasks. As a result, these procedures were adopted for tests with younger gymnasts.

On the tasks included in the usability tests were completed, a questionnaire was delivered to the participants. Being so, at this stage and after the tests conducted, the researcher felt the gymnasts had already understood the application functioning and the insoles propose, and so it was the right time to evaluate their opinion regarding the advantage of use of the Turning Point application and the smart insoles to improve performance. This questionnaire consisted of a assembly of eight questions, answered on a five-level Likert scale (Figure 7.9)

1 - Open the Turning Point application and start using it.
- Click on the icon or wait for the application to load
- Choose the Register button
- Insert the data

2 - Continue to the main menu
- Proceeds to level analysis?
- Reads the instructions?
- Accomplishes 1st task?
- Accomplishes 2nd task?
- Accomplishes 3rd task?
- Sees level reached?

3 - Practice your balances, start with the passé. What feedback have you received?
- Selects "training"
- Selects "balances".
- Selects "passé".
- Presses Start
- Reads the feedback?
- Opens the instructions?
- Needs special help?
- Does she record?
- Waits for the timer?
- Reads final feedback?
- Shares it in the feed?

4 - Now repeat to improve!
- Presses "repeat".
- Needs special help?
- Records it?
- Shares on feed?
- Repeats again? Or goes back to the menu?

5 - Now practise your side leg hold balance.
- Selects "training
- Selects "balances".
- Selects "side leg hold".
- Presses Start
- Reads feedback?
- Opens instructions?
- Needs special help?
- Recording?
- Waits for the timer?
- Shares in the feed?
- Repeats? Or goes back to the menu?

6 - Now that you've practiced, how about checking out how you're doing in the attitude pirouette competition? What's your score?
- Selects "competition
- Selects "pivots
- Selects "attitude".
- Presses Start
- Recording?
- Starts the exercise at the end of the timer?
- Can see final score?
- Reads the feedback received?
- Sees the ranking? Searchs for position?

7 - In your notebook, you will find a list of your main errors. Go to it and check one of the corrections you have.
- Clicks on the notebook?
- Chooses a corrections and reads it

8 - Do you think you have improved your skills after training? Re-evaluate and adjust your level.
- Clicks on the profile
- Clicks on assess level
- Performs all tasks

9 - Go to the feed and find an exercise you like, click on it and interact with it.
- Clicks on the feed
- Scrolls until finding an exercise
- Clicks on it
- Does the "like"?
- "Comments"?
- Clicks on "try"?

Figure 7.8: Usability Tests Tasks

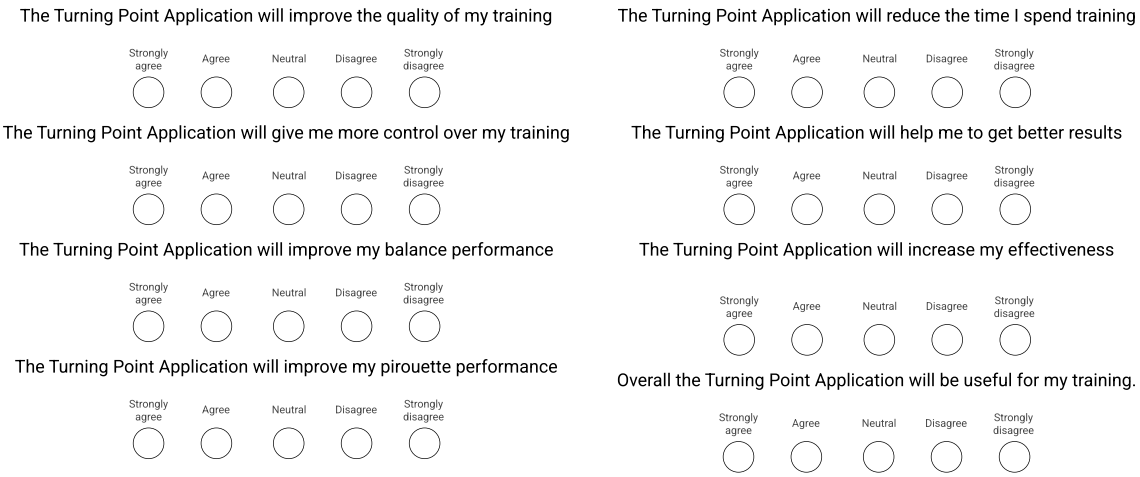


Figure 7.9: Usability Tests Likert Scale

7.2.2 Usability and User Experience Participants

Participants were once again from Aveirogym. Ten gymnasts (all female) aged from 9 to 14 (Mean = 11.3) voluntarily participated in this study, and agreed to be recorded while

doing so. For this phase, none of the older gymnasts were available to enrol in the study, notwithstanding the researcher decided to proceed. After some deliberation, the researcher also concluded that to not involve older gymnasts was not a big deal, because if younger gymnasts with less technological expediency could perform the task correctly, most likely there would be no problem with the older ones.

Table 7.2: First Usability Tests Participants

Participant	Age	Has a Phone	Age Group	Days per week with phone?
P01	13	Yes	Junior	Everyday
P02	13	Yes	Junior	Everyday
P03	11	Yes	Juvenile	Everyday
P04	12	Yes	Junior	Everyday
P05	11	Yes	Juvenile	Everyday
P06	09	No	Initiated	3/4 days
P07	09	No	Initiated	4/5 days
P08	12	Yes	Junior	5 days
P09	10	Yes	Juvenile	Everyday
P10	13	Yes	Junior	Everyday

7.2.3 Usability and User Experience Results and Analysis

To examine the tasks and draw comparisons it was decided to measure the success rate of each assignment and how long did it take the participant to complete it. Inside each task presented to the user, seen on Figure 7.8 in bold, there were subtasks that would also be assessed, also seen on Figure 7.8 with regular font weight. As the subtasks were mandatory to fulfil the main ones, the researcher decided to present only the bold ones to participants.

For the main tasks, two variables were analysed, the **task success** and the **time taken to complete it**. As for the subtasks, success and different option selections were analysed.

Starting with the nine main tasks, all were successfully accomplished by the participants, with a 100% success rate. Regarding the time it took each participants to complete those tasks, there were not big deviations, being the larger variations noted between activities. Because some tasks took longer to complete than others, only the time between participants will be taken into account. However, it was clear that, as the gymnasts got used to the application, their task completion times reduced.

Figure 7.10 presents an overview of the time participants took to complete each task. On the X-axis all the main tasks are represented, while on the Y-axis the timescale, in seconds, is represented. Each colour represents a different participant, being ten in total, and each cross represents the exact time a task took.

All tasks were accomplished with success by all users. The task 7, **level analysis task**, took too long to be completed despite of the few steps to complete in it. Participants had a difficult time to connect the level analysis with the profile section, and spent some time looking for this item in the main menu. For that reason, this was the least successful task. The rest of the tasks were completed within a reasonable time, usually less that one minute, considering the number of steps needed to complete.

As for the subtasks respecting to the **first task**, during application opening, two participants clicked on the screen instead of waiting, two of them tried to login rather than register

Figure 7.10: Main Tasks Time

and had to go back to the right place and all of them inserted the correct data in the correct fields (Figure 7.11). As for the **second task**, only four participants read instructions instead of skipping it, and seven participants acknowledged the level they reached (Figure 7.12). In the first four sub-assignments of **task 3** all gymnasts have chosen the different options, whilst only two read the feedback prior exercise. None have opened the instructions neither the special help. Still in the task 3, only two gymnasts interacted with the record option and eight have correctly waited for the timer to go to zero before starting the exercise, seven of them read the final feedback and only one has shown interest in sharing it on feed (Figure 7.13).

Moving to the **task 4** and respective topics, all gymnasts hit the repeat button and only one needed special help. While two have recorded the exercise, only one has shared it on the feed, three chose to repeat the exercise twice (Figure 7.14). **Task 5** assignments were similar to task 3 and so were there results: all gymnasts chose the training, the balances and have pressed the start button, but one missed the side leg hold. Two of them read the feedback and none opened the instructions. One participant felt the need of special help and four have recorded it. During the exercise, eight gymnasts waited for the timer, two shared on the feed and four repeated the exercise (Figure 7.15).

On **task 6**, three participants missed the competition tab, one missed the pirouettes and all of them pressed the attitude and start button. Only three have recorded and nine waited for the timer, while seven looked for the final score, five have read the received feedback and only three searched for the ranking (Figure 7.16). **Task 7** had seven girls to quickly achieve the notebook and nine found the corrections (Figure 7.17). In **task 8**, seven reached the profile on their own and all have selected the level analyses button and performed the tasks (Figure 7.18). To finalise, **with task 9**, all gymnasts reached the feed, and nine have scrolled down until seeing an exercise which they liked it. All of them clicked on the video and have made a like, while only one left a comment, and five

demonstrated willingness to try it (Figure 7.19).

Figure 7.11: Task 1 Subtasks

Figure 7.12: Task 2 Subtasks

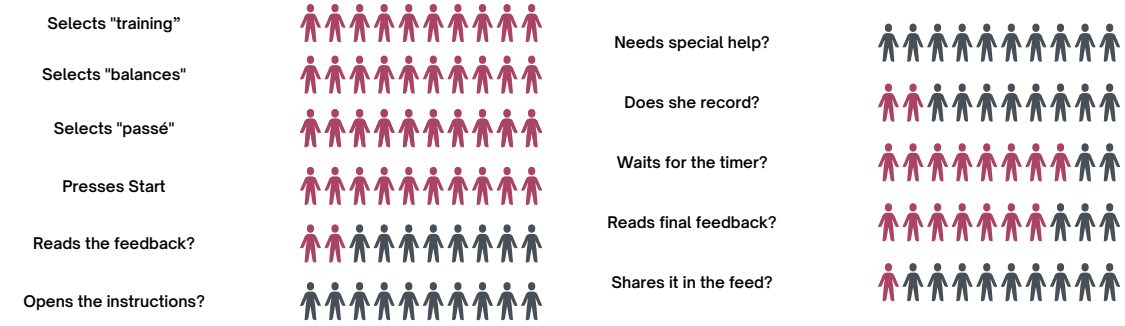


Figure 7.13: Task 3 Subtasks

Figure 7.14: Task 4 Subtasks

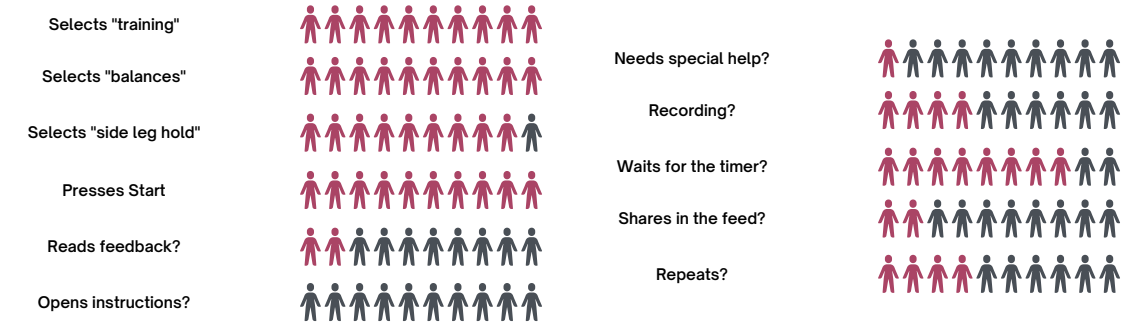


Figure 7.15: Task 5 Subtasks

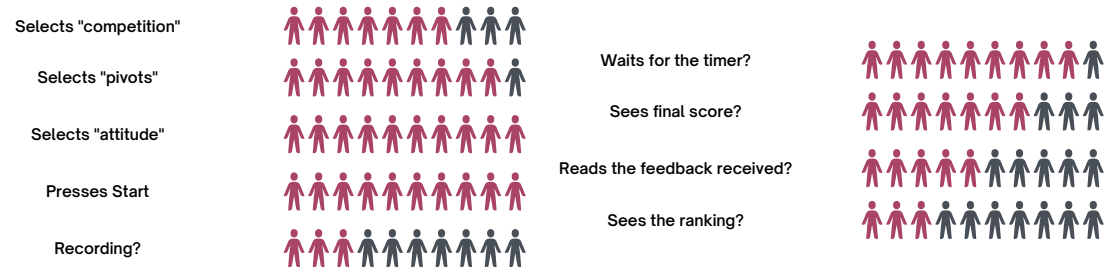


Figure 7.16: Task 6 Subtasks

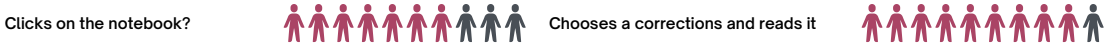


Figure 7.17: Task 7 Subtasks

Figure 7.18: Task 8 Subtasks

Figure 7.19: Task 9 Subtasks

Again, the researcher decided to use ordinal data for the results instead of interval data, this last is used for continuous data where the differences between the measurements are meaningful and represents an incremental increase or decrease in perceived usability. Labelling only the end points, makes it easier to make decisions which are more subjective, and as participants were young this was considered appropriate.

All questions got really positive answers in the range of Strongly agree and Agree, and few Neutral (Figure 7.20). As for the **question 7** - "The Turning Point Application will reduce the time I spend training", responses were the completely opposite, one neutral, three Strongly disagree and six Disagree. When asked why they had answered this way, participants answered they would spent more time using the application and so, more time training. Despite of our intention being to know if they would get to the goal faster with the insoles, the way they have interpreted the question also provides important insight.

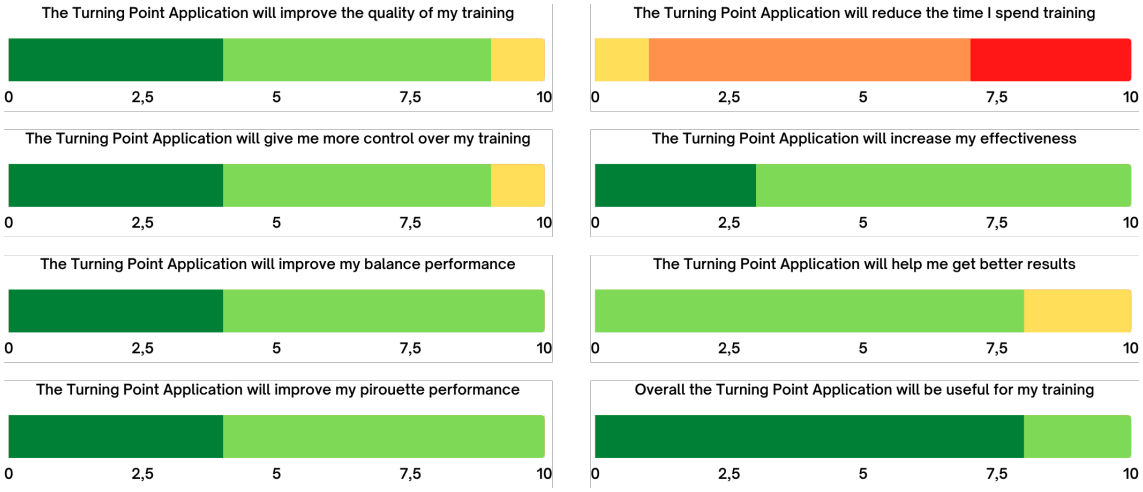


Figure 7.20: Usability and User Experience Tests Results

7.3 Summary

The test conducted with the smart insoles have made it possible to understand that the gymnasts do not feel limited using the insoles in their training sessions if combined with socks and really enjoyed the experience, proving the great potential of this technology in addressing the problem of this dissertation. The usability and user experience tests conducted with the Turning Point application was a great opportunity to learn whether the users would be able to use it properly, whether the activities were achievable and whether there were any aspects to improve or correct. The overall results of the tests were very good with very positive feedback from the participants. Participants thought they would be handled the application at the end of this project's development, for them to use it every day and were delighted and excited with that prospect.

Chapter 8

Conclusions and Future Work

The idea for this project arose from an existing proposal which suggested the creation of an application using the smart insoles to support physical rehabilitation in people with health problems. After researching the characteristics of the smart insoles, it was understood that these had also features that could potentially help rhythmic gymnasts in the learning and improvement of their balances and pirouettes. So, this was the proposal made, and once the idea had been explained, the green light to go forward was given, and the project started.

The goal was to design, develop, and evaluate a proof of concept of a mobile application, directed to gymnasts of rhythmic gymnastics, which would help in the learning and improvement of balance and pirouettes performance. The mobile application would leverage the data of a pair of smart insoles to generate feedback for the gymnasts. In the introduction we presented a hypothetical scenario where the application would inform gymnast on her weight distribution during the performance. If gymnasts weight was off to the left, the app would issue feedback for this to be corrected to the left, or if the *relevé* was low, it would issue feedback for gymnast to raise the heel. it was through carrying out the next steps that this aim was achieved.

Throughout the development of the project and after understanding the current overview of the subject in study, a series of research phases were conducted, where information about the training context and its stakeholders were collected. Co-design workshops with the PICTIVE technique and constant iteration with the participants were carried out in order to develop the proof of concept for the mobile application, meeting users' preferences, as much as possible. Finally and after the conceptualisation of the proof of concept of this application, usability and user experience tests were conducted. It was possible to conclude that the application developed, Turning Point, was operational, complied with what was proposed, and was superbly well received by rhythmic gymnasts.

While developing this project, a critical perspective was developed in the search and selection of information. The ability to conduct research and interviews sessions with participants in the search for key elements to the project was also developed and refined, without losing sight of the need to use and present only the core information. Regarding the co-design sessions, the researcher understood that users also have important ideas during the development of a project which is aimed at them and that these must be valued. Finally, about the implementation, it was realised that the knowledge of various programming languages is essential and an asset when starting a new project, logic, reason, and perseverance are the key in this process and what makes good achievements possible.

This project proved to be a great opportunity that gave me a new perspective on the subject. Having been a gymnast and now a coach, this project has completely changed my perspective on the sport, which I now employ as an advantage during training, using the knowledge acquired on the relationship and interaction with the gymnasts.

It was also learned throughout the whole year that one's will and persistence move mountains, so even when something seemed impossible the answer was just keep going until it was not impossible anymore. To develop this work and grow with it was an incredibly enriching experience, both professionally and personally.

This project contributes not only with a synthesis of insights and knowledge, based on the literature review, but also with the results of in-depth studies with the gymnasts and their context, as well as all the results achieved. The proof of concept if the application design, develop, and evaluated during the project is an added value to any rhythmic gymnastic practice, which enhances learning and eases the acquisition of a better pirouette performance technique. The contributions provided by this project will be valuable to anyone who wants to undertake a project in the area, to coaches who seek to better understand gymnasts and elevate the quality the training sessions, and to gymnasts who wish to upgrade their autonomous training and improve their performance.

8.1 Difficulties Experienced

The fact that the student had never worked with Unity before was a difficult challenge at the beginning of the project, which was slowly yet smoothly overcome with online research. One of the initial decisions to be made caused some doubts: should the application be developed for gymnasts or for coaches. After deliberation and analysis, the decision was made towards the gymnasts due to the bigger possibility range and increasing need, realising midway through the project that user research had confirmed, it was the right decision, both at the participant level and at the final result level.

Difficulties were also experienced with the code that accompanied the smart insoles system, since the could had errors and were not properly working in the beginning, which delayed the development of this project. Since no adaptation of the smart insoles to a smartphone was not developed by the smart insoles research team, it was not possible to perform the final tests on a smartphone, despite of that, components present in the application were tested with participants. This is considered sufficient in the context of a proof-of-concept. Now that usefulness and desirability had been confirmed, the next stages of developed to make it into a fully integrated solution.

Due to the current pandemic state and the lack of possibilities near the team's location, it was only possible to include in the studies participants from only one club, Aveirogym, so there was a lack of diversity and numbers, for the results to be completely assured.

During the development of this project, the greatest difficulty experienced was due to a series of health problems that made the project even more challenging, but making it also more gratifying in the end.

8.2 Future Perspectives

The Turning Point application was developed to assist gymnasts in the balances and pirouette training, which, from the user feedback collected, it clearly delivers. There is still room

for improvement on a number of aspects, as well as the development of new features and options.

Despite of being already design and though out, the application feed, resembling a social media application, was not yet implemented due to dissertation deadlines and deviations from the main theme. It is an interesting task to be performed as it would allow gymnasts to really be connected and exchange knowledge among them. The application lacks also in animations that would make it more dynamic and pleasing to the eye, interconnecting better the screens and making navigation easier. On the profile section, it would be beneficial to add more types of information related to the gymnasts real life and recent competitions and results. To better assist gymnasts with important tasks, like re-evaluate the level as seen on the tests, the application can deliver pop-up balloons with a brief explanation of important issues. The last point relates to adaptation of the QGAIT insoles code to a smartphone, so that a fully functioning and integrated solution could be provided.

As seen throughout the project, gymnasts react very well to challenges and to goal settings, which motivates them and turns out to be an optimal incentive to train better. Although the Turning Point database has a lot of exercises, only the most important exercises in rhythmic gymnastics are featured. For a later stage of the application, it would be interesting to have a complete database with all the options available. The application has the potential to provide a path between gymnasts and coaches for them to maintain regular direct communication, where gymnasts can send coaches their training videos and coaches can give them feedback about them back.

In a new stage, the application should be amplified to also respond to the needs of coaches, and instead of delivering feedback based on performance, it would deliver detailed scientific data read by the smart insoles, throughout the exercise. After consulting a medical podiatrist and experts in the field of sports injury prevention, a feature for movement analysis could be added, taking into account the possibilities of injuries. In tandem, the application could also deliver feedback with the goal of preventing bigger injuries.

It is also desired, even after the delivery of the project, to adapt and elaborate scientific articles with the information acquired during this project, to disseminate knowledge and contribute to the scientific world in a valuable way by increasing the scarce repository in the area.

The Turning Point application project has an enormous potential, with unbelievable gains for the rhythmic gymnastics sport and all stakeholders involved. As with great potential comes great work, even with all the tasks performed, many others are still on standby that could be embraced in the future. Having accomplished what was proposed, the researcher presents this project with great honour and pride, with an incredible sense of accomplishment.

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Appendices

Appendix A: Informed Consent Forms

Paper-based informed consent form

Declaração de Autorização/Consentimento

Universidade de Coimbra
Aluna: Leonor Silva Portugal da Fonseca

Tema da Dissertação: "Smart insoles supporting the execution of pirouettes through a mobile application"

Descrição: Estudo e avaliação da performance de praticantes de ginástica rítmica durante os treinos, em especial na execução de pivots, para o desenvolvimento de uma aplicação móvel, que com o auxílio de umas palmilhas inteligentes, ajude na aprendizagem e melhoria da performance de pivots.

O meu nome é Leonor Fonseca, frequento o último ano do mestrado em Design e Multimédia, na Universidade de Coimbra, e estou a desenvolver o projeto para a dissertação de final de curso, sob a orientação da professora Paula Alexandra Silva.

Sendo um dos meus objetivos produzir uma ferramenta de apoio ao treino de pivots direcionada às ginastas, que vá de encontro a problemas reais e os tente resolver, gostava muito de poder contar com a **participação das ginastas da AGRA ao longo do desenvolvimento da dissertação.** Neste contexto, e nesta primeira fase, venho por este meio, pedir a autorização dos encarregados de educação das ginastas, para proceder à **observação e ao registo de vídeo durante os treinos** e utilizar a documentação para o estudo que estou a desenvolver no contexto da minha dissertação, sendo que este consentimento pode ser retirado em qualquer altura do projeto, sem consequências, através de notificação à aluna.
Todos os dados registados e recolhidos durante as observações, serão apenas **utilizados para fins do projeto** e **não serão disponibilizados a qualquer outra parte ou identidade**, sendo que se o consentimento for entretanto retirado não abrangerá os dados recolhidos e tratados até a essa data.
Estas observações irão decorrer durante 4 treinos que decorrerão entre 25 de fevereiro e 07 de março de 2021.

Gostaria muito de poder contar com todas as meninas. **Qualquer questão** sobre o projeto pode ser esclarecida comigo através do email:
leonorspfonseca@gmail.com
Ou com a professora Paula Alexandra Silva, através do email:
paulasilva@dei.uc.pt

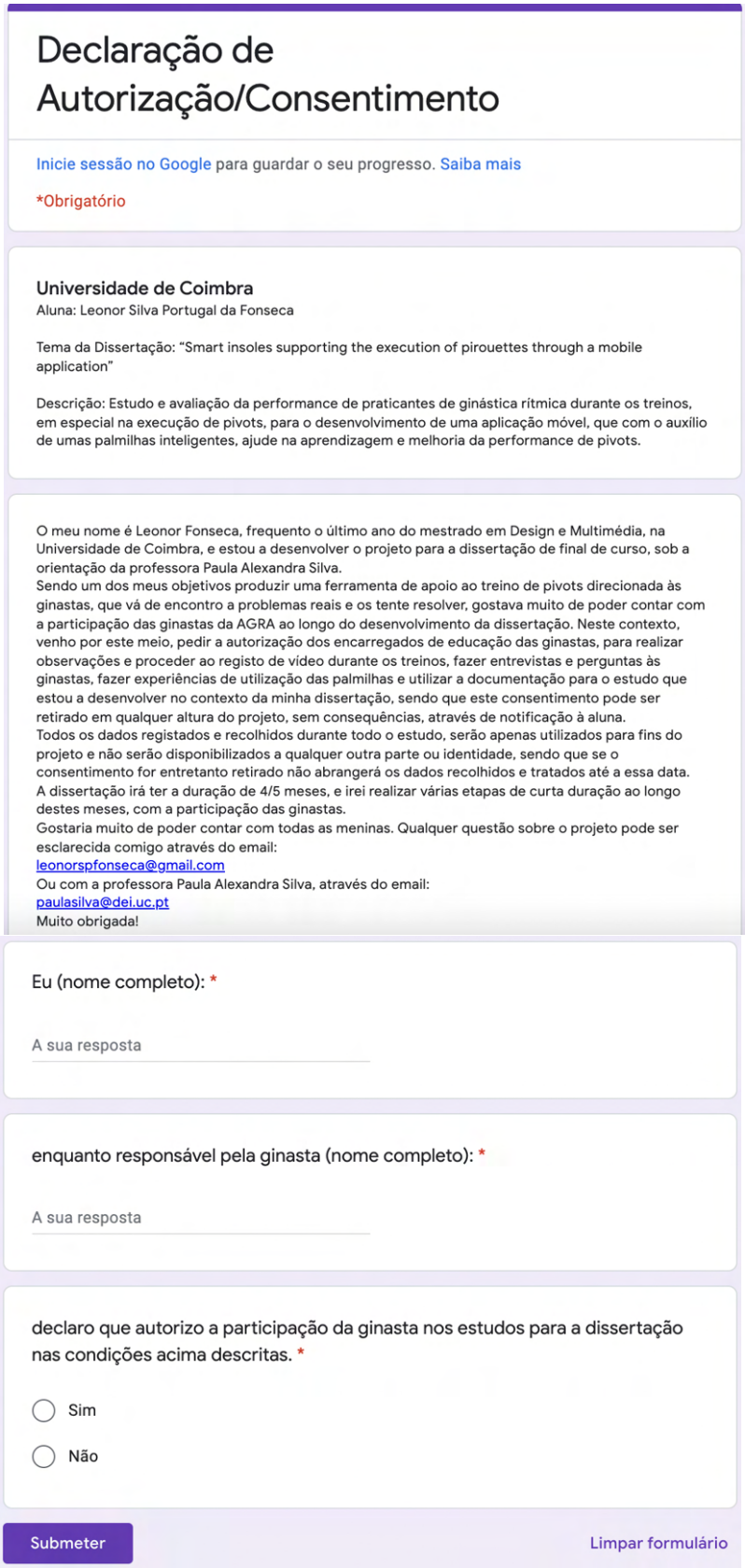
Muito obrigada!

Eu, (nome completo)_____,
enquanto responsável pela ginasta (nome completo) _____
declaro que autorizo a filmagem dos treinos nas condições acima descritas.

Data: _____

Assinatura: _____

Digital informed consent form



Declaração de Autorização/Consentimento

Inicie sessão no Google para guardar o seu progresso. Saiba mais

*Obrigatório

Universidade de Coimbra
Aluna: Leonor Silva Portugal da Fonseca

Tema da Dissertação: "Smart insoles supporting the execution of pirouettes through a mobile application"

Descrição: Estudo e avaliação da performance de praticantes de ginástica rítmica durante os treinos, em especial na execução de pivots, para o desenvolvimento de uma aplicação móvel, que com o auxílio de umas palmilhas inteligentes, ajude na aprendizagem e melhoria da performance de pivots.

O meu nome é Leonor Fonseca, frequento o último ano do mestrado em Design e Multimédia, na Universidade de Coimbra, e estou a desenvolver o projeto para a dissertação de final de curso, sob a orientação da professora Paula Alexandra Silva.
Sendo um dos meus objetivos produzir uma ferramenta de apoio ao treino de pivots direcionada às ginastas, que vá de encontro a problemas reais e os tente resolver, gostava muito de poder contar com a participação das ginastas da AGRA ao longo do desenvolvimento da dissertação. Neste contexto, venho por este meio, pedir a autorização dos encarregados de educação das ginastas, para realizar observações e proceder ao registo de vídeo durante os treinos, fazer entrevistas e perguntas às ginastas, fazer experiências de utilização das palmilhas e utilizar a documentação para o estudo que estou a desenvolver no contexto da minha dissertação, sendo que este consentimento pode ser retirado em qualquer altura do projeto, sem consequências, através de notificação à aluna.
Todos os dados registados e recolhidos durante todo o estudo, serão apenas utilizados para fins do projeto e não serão disponibilizados a qualquer outra parte ou identidade, sendo que se o consentimento for entretanto retirado não abrangerá os dados recolhidos e tratados até a essa data.
A dissertação irá ter a duração de 4/5 meses, e irei realizar várias etapas de curta duração ao longo destes meses, com a participação das ginastas.
Gostaria muito de poder contar com todas as meninas. Qualquer questão sobre o projeto pode ser esclarecida comigo através do email:
leonorspfonseca@gmail.com
Ou com a professora Paula Alexandra Silva, através do email:
paulasilva@dei.uc.pt
Muito obrigada!

Eu (nome completo): *

A sua resposta

enquanto responsável pela ginasta (nome completo): *

A sua resposta

declaro que autorizo a participação da ginasta nos estudos para a dissertação nas condições acima descritas. *

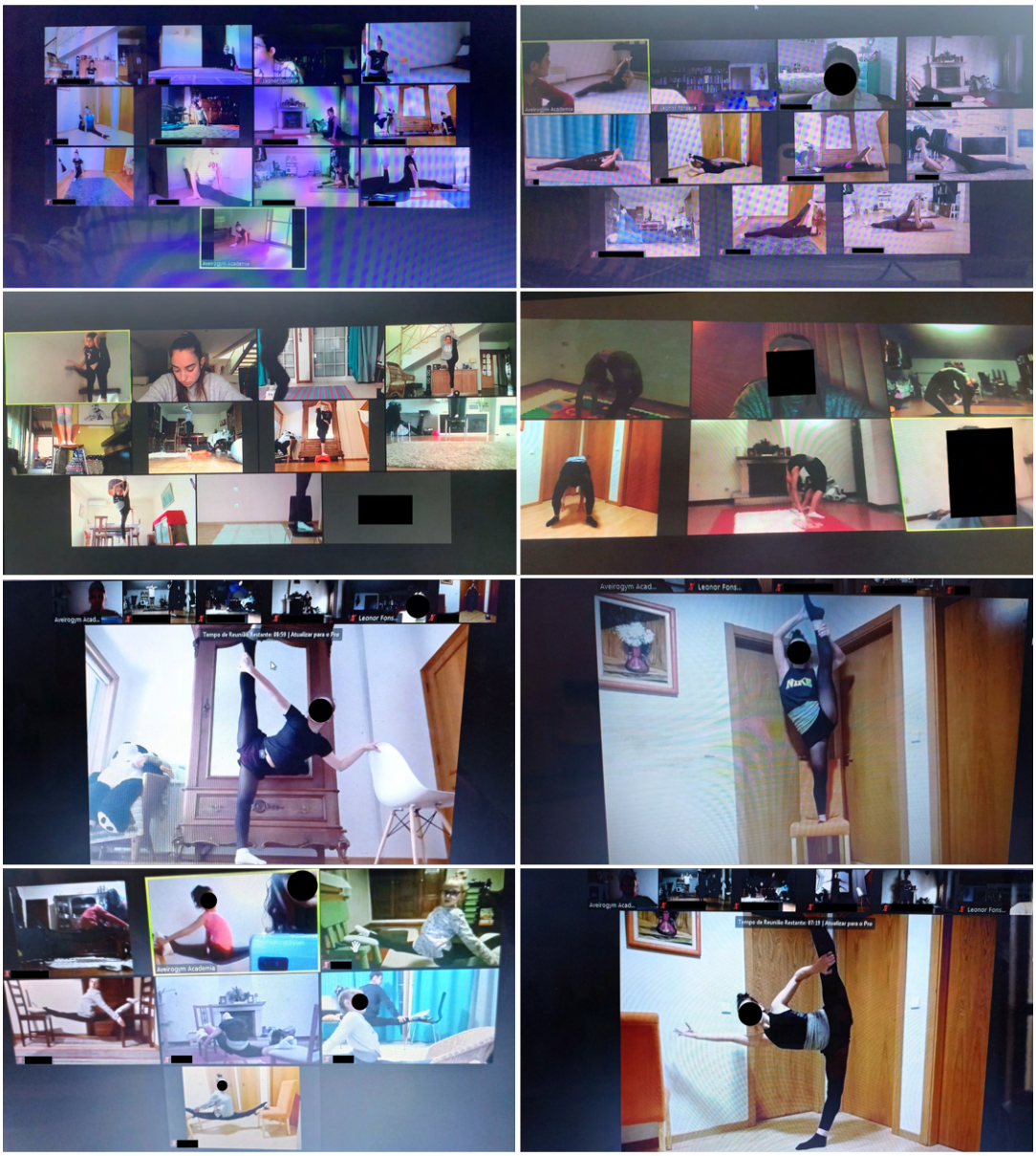
Sim

Não

Submeter

Limpar formulário

Appendix B: Screens Shots of Observation of Training Sessions



Appendix C: Observations of Training Sessions Results

Appendix i: How is the practice organised?

Observation of Training Session - A1

Date	Evidence	Interpretations
March 04 17:30h 19:45h	The training follows a sequence of exercises - Stretching with and without music, Flexibility, Ball technique, Intermediate ballet.	It is important to follow a sequence of logical and well thought out exercises in order to prepare the gymnasts body. The coaches have to spend a lot of time (pre-training) studying this subject, to prevent gymnasts from getting injured and to improve the easiest exercises, so that the more advanced ones have a good technical basis to be properly executed.
March 05 16:00h 17:45h	The training follows a sequence of exercises - Stretching feet and legs with elastic, Warm up with rope and music, Flexibility, Balance training, pirouettes training, Stretching.	
March 09 15:30h 17:30h	The training follows a sequence of exercises - Warm up with rope and music, Flexibility + elastic + chairs, Balance training + ball.	
March 10 15:30h 17:45h	The training follows a sequence of exercises - Warm up with rope and music, Warm up corrections, Flexibility + dynamic, Balance training + ball + step, Pirouette training, Pirouette comparison and correction in group, Ball technique.	
March 10 19:00h 21:00h	The training follows a sequence of exercises - Warm up with rope and music, Warm up corrections, Flexibility, Balance training + ball + chair, pirouettes training, Ball technique.	

Appendix ii: How is the pirouettes practice organised?

Observation of Training Session - A2

Date	Evidence	Interpretations
March 05 16:00h 17:45h	Balance training with help of a support chair, and repetition of the same exercise several times with both legs, *plié* and *relevés*, promenade, with ball. Pirouette training.	As in the previous sample, the pirouettes training has to follow a sequence of exercises to prepare the body for the final goal. The basis of the pirouettes is balance, so it is necessary to first train balance until it is well executed to then start training the pirouettes and be successful in execution. It is also important to train the entrance and exit of the exercise so that this is not detrimental to the performance of the pirouettes and to prevent injuries to the gymnasts.
March 09 15:30h 17:30h	Balance training with the help of a support chair and ball - *relevés* and *battements*, and repetition of the same exercise several times with both legs.	
March 10 15:30h 17:45h	Balance training with the help of a step and a support chair and repeating the same exercise several times with both legs, with ball and support, + step, + promenade, repeating the same exercises several times with both legs. Pirouette training.	
March 10 19:00h 21:00h	Balance training with the help of a support chair and a ball - *relevés* and *battements*, repetition of the same exercise several times with both legs, + on a chair. Pirouette training.	

Appendix iii: Level of difficulty of the training?

Observation of Training Session - A3

Date	Evidence	Interpretations
March 04 17:30h 19:45h	Stretching, all gymnasts can keep up with the training, it is simple and depends only on the gymnast's capacities. The same happens with flexibility, the exercises are simple and the gymnasts understand what they are supposed to do. With the ball, the less advanced gymnasts have some difficulties following some exercises, and often drop the ball. In ballet, the level of the class was more basic, which allowed all girls to easily keep up with the exercises.v	It is possible to see that the training has several levels of difficulty. In the beginning, the warm-up exercises are simple and accessible, consistent throughout the year, so the gymnasts create a routine and prepare their bodies for training. The training is not geared towards more advanced gymnasts, as they sometimes have to do simpler exercises and wait for the less advanced gymnasts. But even so, there are gymnasts who cannot follow the training and some exercises, making many mistakes. This prevents them from improving and can even cause injuries - a small, less advanced gymnast, fell on her head trying to perform one of the more advanced exercises without being prepared for it. As the training is being done online, through the zoom platform, the coaches are not able to help the gymnasts in the more difficult exercises and therefore there is a great discrepancy in the skill levels of the gymnasts.
March 05 16:00h 17:45h	Stretching with elastic band - intermediate exercises - but achieved by all gymnasts once they are frequent exercises. Warm-up with rope and music - repetitive and simple choreographies - reminded before starting, all the gymnasts can do them, the less advanced ones with some mistakes. Flexibility - simple exercises - gymnasts understand what to do, success only depends on their physical abilities. Flexibility with rope - more advanced exercises - so the less advanced gymnasts can't keep up. Balance training is accessible to all gymnasts, the difference is noticeable in the perfection of the performance. When they start balances with a ball, the younger/less advanced gymnasts can't keep up. But the more advanced gymnasts find the exercises easy and could be doing more complicated exercises, the coach even said "Let's not do it with a ball or the other girls will collapse".	
March 09 15:30h 17:30h	Stretching with elastic band - intermediate exercises - but achieved by all gymnasts once they are frequent exercises. Warm-up with rope and music - repetitive and simple choreographies - reminded before the start, specifically for the younger gymnasts, all the gymnasts follow, but the less advanced ones with some mistakes. Flexibility - simple exercises - gymnasts understand what to do, success only depends on their physical capacities. Balance training is accessible to all gymnasts, the difference is noticeable in the perfection of the performance.	
March 10 15:30h 17:45h 19:00h 21:00h (Same training, only gymnasts change depending on their availability)	Stretching with elastic band - intermediate exercises - but achieved by all gymnasts once they are frequent exercises. Warm-up with rope and music - repetitive and simple choreographies - all the gymnasts follow, but the less advanced ones with some mistakes. Flexibility - simple exercises - gymnasts understand what to do, success only depends on their physical capacities. Balance training is accessible to all gymnasts, the difference is noticeable in the perfection of the performance.	

Appendix iv: How long is the average duration of the practice?

Observation of Training Session - A4

Date	Evidence	Interpretations
March 04 17:30h 19:45h	10 min - Stretching 47 min - Flexibility 20 min - Ball technique 45 min - Ballet 2h:02m - of 2h:15m	The training sessions have approximately the same duration (1h:30m - 2h:30m) and the balance/ pirouette training always comes at the end of the session, after the warm up and flexibility, lasting approximately 20/30min in total. A large part of this last part of the training is dedicated to balance and position alignment training, highlighting the importance of good technique and preparation in performance.
March 05 16:00h 17:45h	10 min - Stretching 15 min - Warm up 35 min - Flexibility 10 min - Balance training 5:30 min - Pirouettes training 10 min - Stretching 1h:25m - of 1h:45m	
March 09 15:30h 17:30h	30 min - Warm up 60min - Flexibility 20 min - Balance training, with ball 1h:50min - of 2h	
March 10 15:30h 17:45h	15 min - Warm up 7 min - Warm up feedback 45 min - Flexibility 25 min - Balances, with ball, with steps 20 min - Pirouettes training 10 min - Feedback and corrections 11 min - Ball technique 2h:13m - of 2h:15min	
March 10 19:00h 21:00h	12 min - Warm up with rope and music 12 min - Warm up feedback 40 min - Flexibility 20 min - Balances, with ball, with chair 8 min - Pirouettes training 8 min - Ball technique 1h:40m - of 2h	

Appendix v: Where do gymnasts train?

Observation of Training Session - E1

Date	Evidence	Interpretations
March 04 17:30h 19:45h	P01 - Living Room (same as P02) P02 - Living Room (same as P01) P04 - Living Room P05 - Living Room P07 - Hall P08 - Play Room (same as P09) P09 - Play Room (same as P08) P10 - Hall	The training spaces at home are very different from the training space in the gym. The maximum height is around 2,50m (the average height of a house) and the free space is not much either.The athletes are in several different places, from rooms, to bedrooms, to halls, concluding that the space was only chosen taking into account the maximisation of the free space. This space is mostly the same for all gymnasts every training session.
March 05 16:00h 17:45h	P01 - Living Room P02 - Attic P03 - Living Room P05 - Living Room P06 - Hall P07 - Living Room P08 - Living Room P09 - Play Room P11 - Living Room	
March 09 15:30h 17:30h	P01 - Living Room P03 - Living Room P10 - Hall	
March 10 15:30h 17:45h	P01 - Living Room (same as P02) P02 - Living Room (same as P01) P04 - Living Room P05 - Living Room P07 - Living Room	
March 10 19:00h 21:00h	P03 - Living Room P10 - Hall P11 - Living Room	

Appendix vi: How much space do they need for practice?

Observation of Training Session - E2

Date	Evidence	Interpretations
March 04 17:30h 19:45h	P01 & P02 - 3m x 2m (for 2 gymnasts) P04 - 1,5m x 1,5m P05 - about 2m x 2m P07 - about 2m x 2m P08 & P09 - 3m x 3m (for 2 gymnasts) P10 - 1,5m x 1,5m	Some gymnasts train in larger spaces than accounted for, but because they train via zoom, the camera can pick up only about 3m x 3m. So, even if the gymnasts have more free space, they can't use it because they are no longer visible on camera for corrections and feedback, and a 3m x 3m space to train balances and pirouettes is enough.
March 05 16:00h 17:45h	P01 - 3m x 2m P02 - 3m x 3m P03 - 3m x 3m P05 - 2m x 2m P06 - 2m x 2m P07 - 3m x 2m P08 - 2m x 2m P09 - 3m x 3m P11 - 2m x 2m	
March 09 15:30h 17:30h	P01 - 3m x 2m P03 - 3m x 3m P10 - 1,5m x 1,5m	
March 10 15:30h 17:45h	P01 & P02 - 3m x 2m (for 2 gymnasts) P04 - 1,5m x 1,5m P05 - 2m x 2m P07 - 3m x 2m	
March 10 19:00h 21:00h	P03 - 3m x 3m P10 - 1,5m x 1,5m P11 - 2m x 2m	

Appendix vii: What is the training environment like?

Observation of Training Session - E3

Date	Evidence	Interpretations
March 04 17:30h 19:45h	P01 & P02 - Open living room without furniture and a little fireplace step. Two gymnasts and coach in the same room. P04 - Small living room, with a couch in the middle and a lot of furniture everywhere, very little free space. Alone in the room. P05 - Small part of the living room, little furniture and enough space to train. Alone in the room. P07 - Small hall, with no furniture and enough space to train. Alone in the room. P08 & P09 - Big open play room, with a lot of free space, more than enough to practice. Two gymnasts together in the same room. P10 - Very small hall, with no furniture but with little free space to practice.	Although gymnasts sought out the most open room of the house in order to train well, some did not have enough space in the house, and sometimes had to move furniture around to increase the available free space. Except for the sisters and gymnasts who live with the coach, all others train alone in the room and without interruption.
March 05 16:00h 17:45h	P01 - Open living room without furniture and a little fireplace step. Alone in the room. P02 - Big and open attic, with little furniture and enough space to practice. With the coach in the room. P03 - Average living room with little furniture and enough space to practice. Alone in the room. P05 - Small part of the living room, little furniture and enough space to train. Alone in the room. P06 - Small hall, but with no furniture and enough space to train. Alone in the room. P07 - Average living room, with some furniture but enough space to practice. Alone in the room. P08 - Big living room, but with a lot of furniture, not a lot of space to practice. Alone in the room. P09 - Big and open play room, with a lot of free space, more than enough to practice. Alone in the room. P11 - Not a very big living room and with lots of furniture, not a lot of free space to practice. Alone in the room.	
March 09 15:30h 17:30h	P01 - Open living room without furniture and a little fireplace step. With the coach in the room. P03 - Average living room with little furniture and enough space to practice. Alone in the room. P10 - Very small hall, with no furniture but with little free space to practice. Alone in the room.	
March 10 15:30h 17:45h	P01 & P02 - Open living room without furniture and a little fireplace step. Two gymnasts and the coach in the room. P04 - Small living room, with a couch in the middle and a lot of furniture everywhere, very little free space. Alone in the room. P05 - Small part of the living room, little furniture and enough space to train. Alone in the room. P07 - Average living room, with some furniture but enough space to practice. Alone in the room.	
March 10 19:00h 21:00h	P03 - Average living room with little furniture and enough space to practice. Alone in the room. P10 - Very small hall, with no furniture but with little free space to practice. Alone in the room. P11 - Not a very big living room and with lots of furniture, so not a lot of free space to practice. Alone in the room.	

Appendix viii: How is the feedback given?

Observation of Training Session - I1

Date	Evidence	Interpretations
March 04 17:30h 19:45h	Flexibility training - kinesthetic corrections with the athletes who train in the same space - verbal feedback before, during and after the exercises - visual feedback before the exercises Kinesthetic corrections, coach goes to p2, corrects arms position, corrects foot position and stretches her knee. Moments later, she has to correct her arms position again, stretch her foot and pull her leg - These corrections are always followed by verbal complements reinforcing what is being done kinesthetically ("Bend your foot well", at the same time she is bending p1's foot) (corrective). Verbal corrections in three moments during exercise. Before, it's explained how to execute and main issues to pay attention to ("Right leg up", "Pay attention to her bottom foot, it's bent", "Don't let the belly fall on the supporting leg"), while one gymnast does the exercise, for others to see (neutral and corrective). During the exercise, as gymnasts do it ("Line up the front hand with the back foot", "Don't turn your shoulders")(corrective). After, most obvious mistakes are pointed out and also what needs to be improved. Coach encourages gymnasts to continue and praises what was well done ("Very good!") (corrective and value). Visual Corrections, coach uses one older and more advanced gymnast to follow the explanation and the corrections as they are given (neutral and corrective)	In flexibility training, where the exercises take longer, coaches have time to correct during the execution, so there is a predominance of corrections during. Kinesthetic corrections, since the training sessions are via zoom, are only possible when gymnasts live in the same house and train in the same room as coach, and it is possible to see that these corrections are very effective, because they force the gymnasts to correct what is wrong or to achieve something they could not achieve on their own (for example, for lack of flexibility or strength) After, most obvious mistakes are pointed out and also what needs to be improved. Coach encourages gymnasts to continue and praises what was well done ("Very good!") (corrective and value). Visual Corrections, coach uses one older and more advanced gymnast to follow the explanation and the corrections as they are given (neutral and corrective)Although visual corrections are more frequent than kinesthetic corrections and can reach all the gymnasts, they are also not the most used, as the gymnasts have to move closer to the screen in order to see the exercise/correction well. This type of correction is often used when starting a new exercise and there is a gymnast who gives an example, or at the beginning of exercises when it is necessary to show something to all the gymnasts and thus pass the message more effectively. Verbal corrections are the most prevalent during the entire training; they are used before, during and after the exercises and as a complement to the other two types of feedback. Since gymnasts can be away and not looking at the screen, or even be in the middle of a exercise, and still hear and understand what is being said, coaches use this type of feedback a lot to communicate with gymnasts and try to reach them more quickly and effectively.
March 05 16:00h 17:45h	Flexibility training - kinesthetic corrections with athlete in the same space (p2) - verbal feedback before, during and after the exercises. Kinesthetic corrections, exercise has already started, coach goes to p2, moves her feet (after having already explained verbally) and pushes her heels to the floor (corrective). Verbal corrections are given in three moments. Before, it's explained how to execute and main issues to pay attention to ("Far from the wall and stretch very well. Concern: calves", "The further away the better") (corrective and neutral). During ("Bend your leg", "stretch the muscle") (corrective). After the exercise, ("Ok! Very good, very good", "That's good") (value). Balance training: - kinesthetic corrections with athlete in the same space (p2) - verbal feedback before, during and after the exercises. - visual feedback Visual feedback, at the beginning, the athlete in the same space as coach, does the exercise while coach explains it. Coach also mimics some of the essential movements as she explains (neutral).	

Appendix ix: How does the coach analyse the movement and notice the mistakes?

Observation of Training Session - I2

Date	Evidence	Interpretations
All Observation Sessions	During the exercises, coaches watch the gymnasts and narrow corrections to what they can see. Sometimes, due to the camera angle gymnast has positioned herself, it is not possible to perceive the whole movement and coach may give incorrect feedback, until she asks the gymnast to change place or direction. As for the gymnasts who train in the same space as coach, sometimes the coach go closer to the gymnasts to help them with the exercises, and only realise that the gymnast is already at the limit when they touch them and try to pull the leg higher, thus using kinesthetics to understand how to give corrections.	Coach has only two ways to analyse the movement and understand which corrections to give, by observing the gymnasts training and more rarely by kinesthetic, when they help a gymnast and realise that she is already at her maximum. In order to understand what corrections to give after the observation, coaches base themselves on their empirical knowledge and on what they see and study, without any scientific data obtained from the specific movement to be corrected. This can sometimes lead to generic corrections, which do not apply to that specific gymnast, resulting in useless feedback.

Appendix x: How many corrections are given to one gymnast?

Observation of Training Session - I3

Participant	Evidence	Interpretations
P01	Balance training: 1(√) 1(√) 1(√) Pirouette training: 1(√) 2(√) 1(√) + Congratulatory feedback	As gymnast is already advanced and knows how to do the exercises, corrections are punctual and gymnast corrects them as soon as she hears them.
P02	Balance training: 4(X) + 1 kinesthetic(√) 1(√) 1(X) + 1 kinesthetic(√) 1 kinesthetic(√) 2(√) 1(√) Pirouette training: 1(√) 2(√+ -) 1(√)	She receives several corrections. Being a skilful gymnast still learning, coaches give her several corrections simultaneously and she manages to implement most of them.
P03	Balance training: Congratulatory feedback. Pirouette training: 5(√+ -) 2(√+ -) 1(√) 3(√)	As gymnast is already advanced and knows how to do the exercises, corrections are punctual and gymnast corrects them as soon as she hears them.
P04	Balance training: - - - - - - - - - - Pirouette training: 1(√), 5(√+ -) 6(√+ -)	This gymnast is still learning, she didn't receive corrections in the balances, because there's more gymnasts than coaches and they can't give feedback to all. In pirouettes, gymnast receives several simple corrections simultaneously.
P05	Balance training: Congratulatory feedback + 1(√) Pirouette training: 1(√) 1 (√) 2 (√)	As gymnast is already advanced and knows how to do the exercises, corrections are punctual and the gymnast corrects them as soon as she hears them.
P06	Balance training: 2(X) 1(√) 2(√+ -) 2(X) Pirouette training: - - - - - - - - - -	She is still a beginner, so she only receives corrections for the simplest exercises (balances) and few corrections at a time to be able to pay attention to them. She just trains pirouettes to get used to the movement.
P07	Balance training: 1+1(X+√) + 2(√) 1(√) Pirouette training: 1(√) 5(X) 2 visuals(√+ -) 3(√+ -) 3(√+ -) 3(√)	Gymnast still learning, corrections direct and important. In pirouettes, gymnast receives several simple corrections simultaneously.
P08	Balance training: 2(√+ -) Pirouette training: 3(√) 2(X)	Gymnast still learning, receives a few simple corrections to be able to implement them.
P09	Balance training: 2(√) 3(√+ -) Pirouette training: - - - - - - - - - -	Gymnast still learning, she receives some simple corrections to be able to apply them. In pirouettes she doesn't receive corrections, she just does it to get used to the movement.
P10	Balance training: 2(√) 3(√) 2(√) Pirouette training: 2(√) 3(√)	As gymnast is already advanced and knows how to do the exercises, corrections are punctual, the gymnast corrects them as soon as she hears them.
P11	Balance training: 1(√+ -) 3(√) 1(√) Pirouette training: 1(√) 4(√) 1(√) 5(√+ -) 4(√+ -)	Gymnast still learning, she receives some simple corrections to be able to apply them. In pirouettes she doesn't receive corrections, she just does it to get used to the movement.

Appendix xi: How many corrections does the gymnast applies?

Observation of Training Session - I4

Participant	Evidence	Interpretations
P01	Balance training: All Pirouette training: All	As gymnast is already advanced she understands what to do and can usually implement all the corrections, she receives few corrections.
P02	Balance training: 2 or 3 per attempt Pirouette training: 1 or 2 per attempt	The gymnast is still learning and when she receives many corrections at the same time she cannot implement them all, so some are forgotten.
P03	Balance training: All Pirouette training: All	As gymnast is already advanced she understands what to do and can usually implement all the corrections, she receives few corrections.
P04	Balance training: - - - - - - Pirouette training: 1 or 2 per attempt	As she's still learning, she can't pay attention to more than 2. As seen above, she didn't receive any balance corrections.
P05	Balance training: All Pirouette training: All	As gymnast is already advanced she understands what to do and can usually implement all the corrections, she also receives few corrections.
P06	Balance training: Has difficulties applying corrections (1 per attempt) Pirouette training: - - - - - -	Very initiated and very distracted gymnast hardly ever applies corrections, except when coach gets angry and speaks directly to her. Didn't receive any pirouettes corrections.
P07	Balance training: 1 or 2 per attempt Pirouette training: 1 or 2 per attempt	As she's still learning, she can't pay attention to more than two.
P08	Balance training: 1 or 2 per attempt Pirouette training: 1 or 2 per attempt	As she's still learning, she can't pay attention to more than two.
P09	Balance training: 1 or 2 per attempt Pirouette training: - - - - - -	As she's still learning, she can't pay attention to more than 2. Didn't receive any pirouettes corrections.
P10	Balance training: All Pirouette training: All	As gymnast is already advanced she understands what to do and can usually implement all the corrections, she receives few corrections.
P11	Balance training: 1 or 3 per attempt Pirouette training: 1 or 3 per attempt	As she's still learning, she can't pay attention to more than three, but she can apply more than the other gymnasts in the same level.

Appendix xii: How many times do gymnasts repeat the exercise before and after corrections?

Observation of Training Session - I5

Participant	Evidence	Interpretations
P01	Not constant, sometimes 1 others 3/4.	It's not about the number of times but until she thinks she has had success or the coach gives positive feedback. Maximum 4 repetions.
P02		
P03		
P04		
P05		
P06	Almost doesn't repeat.	It's not about the number of times but until she's had enough.
P07	Not constant, sometimes 1 others 3/4.	It's not about the number of times but until she thinks she has had success or the coach gives positive feedback. Commonly maximum of 5 repetitions.
P08		
P09		
P10		
P11	Not constant, sometimes 1 others 4/5.	

Appendix xiii: Do the gymnasts train alone or only when the coach is watching?

Observation of Training Session - I6

Participant	Evidence	Interpretations
P01	Training session substantially more effective when coach is following or when gymnast knows the coach is looking at her. Otherwise she stops many times.	If she feels the coach's attention, she trains more constantly, without distractions. Because the training rhythm does not depend on the gymnast, it is therefore more certain and constant.
P02		
P03		
P04		
P05		
P06		
P07		
P08		
P09		
P10		
P11		

Appendix xiv: Do they restart after encouragement?

Observation of Training Session - I7

Participant	Evidence	Interpretations
P01	After receiving encouragement from the coach, gymnast smiles and continues to work, more committed.	She feels she's doing a good job and so strives to continue and get more praise. She's motivated and proud of what she's doing.
P02		
P03		
P04		
P05		
P06		
P07		
P08		
P09		
P10		
P11		

Appendix xv: Which objects are used in the training sessions?

Observation of Training Session - 01

Date	Evidence	Interpretations
March 04 17:30h 19:45h	Wall, Gym ball, Ballet bar/chair, Mirror (only two gymnasts had one), Music.	Gym rope for warming up once the rope allows them to do various cardio exercises and because it is a difficult apparatus that requires good motor coordination, promoting coordination training, apparatus technique and cardio while warming up. The wall serves as a support for gymnasts to be able to force some positions on their own, maintaining alignment and correct positioning. The elastic band also allows gymnasts to pull beyond their limits during exercises while training on their own, and also serves as resistance, which promotes strength training and body explosion. The chair has two functions: as a support during the exercises (like a ballet bar) and to increase the degree of difficulty of the flexibility, doing splits with elevation on the front leg. Step, a tool for pirouettes and balance. Gym ball: to train the apparatus technique and to be used for the pirouettes and balances. The mirror, despite being used a lot during training sessions for gymnasts to correct themselves, is not an object used at home, as almost no one has one at their training place. Music is used in various parts of the training and makes the training more rhythmical and pleasant, when the music is cheerful, the gymnasts are in a good mood and active. When the music is slower, some gymnasts stay more concentrated, others get bored and stop working hard and the training stops being productive.
March 05 16:00h 17:45h	Wall, Gym ball, Ballet bar/chair, Mirror (only two gymnasts had one), Music.	
March 09 15:30h 17:30h	Gym rope, Wall, Elastic band, Chair, Gym ball, (Nobody has a mirror), Music.	
March 10 15:30h 17:45h	Gym rope, Wall, Elastic band, Chair, Step, Gym ball, (Nobody has a mirror), Music.	
March 10 19:00h 21:00h	Gym rope, Wall, Elastic band, Chair, Gym ball, (Nobody has a mirror), Music.	

Appendix xvi: Is there any specific object used in the training of pirouettes?

Observation of Training Session - 02

Date	Evidence	Interpretations
March 05 16:00h 17:45h	Elastic band, Chair, Step, Gym ball	Elastic band is not used specifically for training pirouettes but rather for flexibility and to help define the position during balancing, helping gymnast to reach a more extreme position while reducing the force she has to exert to hold the position. Chair, replaces the ballet bar, and helps support the gymnasts when balancing, allowing them to hold the position for longer. It also has the same function as the step (see further), but higher and more challenging. The step also has two functions: 1- a higher level for the gymnasts to go up and mark and hold the balance at the highest point, doing several short repetitions and on the last one staying and holding it; 2- a higher level where the gymnasts hold the balance, staying farther from the floor, increasing their concentration and better execution, due to fear of falling off. Ball, is placed under the heel on demi pointe, forcing the gymnasts to keep it high and creating instability, so that the gymnasts understand how to keep balanced and how to regain their balance in case of distraction. The ball also fulfils its function as a gymnastic apparatus. When they reach a good balance and a good pirouette, they add the ball to the exercise, increasing the difficulty, as the gymnast has to divide her attention and also concentrate on the apparatus. In these observations, only the ball was used as an apparatus, as it is the smallest and the one that does the least damage at home if it falls. The others can also be used for the same purpose.
March 09 15:30h 17:30h	Elastic band, Chair, Gym ball	
March 10 15:30h 17:45h	Elastic band, Chair, Step, Gym ball	
March 10 19:00h 21:00h	Elastic band, Chair, Gym ball	

Appendix xvii: How many gymnasts? And how many coaches?

Observation of Training Session - U1

Date	Evidence	Interpretations
March 04 17:30h 19:45h	17-25 gymnasts 2 coaches	There is always more gymnasts than coaches, which means that the gymnasts cannot receive personalised corrections whenever necessary, because coaches' attention is divided between all gymnasts, and so coaches spend the whole training session overwhelmed with so much to correct, not always managing to reach all gymnasts who need in the correct timing and in such a way that they understand what needs to be done. When there is more than one coach, they divide tasks. One coach gives the exercises and explains, applying corrections when possible, and the other coach just watches the gymnasts and gives corrections when necessary. Gymnasts have to train alone until one of the coaches can pay attention to them and correct their mistakes, because if they only train when coaches are watching, they waste a lot of time standing still.
March 05 16:00h 17:45h	13 gymnasts 2 coaches	
March 09 15:30h 17:30h	10 gymnasts 2 coaches	
March 10 15:30h 17:45h	11 gymnasts 1 coach	
March 10 19:00h 21:00h	5 gymnasts 1 coach	

Appendix xviii: Does the gymnast react to all coaches the same way?

Observation of Training Session - U2

Participant	Evidence	Interpretations
P01	Flexibility training: Coach 1/Coach 2/Coach 3: athlete is receptive, listens and tries to match feedback • Usually successful with corrections Ballet training: Coach 2: athlete is receptive, listens and tries to match feedback • Usually successful with corrections Balance and pirouette training: Coach 1/Coach 3: athlete is receptive, listens and tries to match feedback • Usually more successful in balance corrections, but good performance in both	She's a dedicated athlete with many capacities, she is also one of the oldest athletes and the one who has been doing gymnastics for the longest time. She accepts corrections well and tries, whenever possible, to put them into practice. Whenever she doesn't do it, it is due to lack of ability in some aspect and not for "sloppiness". There is no noticeable lack of will/performance in the different types of training. The athlete seeks to improve her performance since she already knows how to execute the exercises. The gymnast reacts to all coaches in the same way.
P02	Flexibility training: Coach 1/Coach 2/Coach 3: athlete listens to the corrections. If they are simple and easy, she implements them, if they are more complicated or take more effort not so much, and when the coach corrects kinesthetically, the athlete "undoes" the correction very soon afterwards. • When feedback is implemented, she succeeds in the exercise, when she does not implement it, she continues repeating the errors. Ballet training: Coach 2: gymnast is not receptive and rarely implements the corrections, during the training, when the exercises are more complicated or many corrections are presented, she turns off the camera. Balance and pirouette training: Coach 1/Coach 3: athlete is more receptive and tries to respond to feedback, not always successfully\newline • More successful in correcting balance, but notable effort in both	She is a gymnast who understands the feedback but only implements it sometimes. That difference is very much related to the type of exercise being performed, in the more dynamic exercises the corrections are mostly implemented, when the exercises are slower and require more "suffering", most corrections are ignored. (It doesn't depend on the coaches but on the type of exercise)
P03	Flexibility training: Coach 1/Coach 3: Gymnast listens to corrections and cares to correct what's needed to improve performance. • Success rate in implementing corrections is positive. Balance and pirouette training: Coach 1/Coach 3: Athlete listens to corrections and is concerned about correcting what is necessary and improving performance. The athlete has a very good performance in both balances and pirouettes, the corrections she receives are small warnings so that she can "elevate" her performance.	She is a hardworking and committed athlete, always tries to correct her mistakes and is very attentive to feedback. There are no noticeable differences in her behaviour in relation to the different coaches. She is no longer learning the exercises; she is executing and repeating them, correcting small errors in order to improve her performance. Reacts to all the coaches in the same way.

Participant	Evidence	Interpretations
P04	Flexibility training: Coach 1/Coach 2/Coach 3: Athlete listens to corrections and tries to correct what is needed, sometimes she is not successful because she may not have understood what to do and other times because she does not have the physical ability to achieve the correction. • The athlete is committed and attentive, but is sometimes unsuccessful in corrections. Ballet training: Coach 2: Gymnast followed the class and was attentive. Followed coach's feedback, but the execution of the exercises was a bit "sloppy". • Usually successful with corrections Balance and pirouette training: Coach 1 feedback: athlete listens the feedback and is attentive, isn't very successful in implementing the corrections, she performs the exercises but always with errors and with little perfection. • Although she is always attentive and seems to be striving, she is not successful in the performance.	The gymnast is committed and attentive during training, listens to feedback and performs the exercises, but always with flaws and imperfections. Despite the effort, the lack of corrections implementation is due to some lack of physical ability and little understanding of what to do to correct the mistakes. Reacts to all the coaches in the same way.
P05	Flexibility training: Coach 1/Coach 2/Coach 3: athlete listens to corrections and cares about correcting mistakes. • Success rate in implementing corrections is positive. Ballet training: Coach 2: the athlete listens to the corrections and wants to correct what is necessary and to improve performance. Balance and pirouette training: Coach 1/Coach 3: athlete listens to corrections and is concerned about correcting what is necessary and improving performance. • The athlete performs well on balances, with a less good performance on pirouettes.	She is a hard working and committed athlete with many physical abilities. Although she is young, she can keep up with the more advanced gymnasts, reacts well to corrections from all coaches. Because she has physical skills and good body control, she can implement feedback better than the rest of the gymnasts of her age. She reacts to all coaches in the same way.
P06	Flexibility training: Coach 1/Coach 3: athlete performs the exercises, and listens to the feedback, but it is necessary to repeat several times, until she corrects it. Balance and pirouette training: Coach 1/Coach 3: the athlete performs the exercises, but without paying any attention to the feedback and corrections. And as soon as she is corrected, she forgets the correction and does it wrong again.	The gymnast performs the exercises, but without being careful on how perfectly she does them, hardly ever listens to the corrections and hardly ever tries to implement them, unless coaches get angry. And she reacts to both the same way, being more dependent on how they speak than who is speaking.

Participant	Evidence	Interpretations
P07	Flexibility training: Coach 1/Coach 2/Coach 3: athlete listens to corrections and is concerned about correcting what is needed, not always successful in corrections. Ballet training: Coach 2: the athlete left the practice when the ballet class started. Balance and pirouette training: athlete performs the exercises and listens to the corrections, but does not have a high rate of effectiveness and quickly forgets the corrections.	The athlete trains and performs the exercises, but without much care for perfection and corrections. When she is corrected, she almost always implements, but returns to the error immediately afterwards. The athlete reacts to all coaches in the same way.
P08	Flexibility training: Coach 1/Coach 2/Coach 3: athlete trains and listens to corrections, tries to implement them, sometimes unsuccessfully. Ballet training: Coach 2: the athlete follows the exercises and tries to follow the feedback, with little success, due to lack of experience. Balance and pirouette training: Coach 1/Coach 3: athlete listens to corrections and tries to implement them, often unsuccessfully, due to lack of skills.	She is a hardworking and committed athlete who trains and does the exercises. She often fails to achieve a better performance because she does not understand well how to do it. Although she is not one of the youngest, she has the least experience, and sometimes the lack of implementation may be due to inexperience. She reacts to all the coaches in the same way.
P09	Flexibility training: Coach 1/Coach 2/Coach 3: athlete trains and listens to corrections, tries to implement them, often without success. Ballet training: Coach 2: the athlete follows the exercises and tries to follow the feedback, with little success, due to lack of experience in the exercises. Balance and pirouette training: Coach 1/Coach 3: athlete listens to corrections and tries to implement them, often unsuccessfully, due to lack of skills.	She is a hardworking and committed athlete, always trying to execute the exercises, but sometimes without success. She is still inexperienced so sometimes she may not understand the correction or how to implement it. She reacts in the same way to all coaches.
P10	Flexibility training: Coach 1/Coach 2/Coach 3: athlete listens to corrections and cares to correct as needed and improve performance. Ballet training: Coach 2: the athlete listens to the corrections, is concerned about correcting and improving the performance, she presents some difficulties in the corrections once she is a little inexperienced in ballet. Balance and pirouette training: Coach 1 feedback: athlete listens to corrections and is concerned about correcting what is necessary and improving performance. • The athlete performs very well on balances and well on pirouettes, with some pirouettes better than others.	She is a hardworking and committed athlete, always tries to correct her mistakes and is very attentive to feedback. There are no noticeable differences in her behaviour in relation to the different coaches. She is no longer learning the exercises; she is executing and repeating them, correcting small errors in order to improve her performance. Reacts to all the coaches in the same way.
P11	Flexibility training: Coach 1/Coach 2/Coach 3: athlete listens to corrections and tries to implement them, with some success. Sometimes she forgets corrections. Balance and pirouette training: Coach 1/Coach 3: athlete listens to corrections and tries to implement them, often unsuccessfully, due to lack of skills.	She is a hard-working athlete and tries to correct the errors, sometimes unsuccessfully. During training sessions she is attentive to feedback and because of inexperience in some aspects she does not always know what to do, so sometimes she does not implement feedback. Reacts in the same way to all coaches.

Appendix xix: The level of concentration of the gymnast during training (high, medium, low)

Observation of Training Session - U3

Participant	Evidence	Interpretations
P01	Flexibility training: Performs all exercises the best way possible, trying to implement all corrections. Ballet training: Performs all exercises correctly, following coach's words and correcting any mistakes. Balance and pirouette training: Performs all exercises the best way possible, trying to implement all corrections.	Flexibility training: high Ballet training: high Balance/pirouette training: high
P02	Flexibility training: Performs all exercises, sometimes with mistakes, and sometimes does not implement corrections Ballet training: She hardly performs any exercises at all and when she does, she makes no effort to make sure it's well performed. When she doesn't feel like it, she turns the camera off. Balance and pirouette training: Performs all exercises, sometimes with mistakes, and doesn't implement all the corrections.	Flexibility training: average/high Ballet training: low Balance/pirouette training: average/high
P03	Flexibility training: Performs all exercises the best way possible, trying to implement all corrections. Balance and pirouette training: Performs all exercises the best way possible, trying to implement all corrections.	Flexibility training: high Balance/pirouette training: high
P04	Flexibility training: Performs the exercises with some mistakes, corrects errors as coaches say. Ballet training: Performs all exercises, following coach's words, with some imperfection Balance and pirouette training: Performs the exercises with some mistakes and spends some time without training, distracted or still.	Flexibility training: average/high Ballet training: average/high Balance/pirouette training: average/low
P05	Flexibility training: Performs all exercises the best way possible, trying to implement all corrections. Ballet training: Performs all exercises correctly, following coach's words and correcting any mistakes. Balance and pirouette training: Performs all exercises the best way possible, trying to implement all corrections.	Flexibility training: high Ballet training: high Balance/pirouette training: high
P06	Flexibility training: Performs the exercises without care in execution and without perfection, spends a lot of time distracted. Balance and pirouette training: Performs the exercises carelessly, spends a lot of time looking around or standing still.	Flexibility training: low Balance/pirouette training: low

Participant	Evidence	Interpretations
P07	Flexibility training: Performs the exercises with some mistakes, corrects errors as coaches say Ballet training: Left the room as soon as it began. Balance and pirouette training: Performs the exercises with some errors and spends some time without training, distracted or still.	Flexibility training: average/high Ballet training: low (left the zoom room) Balance/pirouette training: average/low
P08	Flexibility training: Performs the exercises with some mistakes, corrects errors as coaches say. Ballet training: Performs all exercises, following the coach's words, with some imperfections Balance and pirouette training: Performs the exercises with some errors and spends some time without training, distracted or still.	Flexibility training: average/high Ballet training: average/high Balance/pirouette training: average/low
P09	Flexibility training: Performs the exercises with some mistakes, corrects errors as coaches say. Ballet training: Performs all exercises, following coach's words, with some imperfections. Balance and pirouette training: Performs the exercises with some errors, and spends some time without training, distracted or still.	Flexibility training: average/high Ballet training: average/high Balance/pirouette training: average/low
P10	Flexibility training: Performs all exercises the best way possible, trying to implement all corrections. Ballet training: Performs all exercises correctly, following coach's words and correcting mistakes. Balance and pirouette training: Performs all exercises the best way possible, trying to implement all corrections.	Flexibility training: high Ballet training: high Balance/pirouette training: high
P11	Flexibility training: Performs all exercises but still with some mistakes, tries to implement all corrections. Balance and pirouette training: Performs the exercises but still with some mistakes, tries to implement all corrections received. Sometimes she stands still.	Flexibility training: high Balance/pirouette training:average/high

Appendix xx: Is the gymnast successful in the implementation of corrections?

Observation of Training Session - U4

Participant	Evidence	Interpretations
P01	Balance training: The athlete receives few corrections since she already performs the exercises well, she receives more minimalist and specific corrections and manages to implement practically all of them. She has a lot of balance skills. Pirouette training: Similarly to balances, she receives few corrections and they are also more specific corrections, being successful in the implementations. She presents controlled spins, but not many(1|2 turns).	She is a very advanced athlete and therefore is no longer in the learning phase. Corrections are more specific and reminders. She already knows what she has to do and is therefore very successful in implementing the feedback. She is more successful with balances than with pirouettes. She hears both generalized and individual corrections and understands which of the generalized ones are for her.
P02	Balance training: The athlete receives several corrections during the exercise, does not implement most of them and coach applies kinesthetic feedback to help her apply the corrections. She has inconsistent balance. Pirouette training: The athlete doesn't pay much attention to corrections unless they are only directed at her. And isn't always able to implement them. She spins well, but is not consistent..	She is a young athlete with physical abilities, but with little work discipline and little focus. She implements more often the corrections that are directed at her and ignores the rest. She usually can perform the exercises, by muscle memory, not so much by paying attention to the feedback.
P03	Balance training: Receives few corrections since she already performs the exercises well, she receives more minimalist and specific corrections, but she manages to implement practically all of them. She has a lot of balance skills. Pirouette training: She also receives few corrections and they are also more specific corrections, being successful in the implementations. Spins smoothly and slowly (2|3 turns)	She is a very advanced athlete and therefore is no longer in the learning phase. Corrections are more specific and reminders. She already knows what she has to do and is therefore very successful in implementing the feedback. She is more successful with balances than with pirouettes. She hears both generalized and individual corrections and understands which of the generalized ones are for her.
P04	Balance training: Receives several corrections and cannot implement most of them. She presents several errors and most of the time when she corrects one, forgets the others. She doesn't have much balance skills. Pirouette training: The athlete does not pay much attention to generalized corrections and does not implement them. When she receives individual corrections she listens, but is not very successful in implementing them. Cannot spin well or hold the position.	She is a young athlete with little experience, still learning and therefore the corrections are more comprehensive, but even so she has some difficulties in applying them. She does not pay attention to generalized corrections, but listens to individual corrections and has difficulties in implementing them.
P05	Balance training: Receives some corrections both specific and comprehensive and strives to implement them with some success. She has good balance skills. Pirouette training: Receives some corrections both specific and comprehensive and strives to implement both with some success. Despite good balance, she has some difficulties spinning and is not always constant (1 turn).	She is an athlete with plenty of abilities and hard working. She receives more specific corrections, is on the threshold between learning and improving. Pays attention to both individual and generalized corrections and strives to improve, succeeding in most of them.

Participant	Evidence	Interpretations
P06	Balance training: The athlete receives corrections and implements hardly any. She is not focused on the training and does not listen to generalized corrections. Only when the coach speaks directly to her. She has no balance and can't perform the exercises well. Pirouette training: The behaviour is the same as in balance. The athlete can't execute the exercises nor pay attention to the corrections.	She is a very young athlete and a beginner with little ability to concentrate. Does not understand the importance of corrections neither feedback, and therefore cannot perform the exercises or show improvements. Perhaps because she is still very young and very energetic, the slower exercises are "boring" and she cannot concentrate.
P07	Balance training: Receives several corrections, can't implement most of them. She presents several errors and when she corrects one, forgets the others. She doesn't have much balance skills. Pirouette training: Doesn't pay much attention to generalized corrections and doesn't implement them. When she receives individual corrections she listens, but is not very successful in implementing them. Cannot spin well or hold the position.	She is a young athlete with little experience, still learning and therefore the corrections are more comprehensive, but even so she has some difficulties in applying them. She does not pay attention to generalized corrections, but listens to individual corrections and still has difficulties in implementing them.
P08	Balance training: Receives several corrections, can't implement most of them. She presents several errors and when she corrects one, forgets the others. She doesn't have much balance skills. Pirouette training: Doesn't pay much attention to generalized corrections and doesn't implement them. When she receives individual corrections she listens, but is not very successful in implementing them. Cannot spin well or hold the position.	She is still an athlete with little experience, still learning and therefore the corrections are more comprehensive, but even so she has some difficulties in applying them. She does not pay attention to generalized corrections, listens to individual ones, but has difficulties in implementing them.
P09	Balance training: Receives several corrections, can't implement most of them. She presents several errors and when she corrects one, forgets the others. She doesn't have much balance skills. Pirouette training: Doesn't pay much attention to generalized corrections and doesn't implement them. When she receives individual corrections she listens, but is not very successful in implementing them. Cannot spin well or hold the position.	She is a young athlete with little experience, still learning and therefore the corrections are more comprehensive, but even so she has some difficulties in applying them. She does not pay attention to generalized corrections, but listens to individual corrections and still has difficulties in implementing them.
P10	Balance training: Receives few corrections, more minimalist and specific and manages to implement them. She has a lot of balance skills. Pirouette training: She receives few corrections and they are also more specific corrections, being successful in the implementations. She presents controlled spins, but not many(1|2 turns).	She is a very advanced athlete and therefore is no longer in the learning phase. Corrections are more specific and reminders. She already knows what she has to do and is therefore very successful in implementing the feedback. She is more successful with balances than with pirouettes. She hears both generalized and individual corrections and understands which of the generalized ones are for her.
P11	Balance training: Receives several corrections during the exercise, can't implement them all. Presents several errors, but can understand and implement some. Does not have much balance Pirouette training: The athlete doesn't pay much attention to the generalized corrections. When she receives individual ones she listens and has some success in implementation. Cannot spin well or hold position.	She is still a young athlete, still learning, so the corrections are more comprehensive, but she still has some difficulties in applying all of them. She pays attention to both corrections, but the individual ones are more successful in implementation.

Appendix xxi: After how many repetitions can the gymnast implement the corrections and improve performance?

Observation of Training Session - U5

Participant	Evidence	Interpretations
P01	Balance training: Implements feedback usually with one correction. Sometimes two in a row (as reinforcement). Pirouette training: Implements feedback usually with one correction. Sometimes two in a row (as reinforcement).	She is an advanced athlete and therefore understands the importance of corrections, it is enough for the coaches to give feedback once and the gymnast understands and strives to implement.
P02	Balance training: Either implements feedback with only 1 correction, or sometimes the coach needs to repeat 3/4 times until the athlete understands. Pirouette training: Either implements feedback with only 1 correction, or sometimes the coach needs to repeat 3/4 times until the athlete understands. Other times without success.	She is a not very constant athlete, either she understands and implements at first or she doesn't implement at all. By "whim" and not by lack of abilities.
P03	Balance training: Implements feedback usually with one correction. Sometimes two in a row (as reinforcement). Pirouette training: Implements feedback usually with one correction. Sometimes two in a row (as reinforcement).	She is an advanced athlete and therefore understands the importance of corrections, it is enough for the coaches to give feedback once and the gymnast understands and strives to implement.
P04	Balance training: Takes 2/3 corrections until she understands. It's necessary to explain and remind her about preview mistakes. Pirouette training: Takes 2/3 corrections until the athlete understands. It's necessary to explain and remind her about preview mistakes. Sometimes without success.	She is an athlete with little experience and sometimes she does not understand the correction and therefore cannot implement it. At times she corrects one mistake and "uncorrects" another, having difficulty on making a fully correct exercise.
P05	Balance training: Implements feedback usually with one correction. Sometimes two in a row (as reinforcement). Pirouette training: Implements feedback usually with one correction. Sometimes two in a row (as reinforcement).	She is an advanced athlete and therefore understands the importance of corrections, it is enough for the coaches to give feedback once and the gymnast understands and strives to implement.
P06	Balance training: Being an athlete who doesn't listen to corrections, she doesn't implement them. It is not related to the number of times it is repeated but to the stiffness with which the coach speaks (upset). Pirouette training: Being an athlete who does not listen to corrections, she does not implement them. It is not related to the number of times it is repeated but to the rigidity with which the coach speaks (upset).	She is still a very young athlete and as she doesn't understand feedback, she doesn't give it any relevance and only implements them when the coaches get upset and angry with her.
P07	Balance training: Takes 3/4 corrections until the athlete understands. It's necessary to carefully explain and remind her about preview mistakes. Pirouette training: Takes 3/4 corrections until the athlete understands. It's necessary to carefully explain and remind her about preview mistakes. Sometimes without success.	She is a young athlete with little experience and sometimes she doesn't understand the correction, so she can't implement it. At times she corrects one mistake and "uncorrects" another. She has difficulty in making a fully correct exercise. And is more attentive when the coach gets upset.

Participant	Evidence	Interpretations
P08	Balance training: Takes 2/3 corrections until she understands. It's necessary to explain and remind her about preview mistakes. Pirouette training: Takes 2/3 corrections until the athlete understands. It's necessary to explain and remind her about preview mistakes. Sometimes without success.	She is an athlete with little experience and sometimes she does not understand the correction and therefore cannot implement it. At times she corrects one mistake and "uncorrects" another, having difficulty on making a fully correct exercise.
P09	Balance training: Takes 2/3 corrections until she understands. It's necessary to explain and remind her about preview mistakes. Pirouette training: Takes 2/3 corrections until the athlete understands. It's necessary to explain and remind her about preview mistakes. Sometimes without success.	She is an athlete with little experience and sometimes she does not understand the correction and therefore cannot implement it. At times she corrects one mistake and "uncorrects" another, having difficulty on making a fully correct exercise.
P10	Balance training: Implements feedback usually with one correction. Sometimes two in a row (as reinforcement) Pirouette training: Implements feedback usually with one correction. Sometimes two in a row (as reinforcement)	She is an advanced athlete and therefore understands the importance of corrections, it is enough for the coaches to give feedback once and the gymnast understands and strives to implement.
P11	Balance training: Takes 2/3 corrections until she understands. It's necessary to explain and remind her about preview mistakes. Pirouette training: Takes 2/3 corrections until the athlete understands. It's necessary to explain and remind her about preview mistakes. Sometimes without success.	She is an athlete with little experience and sometimes she does not understand the correction and therefore cannot implement it. At times she corrects one mistake and "uncorrects" another, having difficulty on making a fully correct exercise.

Appendix xxii: After how many repetitions does the gymnast get tired?

Observation of Training Session - U6

Participant	Evidence	Interpretations
P01	Guided training: Does the exercise whenever the coach is giving training count Autonomous training: 2-stops-1-stops (Balance/Promenade) 4-stops-1-stop (Pirouette)	When the training session is guided, the athlete trains to the rhythm of the coach's voice. When the training is autonomous, the gymnast repeats a few times at the beginning of that training session, but then starts to do 1 or 2 times in a row, followed by long pauses. It is common for her to pause after a well done exercise.
P02	Guided training: Does the exercise whenever the coach is giving training count Autonomous training: 3-stop-2-stops (Balance/Promenade) 2-stop-1-stop-2-stop (Pirouette)	
P03	Guided training: Does the exercise whenever the coach is giving training count Autonomous training: 3-stop (Balance/Promenade) 1-stop-3-stop-1-stop-3-stop (Pirouette)	
P04	Guided training: Does the exercise whenever the coach is giving training count Autonomous training: 5-stop-2-stop (Balance/Promenade) 2-stop-1-stop-1-stop-5-stop (Pirouette)	
P05	Guided training: Does the exercise whenever the coach is giving training count Autonomous training: 1-stop-2-stop-1-stop (Balance/Promenade) 1-stop-2-stop-2-stop (Pirouette)	
P06	Guided training: Does the exercise whenever the coach is giving training count Autonomous training: 2-stop-1-stop (Balance/Promenade) 1-stop-2-stop-2-stop (Pirouette)	
P07	Guided training: Does the exercise whenever the coach is giving training count Autonomous training: 1-stop-2-stop (Balance/Promenade) 1-stop-1-stop-2-stop (Pirouette)	
P08	Guided training: Does the exercise whenever the coach is giving training count Autonomous training: 2-stop-1-stop (Balance/Promenade) 1-stop-1-stop-1-stop (Pirouette)	
P09	Guided training: Does the exercise whenever the coach is giving training count Autonomous training: 2-stop-1-stop (Balance/Promenade) 1-stop-1-stop-1-stop (Pirouette)	
P10	Guided training: Does the exercise whenever the coach is giving training count Autonomous training: 2-stop-1-stop-1-stop (Balance/Promenade) 2-stop-1-stop-1-stop (Pirouette)	
P11	Guided training: Does the exercise whenever the coach is giving training count Autonomous training: 1-stop-2-stop (Balance/Promenade) 8-stop-3-stop (Pirouette)	

Appendix xxiii: Is there improvement over time?

Observation of Training Session - U7

Participant	Evidence	Interpretations
P01	No visible improvement between training sessions.	Very little time between observations (about 1 day between each), so it is not possible to see improvements as it is a process that takes time to show results.
P02		
P03		
P04		
P05		
P06		
P07		
P08		
P09		
P10		
P11		

Appendix D: Interview Guides

Gymnasts Interviews Guide

Gymnasts Interviews

- What is your name?
- How old are you?
- How long do you do gymnastics?
- What class are you in?

- How often do you train a week?
- Which electronic device do you use to attend zoom?
- Do you feel any difference training at home or training at the gym?
- And in which would you rather train?
- Which part of the training do you enjoy the most?
- Which part of the training do you enjoy the least?
- Do you like balances training?
- Do you like pirouettes training?
- Do you like to receive corrections or do you prefer to train without them?
- Do you prefer value or corrective feedback?
- Do you prefer general or individual feedback?
- Do you feel feedback helps you improve performance?
- Do you prefer more prompt or more nice feedback?
- Do you prefer coordinated or individual training?
- Do you train at home out of training hours?
- Do you prefer to learn by reading or through dynamic games and activities?
- Do you remember all feedback received throughout training sessions?
- Would you like an app to help you improve pirouettes performance?

- Why did you choose that spot to train?
- Why did you choose that electronic device?
- How is the pirouette training session structured?
- Are you always able to implement corrections? If not what do you think the problem is?
- How do you feel when you receive different types of feedback?
- Do you spend a lot of hours a day on your mobile phone? If yes, doing what?
- Why do you turn off the camera/leave the room during training sessions?
- Why wont you pay attention to feedback and do not try to implement it?

Coaches Interviews Guide

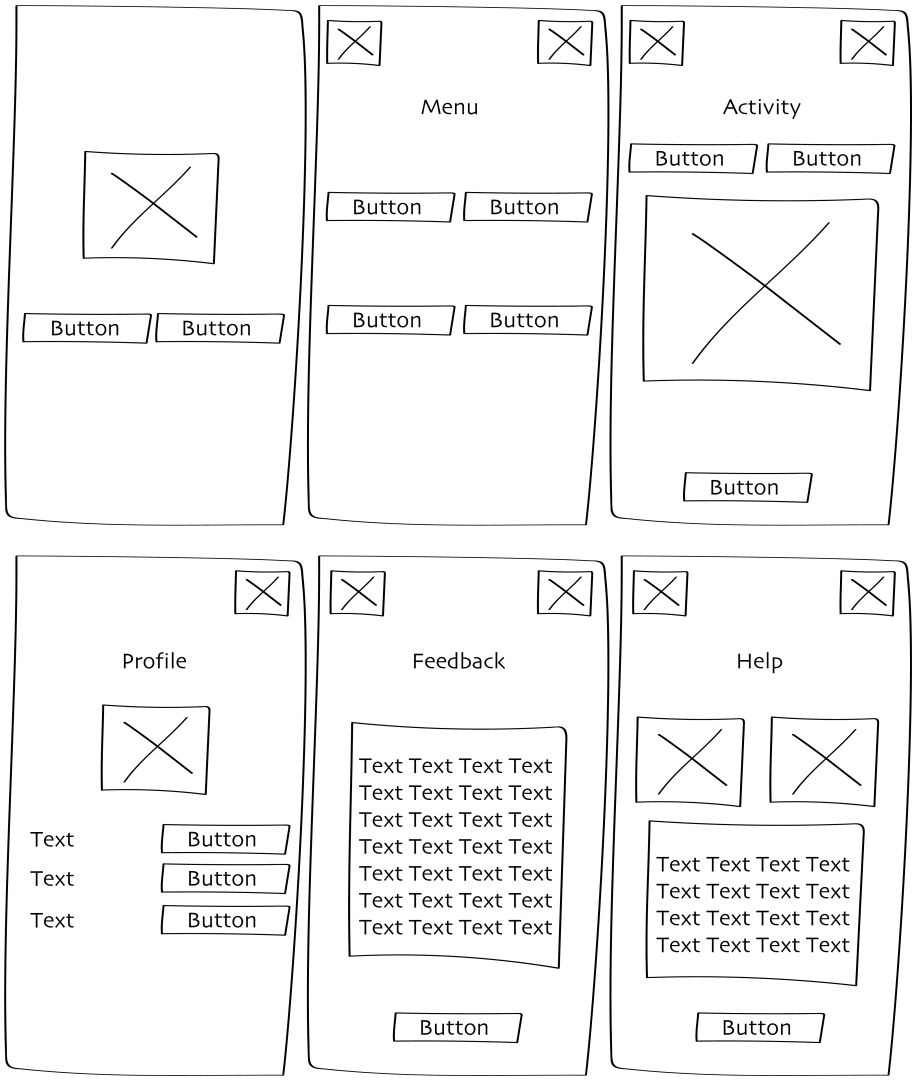
Coaches Interviews

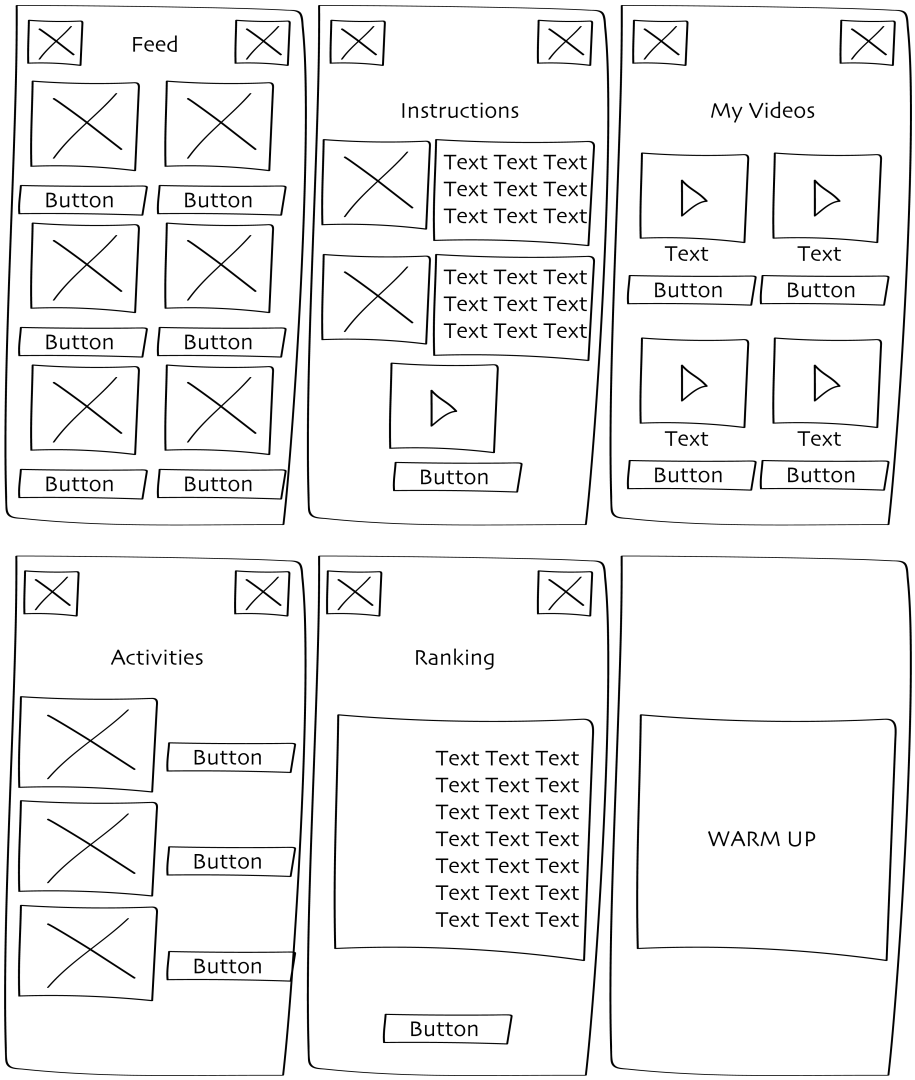
- What is your name?
- How old are you?
- Were you a gymnast before being a coach?
- For how long have you been a coach?

- What gymnastics education degree do you have?
- How long should be the duration of a training session?
- How do you organise your training sessions? How do you decide the exercises?
- And what does a good balance training consist of?
- What about pirouettes?
- What difficulties do you experience? Can you always reach the gymnasts?
- How do you analyse the exercises? And how do you know what corrections to give?
- About this trainings in zoom, what differences do you feel? Positive and negative points?
- How did you adapt to this new reality and what strategies did you use in trainings?
- Do you feel differences in the gymnasts, in the pavilion and in zoom? In which aspects?
- How do you try to motivate them?
- What do you think works better, "less nice" and more direct corrections, or corrections that encourage more and are nicer?
- General or individual corrections? Why? Does it depend on the gymnasts?
- What feedback/corrections do you use during the trainings?
- How do you know how many corrections a gymnast can implement and what is her limit?
- Do you feel they get motivated with corrections or does it make them give up training?- When should you correct an exercise and why?
- What do you have to pay attention to when teaching balances? What about pirouettes?
- Important aspects that I have not mentioned about the training or the gymnasts?
- Would it be pertinent to have scientific technological support during training sessions? Would that allow to have more exact and certain information about the execution of the exercises of each gymnast?

Appendix E: Preliminary Design Proposal

First Design Proposal




Feed
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Instructions
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My Videos
Text
Text
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Activities
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Ranking
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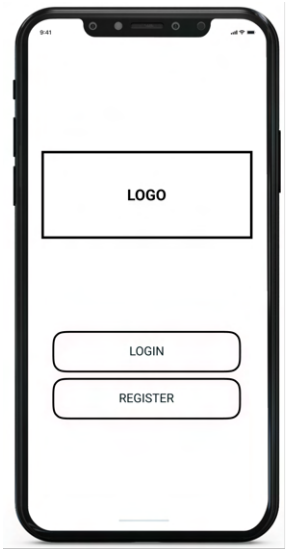
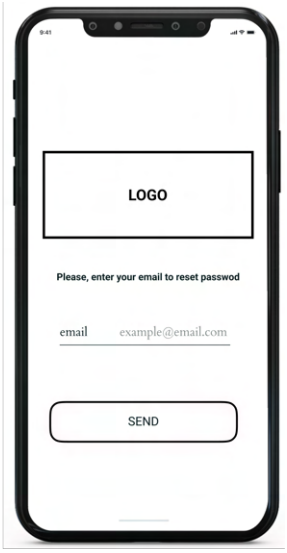
Button
WARM UP

Second Design Proposal

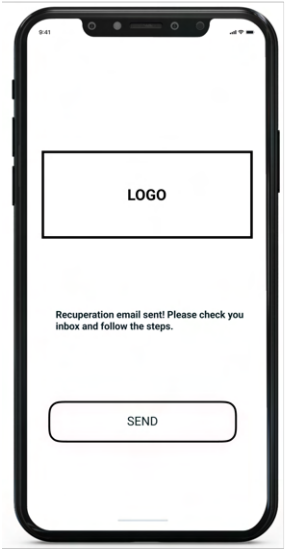


Home Screen

Login Screen



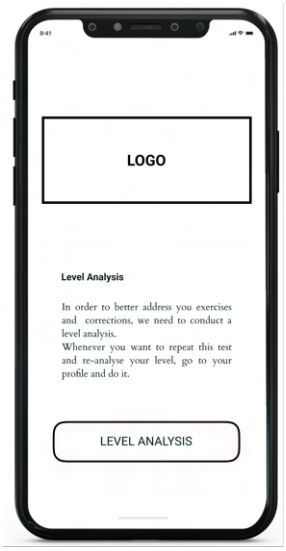
Password Recovery Screen



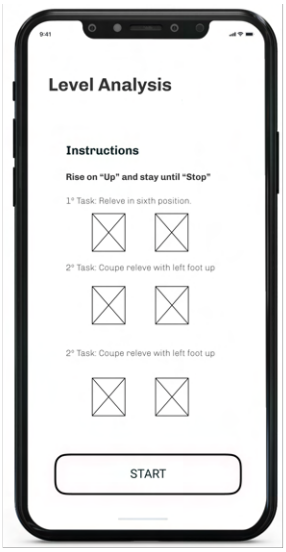
Email Sent Screen

Registration Screen

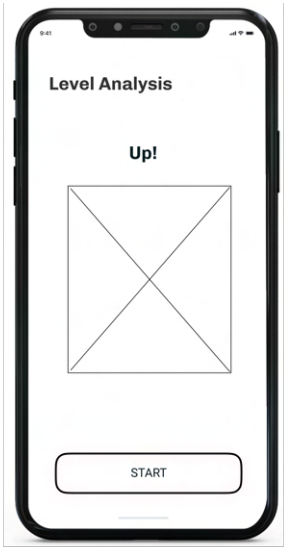
Advice Screen



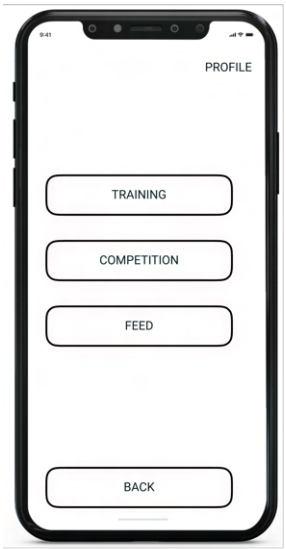
Pre Level Analysis Screen



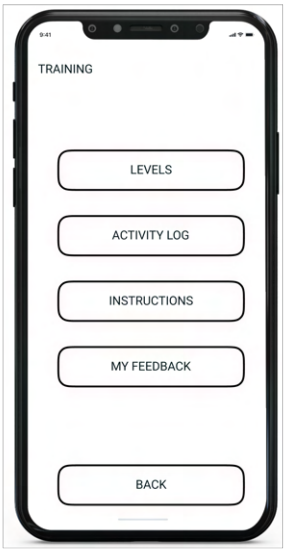
Level Analysis Screen



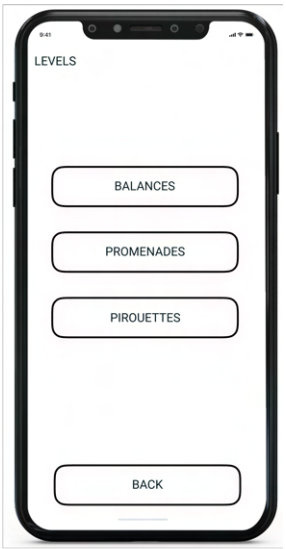
Level Analysis Exercises Screen



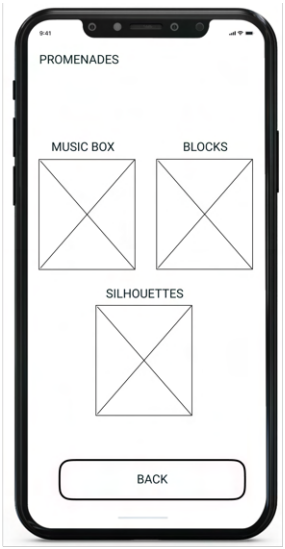
Menu Mode Screen



Menu Screen



Exercises Screen



Activities Screen

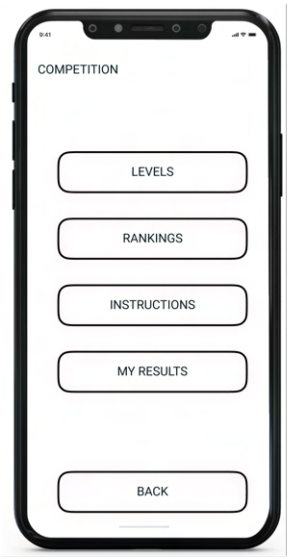
Activitie Log Screen

On Going Activity Screen

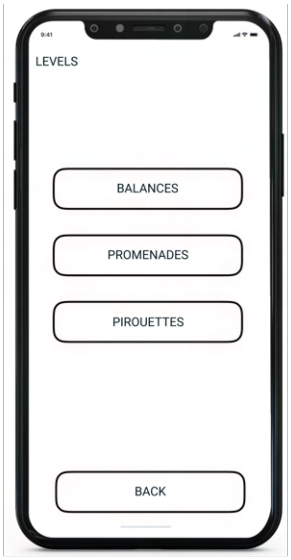
Instructions Screen

My Feedback Screen

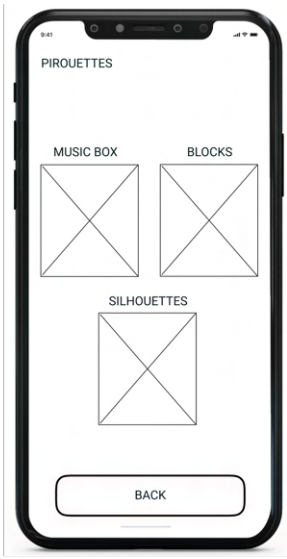
Profile Screen



Competition Menu Screen

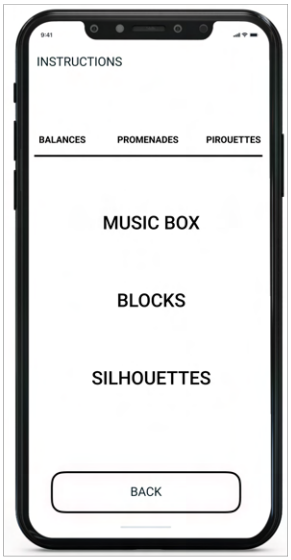


Competition Exercises Screen

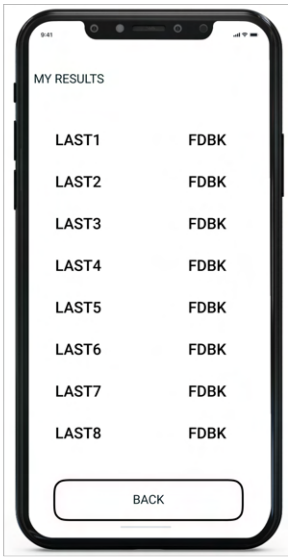


Competition Activities Screen

Ranking Screen



Competition Instructions Screen

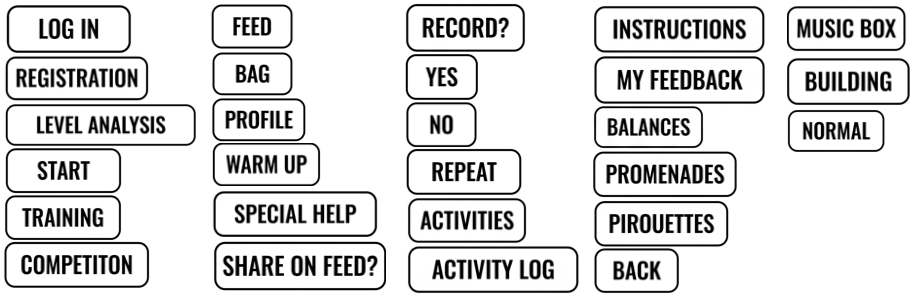


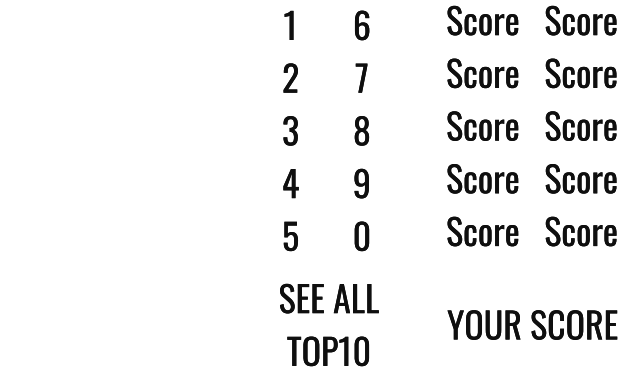
My Results Screen

Appendix ii: Second Design Proposal

Appendix F: PICTIVE Kit and Results

PICTIVE Kit

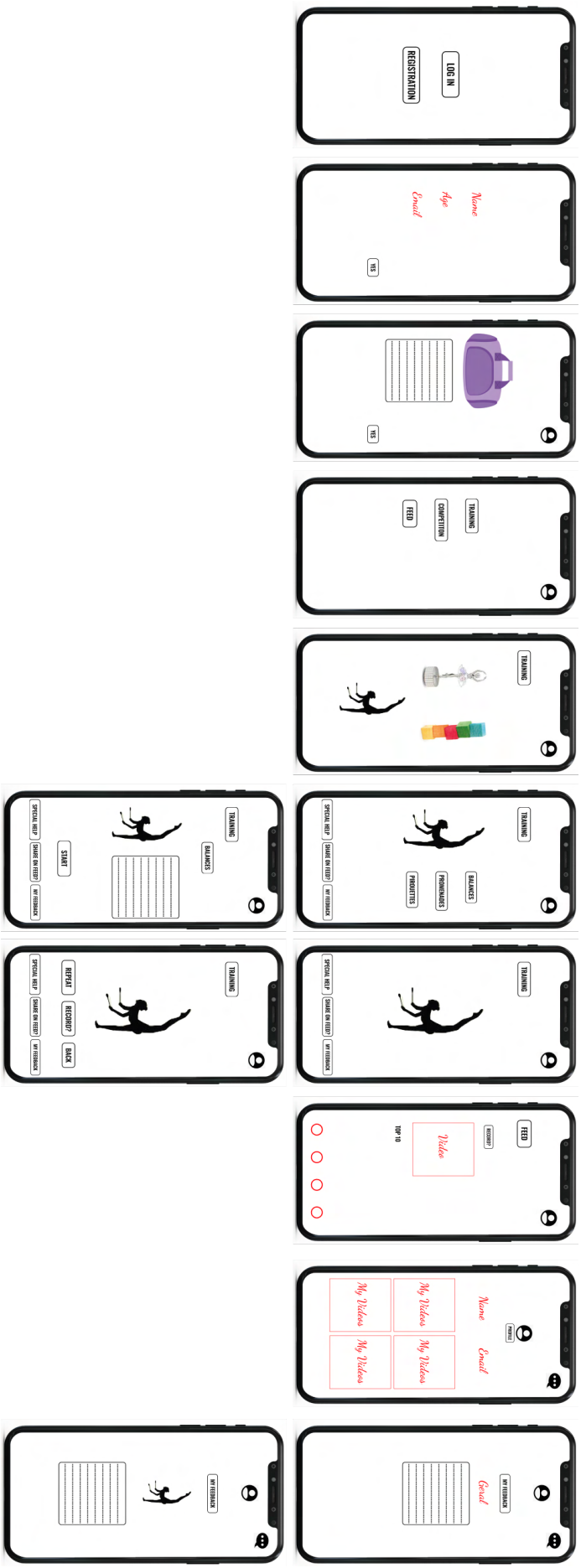




Appendix iii: PICTIVE Sessions Material

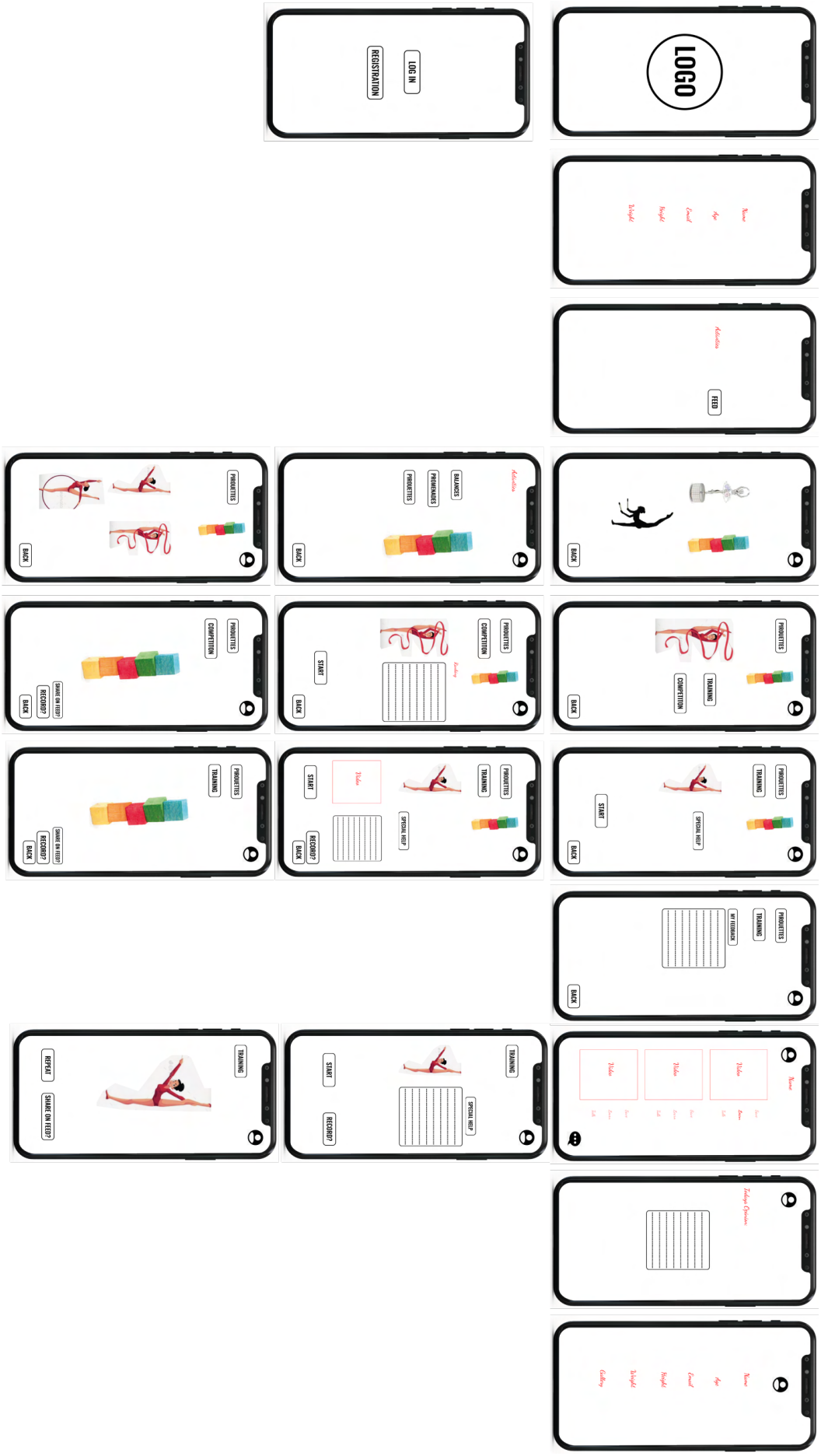
Appendix iv: PICTIVE Results - Participant 01

Appendix v: PICTIVE Results - Participant 02

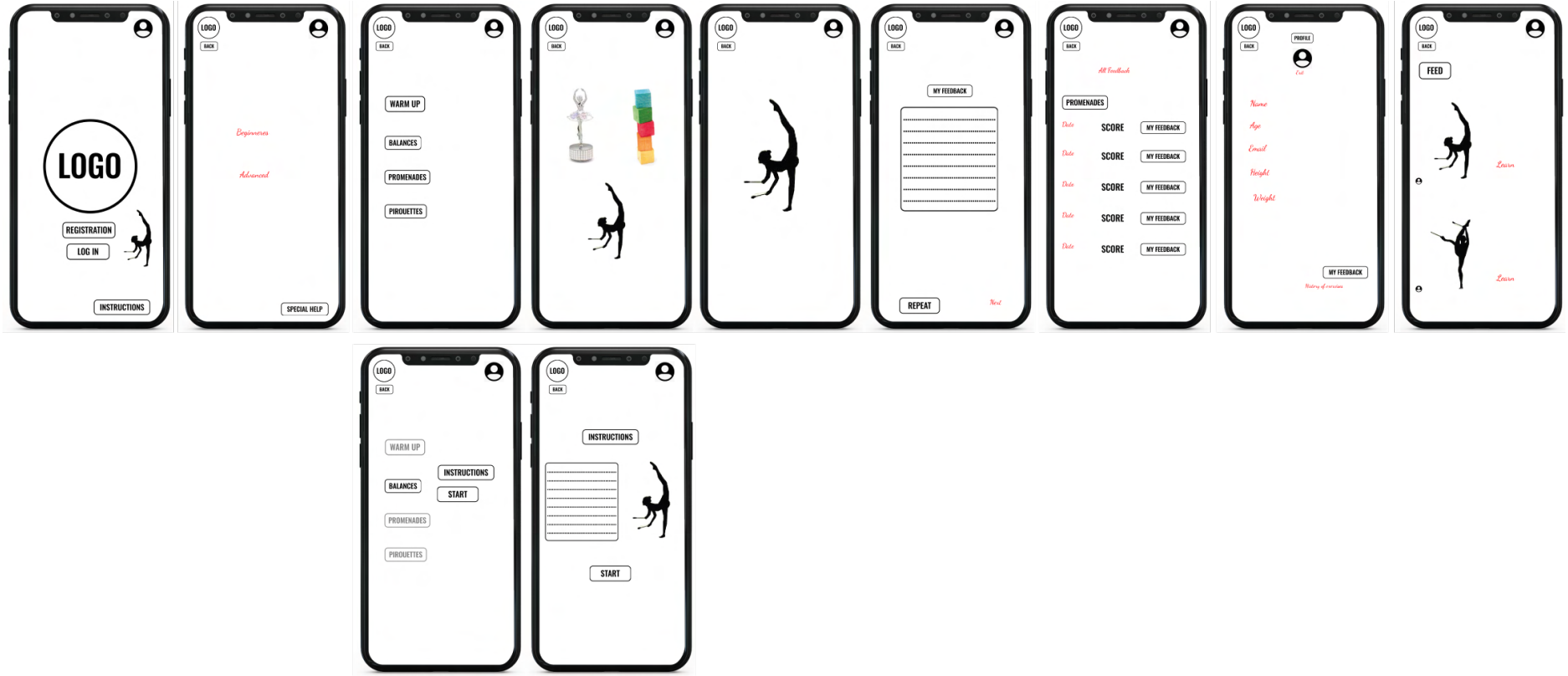


Appendix vi: PICTIVE Results - Participant 03

Appendix vii: PICTIVE Results - Participant 04



Appendix viii: PICTIVE Results - Participant 05



Appendix ix: PICTIVE Results - Participant 06

Appendix x: PICTIVE Results - Participant 07

Appendix G: Application Features Implemented

Reset Password Code

Listing 1: Reset Password Code

```
public void ForgotPass() {
    var request = new SendAccountRecoveryEmailRequest {
        Email = emailInput.text,
        TitleId = "37627"
    };
    PlayFabClientAPI.SendAccountRecoveryEmail(request, OnPasswordReset,
        OnError);
}
void OnPasswordReset(SendAccountRecoveryEmailResult result) {
    Debug.Log("Email Sent");
}
void OnError(PlayFabError error) {
    Debug.Log(error.GenerateErrorReport());
    messageText.text = error.ErrorMessage;
}
```

Appendix H: Balance Values

Table with Balance Values Measured with Gymnasts

Appendix xxiv: Balance Values

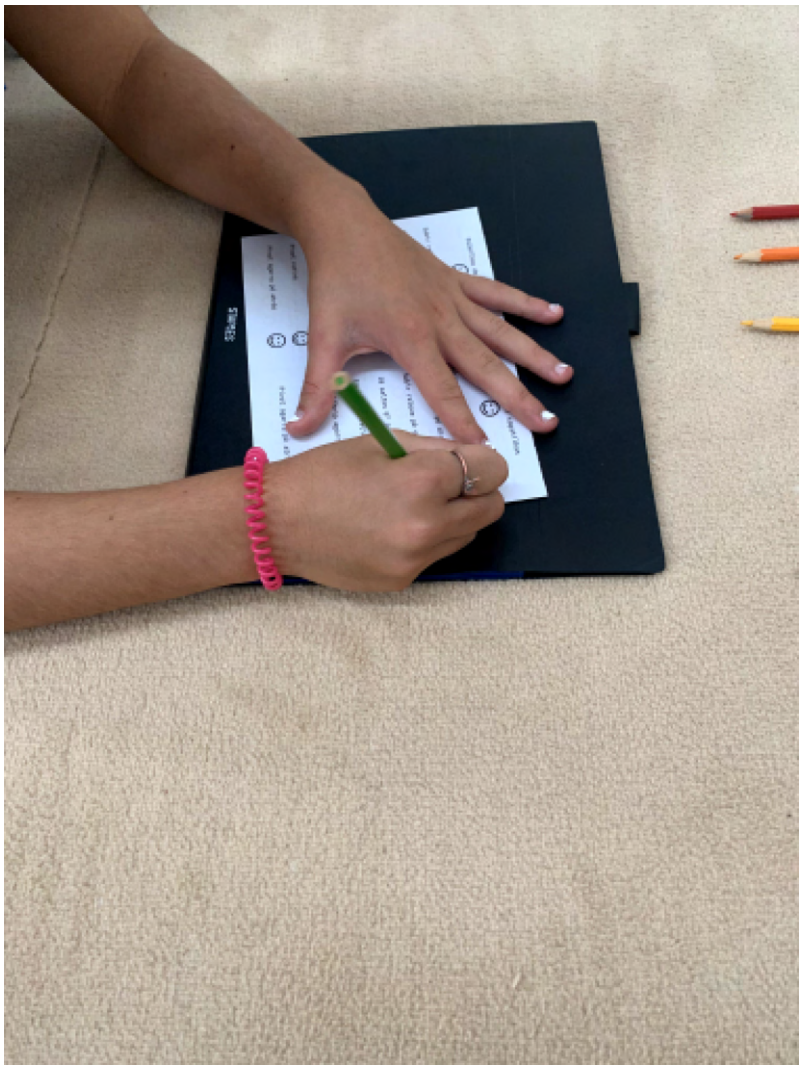
Participant	Age	Shoe Size	Age Group	Value Range
P01	18	39	Senior	Min: 32 | Max: 40
P02	11	37	Juvenile	Min: 30 | Max: 37
P03	11	37	Juvenile	Min: 31 | Max: 40
P04	09	34	Initiation	Min: 23 | Max: 54
P05	14	36	Junior	Min: 30 | Max: 40
P06	13	38	Junior	Min: 32 | Max: 39
P07	11	36	Juvenile	Min: 30 | Max: 39
P08	09	32	Initiation	Min: 22 | Max: 58
P09	17	38	Senior	Min: 31 | Max: 40
P10	10	36	Juvenile	Min: 30 | Max: 38

Appendix xxv: *Relevé* Values

Participant	Age	Shoe Size	Age Group	Value Range
P01	18	39	Senior	> 150
P02	11	37	Juvenile	> 147
P03	11	37	Juvenile	>146
P04	09	34	Initiation	> 127
P05	14	36	Junior	> 145
P06	13	38	Junior	> 146
P07	11	36	Juvenile	> 145
P08	09	32	Initiation	> 122
P09	17	38	Senior	> 147
P10	10	36	Juvenile	> 146

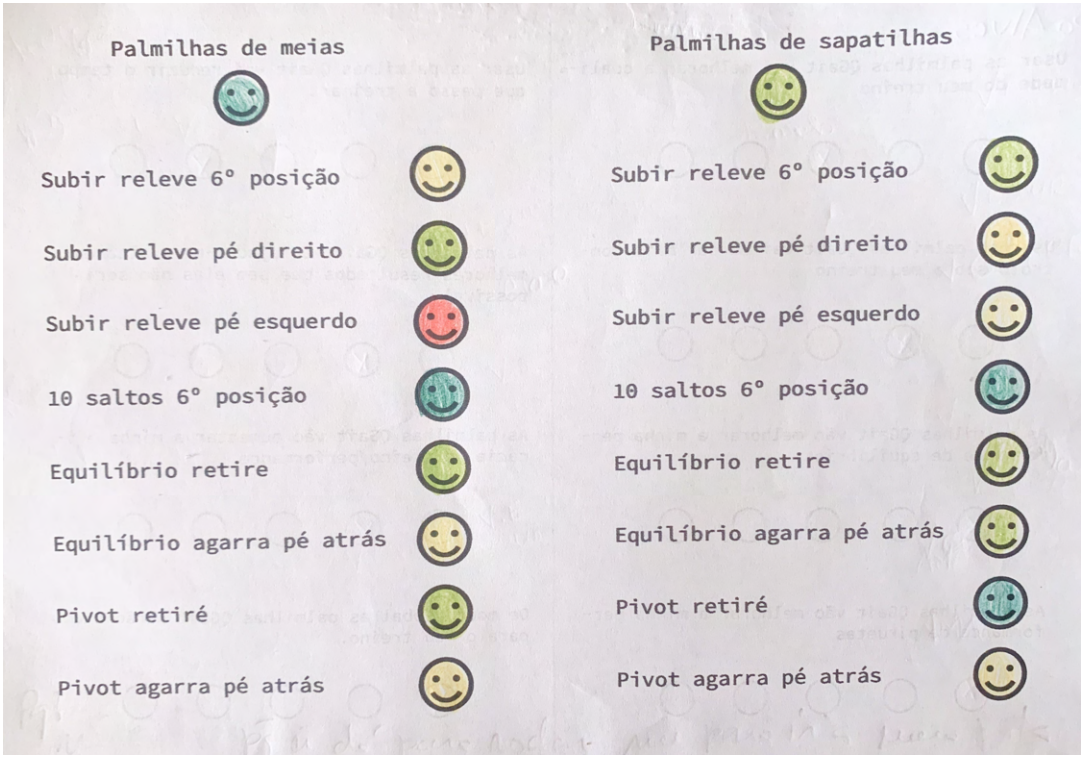
Appendix I: Smart Insoles Tests

Smart Insoles Testes Records

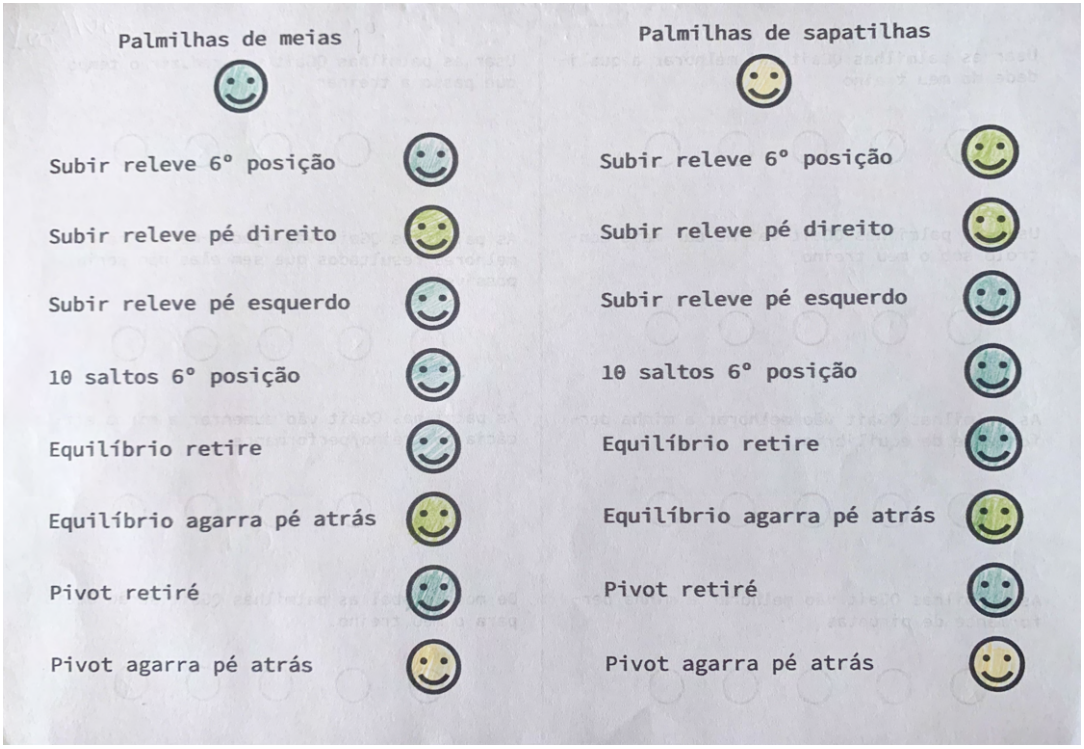


Appendix xi: Smart Insoles Tests Process

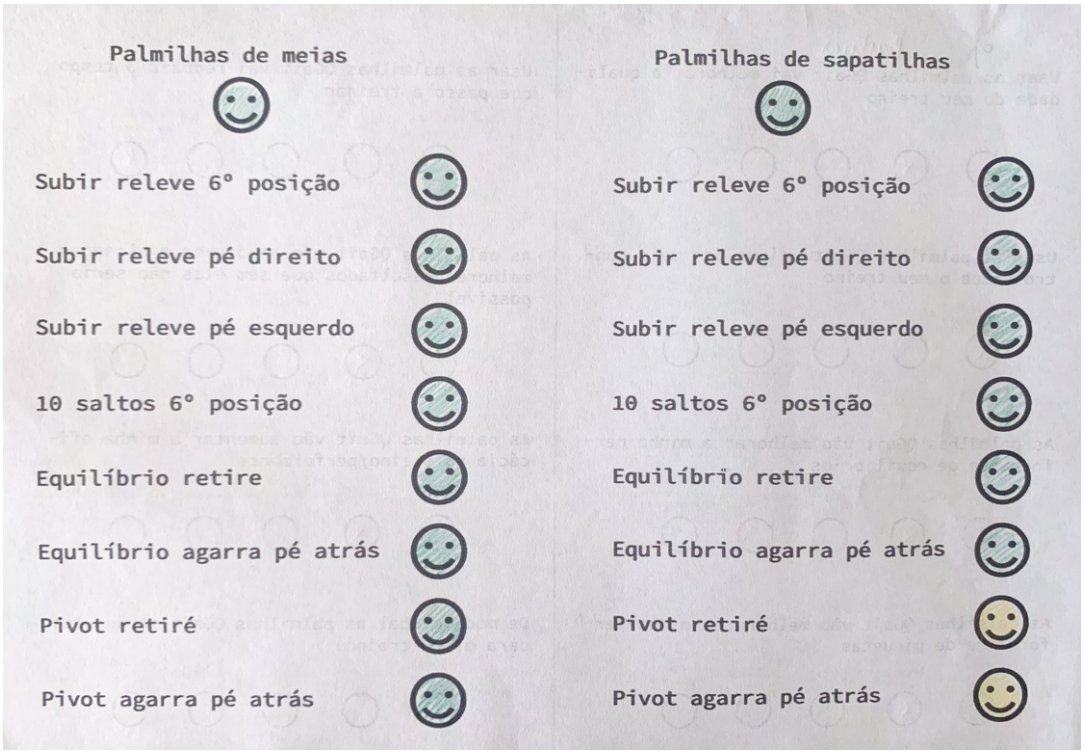
Insoles Testes Questionnaire Answers



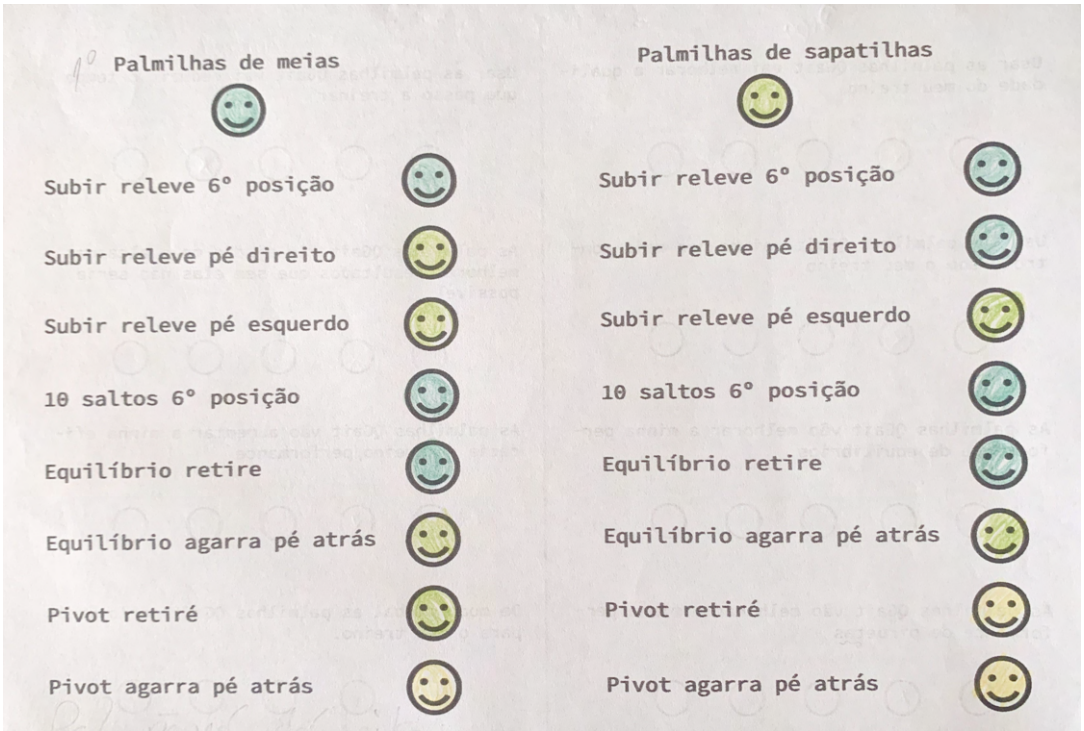
Appendix xii: P01 - Insoles Questionnaire Answers



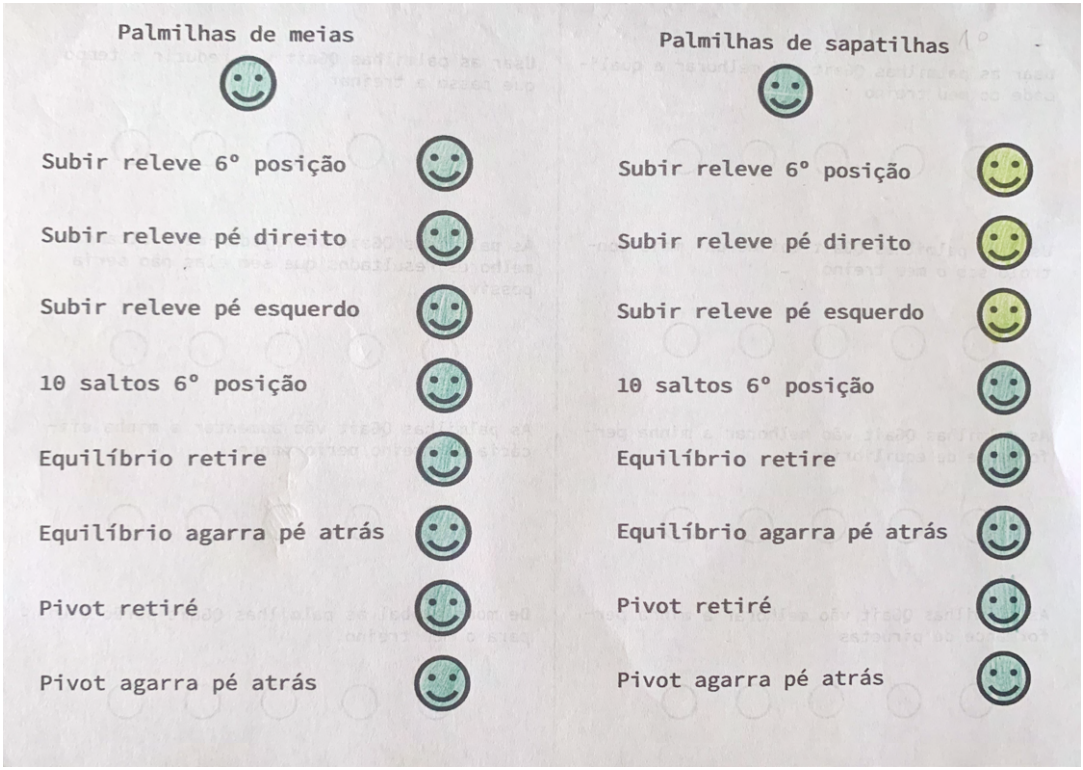
Appendix xiii: P02 - Insoles Questionnaire Answers



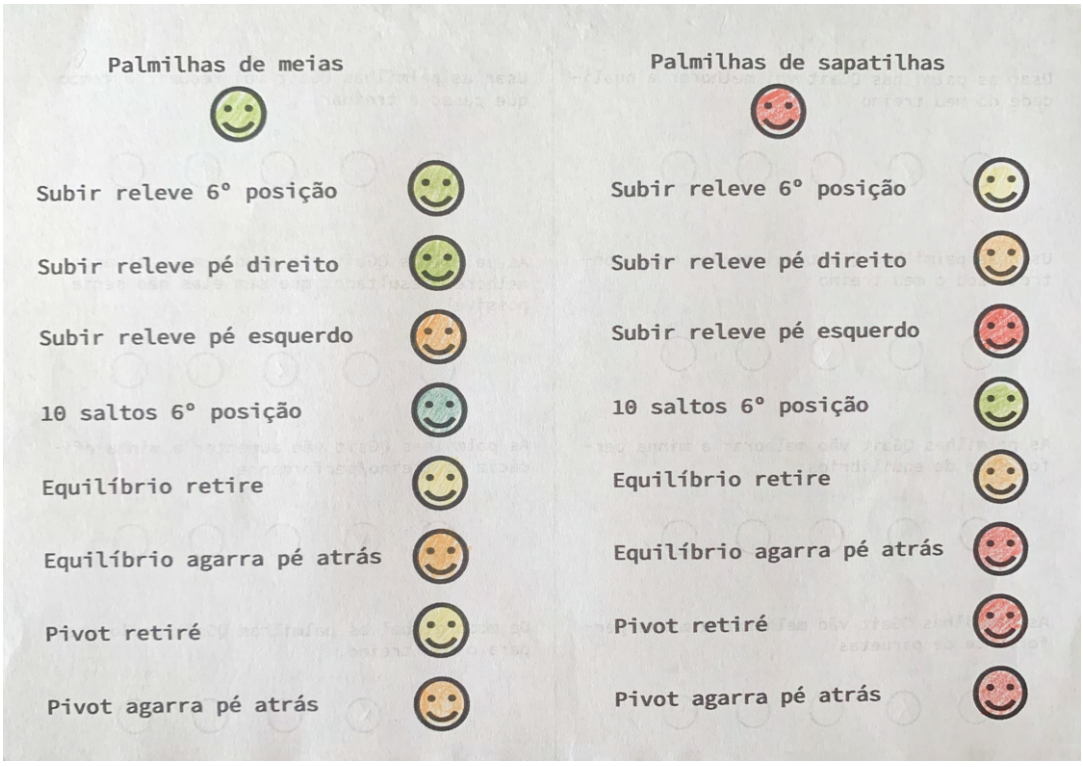
Appendix xiv: P03 - Insoles Questionnaire Answers



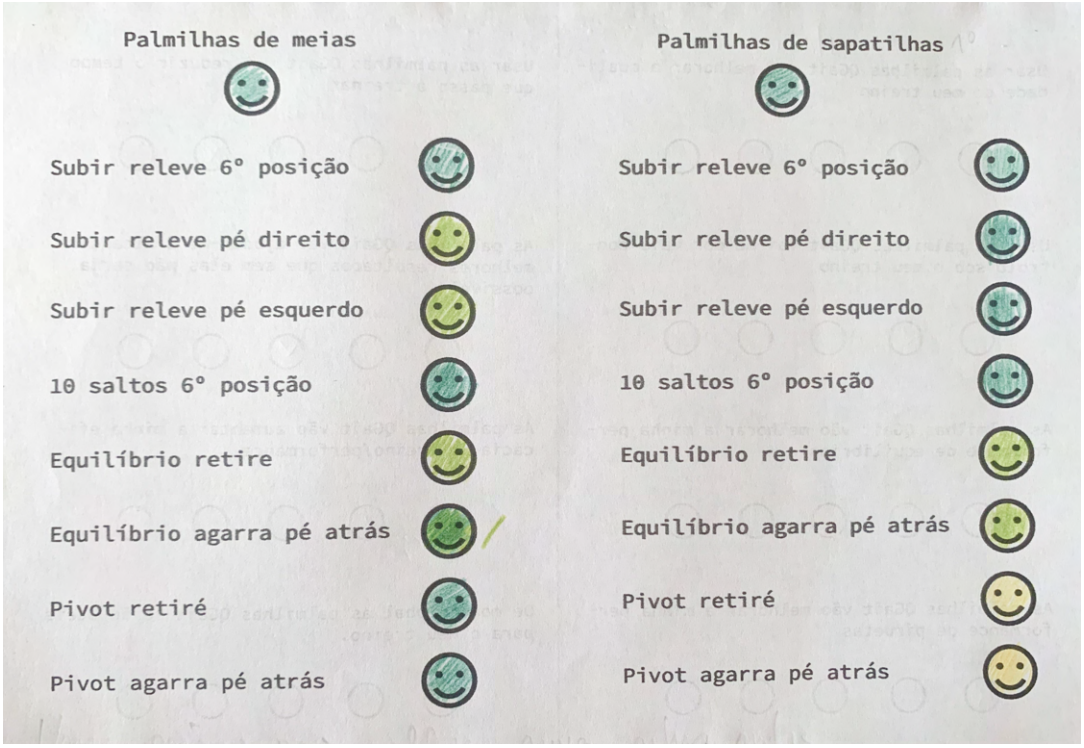
Appendix xv: P04 - Insoles Questionnaire Answers



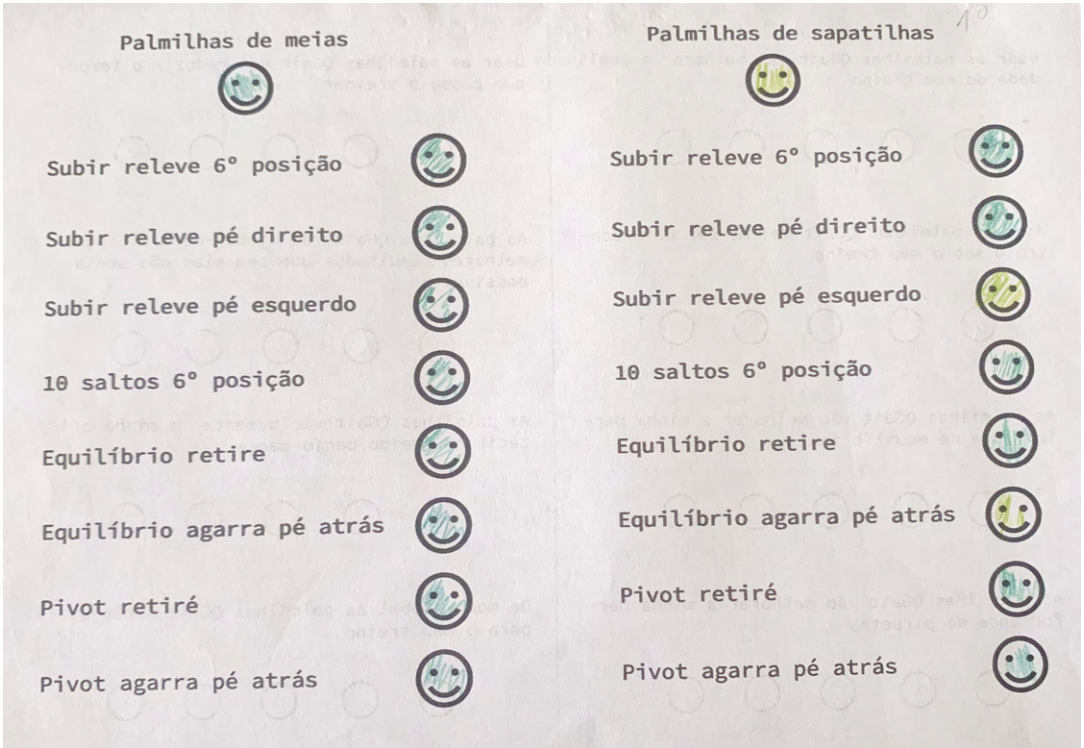
Appendix xvi: P05 - Insoles Questionnaire Answers



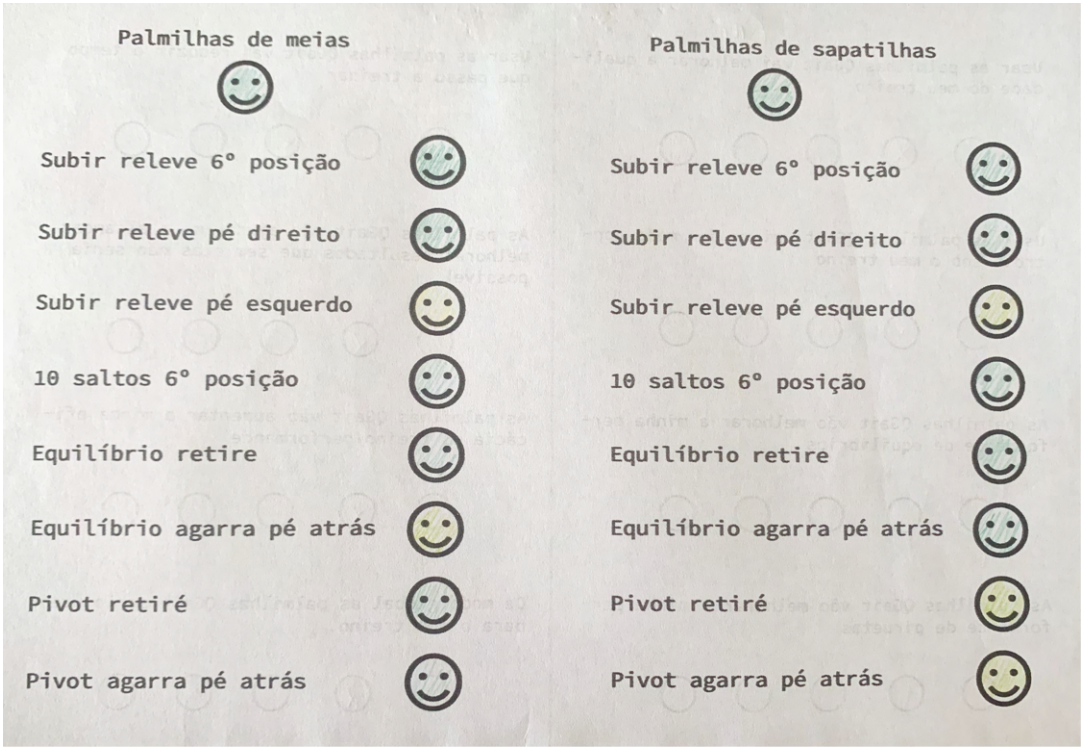
Appendix xvii: P06 - Insoles Questionnaire Answers



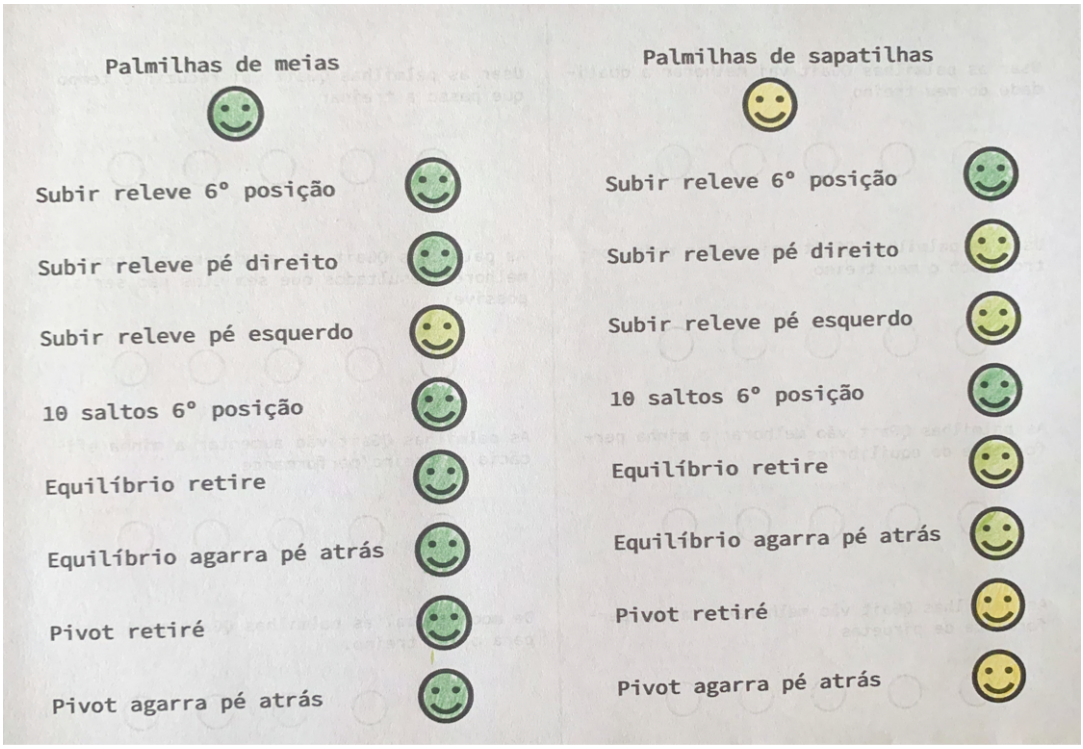
Appendix xviii: P07 - Insoles Questionnaire Answers



Appendix xix: P08 - Insoles Questionnaire Answers



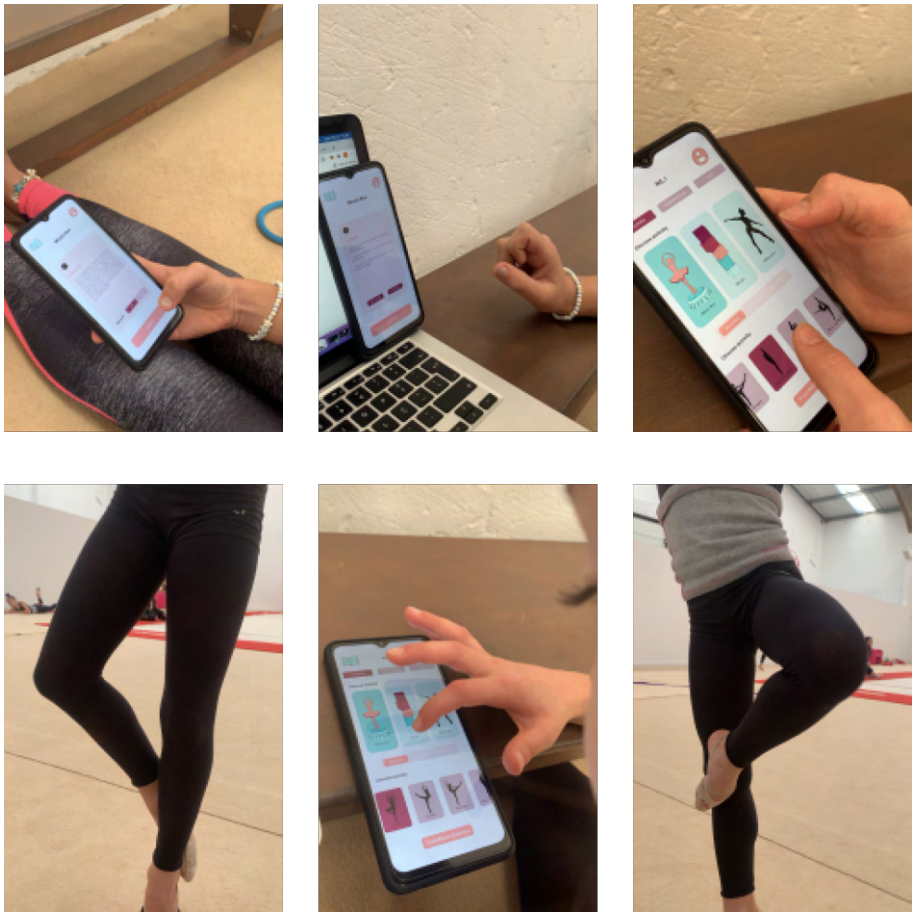
Appendix xx: P09 - Insoles Questionnaire Answers

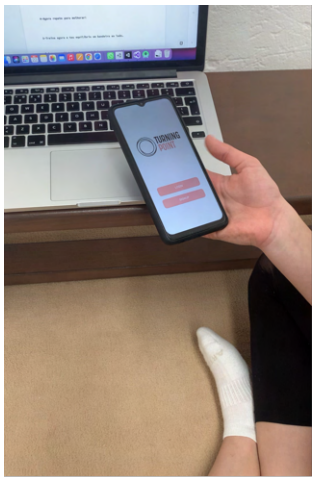
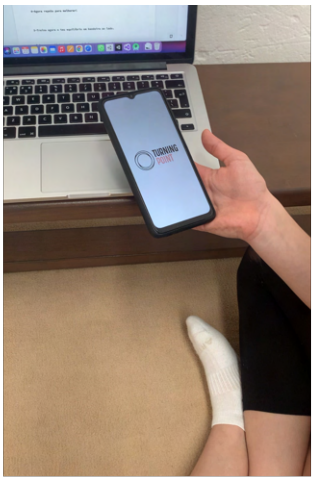
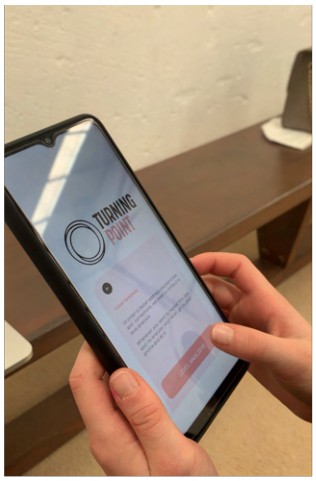
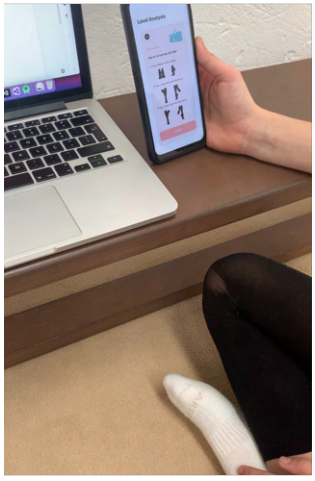
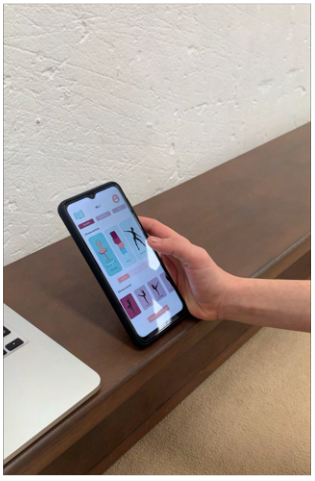
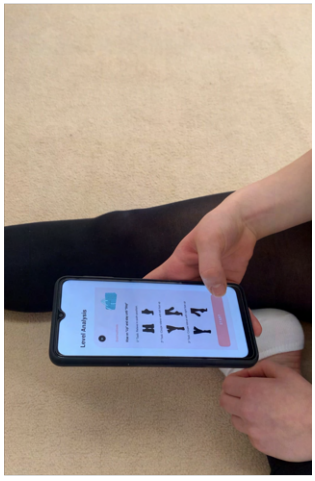


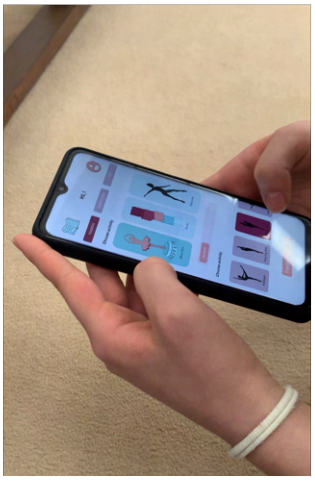
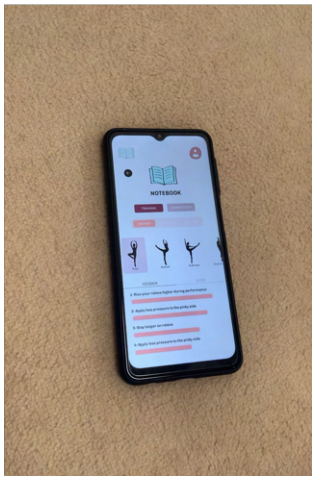
Appendix xxi: P10 - Insoles Questionnaire Answers

Appendix J: Usability and User Experience Tests

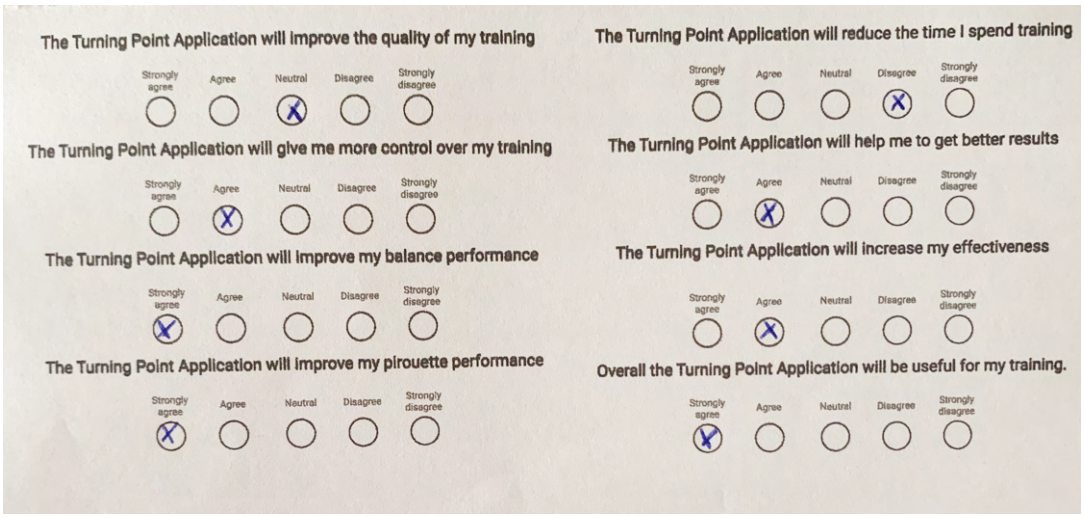
Usability and User Experience Tests



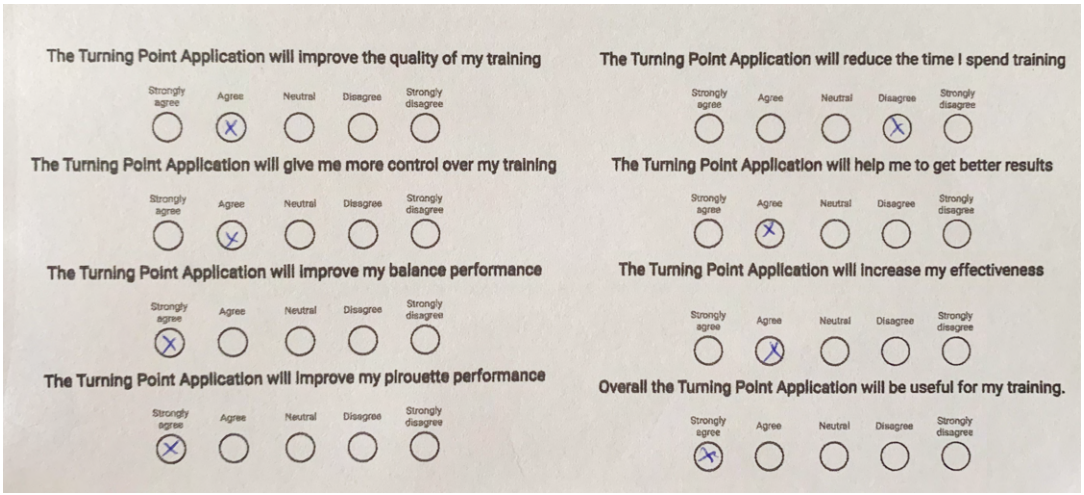







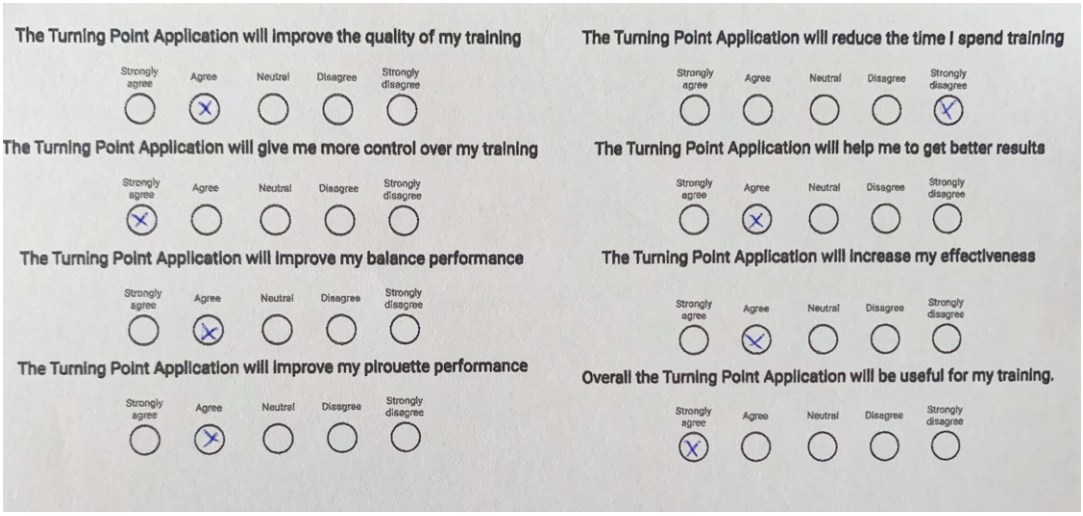
Usability and User Experience Answers



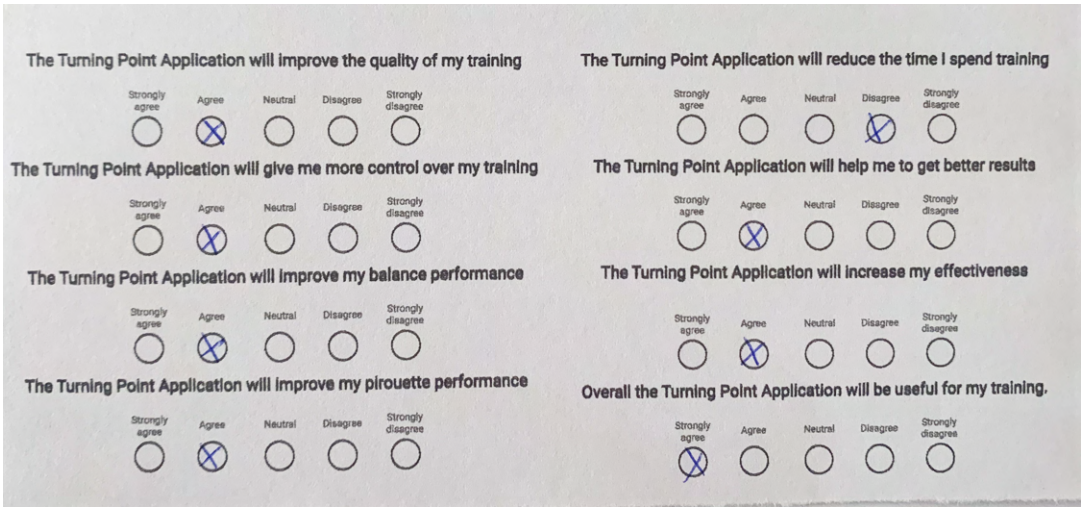
Appendix xxii: P01 - Usability and User Experience Answers



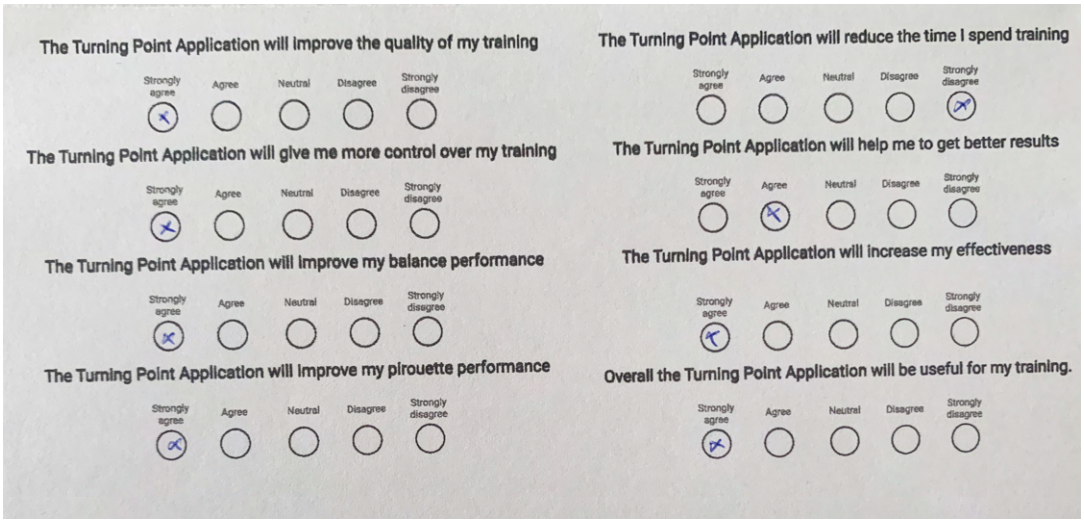
Appendix xxiii: P02 - Usability and User Experience Answers



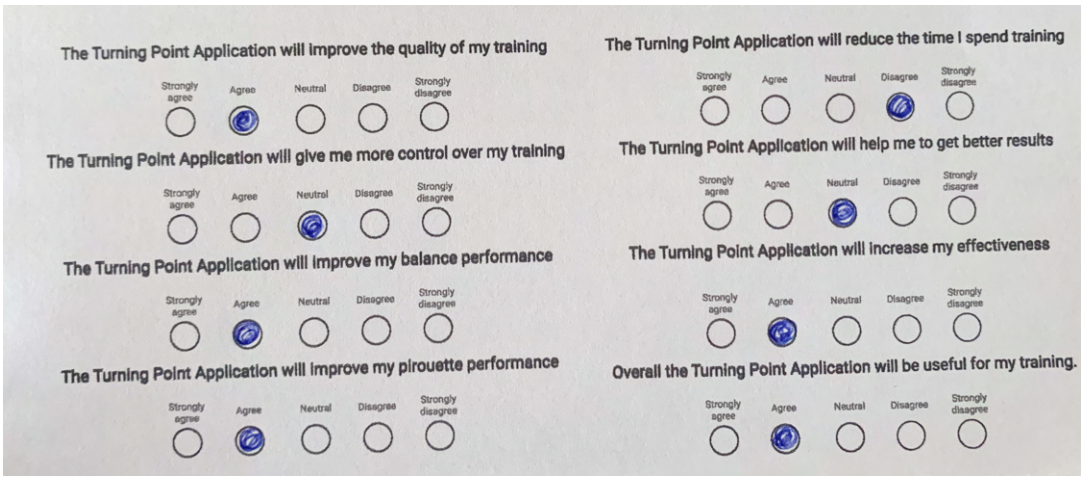
Appendix xxiv: P03 - Usability and User Experience Answers



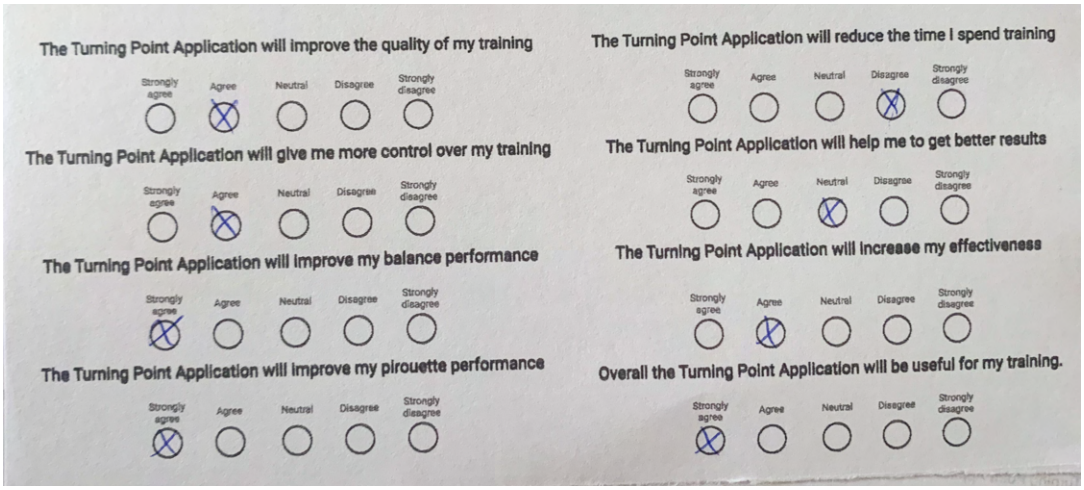
Appendix xxv: P04 - Usability and User Experience Answers



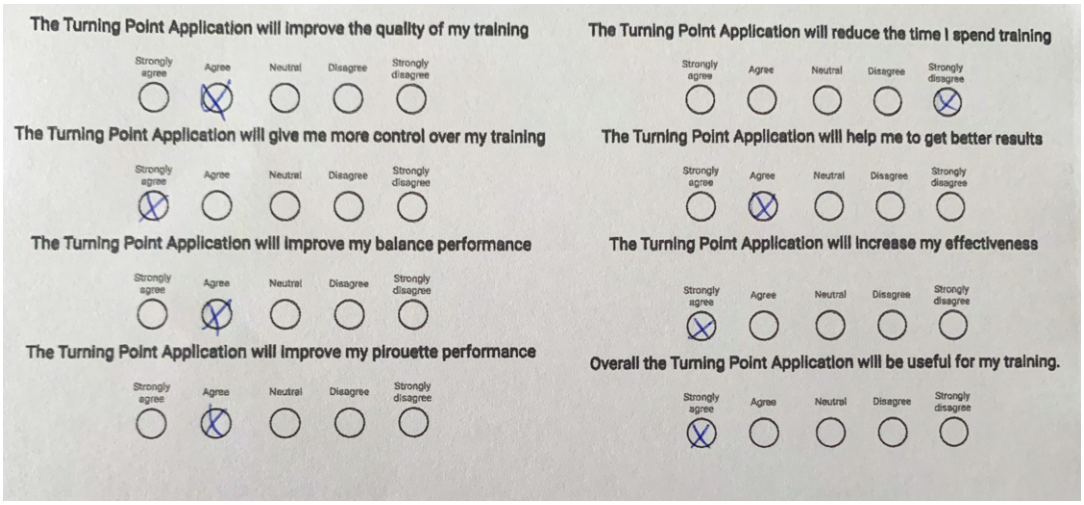
Appendix xxvi: P05 - Usability and User Experience Answers



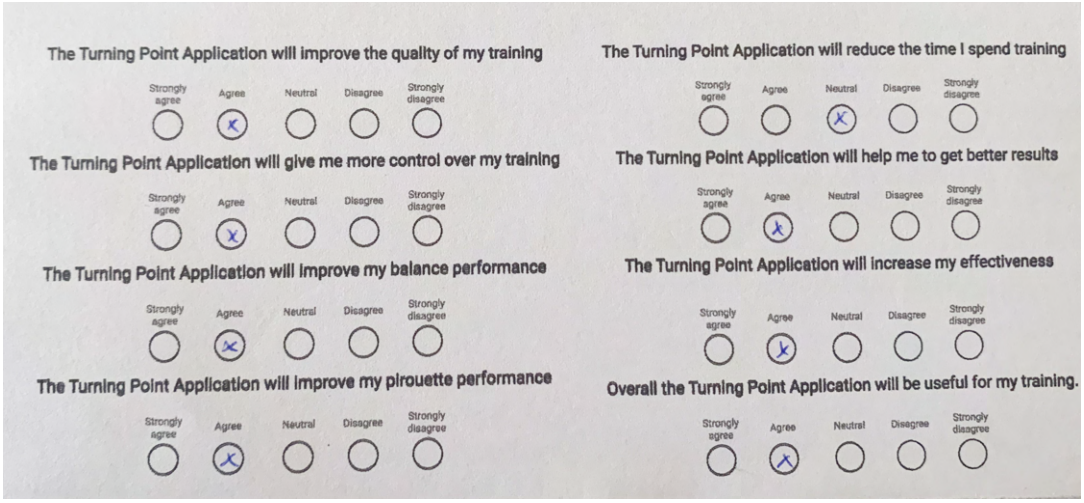
Appendix xxvii: P06 - Usability and User Experience Answers



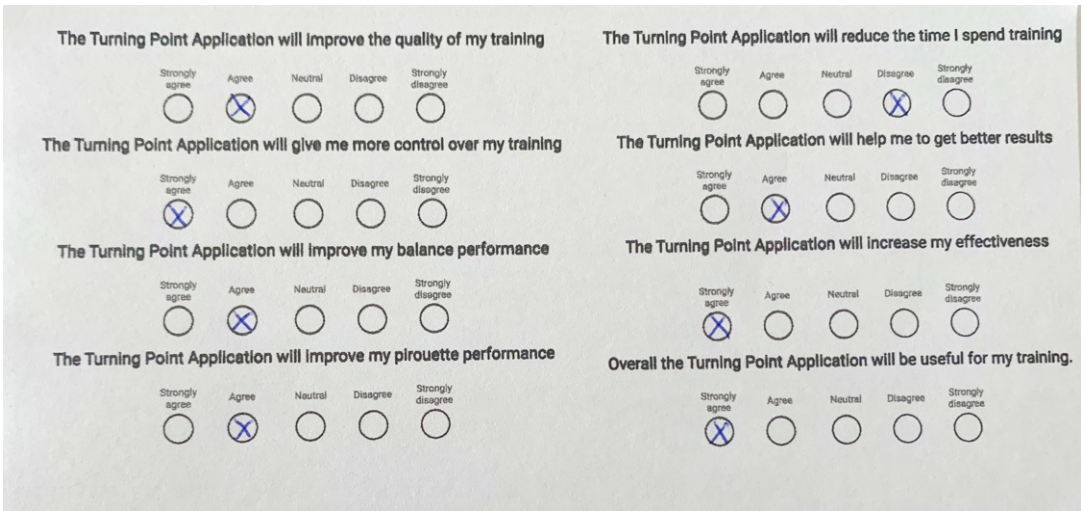
Appendix xxviii: P07 - Usability and User Experience Answers



Appendix xxix: P08 - Usability and User Experience Answers



Appendix xxx: P09 - Usability and User Experience Answers



Appendix xxxi: P10 - Usability and User Experience Answers

Appendix K: Links used for code references

PlayFab SDK for Unity

https://docs.microsoft.com/en-us/gaming/playfab/sdks/unity3d/installing-unity3d-sdk

Authentication - Login With PlayFab

https://docs.microsoft.com/en-us/rest/api/playfab/client/authentication/login-with-playfab?view=playfab-rest

PlayFab Leaderboards

https://docs.microsoft.com/en-us/gaming/playfab/features/social/leaderboardsv2/getting-started

PlayFab Users

https://docs.microsoft.com/en-us/gaming/playfab/features/data/playerdata/quickstart

PlayFab Users

https://stackoverflow.com/questions/69652903/how-do-i-find-my-sql-server-connection-for-azure-data-explorer-database-playfab

Appendix L: Video of the Application

Link to Video of the Application Running

https://drive.google.com/drive/folders/1ick4gixVN0hVo501GMD2Mvaty0domuK-?usp=sharing