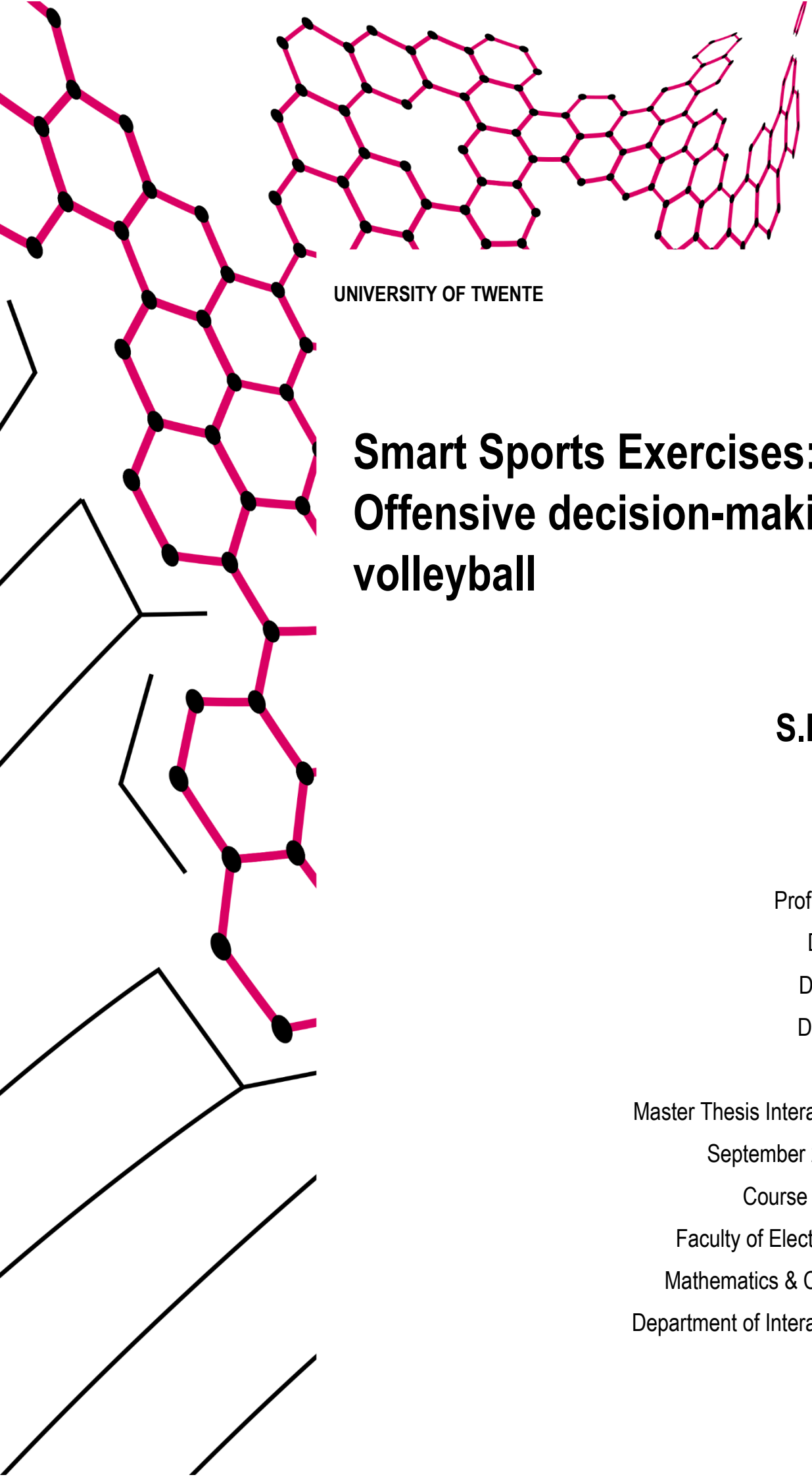

UNIVERSITY OF TWENTE

Smart Sports Exercises: Offensive decision-making in volleyball

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Abstract

The use of technology in sports is becoming more widespread, from video analyses, smart wearables or smart textiles, all kinds of technology is being used to help athletes perform optimal in their sport. A new emerging technology for training purposes is the interactive sport-training games technology, it uses interactive sport-training games for training exercises. What distinguishes these exercises from "standard" interactive sport exercises is the use of gamification to increase engagement. This thesis project is concerned with the development of an interactive sport-training games system that focuses on training the subdomain offensive decision-making in volleyball through an interactive pressure-sensitive floor.

The developed system aims to provide an addition to the traditional volleyball training, to achieve this goal the thesis project was divided into three phases: the theory phase, constructive phase, and evaluation phase. The theory and constructive phase provided an answer to the first research question: *"How can we develop an interactive sport-training games system that trains the multidimensional construct of a volleyball exercise subdomain by using an interactive floor?*" and the evaluation phase provided an answer to the second research question: *"How is interaction technology viewed in general by trainers and players*" and the third research question: "A*re the developed suite-of-games exercises suitable for training the attacking subdomain in volleyball when using an interactive floor?*".

When designing the system, a suite-of-games approach was chosen to train the multidimensional construct of the subdomain because it provides the flexibility and versatility needed for training. The research done on this approach shows that a suite-of-games approach is not as straightforward as initially thought, but the first steps have been taken. Therefore, it is thought that this thesis offers an illustration of how one could design for multidimensional sports constructions.

The evaluation phase consisted out of a user study with nine participants combining quantitative measurements and qualitative interviews to provide an answer for the second and third research question. The results of the evaluation show that the participants are open to integrating the developed system in their own training. The use of interaction technology in sports is positively viewed and the developed exercises were found suitable for training the subdomain. To make the exercises suitable for higher-level playing teams, some refinements, such as the difficulty and dynamics of the exercises, will be necessary.

Acknowledgements

This thesis marks the end of my studies at the University of Twente. I would like to take this opportunity to thank everyone who supported me during this master thesis. First of fall I wish to thank Dennis Reidsma and Dees Postma for their supervision since the start of my graduation process. Your expertise on diverse fields and our weekly meetings allowed me to greatly improve the quality of my work. I also want to express my gratitude towards Dirk Heylen and Armagan Karahanoglu, who agreed to join my examination committee.
Furthermore, I wish to express my gratitude towards all participants of the evaluation, who took the time and effort for reviewing the developed system. I would also like to thank Fahim Salim for his help in reading the interactive floor data. Finally, I would like to thank all my friends and family who supported me along the way.

Table of Contents

1. Introduction

1.1. Motivation

Volleyball is one of the most widely played sports in the world, approximately 800 million people practice volleyball at least once a week [1]. Big tournaments such as the Olympic Games, the World Grand Champions Cup, FIVB Nations League and the CEV Champions League are the podia for volleyball players to show their skills. Without having a well-tuned training, it is not easy for players to perform well during matches, which is why nowadays new training equipment and programs are increasingly being looked at to improve the level of the player. Frequently used training programs are performance-enhancement programs. Performance-enhancement programs are individualised programs that identify and correct an athlete's weaknesses and maximise their athletic potential. A supporting factor in these programs is the use of technology, technologies such as video analysis, match analysis, smart textiles and wearables are being used to tailor the program even better to the athlete. In addition to incorporating these technologies into a training program, a new way of training is emerging that, using technology, enhances the athlete's training experience. Such a trainings system is known as an interactive sport-training games system in the field of Human-Computer Interaction. In an interactive sport-training game the focus lies on learning a sport related skill while performing a physical sport game. By including game mechanic elements, the training of a specific skill can become more appealing for the players [2]. Well known interactive sport-training games systems are Football Labs [3] by Jensen (see figure 1) and TacTowers [4, 5] by Ludvigsen (see figure 2).

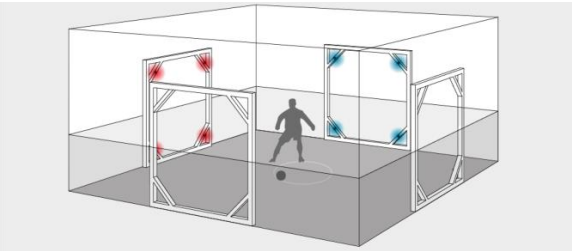

Figure 1 Footbal Labs

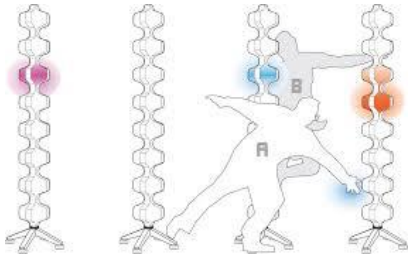

Figure 2 TacTowers blocker exercise game

With the success of the interactive sport-training games systems of Jensen and Ludvigsen in mind and the emergence of integrating technology and sports together, the University of Twente, Windesheim and LedGo, started the Smart Sport Exercises (SSE) project. The SSE project is engaged in the development of an interactive sport-training games system that is suitable for volleyball training. An interactive pressure-sensitive floor is being used to create an immersive training environment for volleyball training. Volleyball skills can be taught to players in a new and creative manner using an interactive floor, enhancing their training experiences. The aim of the SSE project is to support training and coaching in volleyball by providing new insights [6].

Since the use of an interactive sport-training game concept is quite new in the sports and research world [2, 3], there are some uncertainties about using such a system with an interactive floor. Such uncertainties are the difficulty to estimate how easy it is to deploy a training on the SSE system, the willingness of the trainers for implementing such a technology in their trainings and the willingness of usage by the volleyball players.
Another uncertainty is the possibility to create exercises that covers the multidimensional construct of a volleyball skill, skills such as blocking, attacking, defending, passing, or serving a ball. Volleyball is known as a sport in which no match scenario is the same. Therefore, mastering the fundamental skills is very important for a player [7] as volleyball is an easy sport to play but a tough sport to master.

This thesis project is part of the SSE project and will provide an answer to the previously mentioned uncertainties by developing an interactive sport-training games system for a single volleyball exercise subdomain.

1.2. Goal

The goal of this thesis is to create interactive sport-training games that add to traditional volleyball practices. In a traditional volleyball training only the trainer determines how a skill is learned and trained, with the floor as an aid there are more possibilities, due to its versatility, to learn or train certain skills.
When this goal of added value to traditional practices is achieved, an important step is taken towards integrating an interactive floor with interactive volleyball training games for volleyball practices. Furthermore, the achieved goal would provide an illustration of how one could design an interactive sport-training games system for multidimensional sports constructions.

1.3. Scope

To achieve the goal of this thesis project, the scope will be limited to a single volleyball exercise subdomain (volleyball consists out of six subdomains: receiving, digging, blocking, attacking, serving, and setting). Because incorporating the entire volleyball sport with all its techniques into the sport-training games system would be too comprehensive, I decided to focus on a single exercise subdomain. There is also insufficient time to enforce various volleyball exercise subdomains. The attack subdomain, and more specifically the offensive decision-making subdomain, was chosen as the exercise subdomain for this thesis. Because research has shown that the attack skill is the skill to win a match, and decision-making is an important part of ensuring that the attack is successful, this exercise subdomain was chosen. The exercises developed for this subdomain are mainly attack exercises that emphasise on the decision-making aspect during an attack.

Because the training of the exercise subdomain consists of many varying aspects, I decided to use a suite-of-games approach [8, 9]. A suite-of-games approach means that the developed exercises are adaptable to the level of the player, it uses tailor-made goal setting based on the player's capabilities. Due to the adaptability of the suite-of-games approach, its approach is ideal for the volleyball sport with all its training variation. From personal experience, trainers often use different levels of difficulty by making small changes to the exercises to challenge the players more. Therefore, a suite-of-games approach is a suitable way to set up the system because it can provide a lot of the required variety. The developed system assumes that the volleyball player has a basic level of volleyball, which means that the player can easily perform an attacking situation. Reason for choosing a minimum level of volleyball skills is because it involves the largest group of volleyball players, players over 12 years old.

In later chapters more explanation will be given about why the choice was made for the offensive decision-making exercise subdomain and the suite-of-games approach.

1.4. Research Questions

In this section, the research questions that were devised to achieve the thesis goal are presented. The thesis project can be divided into three different phases, the theory phase, the constructive phase, and the evaluation phase. Section 1.5 will further explain what each phase exactly entails. To answer the first two phases, the following research question was established:

RQ 1: *How can we develop an interactive sport-training games system that trains the multidimensional construct of a volleyball exercise subdomain by using an interactive floor?*

This research question was divided into several sub-research questions:

Theoretical
In the theoretical phase of the project, answers were sought to the various knowledge questions about a suite-of-games approach and which exercise subdomain is best suited for the interactive floor. The following questions were answered:

SQ 1.1: What does an interactive sport-training game entail?

SQ 1.2: What characteristics does a suite-of-games approach have?

SQ 1.3: Which volleyball exercise subdomain is best suited for the interactive floor?

SQ 1.3.1: What aspects does the chosen exercise subdomain have?

Constructive
During the constructive phase of the project the rationale theoretically grounded design is translated into a hi-fi prototype. The following design question was answered:

SQ 1.4: How can the characteristics of a suite-of-games be operationalised for offensive decision-making?

The last phase, the evaluation phase, answers the second and third research question:

RQ 2: *How is interaction technology viewed in general by trainers and players?*

RQ 3: *Are the developed suite-of-games exercises suitable for training the attacking subdomain in volleyball when using an interactive floor?*

Because the research questions RQ 3 is quite broad, it was divided into several sub-questions. The following sub-questions were drawn up:

SQ 3.1: How is the attack currently being trained?

SQ 3.2: How is the potential of the developed exercises perceived by trainers and players?

SQ 3.3: How do trainers and players view the suite-of-games approach that is integrated with the interactive floor?

SQ 3.4: Are trainers and players willing to use the developed sport-training games system for training purposes?

1.5. Approach & Document Structure

As mentioned before in section 1.4, the thesis project was divided into several phases to answer the research questions and sub-questions. The phase contents are summarised more extensively below, the theoretical phase is divided into three sub-phases to make is more manageable.

Phase 1: Theoretical

Sub-phase 1a: Theory
The first sub-phase of the theoretical phase focuses on giving background information about what an interactive sport-training game and a suite-of-games approach entail. The second chapter will provide this background information and thereby answer the sub-questions 1.1 and 1.2.

Sub-phase 1b: Determining exercise subdomain
The determination for the chosen exercise subdomain offensive decision-making is further explained in this phase. Existing literature about volleyball exercise subdomains and the importance of each exercise subdomain to a volleyball match was used to determine the chosen exercise subdomain.

Subsequently, the various aspects of the offensive decision exercise subdomain were determined based on literature and iterative design. This determination of the exercise subdomain is discussed in chapter 3 and an answer is also provided to sub-questions 1.3 and 1.3.1.

Sub-phase 1c: Determining exercises

After the determination of the offensive decision-making exercise subdomain, exercises within the form were created based on the aspects within the exercise subdomain. During the process of creating the exercises, research was conducted regarding which volleyball skills/behaviours lend themselves for training using a suite-of-games approach. To choose suitable exercises, I looked at the results of a fellow Smart Sports Exercises researcher. She had done research on different exercises that are considered suitable for an interactive floor. In addition to this information, I held a brainstorm session on suitable creating exercises and consulted literature for various exercises that are related to offensive decision-making.

Chapter 4 deals with this phase by dividing the chapter in two sections. In the first section of the chapter the exercises with their corresponding levels and contribution to the aspect will be explained, then in the second section the final design of the exercises will be presented.

Phase 2: Constructive

The second phase is concerned with the implementation of the offensive decision-making exercise subdomain and the associated exercises and levels. During the development of the exercises, a pilot study was also conducted with the floor to see if the exercises were visually clear and intuitive on the floor. This constructive phase of the project and the associated sub-question 1.4 is discussed in chapter 5.

Sub-phase 3: Evaluation

The last phase of this thesis project is the evaluation session phase, in this phase the floor with its exercises was evaluated by interviewing volleyball trainers and players. By interviewing trainers and players and showing them the functioning of the floor and its exercises, their willingness regarding using such a floor for training sessions was looked at. Furthermore, they were asked what they thought of the wealth of exercise possibilities with such an interactive floor and their thoughts about the developed exercises in general. Chapter 6 deals with the evaluation phase and answers the second and third research question and sub-questions.

Chapters 7 and 8 deal with the discussion, limitations, and conclusions of the thesis project.
The table below provides a brief overview of where each research question and sub-questions are answered.

Chapter	Research question
2	SQ 1.1 and SQ 1.2
3	SQ 1.3 and SQ 1.3.1
5	SQ 1.4
6	SQ 3.1, SQ 3.2, SQ 3.3 and SQ 3.4
7	RQ 1, RQ 2 and RQ 3

Table 1 Overview of which RQ or SQ is answered in which chapter

2. Background

This chapter provides an introduction on the available literature in the field of exertion games and interactive sport-training games systems. From there it is explained what a suite-of-games design entails and why this design approach has been chosen. Section 2.1 will answer sub-question 1.1 "*What does an interactive sport-training game entail?*" and section 2.2 will provide an answer for sub-question 1.2 "*What characteristics does a suite-of-games approach have*?".

The contents of this chapter are for a large part reused from a previous conducted literature research [10]. This preliminary research extensively investigated the suite-of-games concept and its counterpart the point design. For a more in-depth explanation of the various components of interactive systems, please refer to the preliminary study.

2.1. Interactive Sport-training Games

Before explaining the concept of an interactive sport-training games system, the difference between such an exercise and an exertion game will be explained first to avoid ambiguity between the two terms. Most people have had an experience with exertion games, they are often used by commercial game consoles, rehabilitation programs or mobile applications. In addition to commercial systems, researchers from the Human-Computer Interaction research field are also developing and researching exertion games to see, for example, whether the use of such games is beneficial for someone's health [11, 12] or just to discover novel play experiences [13-15]. An exertion game is a game in which the users' bodily actions are at the centre of the experience, fostering physical exertion as part of the interaction in a game [16, 17]. Thus, the traditional combination of mouse, keyboard and gamepad interactions are a thing of the past with these games. To avoid uncertainty about what an exertion game entails, the definition of F. Mueller et al. [18] was used during this thesis project.

"An exertion game is a digital game that utilizes physical exertion interactions where the physical effort is a key, if not the dominant, determinant in reaching the game's goal" – F. Mueller

A popular company known for their use of commercial exertion games is Nintendo, with the introduction of their Wii console they created a whole series of exertion games. Later, they did the same for their Nintendo Switch console. Well known exertion games are Wii Sports, Just Dance, Wii fit and Ring Fit Adventure. Wii Sports is an exertion game consisting out of several sport simulations. Players use the Wii remote to mimic actions performed in real-life sports, such as throwing a punch in boxing (see figure 3). Just Dance is a motion-based dancing game where the players perform various dance choreographies of a song (see figure 4) and Wii Fit focuses on training one's general fitness by using different yoga, strength, and aerobics games. Ring Fit Adventure is the successor to Wii Fit. Exertion system beyond the console market exist too. For example, the computationally augmented bikes from Zwift[1] where stationary bikes are connected to the internet (see figure 5). Participants compete in competitive races with their avatars on virtual cycling tracks, and the rider's score is distributed among them.

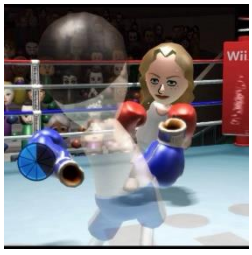

Figure 3 Wii Sports boxing

Figure 4 Just Dance

Figure 5 Zwift

[1] https://www.zwift.com/eu

With the definition of F. Mueller regarding exertion games in mind, I looked at the difference between an exertion game and an interactive sport-training game. The difference between exertion games and interactive sport-training games is that the latter is more a mix of an exertion interface with games and a training interface. Where an exertion interface uses elements from sports to encourage fun as well as physical and social activity, a training interface is used to train different elements in sports and aiming to improve either the users' physical condition or a specific set of skills. An interactive sport-training game is therefore more focused on learning a skill or improve the engagement [6] in the sport that is presented in the game instead of just the physical activity. By including game mechanic elements in the games, the training of a specific skill is more appealing [2] and the "have fun" mentality of the athlete and the "work hard" mentality of the coach is brought closer together [19].

In the introduction chapter, two examples of interactive sport-training games systems were mentioned who also focus on training a specific skill. With Football Lab it is the anticipation skill and with the TacTowers it is the improvement in an athletes' psychomotor abilities. The context is extremely important in interactive sport-training games as it facilitates perceptual reactions and movement patterns. Movement patterns refer to the characteristic's movements of a sport, each sport has its different movement patterns to make the sport unique. Perceptual Reaction refers to the way players can perceive a situation, react accordingly, and anticipate situations before they arise. In volleyball, for example, this means reading the opponents movements and based on the perceived actions the player acts on it.
Other examples of interactive sport-training game systems are the SPRINT rowing training system (see figure 6) and the Bouncer handball system (see figure 7). The SPRINT rowing training system focuses on training three areas of a rower: technique, energy management and team coordination. Team coordination is evaluated by comparing a user's motion to a virtual mate reference one, which can be artificially generated by the trainer or based on a real expert performance [20]. The Bouncer handball throwing system [21] focuses on training penalty shots, accuracy, and reaction time. The player can play three games by throwing the ball against a frame strung with wire, the frame returns the impacting ball speed and the ball coordinates. Based on the data of the frame, the system shows the user if he or she executed the exercise well. What makes these systems interactive sport-training games systems is the systems focus on training a specific skill through playing games whose context is related to the sport being practiced.

Figure 6 SPRINT rowing training system

Figure 7 The Bouncer system

With the above explanation about what exactly a sport-training game system entails, the sub-question "*What does an interactive sport-training game entail?*" has been answered. An interactive sport-training game is a physical interactive game where the focus lies on learning a skill or improve the engagement of the performed sport, adding game-elements to the game makes training a skill more appealing.

2.2. Suite-of-games Approach

When devising and developing the volleyball exercises, it is important that the players remain motivated. One way to do that is by not making the exercises monotonous. After all, having monotonous exercises creates boredom [22]. When people are bored, they are less persistent and more gregarious [23], impulsive [24] and uninterested [25] which could negatively affect an athletes' performance. A study done by F. Velasco and R. Jorda [26] researched an athletes' proneness to boredom and saw in their findings that repetitive tasks were the number one cause of boredom among the athletes. Other causes were a negative mood, teammates showing lack of interest, periods of waiting and lack of competitiveness and goal setting. That repetitive and monotonous tasks are the main cause of boredom is not entirely surprising since boredom and monotony are closely related [27].

A way of preventing athletes from getting bored during an exercise is to setup a variable technology infrastructure. By using technology during practices, episodes of boredom can be reduced in athletes [26]. The usage of the SSE interactive sports floor and the usage of a design approach that supports variation, such a technological infrastructure for training can be realised. A design approach that supports variation and flexibility is the suite-of-games approach. This design approach makes it possible for the player to perform multiple aspects of an exercise. A suite-of-games approach is known for its capability to present a set of games fitting a person where each game is adaptable and uses tailored goal settings based on the player's capabilities [8, 9]. In the context of this thesis project and in answer to sub-question SQ 1.2, a suite-of-games approach is interpreted as follows:

A suite-of-games approach is an interactive sport-training games system that harmoniously trains the multidimensional construction of a particular sport technique through various games/exercises. Variation can be applied within those exercises so that they can be made more difficult for the athlete.

This definition is based on van Delden's definition of a suite-of-games approach [8]: "*multiple games that each can be selected and adapted depending on personal capabilities and interests.*" and my own interpretation of what it takes to use a suite-of-games approach for a sport that uses a multidimensional construct.

The use of a suite-of-games approach within the HCI interactive sport-training games research field is still quite new, usually a point design approach is used [28]. A point design approach is characterised by having one approach to practice an interactive training for a specific sport. This entails that the user of the system can only train a certain exercise subdomain in one way, the system has no variations. As a result, the systems are very specialised in letting the athlete perform that particular action.

An example of a point design approach is the Virtual Reality handball system [29] (see figure 8), this system focuses on improving motor behaviour and uses the handball goalkeeper and thrower duel scenario. The player assumes the role of goalkeeper and must stop the thrown balls in a Virtual Reality environment, after each throw the effects on the goalkeepers' reaction was examined. With each digital throw the same scenario is used for training the goalkeepers' motor behaviour. Because training is done by using a single scenario, these types of systems are very specialised in training the player on a particular action.

Figure 8 Virtual Reality handball

This specialisation on a particular action has the result that a player can fully put his or her focus on the skill to be trained and master the relevant scenario more quickly because of the absence of other parameters. For sports such as curling, darts and running, for example, training on a specific scenario is very useful because in these sports the specialism in specific scenarios is asked. In curling it is sliding a stone over the ice, in darts throwing the dart into the board and in running it is adopting the correct posture. While it is useful for these sports to have a training system that focuses on specific scenarios, it is not always the optimal solution for other sports. In team sports for example, excelling in a certain scenario is not desirable because multiple independent variables are involved during a game situation in the form of, for example, teammates and opponents. It is more important in these sports that the skill is trained in general than for a specific scenario.

As seen in the VR handball example, a disadvantage of using such a point design approach is that repetitiveness can easily creep in because of always performing the same scenario. The player is no longer challenged once he or she has mastered the scenario. Because a suite-of-games approach makes use of variation within the exercises, the chance of repetitiveness is much less present. Furthermore, handball is a multidimensional sport in which every scenario is unique. By using a suite-of-games approach, the training of this multidimensional sport comes better into its own.

A system that uses a suite-of-games approach is the Virtual Trampoline Training Space [30], this system emerges an athlete in a digitally augmented exercise environment for training jumps (see figure 9). By letting users perform in multiple jumping games and give (delayed) feedback, a safer, faster, and more engaging sports training is created. By training the athletes through different training games, boredom is prevented because the variation in scenarios challenges the athlete.

Figure 9 Trampoline jump exercise

Interactive floor

The developed system of this thesis project uses an interactive pressure-sensitive floor from LedGo. The floor consists out of multiple pressure sensitive panels that can display video (see figure 10). Furthermore, the floor can get the coordinates and weight of the pressure put on a panel. This versatility of the floor makes it ideally suited to develop an interactive sport-training games system. Because volleyball is a multidimensional sport where different aspects come together and no game situation is the same, a suite-of-games approach is used. The interactive floor lends itself well to this rapprochement because it offers many implementation choices regarding the design of different training exercises. The interactive floor will take on the role of a volleyball court, players and trainers will perform the various exercises developed on the floor.

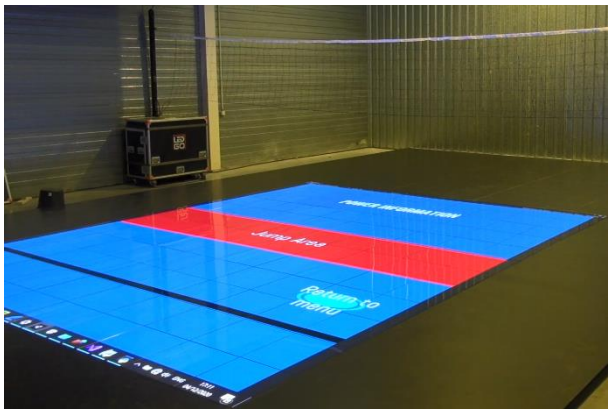

Figure 10 The interactive floor by LedGo

Chapter 3 will explain more about how the choice regarding the subdomain offensive decision-making was made and how the subdomain was translated into the conceptual structure of the suite-of-games approach.

3. Exercise Subdomain

After reading literature about what exactly an interactive sport-training system entails and why the choice was made to use a suite-of-games approach, the next step in the theoretical phase was taken: determining the exercise subdomain for the interactive floor. How this provision went is explained in this chapter.

3.1. Goal

The purpose of this chapter is to answer the third sub-question "*Which volleyball exercise subdomain is best suited for the interactive floor?*" and its sub-question "*What aspects does the chosen exercise subdomain have?*".

3.2. Approach

To determine what an interesting form of exercise for the interactive floor could be, I consulted literature. The literature was searched on three topics; the most important characteristics of a volleyball player, what volleyball techniques there are and which of these techniques have a major influence on losing or winning a match. Reason for looking at literature regarding these three topics is because the purpose of the interactive floor is to present an innovative way of training, by choosing a form of exercise that can directly contribute to winning a match, the usefulness of such a floor would be increased.

3.3. Summary Relevant Literature

There are six volleyball techniques that every volleyball player must master in order to be able to play volleyball; receiving, digging, blocking, attacking, serving and setting [7] (see figure 11). These techniques are considered the fundamentals of volleyball, one starts with learning these techniques at the earliest in their youth (from 12 years old). Over time, these basic skills are extended with other 'sub' skills such as serving a ball using the float or top-spin technique. In addition to mastering the fundamental skills, certain characteristics of the player are also important to perform as optimally as possible during a training or match. Characteristics such as vertical jumping, agility, speed, handling speed, height, tactical insight, and romp power are important for defensive and offensive manoeuvres performed by the volleyball players [31-35].

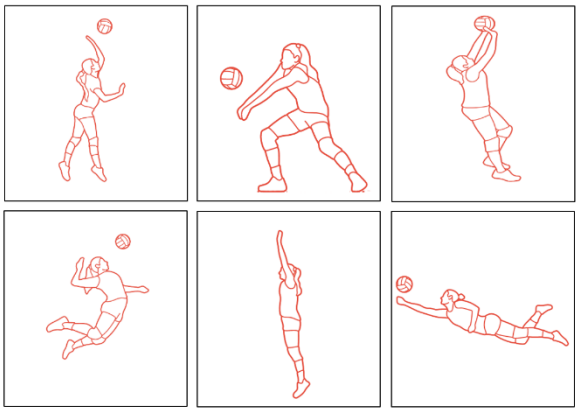

Figure 11 Full volleyball playing sequence; serve, pass, set, attack, block and dig

Although every skill is important for playing volleyball and every players' characteristic attributes contribute to the execution of the skills even better, certain skills are more important in volleyball as they can even determine whether a team will lose or win a match. The fundamental skills that have a strong correlation with the result are the three scoring skills: serving, blocking, and attacking. Studies have shown that technical elements such as serve points, reception errors, attack, and block, both in errors and points, are the predictors of a team's success during a set [36-39]. Yet there is a difference in effectiveness between the three skills, the attack skill is seen as a more important factor for winning a set. Studies [40-42] that analysed multiple matches showed that the serve and block skill, while they can be very effective, have less of an effect on a positive outcome. They serve more as an aid for the overall game than for the outcome of the match. A study done by D. Rodriguez-Ruiz et al. had a similar result as they saw attacking as the highest point-scoring technical action in European men's volleyball [43]. Looking at these studies, the attacking technique emerges as the most important skill to have to win a match.

3.4. Brainstorm Session

In addition to the literature read, I also held an individual brainstorm session in which various exercise options for the interactive floor were examined. For each subdomain, different exercises were devised who lend themselves to the interactive floor. The subdomains were: attacking, blocking, serving, passing, player positioning, and defence. When devising the exercises, it was also considered whether the exercise subdomain is also suitable for a suite-of-games approach.

Early in the brainstorming process it emerged that the exercise subdomain player positioning was not suitable for a suite-of-games approach. It was found to be more suitable for a point design approach. With a suite-of-games approach, it is all about the variation within the exercises and the game-elements that are added to the training exercise. This is not very useful when learning the positions and rotation schemas because players must know exactly where to stand after a rotation. The best way to train and learn positions is to explain and carefully practice the steps and not be distracted by 'fancy' game-elements. Therefore, the addition of a game-element will not have an added value for this exercise subdomain. With the elimination of the player positioning exercise subdomain, exercise ideas for the other exercise subdomains were further developed.

After coming up with possible floor exercises, two other exercise subdomains were also found not suitable for the floor. The defence exercise subdomain and the pass exercise subdomain. These exercise subdomains were found unsuitable for the floor because there is too much technique involved that has to do with the hand movement/placement and the body position of the player. These movements and positions cannot be displayed on the floor or recognised by the floor without the use of other tracking methods such as video tracking. Because of these limitations of the floor, the exercise subdomains were dropped. The serve, attack and block exercise subdomains do have properties for exercises that can be shown on the floor, for example, showing targets for serving and attacking, showing the footsteps of an attack pass or a block walking pattern. 11 exercises were created for the attack, 4 exercises for the block and 8 for the serve.

3.5. Chosen Exercise Subdomain

With the result from the literature indicating that the attack is an important skill for winning a volleyball match and the result of the brainstorming session also indicating that the attack is a suitable form for the interactive floor, the choice was made to choose the attack as the definitive exercise subdomain. Furthermore, most exercises were created for the attack, this also weighed in the decision to choose the attack as the final exercise subdomain.

The attack consists of several areas, such as the four-step approach, decision-making, spike velocity and jump height [7, 44, 45]. The area addressed in this thesis and the answer to the sub-question "*Which volleyball exercise subdomain is best suited for the interactive floor?*" is the offensive decision-making skill as decision-making is an important aspect of the volleyball game. It is a key element for performance in the volleyball sport [46]. Reason for not focusing on multiple areas of the attack skill is because the scope of the project would become too big, and the decision-making aspect is seen as the aspect most suitable for integration with the interactive floor as the other areas require more data inputs than just the floor to train them properly.

3.5.1. Decision-making

Because volleyball is a team sport, every player on the team wants to play well. Playing well means choosing the right course of action at the right time, executing that action efficiently and repeating it throughout the match [47]. To be able to perform these physical and cognitive actions during a match, the player will need to have the decision-making skill [48]. A player that has obtained the decision-making skill can more easily take into account the abilities of the opponent, the physical conditions in which the game is being played, and their own abilities [49, 50]. Decision-making is thus a very important skill to have, it increases the chance of a player making the right decision during a match

and therefore creating high level performance of the player. In addition, a player's well-developed decision-making skill ensures that he or she can act quickly in a situation without losing the initiative [51].

In volleyball, the players who occupy a position at the front of the net, such as outside hitter, setter, and opposite hitter, use their decision-making abilities the most. Especially the setter is continuously making decisions about the attack, in this thesis project I focus on the decision-making skill of the outside hitter instead of the setter. The choice for not choosing the decision-making skill for the setter is because the technique the setter needs to determine the decisions is not possible with the interactive floor alone. Especially the hand technique is very important with a setter and this technique cannot be optimally supported by the floor, which is why it was decided to train the decision-making skill of the outside hitter.

3.5.1.1. Decision-making aspects

The concept of decision-making is not a concept that can be viewed from a single angle, it consists of several aspects. An important aspect of decision-making is being able to read the opponent, this means that the player knows where his or her opponent is and how the opponent will react to the ball that the player is going to play. In addition to reading in the opponent, the speed in which a player absorbs information from the playing field is also an important aspect. Being able to absorb information quickly has the advantage that empty spaces in the playing field can be found more quickly, this could cause the player's scoring percentage to increase. These two aspects come together under the dimension: tactical skills. In addition, there are two other dimension that relate to the decision-making skill: the technical and the physical skills dimensions.

The technical dimension relates to the technical attacking skills of a player, the dimension can be divided into the three aspects: accuracy, tempo, and execution variability. The accuracy aspect is a broad concept, several techniques are required to be able to exercise the accuracy aspect. That is why this aspect is divided here into two other aspects: timing and placement.

The physical skills dimension is not only important for the decision-making skill, but also a dimension that pertains to the entire volleyball sport. Having well developed physical skills is essential when practicing a sport [52], without having well developed physical skills it becomes very difficult to carry out the tactical and technical dimensions of the decision-making skill. The physical skills dimension is divided into the two aspects: explosiveness and agility. By dividing the decision-making skill into multiple dimensions and aspects, the concept becomes more manageable. All the mentioned dimensions and aspects together create the following tree:

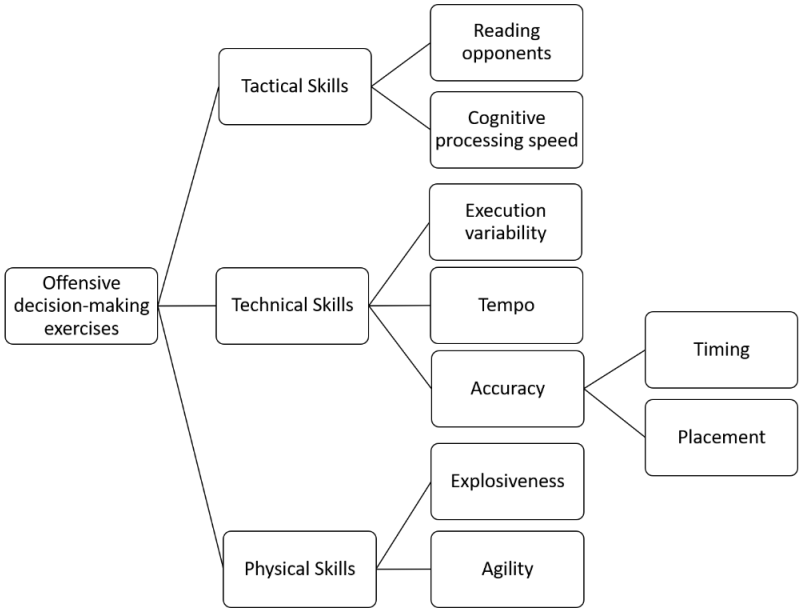

Figure 12 Offensive decision-making aspects tree

The division of the decision-making skill into tactical, technical and physical skill dimensions correlates with the found literature [53, 54]. The presented tree provides the answer to the sub-question "*What aspects does the chosen exercise subdomain have?*", the section written below will provide more information on what each aspect entails and how it relates to the offensive decision-making skill.

3.6. Aspects Elaboration

This section explains the several dimensions and its aspects and sub-aspects with the help of the found literature.

3.6.1. Tactical Skill

A player's tactical skill is important for making the right decisions during a match, being able to see the play-space effectively can increase the chance of scoring [55]. In sports, tactical skills are defined as follows [56]:

> *"The decisions and actions of players in the contest to gain an advantage over the opposing team or players".*

This definition of tactical skills can then be divided into two different aspects [56, 57]: reading opponents and cognitive processing speed.

Reading opponents

Reading opponents necessitates the ability to process and scan the environment, as well as the ability to incorporate relevant information into existing knowledge [58-60]. Players who have developed this skill well can therefore quickly recognise situations and read the game, it can even ensure that a player knows what is going to happen before the ball has contact with the setter or the attacker [54, 61-63]. Furthermore, this aspect will train the working memory of the players. Working memory refers to the small amount of information that is used with the execution of cognitive tasks [64]. It is an important aspect for the tactical skill in sports [65]. By training a players working memory, a solid bases can be formed for attention, anticipation and strategic thinking [66].

Cognitive processing speed

In addition to being able to recognise the opponent's behaviour and the situation on the field, the player's ability to react quickly to the information obtained from the environment is just as important. Especially at a higher level it is necessary for a players' success to interact quickly in a changing environment and to select and execute adequate actions [67]. Being able to act quickly based on the information obtained has to do with a person's cognitive processing speed. Cognitive processing speed can be defined as "*the ability to process information rapidly and thereby have the ability to perform higher-order cognitive tasks*" [68]. Especially in volleyball, where the short time of reaction to changing situations is important, being able to process the environment quickly and respond quickly in a limited time is a benefit for a player's gameplay [69-72].

3.6.2. Technical Skill

In addition to the tactical skill, decision-making contains the technical skill as well. The technical skill is just as important as the tactical skill because without technical skill, a player cannot execute his or her tactical skills. As technical skills are a very broad dimension, multiple aspects have been created. Based on the found literature [73, 74], the technical skill has been divided into three aspects:

- Tempo
- Execution variability
- Accuracy

Tempo

While cognitive processing speed is mainly about being able to process information quickly, with the tempo aspect it is all about being able to perform a technical action as quickly as possible. Various studies have shown that the use of fast tempo spikes increases the players' chance of scoring a point [75-77]. Players who perform a high impact quick attack by having the ball played to them in 1st tempo increase their chance of unbalancing the opponent [78]. Tempo is thus an important aspect of the technical skill because it can cause one to 'outrun' his or her opponent.

Execution variability

Another important aspect of the technical skill is the ability to perform different attack techniques. The ability to perform a spike, tip or topspin attack provides variation in the attack game and reduces the predictability of a player or team. This unpredictability of a team is a key factor in creating uncertainty for opponents [79]. Variability in execution is thus a functional necessity, as it allows players to adapt to the changing constraints of the environment, increase their performance, and their decision-making skill [80, 81].

Accuracy

As mentioned before, accuracy is an important aspect of a technical skill, without accuracy it becomes difficult for the player to score a point. To score this point, speed also comes into play as speed and accuracy are integrally linked with each other. Both speed and accuracy share a relationship, as suggested by theories such as the impulse-momentum theorem [82] and speed-accuracy trade-off [83, 84]. This trade-off is apparent, for example, in a volleyball attack, where a fast but inaccurate attack may result in a fault, whereas a 'slow' attack with a focus on accuracy may be more easily caught by the opponent. Speed of execution has thus an important relationship with accuracy, they ensure, together with execution variability, that one has the technical skill to be able to perform the tactical skill. The accuracy aspect is divided into two sub-aspects: *timing* and *placement*.

Timing

Timing within accuracy involves being able to play the ball towards the correct position at the right time. An opponent's playing field changes continuously, a player never stays in the same place for long. This continuous movement creates vulnerable spots on the field that can earn points. When a player can play the ball in a timely manner in combination with the attack speed, the ball can hit an opponent's vulnerable spot more quickly and thus score a point. Training the timing aspect increases the performance of accuracy and thus increasing the performance of the player overall [85].

Placement

Placement is another important aspect of accuracy; it involves placing the ball where the player wants it to be. Without placement, a player cannot play accurately, he or she misses the spot where the ball should have been played. Consistency is important when placing the ball correctly, as putting a ball down correctly one time does not mean that someone can play accurately. The development of placement is therefore also seen as a fundamental part for volleyball players [86].

3.6.3. Physical Skills

As volleyball is considered a complex and skill-based game, it requires well-developed motor coordination from its players such as control, balance and speed of movement [34]. Fortunately, playing volleyball already positively affects the development of the physical abilities such as explosive strength, repetitive strength, speed, and movement coordination [87]. Nevertheless, these physical skills will have to be trained to achieve an even greater performance with the technical and tactical dimensions, as the success of a volleyball game mainly depends on the speed without a ball, the speed of direction change and rhythm, jumping and agility ability [88]. In this thesis project the focus will be on the explosiveness and agility aspects within the physical skills aspect because they are important for the attack and there was not enough time to work out all physical abilities. The physical skills dimension can always be expanded in the future for other training formats.

Explosiveness and agility are important aspects for a player when attacking the ball, the two aspects together are also known as power [89]. Power is considered a fundamental aspect of successful athletic performance [90]. A "powerful" player can make defending the attacked ball much more difficult for the opponent because of the high impact speed of the ball and therefore, for example, making it jump off the opponent's arms more quickly and scoring a point. To create this situation, the player must have well developed physical skills. Therefore, training their agility and explosiveness skills is essential.

Agility

Agility is an important component of the physical skill, it has been adopted by several authors [91-93] with the definition as "*a rapid whole-body movement with change of velocity or direction in response to a stimulus*" [94]. In volleyball this entails having the ability to move quickly and accurately, albeit being it on the floor or in the air, to ensure a correct body position towards the ball. By having the correct body position towards the ball, the ball can be changed direction at the last moment and thus giving an advantage over the opponent.

A whole-body movement that is also important in addition to turning the body is the player's footwork, the speed of the footwork to be precise. Although volleyball players do not have to sprint long distances, players are always on the move by taking three or four steps towards the ball. Different techniques such as the side-shuffle and back pedal are used for these movements, the exercises developed for the agility aspect will focus on these shuffle techniques because the interactive floor can track footwork movements and not whole-body movements.

Explosiveness

Explosiveness is the ability of the neuromuscular system to generate high action velocities in a short time frame [95]. Speed is thus an important factor in performing explosive actions because it is already mentioned within the agility aspect, the explosiveness aspect will therefore focus on the strength component. Explosive strength is a crucial fundamental aspect of a successful volleyball performance as it is dominant in the actions of blocking and spiking. Training a players' explosiveness with strength training improves their performance in jumping and arm strength. Players who execute strength training based on explosive movements during the competitive season improve their upper extremity performance [96]. Exercises developed for the explosiveness aspect will focus on the improvement in upper and/or lower extremities.

4. Design

After the determination of the offensive decision-making exercise subdomain and its aspects, exercises were developed with associated exercise levels. This chapter will describe the design of the exercises, the first part of the chapter explains the realisation of the exercises and the second part presents the final design of the exercises.

4.1. Exercises Realisation

This section of the design chapter explains how the exercises contribute to their aspect and how a lo-fi prototype would look like. The exercises that have been realised are based on my own volleyball experience as a player. Because I have more than 10 years of experience as a competition volleyball player, I have a good idea of what is required of a player during a match and training. Furthermore, during the evaluation phase, interviews were held with trainers and players who gave their opinion on the relevance of the exercises.

4.1.1. Tactical Skill

A player's tactical skill, as indicated in the previous chapter, is concerned with knowledge of in-game actions, and understanding actions within the context of the game. With these characteristics in mind, several exercises have been devised that require the player to properly read the playing field. The developed tactical skill exercises will be explained below.

Reading Opponents

Panel Attack

The focus in this exercise is on being able to read the opponents current playing field and make the right tactical choice given the environment. A setter and an outside hitter perform an attack from the left side of the field, during this attack the player must look at the opponent's playing field and determine which square on the field yields the most points. The opponent's field is divided into different coloured squares, each with its own number of points and colour. The player who has the most points after three attacks wins the exercise.
The numbers and colours on the squares are assigned randomly to make the exercise more challenging for the players. Because of this randomness, the player must be able to read his or her environment well to make the right decision of hitting the panel with the most points. This observation of the playing field results in improving the players' tactical insight and decision-making skill.

The game-element in this exercise is the element of earning points, through earning points a competitive atmosphere can be created. With such an atmosphere, players can be more stimulated to perform the exercise well and thus improving their tactical skill.

In addition to performing this exercise with an outside hitter, the exercise can also be performed by a setter (see figure 13) or from an attacking position behind the three-meter attack line (see figure 14). By moving the attack to the setter, the team has an extra offensive player. When a setter has offensive qualities, this can be an advantage in the attacking game of the team as it can serve as the element of surprise. Letting a player perform an attack from behind the attack line creates an attack with a wide attack range. A study done by G. Fellingham, L. Hinkle, and I. Hunter has shown that a quick attack from the attack line is an important component for the attacks' success rate [77].

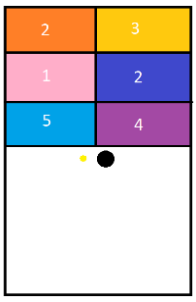

Figure 13 Panel attack from setter position

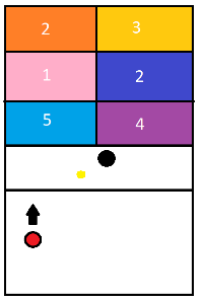

Figure 14 3-metre panel attack

The panel attack exercise has three different levels, in the first level an attacker is performing an attack without any opponents and in the second level the player is performing an attack while two players are trying to block the ball (see figure 15). In the third level, a full field occupation is depicted on the playing field, two blockers and four field players. The placement of these players is determined by the chosen scenario by the trainer or player. There are four static scenarios from which a player or trainer can choose. Each scenario has a fixed panel where the maximum amount of 10 points can be achieved. The other panels change value and colour with each attack. Reason for determining the static 10-point panel is because this spot is the weak spot of the opponent's defence. Determining this location was done by comparing different attacking and defensive strategies.

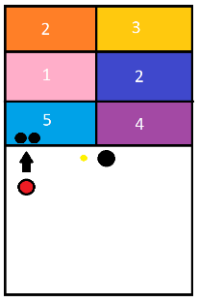

Figure 15 Level 2 panel attack

Below are the four scenario's one can choose from when playing in the third level:

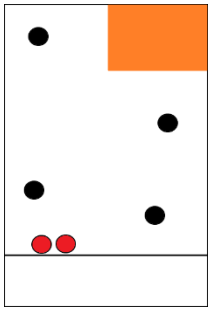
Figure 16 Scenario 1

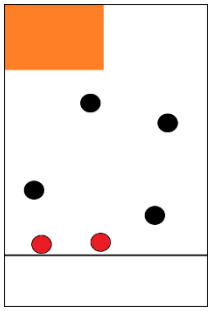
Figure 17 Scenario 2

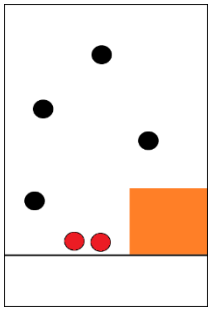
Figure 18 Scenario 3

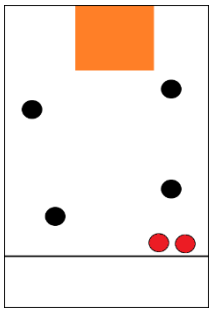
Figure 19 Scenario 4

The black circles represent the field players and the red circles the block players. The positioning of the field players is mainly diagonal along the block and in the back for the long ball that can be played. The coloured area shows the weak spot of the defence, in the exercise this will be the panel with 10 points.

Besides the three mentioned levels, adding attack combinations can also increase the difficulty of the exercise. Known attack combinations are the Cross Play and the X Play walking patterns[2].

Cognitive Processing Speed

The aspect of cognitive processing has two exercises; Touching Colours and Take Aim. Each of these exercises trains a player's processing speed in a different way. The Touching Colours exercises focuses on training a player's responsiveness/reaction time and the Take Aim exercise focuses on training a player's attitude.

Touching Colours

The touching colours exercise focuses more on the response and reaction time skill than placing the ball in the square with the highest points. The exercise will require the player to stay sharp and trying to increase their pace.

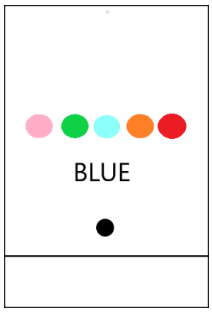

Figure 20 Touching Colours starting point

The exercise starts with a player standing on the footsteps displayed by the interactive floor. The floor then shows which colour the player must run to and tap, after tapping the colour the player returns to the starting position (see figure 20). The player who is fastest at tapping the colours correctly 5 times is the winner. This exercise has three levels, level one is tapping the colours 5 times as quickly as possible. At level two this is increased to 10 times and at level three to 15 times. In addition, the positions of the circles change in the second and third level. In the second level the circles are moving up and down and in the third level

[2] https://howtheyplay.com/team-sports/Four-Effective-Volleyball-Combination-Plays

the circles move over the entire field. Adding position change to the circles ensures that a different situation occurs each time, this makes the exercises more challenging for the player.

Even though this exercise does not use a ball, training a player's response and reaction time skill is important for properly executing the tactical skill dimension. By improving the response and reaction time of the player, he or she can see more quickly where the ball can be played tactically because they are more aware of their surroundings. Everything that is not relevant to the situation will be filtered out. This exercise is based on the idea of the SMARTFit strike pods[3] and BlazePods[4].

Take Aim

The Take Aim exercise focuses on training a player's attitude, as players must be able to react quickly and make decisions during the volleyball game. Attitude training in this context means that the player trains on observing what is happening in the field while executing an attack and make a last-minute decision about the placement of the ball.

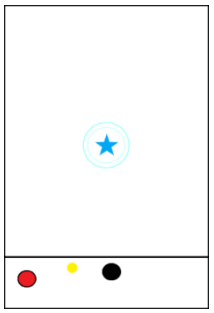

Figure 21 Take Aim

In this exercise a player will perform an attack, when the player pushes off the floor to jump a target will appear random on the other side of the field. Figure 21 shows how the exercise situation looks like when somebody is in mid-air. The player must then try to hit this target. Because the target only appears on the field at the last moment, the attacker must remain very alert and react quickly to be able to hit the target. Take Aim has thus three phases, jump, observe, and decide.
The creation of this exercise is based on personal experience as a player with exercises in which balls were thrown behind your back and you had to react quickly to this ball by catching or attacking the ball. This "not knowing where the ball is" situation has led me to devise this exercise, instead of a ball, the location of the target is not known as it becomes visible at the very last moment.

To keep the game challenging for the players, three levels have been defined. In each level the randomly placed target has a different size, in level 1 the target is the biggest and in level 3 the target is at its smallest.

[3] https://smartfitos.com/smartfit-products/
[4] https://gymbiz.nl/blazepod/

4.1.2. Technical Skill

As mentioned in section 3.2.2, a player's technical skill ensures that the tactical skill can also be performed as desired. Because only an interactive floor is being used with these exercises, the playing technique, such as foot placement and arm height when attacking, of the player is not considered in the developed exercises. If jump sensors and video images could be used, the exercises could be expanded even further because then it would be possible to look at the arm swing or the height of the attack jump. But because these techniques were not available or reliable during the thesis project, it was decided to only create exercises who are suitable with only the floor.

Execution Variability

Switching Attack Types

The switching attack types exercise focuses on the ability of attacking the ball with different techniques, this technical skill is frequently trained by trainers from my own experience as player and trainer. That is why this exercise has been developed to train a player's attacking variety.

The interactive floor will determine the player's attacking technique by giving the field a specific colour, there are three different attack techniques asked from the player:

1. Spike straight ahead when the floor is purple.
2. Spike slanted to zone 5 when the floor is yellow.
3. Short ball behind the block (tip) when the floor is blue.

By having players perform different hitting techniques, their game will become more varied and therefore more unpredictable for opponents. Training the hitting of a ball diagonally or straight ahead has the advantage that the player can adjust his or her attack based on the opponents' block. For example, if the block keeps the straight direction closed, the player can spike the ball diagonally and if the diagonal spike direction is blocked by the block a player can spike straight ahead. In addition to being able to execute the spike in different directions, the tip technique in volleyball also has an important contribution to create a varied attacking game. Tipping a ball is mainly used in two situations: to create deception or using it as a last resort to get the ball over the net. If the ball is poorly played by a teammate or the performed spikes are ending up in the block, the tipping technique can be a solution. This is because the tipping ball is often played behind or just next to the block, so that the opponents cannot reach it properly to catch the ball. A side note to the tipping technique is that it cannot be performed too often because the opponent will then anticipate it.

This exercise has three levels, the first level contains no field players or blockers, the second level contains two blockers, and the third level is a full field occupation of six volleyball players. The challenge in this exercise is to respond in time to the desired attacking technique while also requiring tactical insight from the player by playing the ball in such a way that it yields a point. A player has to perform the attack five times for the exercise to be completed. The figures below show how the exercise would be displayed for each colour on the interactive floor.

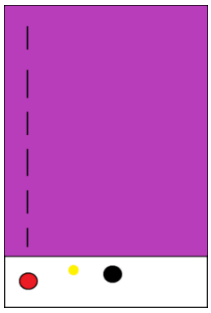

Figure 22 Straight attack

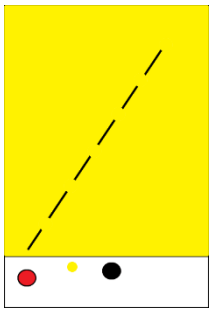

Figure 23 Diagonal attack

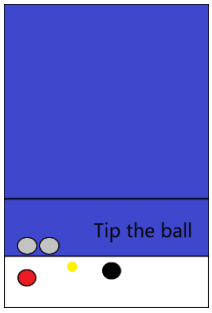

Figure 24 Tip attack

Tempo

The tempo aspect has two exercises that focus on being able to quickly execute an attack in different situations: stationary and dynamic. The exercises are explained in more detail below.

Rapid Attack

The purpose of the Rapid Attack exercise is to perform as many stationary attacks as possible within a given timeframe, the player with the most performed attacks wins the exercise. The speed of the hitting arm is trained in this exercise, having a quick hitting arm is beneficial when performing quick attack strikes. Fast attacks can ensure that the opponent has no or not enough time to react to the attacking ball. A situation that can arise by a quick attack is the unbalance of the defending block, the cohesiveness of the block can be pulled apart and make it easier for the attacker to score a point [97].

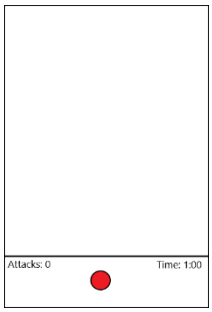

Figure 25 Rapid attack

To prevent the exercise from becoming too repetitive and thus boring for the player, different levels have been devised. The first level of this exercise has a countdown timer of 60 seconds, the second level has a countdown timer of 30 seconds and the third level has 15 seconds on the clock. By decreasing the time, the player is challenged to perform his or her attack faster and faster. Furthermore, because the player is challenged to perform as many attacks as possible, the players can compare each other's score after the exercise and make a kind of competition of who can perform the most attacks in a certain timeframe. Figure 25 shows the starting point of the player when playing Rapid Attack.

Rapid Setter Attack

The aim of this exercise has a lot in common with the Rapid Attack exercise, here too the attack speed of the player is trained. Instead of only training the hitting arm, the speed of the attack is now also trained by attacking a played ball from the setter. In this exercise the player will have to consider his or her run-up, the velocity of the ball and stroke speed. The importance of this exercise, regarding the tempo branch, is that the efficiency of an attack increases when the ball's flight time becomes shorter [98]. Figure 26 shows the floor display when playing the game.

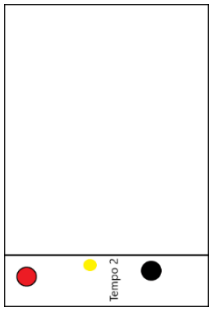

Figure 26 Rapid Setter attack

The player has 10 attempts to make a spike attack at the specified ball tempo. The first level has a ball tempo of 3, the second level has a ball tempo of 2 and the third has a ball tempo of 1. Figure 27 shows what the different ball tempos would look like.

With a ball tempo of 1, a fast ball is played with the ball just above the net edge and whereby the attacker starts his attack 4 step approach as soon as the setter has the ball in his or her hands. A ball played in the second tempo is about 20 centimetres above the net. Players who attack the ball in a first or second attack-tempo have an increased chance in scoring during transition and it also strongly dimmish the probability of the opponent forming a cohesive block [76, 99]. The reason for not having a cohesive block is because the second player (the middle blocker in most cases) who connects to the block is still on its way to the block. Thus, making it easier for the attacking player to score a point.

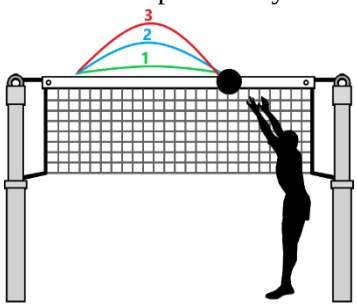

Figure 27 Ball tempos

The third tempo balls are used when a setter cannot easily pass the ball to the attacker, the ball is played at its highest in this situation, so that the attacker has enough time to adjust his or her attacking approach. The disadvantage is that the opponent can anticipate the attacks well, as they have enough time to set up the organisation properly.

Accuracy

As accuracy is seen as "*the ability to control movement in a given direction or at a given intensity*" [100], several exercises within the timing and placement aspect have been developed. The exercise under the timing aspect mainly involves having the player time correctly to hit a target. The exercises of the placement aspect focus on the coordination of the players and their consistency. All developed exercises are realised through my experience as a volleyball player and trainer.

Timing

Hit the Target

In this exercise, a player will attack in the front zone of the field. The front zone positions are left winger, centre, and right winger. The player performs an attack and tries to hit the target displayed on the opponent's field. To make the exercise more challenging, the target will also be able to move across the field so that the player is more challenged to perform his or her spike as accurately as possible. The player who ultimately hits the target most often after three attempts will win the exercise.

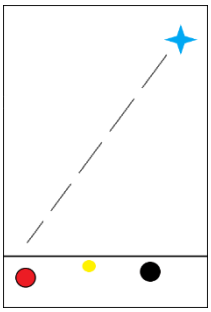

Figure 28 Level 1

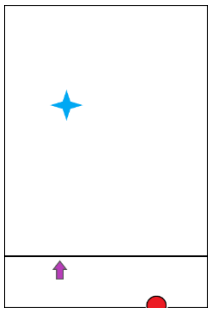

Figure 29 Level 4

The first level of this exercise consists out of hitting the target displayed in zone 5, zone 5 from the attackers' perspective is located at the back left of the playing field. In the second level the target is moved towards zone 1, zone 1 is right back (see figure 28). The reason for choosing zone 1 in the second level is because when attacking a ball straight towards that position, the ball passes the block and is therefore difficult for the opponent to defend. Because the ball passes close along the outer court line and the block, it is more difficult for the opponent to estimate exactly where the ball will fall. At the third level, the visualised target will move across the entire playing field.

In the fourth and final level, the player will start from the baseline. From this position, the floor indicates where the player must perform his or her attack towards the moving target (see figure 29). The difficulty in this level is that the attack now must be performed from any given position, this requires extra concentration and technique from the player.

Placement

Brick Destroyer

The Brick Destroyer exercise is based on the Arkanoid game, as in Arkanoid, a player will have to remove all the bricks from the playing field to complete the game, in this case the exercise. Instead of a ball with a paddle destroying the bricks, the player must perform an accurate attack to remove the bricks. The level of difficulty in this exercise lies in the size of the bricks, in the first level the bricks are at their largest (see figure 30). From level one to level three the bricks will get smaller, and the pattern of the bricks will become more challenging for the player.

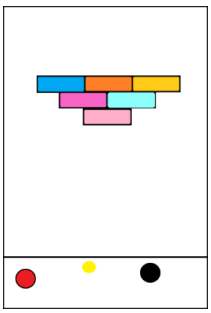

Figure 30 Brick Destroyer

In addition to the established level of the exercises, the exercises can be made even more challenging by adding field players and blocker in the field. This increase of players makes the attacker's sight more difficult and requires more concentration and accuracy.

Smash Attack

The Smash Attack exercise focuses on repeatedly accurately placing a ball on a rectangular surface using a spike attack. During the exercise, two players are standing on the playing field whereby each of whom must stand behind the visualised bar. The players may not cross this line or step on it, if they do the exercise is over. The purpose of this exercise is for the players to perform a spike attack at each other by letting the ball touch the rectangle surface first. The pair who does this sequence for the longest time will win the exercise. The difficulty of this exercise lies in consistently performing a spike attack for as long as possible. Only by applying the correct technique and placement can the player perform this exercise correctly.

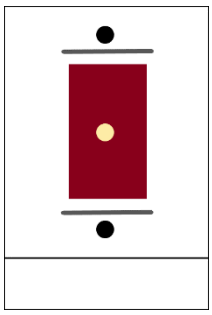

Figure 31 Level 1

To make it more challenging for the player, the game consists out of three levels. With each level that the player goes up, the rectangular surface gets smaller. So, the first level has the largest surface and the third level the smallest. Figure 31 shows level one where the rectangle is at its largest.

4.1.3. Physical Skills

Without well-developed physical skills, it is almost impossible for a player to perform technical and tactical exercises. For this dimension, the focus is on improving agility and explosiveness of volleyball physical skills. The exercises will be explained in more detail below.

Agility

Sprint

Having the ability to recover quickly after repeated sprints is important, it is associated with superior performance in team sports [101, 102]. This ability of recovering quickly also applies in volleyball, as volleyball players are required to repeatedly produce maximal efforts with brief a recovery period over an extended period of time [103, 104]. In this exercise a player's raw explosive power is trained in a sprint exercise, by doing this exercise a player's anaerobic capacity will be increased. This increase in capacity is crucial for a player's ability to maintain an elevated intensity of play when playing in professional leagues [31, 105, 106].

The exercise consists of three levels, each level has its own parkour and as the level increases, the sprint exercises become more difficult. The player who completes the sprint parkour fastest is the winner of the exercise.

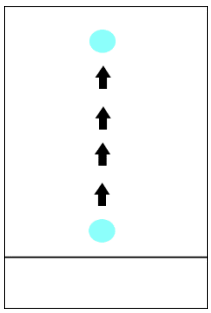

Figure 32 Level 1

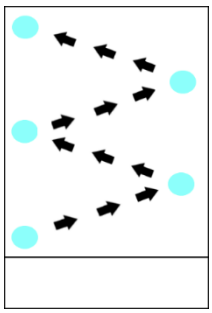

Figure 33 Level 2

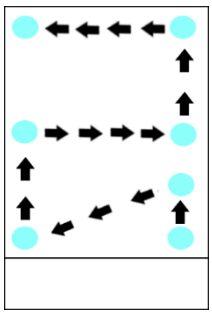

Figure 34 Level 3

Level one (see figure 32) the player must perform a dash forward, level two is asking the diagonal shuffle technique from the player (see figure 33). Finally, the third level consists out of a combination of the first and second level (see figure 34).

Explosiveness

Explosive Jump

The explosive jump exercise is a plyometric training, a plyometric training, also commonly called jump training, is a training that stresses the musculotendinous unit of an individual [107, 108]. The plyometric explosive jump exercise trains the musculotendinous unit by letting a player perform the 4-step attack approach and thereby improving their vertical jump performance [109]. A literature study done by A. F. Silva et al. [110] saw an increase in the vertical jump height when they compared multiple studies researching the effect of using plyometric training to improve a players' performance.

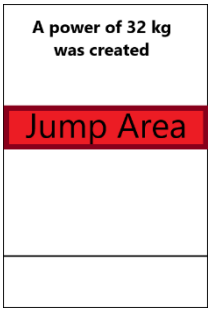

Figure 35 Explosive Jump

The explosive jump exercise has a different set-up than the other floor exercises, the exercise mainly serves as an aid for the trainer during the plyometric training. In this exercise, the player trains the explosiveness that emerges from the attack jump. The player performs the 4-step approach in which steps 3 and 4 takes place in the jump area, from there the player jumps forward out of the jump area and starts the jump again.

To increase the explosiveness of the jump, the player will have to have the correct posture and stroke movement, since these aspects cannot be measured with the floor, the floor will serve as an aid for the trainer. The floor will show how much 'power' is released during the player's jump; based on the jump data the trainer can give aid to the player to increase the explosiveness of the attack. The 'force' that the floor weighs is the weight in kg that is released by the player when he or she pushes off the floor (see figure 35). Because this exercise serves as aid for the trainer, there are no different difficulty levels.

4.2. Result

In this section the definitive implementations of the exercises are explained, with the help of a small pilot study, several feedback sessions with the supervisors, and lo-fi prototyping, these definitive exercise implementations were iteratively established. The goal of the pilot study was to examine whether the developed exercises were correctly displayed on the interactive floor and whether the exercises were intuitive during use. The pilot study was conducted at the LedGo facility with other researchers from the Smart Sports Exercises project, the researchers and I acted as volleyball players during the study.

Panel Attack

The panel attack exercise has been given a different look compared to the sketches displayed in 3.2. This change in design came about because players indicated that having multiple different colours and digits puts a heavy cognitive load on the exercise. The many colours and digits demanded too much concentration from the players when performing an attack. It was therefore decided to use a heat map colour pattern (see figure 36), as concentration is an important facet in the exercise, the colour green was chosen as it stands for motivation and focus [111, 112]. Besides the use of a heat map, the number of different digits were reduced to three (10, 5, 0) and four (10, 7, 5, 0). The number of different digits used during the exercise is determined per level.

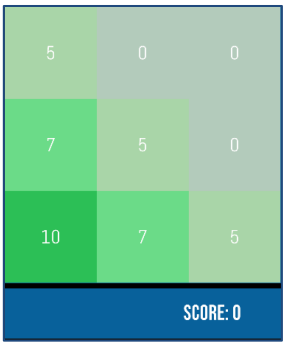

Figure 36 Level 1

The heatmap is set up in such a way that the panel with the highest value (10 is the highest value) has the brightest colour green, then the adjacent panels get a light green colour and the panels adjacent to those panels an even lighter green colour. The remaining panels are given a greenish grey colour. The lighter the colours become, the lower the values of the panels become. In the first and second level the four different digits are used. The brightest green panel has the value 10, the adjacent 7 and the

adjacent panels have the value 5. The other panels have a value of 0. Reason for choosing these digits is because they are close to each other in terms of value but not close enough together that there is no big difference when performing the exercise. Three different digits are used on the third level, the digit 7 is omitted here. The digit 7 has been omitted to make it even more difficult for the player to get a high score. Furthermore, it is extra important in the scenarios that the panel with the 10 value is hit because that is the weak spot of the opponents. By omitting the digit 7, the focus is more on the panel with the value 10.

In addition to changing the colour scheme and numbers, a block shadow has been added to the block in the second level (see figure 37). By adding a block of shadow, the player is prevented from simply scoring a point behind a block, by placing the shadow, the situation becomes more realistic since in a normal game situation there is a player standing here who catches the ball. The block shadow is only placed in the second level as it caused too much overlap with the placed fielders in the third level. This overlap was mainly caused by adding range circles around the field players, by given the field players these circles the scenarios were experienced more realistically.

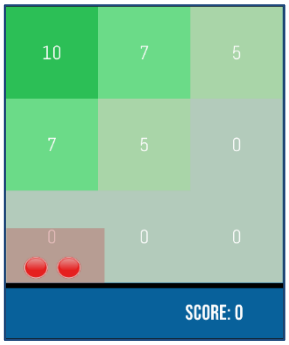

Figure 37 Level 2

Finally, a few visuals have been added to the exercise to make it clearer to the player what exactly happened after attacking the ball. A visual cue that is implemented is the playing of an animation on the spot where the attacked ball landed, through this visualisation the player immediately sees where the ball was at the time of landing. This uncertainty of landing position was also a comment that players made while performing the drill, by displaying the animation this is no longer a problem. Another visualisation that has been added to the exercise, is the green or red glow of the playing field when something is hit. The field will display a green glow when one of the panels is hit by the attacked ball, if the ball hits an opponent or a block shadow the field will have a red glow. By visualising these glows after each ball, the player knows whether the ball was right or wrong and is stimulated to improve or persist. Choosing the red and green colour has to do with the fact that red is mainly associated with doing wrong and green with something good or positive [113, 114]. The figures below show the final designs of the scenarios available in the third level.

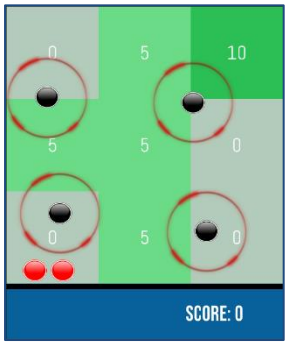

Figure 38 Scenario 1

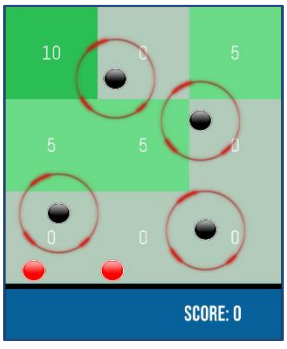

Figure 39 Scenario 2

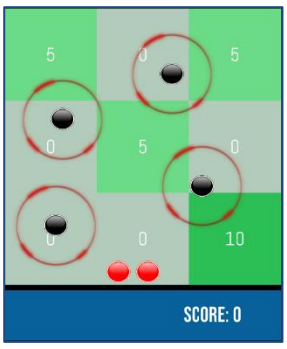

Figure 40 Scenario 3

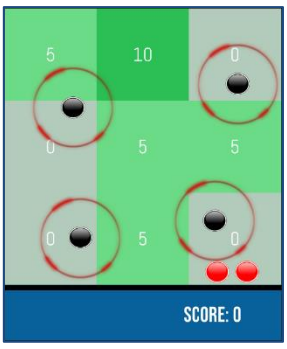

Figure 41 Scenario 4

Touching Colours

The first design of the Touching Colours exercise had the circles lined up and all the colours were visible, the pilot study indicated that making all colours visible in advance causes too much cognitive effort for players and placing all circles on one line did not provide the desired reaction time. These advices have been applied in the final design, the circles in the first and second level are now displayed in a half circle around the player and the colour of the circles is grey by default.

Only when the colour of the circle is requested will the colour become visible to the player and the remaining circles keep its grey colour. By placing the circles around the player, the player can touch the circle more quickly and better fulfil the purpose of the exercise. Furthermore, the exercise has been flipped, so the back of the player is no longer facing the net. The flipping of the exercises was done because several trainers pointed out during the interviews that facing the volleyball net with your back is seen as not done in volleyball.

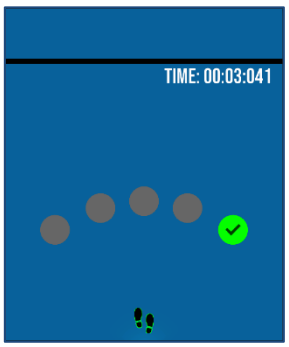

Figure 42 Correct circle

The exercise has also implemented some light visualisations to indicate the player if he or she is doing the exercise right or wrong. If a coloured circle is touched by the player, the circle will light up and a check mark is shown (see figure 42). Furthermore, the footsteps get a green outline indicating that the correct circle is touched. When a player returns to the footsteps, the light and the check mark will become hidden again and the footsteps get a neutral blue outline. If a wrong circle is hit, the circle in question will get a red glow, the footsteps a red outline and a cross will be visible (see figure 43). When the correct circle is hit, all red colours are turned off and the cross hidden, then all green colours are shown and the check mark icon.

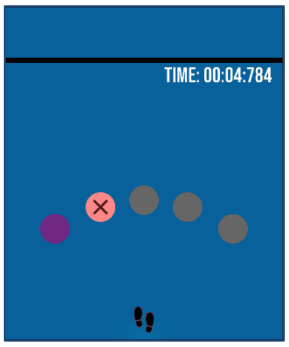

Figure 43 Wrong circle

Because all circles have a grey colour by default and only change colour when requested to do so, the text below the circle with the colour to be touched has become redundant, so this text has been removed as it had no added value for the exercise. Finally, a spotlight has been placed under the footsteps for accentuation.

Take Aim

The take aim exercise has not undergone much change from the lo-fi prototype, the visualisations have been sharpened while the game mechanics have remained the same. The target that appears while a player is in the air is an orange pulsating visualisation, the colour orange has been chosen because it is a contrasting colour to the blue colour of the playing field. If the attacked ball collides with the target or the playing field, the visualisation is destroyed. In addition to the target visualisation, a jump visualisation has also been added to the exercise, this visualisation gives a kind of ripple effect when the player pushes off the floor. The visualisation has a greenish colour so that it does not take too much attention from the target visualisation (see figure 44). Finally, a text has been added at the bottom right that keeps track of the number of times the target has been hit by a ball. The figures below show the final design per level of the Take Aim exercise. The jump effect is for every level the same.

Figure 44 Level 1

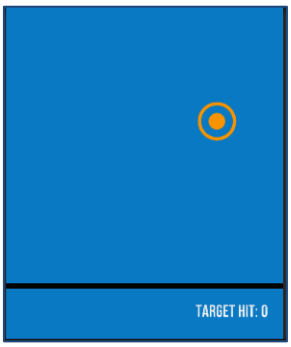

Figure 45 Level 2

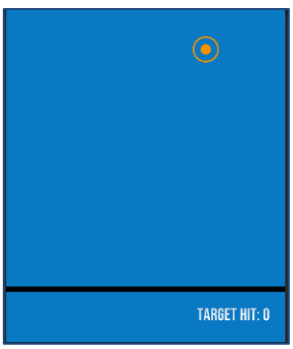

Figure 46 Level 3

Rapid attack & Rapid Setter Attack

The Rapid Attack and Rapid Setter Attack exercises underwent some changes regarding their game mechanics, mainly visual characteristics have been applied. The Rapid Attack and Rapid Setter Attack exercises are referred here together because they have the same visual additions.

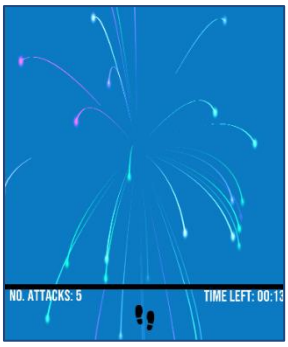

Figure 47 Rapid Attack

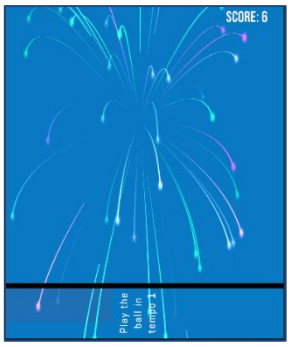

Figure 48 Rapid Setter Attack

Since just executing the attacks and increasing the score per ball does not look very attractive design-wise, a firework animation visualisation has been developed that will be played every time the ball hits the playing field (see figures 47 and 48). The fireworks contain blue and pink colours, light colours have been chosen because otherwise it would be too bright on the eyes for the players. In addition, each time a firework animation is executed a single firework sound fragment is played for adding the firework effect. Lastly, the score text of the Rapid Setter Attack exercises has been moved to the top right corner of the field, this because the text was not legible as there is usually the setter position.

Switching attack types

The Switching attack types exercise has not seen many changes since the lo-fi prototype mentioned in section 4.1.2. The biggest change is the colour scheme of the exercise, where the colours dark blue, purple, and yellow were used, to indicate which type of attack to perform, now the colours orange, purple and light green are used (see figure 49). The reason for choosing these colours instead is because they are split complementary colours to each other, the previous colours were not. Furthermore, the yellow background colour made reading the letters in the field more difficult. The mentioning of the text in the playing field takes us directly to the second change in the exercise, as text is now being displayed on the field that indicates which attack technique must be performed. By indicating on the field which type of attack must be performed, there is no confusion among the players. In addition, a red shadow is shown to clarify the direction of the attack even more.

Figure 49 New colour scheme

A final change made in the Switching attack types exercise is to match the two-person block to the type of attack being performed. When attacking straight ahead, the straight ahead is closed with the block and when attacking diagonally, the block closes off the diagonal. Adjusting the block to the type of attack gives players the feeling that they are in a real game setting, the static placement of block undermines this. The figures below show the change of block position based on the displayed colour. Furthermore, figure 53 shows what the field occupation looks like in the third level, this field occupation is the same for every colour except for the block that changes its position based on the colour.

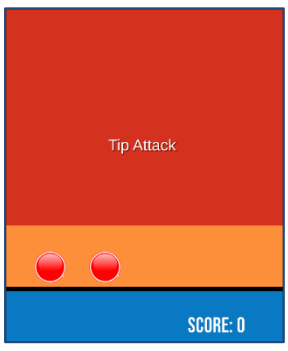

Figure 50 Level 2 tip attack

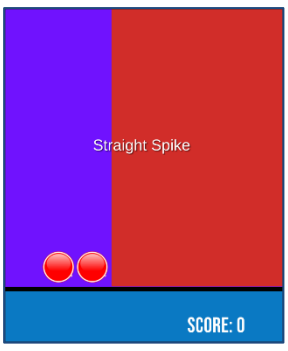

Figure 51 Level 2 straight atttack

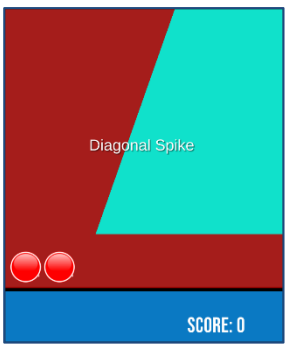

Figure 52 Level 2 Diagonal attack

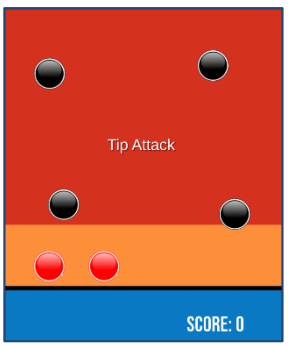

Figure 53 Level 3 tip attack

Sprint

With the sprint exercise, light visualisations have been used to make the exercise more attractive, the entire sprint parkour is lit up with arrows and circles. When a player stands on a circle or runs over an arrow, the light will go out and the circle will turn green to indicate that the player has been there. If an arrow is not touched by the player, the light of the arrow will go out automatically when the next circle is hit, when the entire parkour has been covered all circles and arrows that are not extinguished are still extinguished. Furthermore, the sprints are more spacious and the sprint of the first level has become longer, on the advice of players because they found the sprint too short (see figure 54). In addition to visual light effects, some information and encouragement texts have also been added, for example the start position is now indicated with text and the player will be told to continue like this after completing the sprint. The “Good job sprinting” text is being displayed for three second so the sprinter can see it and see his or her time (see figure 55). Figures 56 and 57 show the final design of the second and third level.

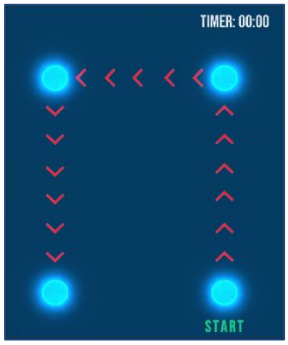

Figure 54 Level 1

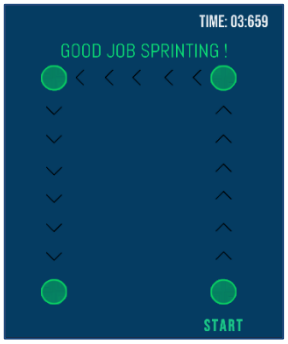

Figure 55 Level 1 completed

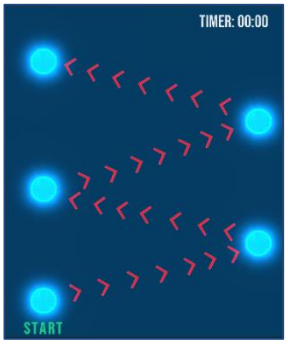

Figure 56 Level 2

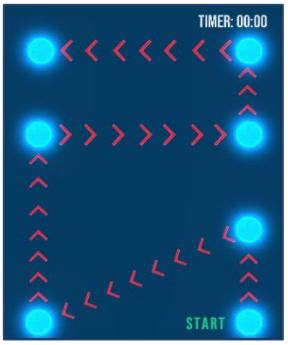

Figure 57 Level 3

Explosive jump

As in the lo-fi prototype, the jump area has been given a red color with the white text "Jump Area" in it. As mentioned in section 4.1.2, this exercise does not contain any levels because it serves as an aid for the trainer, therefore it was decided to place the "return to menu" button on the field so that the trainer can exit the exercise at any time (see figure 58 next page). Furthermore, everytime a player takes- off in the jump area a white take-off animation is shown.

With the first three jumps that a player performs, it is displayed how many kilos were released. When the player starts jumping again, it is shown how many percent less or more power has been generated in the current jump compared to the average weight of the first three jumps (see figure 59 next page). The first three jumps are used because after three jumps an idea can be sketched of how the player jumps and the fatigue has not yet struck. By showing the percentage to the player and trainer of the jump, it can be reasoned to make this percentage more stable so that there is not that much difference in power with each jump.

A player will perform a total of 10 jumps. After performing 10 jumps, the red jumping area will be grayed out for five seconds and the results of the jump session will be displayed. The result shown contains the highest increasing percentage in jump power and the associated weight that was produced (see figure 60 next page). After the 5 seconds, the jump area turns red again and the player can do the exercise again.

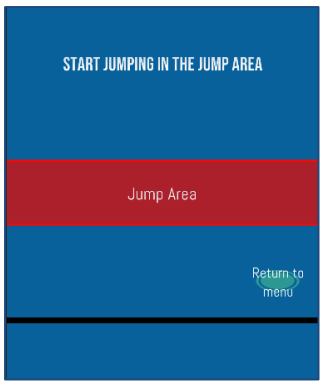

Figure 58 Start screen

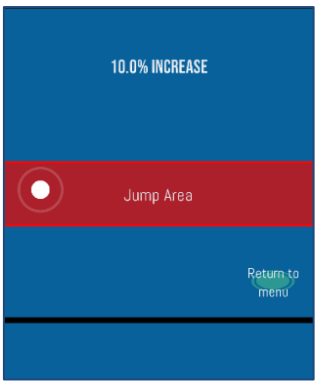

Figure 59 Jump executed

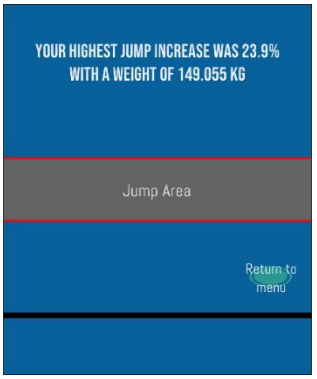

Figure 60 Jump results

Hit the Target

The displayed target in the Hit the target exercise has been changed from a static target visualisation to a red slow rotating target. The rotating target animation also gets bigger and smaller during the exercise, this to challenge the player even more when practicing the exercise. The target animation is for every level the same since the focus lies more on the different positions of the target in the levels. Besides the target, does the attack place indicator from the fourth level also contain an animation. This animation makes a pulsating movement and has a purple colour. Finally, the player's score is shown by the text at the bottom right of the field. The figures below show the final design for each level, the purple dot in figure 64 is the attack position.

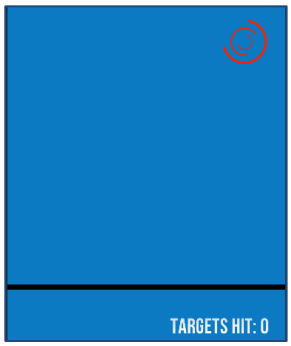

Figure 61 Level 1

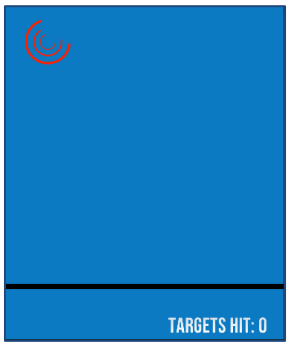

Figure 62 Level 2

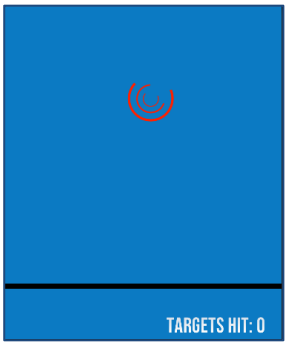

Figure 63 Level 3

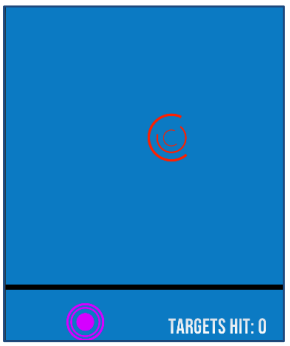

Figure 64 Level 4

Brick Destroyer

The Brick Destroyer exercise uses different coloured stones, the colour scheme of the bricks is similar to the Arkanoid game except for the bricks being darker as the Arkanoid colours were too bright on the floor. The placement of the stones is determined by a text file containing the numbers of the stones, the advantage of this is that the placement of the stones can easily be adjusted. In the current situation of the Brick Destroyer exercise, it does not matter where which stone is on the playing field as all stones have the same properties, this was not the case before if each brick had its own hit point property. When a stone had a hit point value of 1, the stone only had to be hit once to be destroyed, a stone with the value 2 for the hit point property had to be hit twice to be destroyed and so on.

However, this feature was not retained because it made the exercise take too long and was therefore less enjoyable. To be destroyed, all bricks now only need to be hit once with the ball. To make the exercise even more visually appealing, an animation has been added to the bricks when they are destroyed. When a brick is hit it will now show an animation of debris in the colour of the destroyed brick.

The figures below show the final designs of the Brick Destroyer levels, figure 66 shows the mentioned destroy effect when a ball hits the brick on the interactive floor.

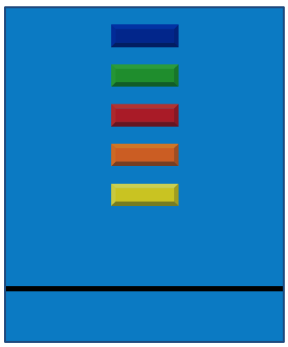

Figure 65 Level 1

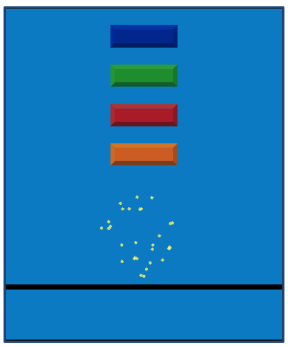

Figure 66 Brick destroy effect

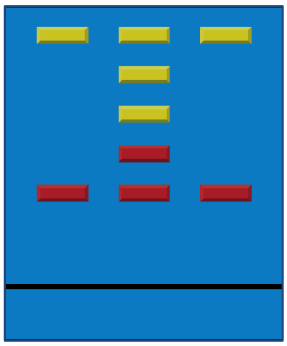

Figure 67 Level 2

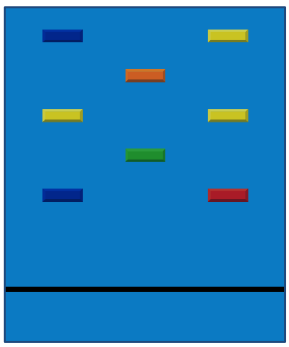

Figure 68 Level 3

Smash attack

The Smash attack exercise has remained the same since the lo-fi prototype, two players must hit a rectangular area together for as long as possible. The rectangular area is halved every level between the lines that keeps the players from ending the exercise.

To make the exercise clearer to the player, the playing time of the two player is shown on the court, the time is shown outside the eye of the playing player so that they are not distracted from the continuously increasing time. Furthermore, a little animation has been added when the ball hits the rectangle surface. The figures below show the final design per level, the white dot shown in the figures is the animation displaying the location of the smashed ball.

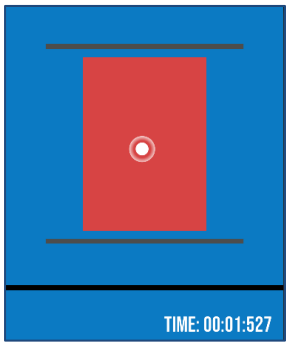

Figure 69 Level 1

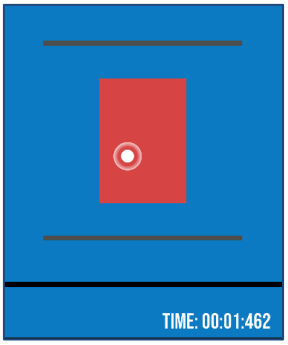

Figure 70 Level 2

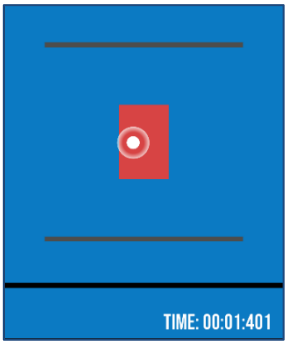

Figure 71 Level 3

Remaining screens

To perform the exercises, the user (be it the player or trainer) will go through different navigation screens. The structure of the exercise's application is the same as the tree structure mentioned in section 3.5.1.1. When starting up the exercises application, the user is presented with the three dimensions: tactical, technical, and physical. The user can then choose one of these dimensions to train.

A yellow background and blue buttons have been chosen for the final design because these colours can be found on a volleyball ball. These colours can be changed to for example represent the club colours. Figure 72 shows the final design of the main menu.

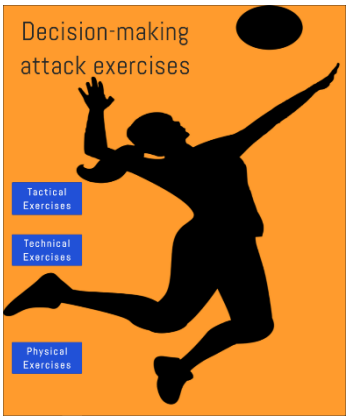

Figure 72 Main menu

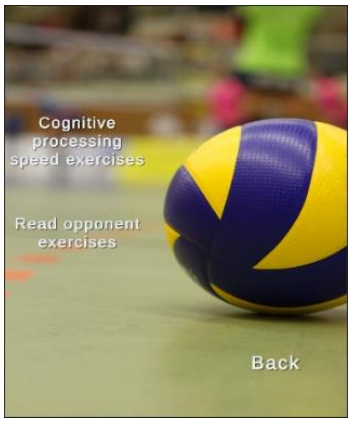

Figure 73 Aspects selector

After a choice has been made between the three dimensions, the player is led to a new screen showing the aspects that fall under the chosen dimension. The aspects selection menu (see figure 73) can be recognised by the background with a volleyball ball displayed. A back button has also been added so that the player can return to the main menu at any time.

When a choice has been made regarding the aspects, the player is led to the exercise selector of the chosen aspect (see figure 74). There the player can choose which exercise he or she wants to perform. The exercise selector screen has a neutral black background with white text indicating the exercises and the back button where the exercises have a blue background and the back button a red one. When a player taps a button, the background in question will get a dark shade so that the player knows that the button is being clicked.

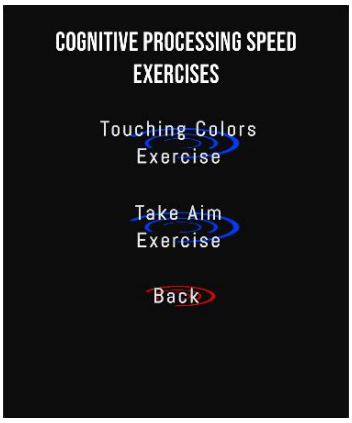

Figure 74 Exercise selector

After the end of an exercise, a light blue screen is displayed with the statistics of the exercise performed. What is being showed depends on the exercise, statistics that can be shown are the achieved score or the time needed to complete the exercise. Furthermore, the player can choose from the two options: replay the exercise or return to the previous exercise selector screen. Only the Explosive Jump exercise does not use this "exercise finished" screen, because the statistics are already shown on the interactive floor and the user can exit the exercise at any given moment. The two figures below show what a user sees when completing an exercise.

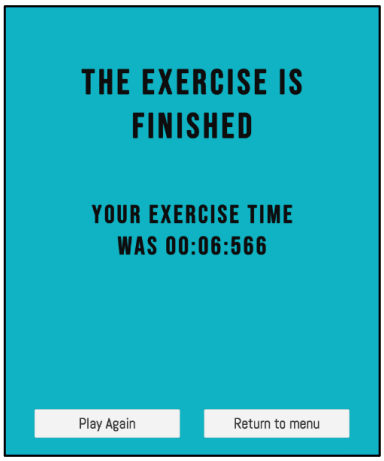

Figure 75 Finished screen with time

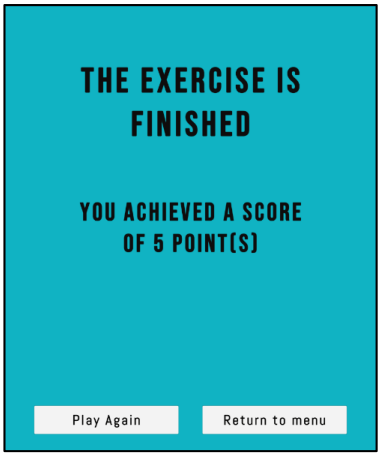

Figure 76 Finished screen with points

5. Implementation

After describing the floor exercises designs, the next phase of the thesis project was started, the constructive phase. This chapter is divided into four sections, together they give an answer to the fourth sub-question: *How can the characteristics of a suite-of-games be operationalised for offensive decision-making?*

5.1. Global Architecture

The developed system consists of four parts: the interactive floor, the floor application, the server, and the exercises application. The interactive floor consists of various pressure-sensitive panels that are connected to each other. By means of an HDMI cable, an exercise can be displayed on the floor via a computer. The floor itself also contains software that makes it possible to determine the weight on a panel and to request the coordinate of the weight. The external python floor application, developed by fellow researcher F. Salim and expanded by me, makes it possible to retrieve data from the floor. The floor data is then sent via this external application to the locally running Python server, this server sends the data to the exercises application. The exercises application is an application that is run in Unity, the application processes the received data and then determines what influence the data has on the game. The exercises application is connected to the interactive floor by means of the HDMI cable, the figure below shows the described flow of the system.

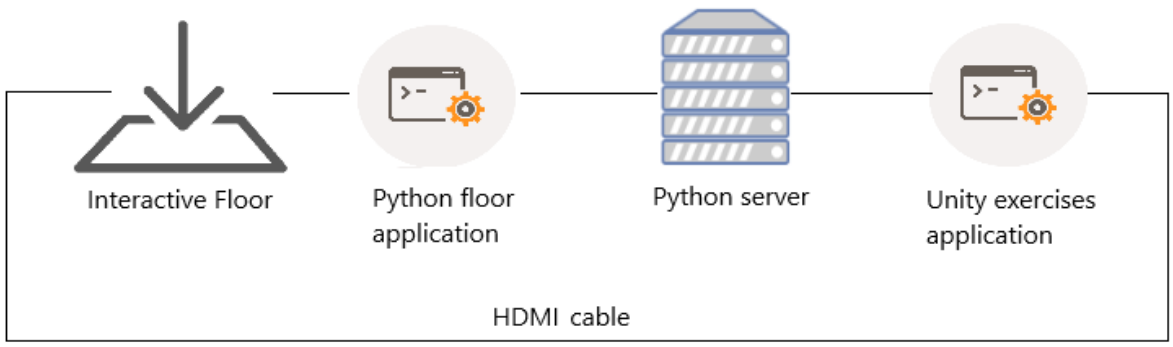

Figure 77 System flow

Not all exercises developed use the floor data, some exercises are played using the mouse. The flow of the system remains the same, except that in these exercises the floor data is not requested by the Unity exercises application. Exercises that do use floor data are: Touching Colours, Sprint, and Explosive Jump, they use the floor data because no ball detection is necessary to play these exercises. Section 5.3 will explain more about why some exercises work with the floor data and some do not.

5.2. Network

The connection between the floor and Unity exercise application turned out to be a success, when a player (researcher) was on the floor, the floor data was immediately registered by the Unity application. This live connection was a breakthrough for the floor as it was previously not possible to get real-time data to work with a Unity application.

5.2.1. Floor Application

The connection between the floor application and the interactive floor is possible through the PosiStageNet protocol of the interactive floor. In this context, the floor serves as a kind of server that holds data from the players on the floor and the Python floor application is the client that continuously requests the data each time from the floor by means of a socket connection. When the floor application has received the floor data, it converts the data into a floor object consisting of the x and y coordinates and the weight of the data point. In addition, the floor application itself creates a time attribute by taking the current time in seconds minus the number of seconds of the application's

runtime. The time attribute is created because it is later used in the jump detection method. To make the floor object usable for the exercises application, the time attribute of the floor object is adjusted to the ISO 8601-1: 2019 .Net Json string format. After this adjustment, a Json string is created from the floor object and sent to the server using a client socket connection.

5.2.2. Server

The server is a multithreading Python socket server, with the aim of sending all the data from the floor application to the exercises application over a local TCP connection. The choice for a multithreading implementation instead of single threading is because the server must listen to multiple clients at the same time. By using multithreading, the server can listen to the floor and exercises application at the same time and sending the data directly, thereby creating a real time data stream. Besides the choice made regarding the use of multithreading, I also decided to use a TCP socket connection instead of a REST implementation. Not using a REST implementation has to do with the speed with which requests can be handled. With a socket implementation there is a constant connection between the server and the client, a REST implementation does not have this and so a connection must be made constantly again and again. Furthermore, the overhead with REST is greater than with a socket connection, since the server only must forward data over a local connection, the overhead created by the HTTP protocol will cause the speed of the communication to drop. A socket implementation therefore provides a better performance as it is better at handling high data loads and has a bi-directional nature. The socket implementation uses the TCP protocol instead of the UDP protocol because TCP ensures that the packets that are sent also arrive at the receiver and TCP has an in-order data delivery. Having an in-order data delivery is a requirement because the data must be sent in the correct order, otherwise, for example, footsteps will be detected incorrectly. UDP cannot guarantee in-order data delivery, the data read by the receiver can be out-of-order from the sender's writes.

5.2.3. Exercises Application

The Unity exercises application uses the TcpClient package to set up the connection with the server, when a connection is established a thread is created in which the connection is kept alive. Every datapoint that arrives at the application is converted to the object named FloorDataObject, the object consists of the following properties:

- X coordinate
- Y coordinate
- Weight
- Time

Each created FloorDataObject is sent to the FloorDataHandler script, which then filters and sends the object to the manager script of the current exercise. The manager of the current exercise determines what will be done with the FloorDataObject. Besides serving as a data distribution point for the floor data, the FloorDataHandler script also filters the floor data so that it is more usable for the exercises. The filtering involves flipping the y coordinate and converting the time string to a DateTime object. The y coordinate must be reversed because the interactive floor has an inverted y-axis, the coordinate (0,0) is not located at the bottom left but at the top left of the grid. The conversion of the y-axis is done in Unity with the help of a CSV file containing a conversion table, when the Unity application is started, the CSV file is read, and all y coordinates are stored in a dictionary. This dictionary is then accessible throughout the application, the FloorDataHandler script uses this dictionary for converting the y-axis.

DateTime conversion
The Json data string that is sent to the Unity exercises application is read (deserialized) by the JsonUtility package from Unity. However, this package has the problem that it cannot generate DateTime objects from a DateTime string. When deserializing the Json string to a FloorDataObject, JsonUtility does not recognise the DateTime string and creates an empty DateTime object. The reason for this empty DateTime object is because JsonUtility can only handle simple variable types such as, int, string, and float. After trying several other serializer packages it was determined to convert the DateTime string to a regular string so that the JsonUtility can process the data. Other serializers were not chosen because the conversion speed was to slow for the application to run smoothly with the floor.

In the FloorDataHandler script, the time attribute will be converted to a DateTime object according to the ISO 8601-1: 2019 format. This format is used because .Net uses this as the standard format when serializing Json data. Converting the time to a DateTime object is necessary because working with time with DateTime objects is easier in C# than with times in a string format.

5.3. Sensing

After establishing the connection between the server and the exercise application, the floor data is used to see if there is an interaction between the location of the data point and the objects in the training exercise. To determine whether an interaction takes place within the game, for example tapping a coloured circle, different sensing components are used. These different methods are explained in section 5.3.2. Before explaining the sensing components, the identified risks are explained first.

5.3.1. Risks

Before and during the development of the training exercises, a few risks emerged related to detecting objects on the interactive floor. After consultation with other researchers and studying floor data sets, the following three 'risks' were identified: *false positives*, *misclassification,* and *multiple weight points*.

False positives
The false positives risk concerns the incorrect registration of an object on the floor that is not there, there is, as it were, a ghost on the floor. Having these “ghost touches” can cause miscommunication between the floor and the exercises, as the floor signals to the exercise that something has been hit on the floor even though this is not true. To suppress these ghost touches, a filter must be placed, a filter ensures that only the data that is useful for the exercise is sent to the exercise. In this project it was decided to apply a weight threshold filter, all data points that fall below the threshold with their weight are not sent to the server. The threshold in this project is set at 2000 grams, as an average a ghost touch had a weight of ±1500 grams.

Misclassification
Another risk is the misclassification of objects on the floor, a ball that is registered as a player or vice versa. In addition to the misclassification of these objects, a ghost touch can also be registered in this risk and subsequently be misclassified. Part of this misclassification has already been solved by using the false positives weight threshold, thereby thus reducing the chance of the identification of ghost touches. To be able to distinguish between a ball and a player, floor data was looked at in which players walk across the floor and are trying to hit a projected floor target with a ball. From this data it emerged that the position where a player stood or walked, many data points were clustered together for a period of at least 3 frames. A single frame in this context equals a single floor data point. Because of this clustering of datapoints for multiple frames it was possible to identify a player on the floor and track the movements.

Detecting the balls who were contacting the floor was more difficult than detecting a player as many balls were not picked up by the floor. The used floor data set for detecting balls consisted of three different types of spikes; tip spike, soft spike, and hard spike, each spike was performed 20 times on the floor. When analysing the floor data with the corresponding video data, it showed that less than half of the spiked balls, with any type of spike, were registered through the floor. Furthermore, the data also showed that there is a lot of differences in the number of datapoints between two people spiking the ball with the same technique. Where one player had over 200 datapoints when performing a tip spike, another player had 6 datapoints for the same number of spikes.

Causes for poor registration of spiked balls was due to the weight of the ball and the contact speed between the floor and the ball. The floor tiles are not sensitive enough to detect fast moving objects. Because of this result of unpredictability, it was decided to not include ball detection in this project. Detecting a player on the floor has, on the other hand, been realised, this is explained in more detail in section 5.3.2.

Multiple weight points
The third risk that has been considered before implementing the exercises is the multiple weight points risk, multiple weight points occur when a player is standing on the floor, as one has two feet on which they are standing. The risk that can occur here is that each foot is registered as a separate object, two people are registered while only one is on the floor. To avoid this incorrect classification, the distance between the two objects should be considered, if they are within one meter of each other, they should be seen as one object. Because in the exercises devised there is no situation where players are close to each other and it was not yet possible to determine with certainty which datapoints stream tracker belongs to which player. It was decided that dealing with this risk falls outside the scope of the project and therefore no action was be taken.

5.3.2. Sensing Components
Within the exercise application different ways are used to play an exercise, data from the floor or mouse clicks can be used. As mentioned before, the exercises Touching Colours, Sprint and Explosive Jump make use of the floor data and the other exercises can be played by mouse clicks. Still, both methods have a similarity, they both use colliders and raycasts to determine whether something has been touched on the floor. This section will explain how colliders, raycasts and detection methods are used for the training exercises.

Colliders & Raycast Pointers
To find out in Unity whether a certain object has been hit or not, colliders are used. Colliders are components that provide collision detection using their various ‘Bounding boxes’. A bounding box is a green line that surrounds a game-object. When something is intercepting the bounding box, Unity sees this as a collision and stores the data of the object(s) that is causing the collision.

With the bounding box in place, the object is actively checking whether it is being crossed or not. A raycast is used to activate this trigger of the collider. The raycast is an imaginary "laser beam" from the mouse position or floor coordinate that continues to shine in a straight line until a collider is hit in the scene. When the raycast hits a collider, information about the hit object and the location where the object is hit is sent back. Based on this information, it is determined if the correct object was hit or not.

Player detection
To determine whether a player is on the floor and not a ghost touch, a method is created who determines whether the data coming in from the floor is a person standing on the floor. Determining whether a player has been detected is done by looking at the weight of the data point and its frequency. If there are several data points that are higher than the maximal weight of the player times three and these points also happen more than three times in a row, a person is said to be standing on

the floor. When the weight of the data points is below the maximal weight, but persists for more than 15 data points, this is also seen as a person on the floor. The method will return true if it is determined that a player is standing on the floor, otherwise the method will return false. The maximal weight of a player is determined per exercise as speed plays a factor.

Difficulty player detection

The method used to detect a player on the floor works fine when receiving correct data from the floor, but this is not always the case. The floor is not always accurate in determining the x and y coordinate of the data point. Objects hit by a player with their foot are not always registered. The floor indicates that the data point is outside the collider of the object when it is not. The accuracy of the floor tiles is therefore not always reliable, this was also confirmed during the pilot study with the floor. When testing an exercise, it appeared that some tiles of the floor sometimes get stuck so that they are not able to record data, this only happened a few times and was solved by standing on the tile a few times, but this can cause complications in an exercise. Especially in the Touching Colours exercise this is not an ideal situation as the player must be able to select the circles.

Jump detection

The jump detection method is used by the Explosive Jump exercise, which determines when a player is pushing off the floor, when the landing starts and what the highest jump power was. To determine when a player pushes off, the average weight of the player is first determined. After determining the average weight of the player, it is checked whether the current data point has a percentage increase of 15 percent over the average weight. When this is the case and it holds for three consecutive data points, the player is said to be busy with his or her take-off. Then, at each subsequent data point, it is checked whether the weight is higher or lower than the previous weight, if the current weight is greater than the previous weight, the current weight becomes the highest weight. When a drop is detected, the highest weight is sent back to the exercise manager and processed further. The determination of a drop is done based on data points that decrease in weight for more than three consecutive data points. The reason for registering the drop after three consecutive decreasing data points has to do with the accuracy of the interactive floor. When detecting a jump, it emerged that the weights of the data points do not always move gradually, this means that when someone is suspended in the air during a jump, not all data points decrease in weight. Sometimes some data points go up for one or two frames while there should be a decrease. By recording the drop over a longer period, over three frames, it is no longer an issue. But for future research a second look should be taken at the floor to avoid this problem.

To prevent a landing from being a jump take-off, the time of the data point is also considered when determining the increase in weight. If the time of a data point falls within the end time of the descent and falls within the end time plus 2.6 seconds, it is said that this is a landing and not a new jump. The determination of the 2.6 seconds is based on trial and error with the generated jump data set from the pilot study.

5.4. Implementation Exercises

As indicated earlier in the previous sections, the exercises application uses various packages, scripts, and objects to make the exercises playable. The application is built in Unity version 2019.4 and uses the Universal Render Pipeline, this pipeline ensures that light effects, such as in the sprint and rapid attack exercises, can be displayed. To allow the different objects in the training exercise to interact with the player, different scripts are used. Almost every object has its own script, which tells the object what to do if an action takes place. An example of this are the sprint circles in the sprint exercise, each circle uses the same script that says: "*If a player stands on me then switch off the circle light and give the circle a green colour*". This action is therefore performed for each sprint circle. There are also scripts that can perform actions on multiple objects at the same time, in this application these are the so-called manager scripts, for example, they receive the floor data and then determine

what should be done with it. A manager script that performs such an action is the explosive jump manager script, this script ensures that when a player jumps in the red area, the floor data is sent to the jump detection method in the FloorDataHandler script.

As mentioned in section 5.2.3, the TcpClient package is used for establishing a connection with the server. When a connection is established, a thread is made on the Unity main thread. This occupation of the connection thread on the main thread poses a complication when certain Unity actions must be executed within a training exercise. Such an action is for example changing the sprint circle colour, to change the colour Unity uses the main thread. Unfortunately, it is now occupied by the connection thread. To gain access to the Unity main thread, a script developed by Pim de Witte [115] is used. What this script does is putting the actions to be performed in the main thread queue and then instructs Unity to execute those actions. After executing the actions, the connection thread continues on the main thread.

6. Evaluation

This chapter addresses the third and final phase of the thesis project, it presents the data analysis and results of the interviews. The first part of this chapter explains the created evaluation protocol, the evaluation protocol addresses the second research question (RQ 2): "*How is interaction viewed in general by trainers and players"* and third research question (RQ 3): "A*re the developed suite-of-games exercises suitable for training the attack subdomain in volleyball when using an interactive floor?*". The second part (Section 6.6) provides the results of the held thematic analysis of the interviews.

6.1. Goal & Research Questions

The purpose of this evaluation protocol is to gain insight into four areas: the trainers and players view on interactive technology, the willingness among the participants to use the interactive floor, the participants willingness to use the developed exercises, and how is the use of a suite-of-games approach for training purposes viewed. By conducting this evaluation, trainers and players will be exposed to a new technology that can be used as training aid and thereby potentially broaden their vision of how to provide and execute a training.

The word suitable in the addressed research question RQ 3 can be interpreted in different ways, within this evaluation protocol the word suitable is characterised with the following characteristics: added value for existing exercises, variety, willingness to use, and facile integration.

6.2. Method

Due to the COVID-19, in-person assessment methods were not recommended to perform. This leaves a few evaluation methods: surveys, interviews, and diary studies. The diary study method was not considered for this evaluation, as this evaluation is not intended to record a participant's activities, habits, thoughts, or opinions during their daily activities. Furthermore, the interactive floor is still under development, which means that no weekly use can be made of the floor by trainers and players because it is not yet ready for consumer use. The floor must become more reliable before it can be used in training.

Usability testing methods such as desirability testing or live experiments [116, 117] would have been the most suitable for evaluating the system, as the trainers and players would test the floor using it in a training environment and could provide immediate feedback on their experiences with the floor and its exercises. Conducting usability testing methods has the advantage of gaining a better understanding of the environment and context a trainer would operate the system in and capture information that affect the use of the interactive floor. Furthermore, it would provide insight into user satisfaction, ease of use, and usefulness. But unfortunately, these testing methods were also not be feasible due to COVID-19.

After eliminating the previous mentioned methods, two remained: surveys and interviews. In determining which method(s) would ultimately be used for the evaluation, the type of information needed to answer the research question was considered. There it emerged that a qualitative approach would be best suited to answer the research question, as it was preferred to have an extensive description of the participants' experiences with the floor. Furthermore, the evaluation type is a formative evaluation, this because the created system is still under development and one of the sub-questions' goal was to find out what the trainers thought of the systems' concept.

With these points in mind, it was chosen to use the semi-structured interview method. The reason for not choosing surveys or a combination of interviews and surveys was because the surveys would contain open questions and surveys with open questions are often not completed in full. Normally, participants only answer the open questions if they feel they can contribute something [118].

Furthermore, going through several floor exercises takes time, this could increase the chance that people would not complete the survey.

To provide insight into how the evaluation would be carried out if there was no Coronavirus, a research protocol has been set up for the sprint exercise, this protocol can be found in Appendix A.

6.3. Respondents

After getting the green light from the ethical commission for conducting interviews, purposive sampling was used for seeking volleyball trainers and players of all levels for the interviews. Purposive sampling was chosen because people associated with volleyball are a better primary data source for the research questions' goals and objectives. The participants were recruited by sending emails to various volleyball clubs. In the e-mail it was asked whether there were trainers and players who would like to make themselves available for an interview about the use of an interactive sport-training floor.

When a respondent made himself/herself available for an interview by sending an e-mail to me, an information brochure (Appendix B) about the research being conducted was sent by me. When the respondent agrees to the terms of the interview, the trainer or player was asked to sign the consent form (Appendix C & D) and upload it via a SURFdrive link that was provided by the researcher.

The aim was to recruit between 10 and 15 people. Eventually sampling was discontinued after the ninth participant as no new results emerged during the interviews and the recruitment of willing participants went going slowly.

6.4. Protocol

The interviews were conducted digitally with the communication tools Google Meet or Microsoft Teams. Two data types were collected during the interview: video and text. Microsoft Word was used for note taking and recording features from Google Meet/Microsoft Teams for recording the interview video.

At the beginning of the interview, a few questions were asked that created a profile of the interviewee. This profile was later used in the data analysis to distinguish between the trainers and players. After these few questions, there was a short introduction to the project and the concept of an interactive sport-training floor was explained. After the introduction, the interviewer shared her computer screen with the interviewee to show the developed exercises. See Appendices E and F for the English and Dutch interview questions.

During the interview, not all exercises and the corresponding levels were shown to the interviewee, because showing that many exercises would become too intensive and therefore detract from the interview quality. Instead, the following five exercises were shown to the interviewee: Panel Attack, Touching Colours, Jump Explosion, Rapid Attack, and the Sprint exercise. For each exercise shown, it was explained what was expected of the player to perform the exercise and what the exercise contributes to training the attacking skill. After walking through the exercises and their levels, the participant was asked if he or she would like to try some of the exercises themselves. After that, questions were asked regarding their experience with the shown exercises and the concept of an interactive sport-training floor. During the walkthrough of the exercises, the interviewee could make a comment about the exercises at any time.

Time & Location

The interview period was between 08-01-2021 and 05-02-2021. Since the interviews were digitally conducted, a location was not agreed upon. The time of the interview was mutually agreed between the participant and the interviewer, on average the duration of an interview was 40 minutes.

Data Storage
The interview data was stored on an encrypted disk with BitLocker, furthermore the consent forms were uploaded to a SURFdrive server that meets the GDPR data storage requirements. The research data will be stored at least 10 years according to the VSNU guidelines.

6.5. Analyse

To answer the research questions mentioned in the intro of this chapter with the interview data, a thematic analysis approach was taken. Thematic analysis is a common form of analysis for qualitative data [119], it analyses the data in a systematic and rigorous way by identifying, analysing, organising, describing, and reporting the themes found within a data set [120].
The choice to use thematic analysis as the analytical approach is because thematic analysis is known to be a valid and flexible way of analysing qualitative data by identifying patterns of meaning that in turn help to answer the research questions. Other quantitative data analyses approach such as content, narrative or discourse analysis were found to be less fitting for answering the research questions. Content analysis for example, is more a quantitative analysis method and can therefore loos the richness of information given by the participants. Narrative analysis is more about interpreting data that have a storied form, as the research questions cannot be answered by analysing how people are representing themselves or their experience to themselves, this analysis approach was found unfit. Finally, discourse analysis analyses the language within the culture and society it takes place, this is not relevant for answering the research questions.

The qualitative thematic analysis approach was carried out according to the six steps of researcher L. S. Nowell et al. [121]. Below, it will be explained per phase how this was carried out.

Phase 1: Familiarising yourself with the data
As section 6.4 data storage already indicated, the interview data (e.g., the interview video and interview notes) was stored on an encrypted BitLocker disk and the consent forms on a SURFdrive server. On the BitLocker disk a folder was created per interviewee with a unique identifier, all the data of the interviewee was stored in that folder and each file was archived with dates to provide an audit trail.

Phase 2: Generating initial codes
The first-round generation of the initial codes of an interview was done right after the interview was finished, the interview questions were looked at and different codes were generated. Because the information is still fresh in the mind of the researcher, what is in the data and what is interesting about it is known to the researcher. The second round of coding took place 1 to 2 days after the interview was conducted, the video of the interview was watched and missed codes were added to the coding list. By doing a second round of coding a few days later, the data is looked at with a 'fresh look' and possible forgotten code is added. The coding list was a Word document that contained all codes of all the interviews conducted.

Phase 3: Searching for themes
In the third phase, the different codes will be sorted and collated into themes. When creating the themes, DeSantis and Ugarriza's [122] definition of the concept of a theme was used: "*A theme is an abstract entity that brings meaning and identity to a recurrent experience and its variant manifestations. As such, a theme captures and unifies the nature or basis of the experience into a meaningful whole*". With this definition in mind, themes were written down after each interview that in the researchers' view were relevant to the codes. During the interviews and various coding rounds more and more themes were noted.

Phase 4: Reviewing themes
In the fourth phase, the devised set of themes were refined. The coded data extracts for each theme were reviewed to consider whether they appear to form a coherent pattern. For each individual theme, the validity was considered for determining whether the themes accurately reflect the meanings evident in the interview data set as a whole. To determine the reflectiveness of the themes regarding the data set, all interview videos were revied after the last interview to assess whether there were themes missing or themes not reflective enough. Some themes needed to be broken down further into sub-themes to make the data more readable.

Phase 5: Defining and naming themes
The fifth phase consisted out of determining what aspect of the data each theme captures and identify what is of interest about them and why [120]. For each individual theme, a detailed analysis was written down about what story each theme told and considered how each theme fit into the overall story about the entire data set in relation to the research questions.

Phase 6: Producing the report
After establishing the final themes, the process of writing down the results of the interviews was started. Besides describing the qualitative thematic analysis results, these results are reinforced with qualitative data from the interviews. The quantitative data provides more insight into the overlap between existing exercises, the most frequently named missing exercise(s), the number of participants that knew about the interactive floor concept, the number of participants that would use the interactive floor, the number of participants that would use the developed exercises and the most frequently given advice regarding the developed exercises. This qualitative data will mainly be presented in chart form. Section 6.6.4 will describe the results of the thematic analysis and the quantitative data; the results will provide an answer for the evaluation questions.

6.6. Results
This section will deal with the results of the thematic analysis. After reviewing and coding the interview data in the first and second phase of the thematic analysis, several themes were written down to represent the interview data. This representation of the interview data into themes will be discussed in section 6.6.2. Section 6.6.4. will deal with the results of the interviews and the answer to the research questions are discussed in the next chapter.

6.6.1. Characteristics Participants
A total of nine people were interviewed, six of whom hold the position of trainer and three of player. Of the trainers, four people gave training at youth level, the other three trainers gave training at the premier league level (Dutch Eredivisie) or had experience at that level. Among the players, two played at the first-class level and the other at the first division level. Seven participants did not know in advance of the interview what an interactive floor entailed; two participants did because they had also done projects with an interactive floor. When the participants, who had not heard of an interactive floor concept before, were asked what they thought the floor entailed the answers varied. Some participants saw it as a floor that monitors players, another saw it as a floor that projects movements or it was a floor that displayed the sports field layout.

6.6.2. Themes Determination Process

After completing the first and second phase through two rounds of coding per interview, I started with the third phase of theme generation. The first themes created were mainly based on the interview structure. Sub-themes were written down under these six themes after each interview and thereby creating the following table:

Own attack exercises	**Developed exercises**	**Interactive floor concept**	**Suite-of-games concept**	**Interactive floor as aid**	**Acceptance**
Training aids	Characteristics	Added value	Conceptual aspects structure	Data-driven	Floor acceptance
Training focus	Recognisability	First impression	Advantages		Exercises acceptance
Most used attack exercise	Distracting game-elements	Areas for improvement			Player level
Most valued exercise component	Areas for improvement				
	Exercise(s) missing				
	Would not use exercise				
	Added value				

Table 2 First drafted themes

After defining the themes in the third phase, I moved to the fourth phase where I looked at the themes and sub-themes again. When re-analysing the themes, it emerged that the themes did not properly represent the research questions and sub-questions. To avoid redefining themes that do not correctly represent the research questions, I asked myself the following question: "*What do I hope to get as an answer from the sub-questions?*". With this question in mind, the following answers emerged:

- **SQ 3.1:** How is the attack currently being trained?
  - Similarity between the developed and existing exercises.
  - Acceptance of technology.
- **SQ 3.2:** How is the potential of the developed exercises perceived by trainers and players?
  - Similarity of the digital variants to an extent.
  - The unique contribution of this technology to training.
  - The added value.
  - Acceptance of the interactive sport-training games technology.
- **SQ 3.3:** How do trainers and players view the suite-of-games approach that is integrated with the interactive floor?
  - Validation of the suite-of-games concept.
  - Validation of the overall concept and its implementation with the interactive floor.
- **SQ 3.4:** Are trainers and players willing to use the developed sport-training games system for training purposes?
  - Acceptance of the developed exercises.
  - Acceptance of the used technology.

Looking at the answers, many sub questions have corresponding expected answers, the expected answers in some cases refer to the same themes such as validation, acceptance, and areas for improvement. Other themes that came up with the expected answers are flexibility in focus, conceptual structure, level determination and possibilities. All these themes together provide the following theme structure per sub-question:

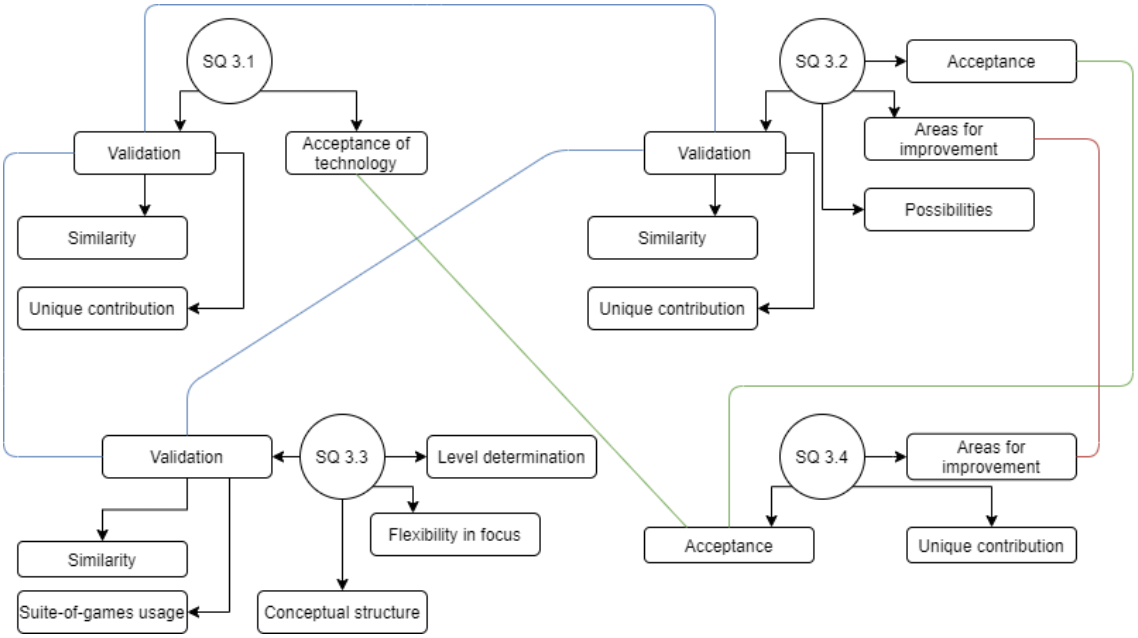

Figure 78 Theme structure per sub-question

After mapping these themes, I compared them with the previously generated themes from table 2. From this comparison it emerged that many themes from the table can be placed under the themes of the sub-questions, the themes in figure 78 reflect the interview dataset well. The reason for this reflection is the structure of the interview questions because the questions are grouped in such a way that they have an indirect relationship with the sub-questions.

Because the themes of the sub-questions reflect the interview dataset, it was decided to use these themes as the definitive themes. This means that there are a total of seven main themes and three sub-themes (see figure 79).

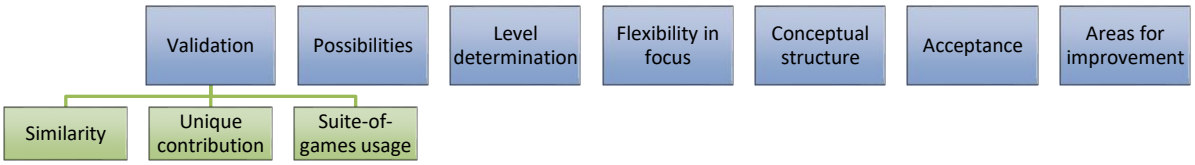

Figure 79 Final themes and sub-themes

6.6.3. Final Themes

After concluding phase 4, phase 5 was started with determining what aspect of the data each theme captures and identify what is of interest about them and why. Below, a description of the final themes is given.

Validation. The validation theme provides insight into the given opinion towards the exercises and the suite-of-games approach concept. The information from the theme will provide an answer to the question whether the developed system is deemed good enough for training, this validity is determined by looking at the similarity between existing exercises and the developed exercises, the unique contribution that the developed exercises bring and the conceptual use of a suite-of-games approach.

> Similarity. The similarity subtheme looks at the corresponding properties between the developed exercises and current exercises, the theme also looks at the understandability of the developed exercises. If there are corresponding properties, it could entail that the volleyball players and trainers recognise the meaning of the exercises easier and therefore validate the new exercise because it makes sense to them.
>
> Unique contribution. The unique contribution subtheme provides insight into the unique characteristics of the exercises developed in the suite-of-games concept and how this goes together with validating the general system concept.
>
> Suite-of-games usage. The suite-of-games usage subtheme provides insight into the use of exercises to train an aspect. By finding out how trainers train subdomains or aspect, possible comparisons can be drawn with the developed exercises.

Possibilities. The possibilities theme provides insight into the versatility the multiple aspects can offer. If the data shows that the number of possibilities is perceived as positive, conclusions can be drawn that help support the suite-of-games concept used.

Level determination. The level determination theme provides insight into whether the participants are satisfied with the build-up of the difficulty levels in the exercises. Gaining insight into this helps to draw conclusions about the satisfaction of the developed exercises and the acceptance of the used suite-of-games approach.

Flexibility in focus. The flexibility in focus theme provides insight into the added value of being able to choose flexibly from multiple aspects. Having this flexibility regarding the aspects gives the user the ability to focus more on a certain aspect instead of multiple, it can help the player to master a skill more quickly. This theme will look at the advantages and disadvantages of the flexibility in focus.

Conceptual structure. The conceptual structure provides insight into whether the participants found the proposed structure logically constructed and what feeling is experienced when making use of such a structure. By knowing what the participants thought of the aspects, it can be determined whether the implementation of the offensive decision-making training subdomain was correct.

Acceptance. The acceptance theme provides insight into whether the participants would or would not integrate the developed system in their current training and why they would or would not integrate it. By knowing the willingness of using the developed system, an answer can be given to the fourth sub-question.

Areas for improvement. The areas for improvement theme provide insight into what the participants did not like, miss, or found distracting about the developed sport-training games system. By knowing what participants would like to see improved within the system, conclusions can be drawn about what is needed for the participants to use the system for training the volleyball subdomain offensive decision making.

6.6.4. Interview Results

In this section the results of the exercises will be discussed through different topics mentioned by the participants during the interviews. The themes of the thematic analysis are incorporated into the topics. The quantitative interview data is presented in the form of charts.

Recognisability

The subject of recognisability was frequently mentioned by the participants, it was indicated that the exercises were found recognisable because of their overlap with existing exercises. The participants found the developed exercises also recognisable because of their similarity with their own exercises regarding the competitive atmosphere and shared exercise goals. Because of these similarities, and similarities is a sub-theme of validation, this topic can be linked to the theme of validation. In addition to the similarities in terms of overlapping, competitive atmosphere, and exercise goals, participants also indicated that the developed exercises were easy to understand. Especially the Panel Attack, Sprint, Touching Colours and Rapid Attack exercises were found to be easy to understand because of their overlap with the existing exercises used by the participants (see figure 80). The Panel Attack exercise for example was found to be overlapping with the exercise "full attack", in this exercise the players perform the whole attack sequence of serve, pass, set and spike. Furthermore, the participants indicated that the Sprint exercise overlapped with the warming-up exercise relay race and the Touching Colours exercise overlapped with a reaction time exercise in which four people stand in a circle and play the ball as difficult as possible towards each other for a set amount of time. The Rapid Attack exercise was found to be overlapping with an exercise in which players hit the ball against the wall with a bounce for as long as possible to practice their spike stroke.

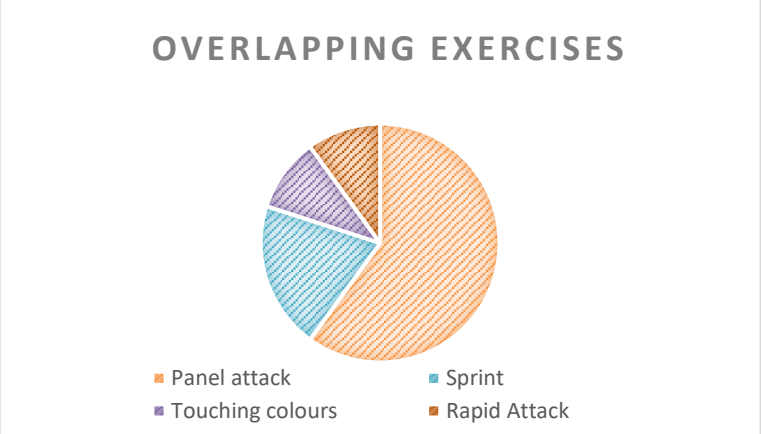

Figure 80 Overlap between existing and developed exercises

Attractiveness of an exercise

Attractiveness of an exercise is another topic that came up during the interviews, participants indicated which elements within an exercise appealed to them. Because this topic looks at the use of an exercise, this topic falls under the themes of acceptance and validation.

According to the participants, the attractiveness of an exercise was mainly determined by one element: the competitive atmosphere. Points scoring or fastest time obtaining exercises were found to be more attractive because it offers players more challenge and self-reflection. It was noted however by trainers and players that the team spirit must be always maintained during the competitive exercises, creating a competitive atmosphere must not come at the expense of the team spirit. In addition to a competitive atmosphere within an exercise, teambuilding and fatigue were also seen as important components for the attractiveness of an exercise.

Unique contribution

When showing the developed exercises, participants frequently indicated that the exercises made a unique contribution to training the subdomain. The theme of unique contribution was explicitly mentioned by the participants; hence the topic of this header is the same as the theme from the thematic analysis.

The visual cues, data-driven analyses, and the pressure relief when using the floor were found to be the unique contributions of the developed system according to the participants.

"The interactive floor and its exercises are an enrichment for the field of sports and technology"

- Multiple participants

Participants indicated that the use of visual cues in exercises improves the learning ability of the players because visual cues are more motivating than a verbal explanation. The contribution of data-driven analyses to the exercises was seen by the participants as a useful way to better map the performance of a player. Some trainers themselves already used data-driven technologies such as VERT and Data Volley. By offering data-driven analyses, the participants indicated that it was possible to find out faster what went right or wrong during an exercise. The use of data-analysis was mentioned as a big enrichment for the player and the trainer because the player can reflect more on what went right or wrong and for the trainer it offers more certainty about the performance of his players.

"Measuring is knowing"

- Multiple participants

The contribution regarding pressure relief refers to the use of the developed system as an aid. Participants indicated that using the system as a training aid can take the pressure off the preparation of an exercise, as the floor makes it easier to digitally display needed sports hall attributes such as cones and mats. It was also indicated that the use of the system makes trainers less dependent on the number of people present at a training.

Versatility

Versatility and the interactive floor were often mentioned by participants in the same breath. The topic of versatility falls under the themes of possibilities and unique contribution, as participants indicated that versatility provides many unique training experiences and provide the possibility to train offensive decision-making in its entirety. Trainers indicated that the versatility of the interactive floor gives them the possibility of giving more in-depth coaching to their players. Having the ability to provide this more in-depth coaching allows them to create multiple specific and challenging exercises on a particular aspect. This possibility of having multiple exercises for training an aspect, according to the participants, matched how they currently train their skills. The interviews showed that trainers use different exercises to train a dimension such as technical skills by splitting the attack into different parts and train these parts separately.

Tailored experience

Another topic that came up among the participants when discussing the topic of versatility was the topic of a tailored experience. By offering versatility, exercises can also be more tailored, according to the participants. The topic of tailored experience therefore falls under the themes of level determination and suite-of-games usage. When talking about the subject of tailored experience, participants indicated that they liked the fact that different levels are present for each exercise. It creates a more customised experience for the players and the learning curve would be more gradually because of the low threshold according to the trainers. In the interviews, trainers mentioned that they determine the difficulty level of an exercise in their head by taking a general training exercise and add or remove an element to it, the exercise would then be played by alle the players. As a result, certain players within the team will find the exercise too easy or too simple. To prevent this, trainers indicated that they would rather do a more difficult exercise than a too easy one. With the option of flexibly choosing the difficulty level of an exercise, a more tailored exercise was trained according to the participants.

Structure
The subject of structure was mentioned many times by the participants, the subject falls under the themes of flexibility in focus and conceptual structure. The topic falls under these themes because the layout of the exercises was described in this topic.

The chosen structure of splitting the subdomain into different dimensions and aspects was found to be appealing by the participants, the three dimensions were found to be corresponding with the dimensions they also use in their attack training; technical and tactical. The participants considered the physical skills dimension more as a dimension that can be used for the warming up phase of the training because it is a rather broad dimension. The physical dimension could namely be placed under other volleyball subdomains. The majority of the trainers indicated that they mainly train the technical dimension of the attack, the tactical dimension is usually introduced later when the players have obtained a basic attack technique. Teams playing at the premier league or division level mainly focus on the tactical dimension because, according to the trainers, the technical skills of the players are already optimally developed.
Because of the clear separation between the different dimension and aspect, trainers indicated that they were more flexible in putting their focus on a single aspect. This flexibility in focus makes it easier to train more purposefully and efficiently, resulting in more targeted feedback, according to the trainers and players. Furthermore, because of its division in multiple aspect, the attack was found to be more completely trained.

"*Provides a wider range of exercise possibilities*"

- A player

Willingness to use
During the interviews, the participants indicated their willingness to use the developed system for training. This topic of willingness to use falls therefore under the theme of acceptance as the topic provides insight into the acceptance regarding the integration of the developed system into existing training sessions. All participants indicated that they would like to use the interactive floor as training aid and a majority would use the developed exercises as well. Participants indicated that the floor and its exercises provide clarification, awareness, information, encourages player development, and makes it easier to learn or improve skills.

"*New way of training*"

- Multiple participants

That not every participant knew what an interactive floor entailed did not affect the willingness to use the floor for training purposes. They were enthusiastic about the possibilities that interactive technology could offer. Many trainers use technology in combination with various attributes in their training sessions, the technology serving mainly as a tool to create insight into the player's performance. Trainers who do not use technology, stick to using the sports hall attributes such as mats, hoops, and pawns. The mentioned reasons for not using technology in training were money or inexperience in being a trainer.

There was a small division regarding the willingness of usage regarding the developed exercises (see figure 81). Although all participants were positive about the exercises, not everyone wanted to use all exercises or certain exercises had to be made more complex. The Rapid Attack and Sprint exercises were the exercises that were not considered suitable by some participants. A player indicated that the sprint exercise is too far removed from the attack and therefore is not seen as an attack training. The sprint exercise was seen more as a separate aspect that applies to all volleyball practice forms instead of just the chosen subdomain. The Rapid attack exercise was not found suitable because of its exercise purpose. Two trainers felt that having a fast spike arm comes with the level at which a player plays'. According to the trainers, players who train and play at a high level would already naturally have a fast spike arm and therefore making the Rapid Attack exercise redundant.

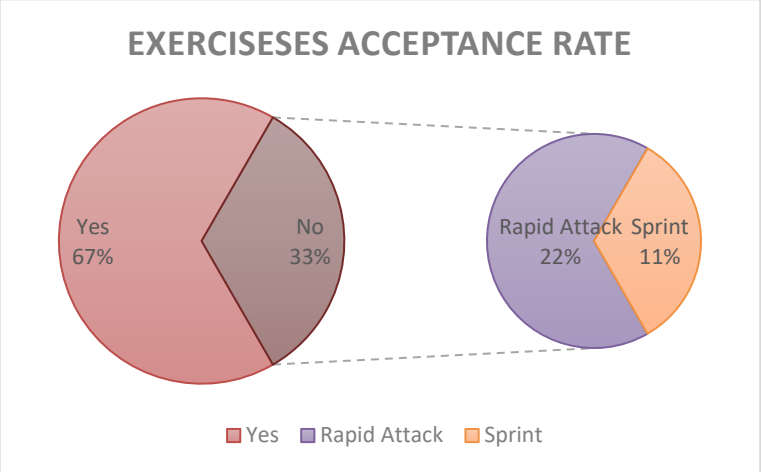

Figure 81 The developed exercises acceptance rate

The players and trainers who did want to use the Rapid attack exercise, saw the exercise more as a nice and basic way to train their spike. They did indicate that they would like to use the exercise in a not stationary position, because the attack is a fluid running movement.

Caveats

During the interviews, some caveats emerged regarding the developed system. These comments mainly concerned improvements compared to the currently developed system. This caveats topic falls under the theme areas for improvement because the caveats made mainly concerns future improvements to make the system more complete.

Missing components

Adding blocks for complexity and making the exercises suitable for multiple people were the components that were often missed by the participants. Currently, most of the exercises are set up so that a single player can train with them, this would mean that fellow teammates would stand by and get cold. This boredom and letting the muscles get cold is something that trainers said to always try to avoid during training. Trainers indicated that they would let the players do other exercises, but ideally, they would have wanted the exercises to be played by several players at the same time.

The components missed by the higher playing and training participants was the creation of dynamic scenarios and adding multiple panels to increase the complexity in the Panel Attack exercise. The Panel Attack exercise should be slightly modified for these participants. The participants were enthusiastic about the purpose of the Panel Attack exercise, but the third level should be more dynamic and

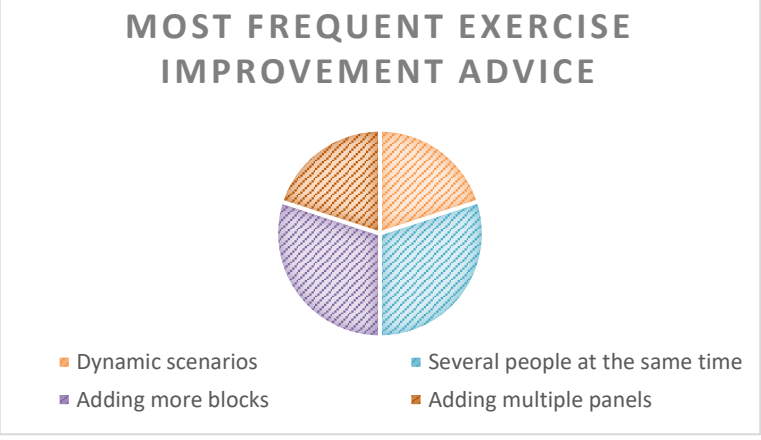

Figure 82 Missing components of the developed exercises

complex than the now static scenarios. Trainers indicated that they should have the option to place the opponents themselves on the playing field instead of the static placement. This is also how they currently train for an opponent by using the full 6 vs. 6 formation. Adding more blocks and multiple panels would also add complexity according to the trainers and players. See figure 82 for an overview of the missing components in the developed exercises. The larger the area of colour, the more the component was missed by the participants.

Missing exercises

Certain exercises were missed by the participants, the missing exercises were the attack approach, the spike technique, more analysis driven exercises and the entire attack game (see figure 83). Especially the attack approach was missed as an exercise because this is seen as the most essential part of the attack, the attack starts with the execution of these 3 or 4 steps. The missing spike technique exercise had to do with training the hand position during the attack spike, in volleyball different hand techniques are used to attack a ball. More analysis driven exercises were missed by trainers and players because these types of exercises provide more self-reflection and insight into their performance. The full attacking game (serve, pass, set and attack) was also missed by a few trainers and players because they train the attack in this manner themselves, it would make the exercise feel more complete if the full attacking game were integrated.

Figure 83 Missing exercises mentioned by the participants

Other attention point

Reliability was occasionally mentioned as a point of attention for the floor and the exercises. It was mentioned that the floor should be reliable to use and should consist of a material that provides enough cushioning and the possibility of diving for the ball.

6.6.5. Answers Regarding the Sub-questions

This section presents the answers regarding the sub-questions of research question 3:

SQ 3.1: *How is the attack currently being trained?*

The results indicate that the exercises used by the participants have similarities with the developed exercises, they overlap with each other by sharing the same goal or competitive experience.
The participants seem to accept the use of floor technology as an aid for training sessions, it takes the pressure off the trainers when preparing for a training session or analysing training data. It is no longer necessary to look for sports hall attributes in advance, the interactive floor can display them. The versatility of the technology really appealed to the participants; every participant indicated that they would like to integrate technology in a training session. Several trainers already used technology in their training, other trainers not yet due to lack of money or inexperience as a trainer.

SQ 3.2: *How is the potential of the developed exercises perceived by trainers and players?*

All participants indicated that the exercises developed represented the subdomain offensive decision-making well. The exercises bring an added value of recognisability, comprehensibility, and usefulness.

Furthermore, the results show that the unique contribution of gamification, level determination, data-driven insight and goal-oriented training enriches the exercises and increases their potential to be accepted. The versatility of the exercises seems to also have a great influence on the willingness to integrate them and use interactive sport-training games technology for training purposes. It was indicated by the participants that this kind of technology and exercises prevents a player from getting bored after performing the exercise several times. The competitive atmosphere during the exercises is also appreciated by the participants, but it should not stifle team spirit by being too competitive. Not all exercises proved to have equal potential for all playing levels, with a few adjustments this can be remedied.

SQ 3.3: *How do people view the suite-of-games approach that is integrated with the interactive floor?*

The conceptual structure of the offensive decision-making aspect was found understandable and logical by all participants because all aspects are interconnected. The acceptance of the structure is partly because trainers and players themselves also divide the training into the technical and tactical dimensions. The results also show that the structure of the exercises and its levels are experienced as logical because of the low threshold. Having a low threshold ensures that people will master a skill more quickly and that learning the skill is considered more fun because it is easier for them. Furthermore, the set-up structure ensures that training can be much more specific and therefore results in more result-oriented training.

The comment made by a player about not finding the sprint exercise to fit under only the attack, reinforces the choices made about the established conceptual structure. The three dimensions can easily be extended to other volleyball sub-domains. The physical skills dimension is structured in such a way that it can also be used for other volleyball skills, which in turn contributes to the versatility of a suite-of-games approach. Finally, the results showed that the entire concept with the interactive floor enriches the training area, the developed system brings a lot of clarification and motivation to the exercises.

SQ 3.4: *Are people willing to use the developed sport-training games system for training purposes?*

The results overwhelmingly show that the participants want to use the interactive floor for training purposes, the participants indicated that they looked with new eyes at the possibilities to train offensive decision-making in volleyball with the help of technology. The willingness to use the developed exercises was also high, the participants were enthusiastic about using different exercises to teach players the skill of offensive decision-making in a new way.

7. Discussion & Recommendations

This chapter will provide answers to the research questions that were defined in section 1.4. Each research question is briefly answered before moving on to the discussion points that emerged from the research question. Finally, this chapter discusses the project's limitations as well as suggestions for future research in this area.

7.1. Research Question 1

7.1.1. Answering Research Question 1

Research Question 1 stated:

How can we develop an interactive sport-training games system that trains the multidimensional construct of a volleyball exercise subdomain by using an interactive floor?

Developing an interactive sport-training games system for a sport with a multidimensional construct roughly consists of the following three components: training with a suite-of-games approach, appropriate levels implementation, and choosing a certain aspect or subdomain. By opting for a suite-of-games approach, the possibility is offered to harmoniously train the multidimensional construct of the sport by means of various exercises. The suite-of-games approach is characterised for its flexibility, capability to present a set of games, fitting a person where each game is adaptable, and the usage of tailored goal settings based on the player's capabilities. To offer the variety of what a suite-of-games is known for, different levels will have to be created. Having these levels provides the tailored experience that a suite-of-games approach is known for. Furthermore, having levels ensures that people are becoming less bored because the player is challenged during the exercises.

Before different exercises with multiple levels can be developed, a choice will have to be made about which aspect/subdomain of the sport will be trained. By focusing on a single subdomain, in this project the offensive decision-making subdomain, more focused exercises can be developed that allow the player to train and therefore perform optimally as a result. This goal orientation ensures that an interactive sport-training games system comes into its own. When determining the subdomain, it is important to determine which subdomain lends best to the interactive floor and its possibilities, because not every exercise form is suitable for integration with the floor. One way to find out which subdomain is suitable for the interactive floor is to hold brainstorm sessions in which exercises are devised for multiple subdomains, which is also done in this thesis project.

After determining the subdomain, all exercises and the associated levels can be worked out and placed under the dimensions and possible sub-dimensions of the multidimensional construct of the chosen subdomain. The way in which the current structure of dimensions and aspects is structured in this thesis makes it largely applicable to other team sports that contain a multidimensional construct, such as football and handball.

7.1.2. Discussion with Literature Findings

In this thesis, I choose to divide the chosen subdomain into three different dimensions: tactical, technical, and physical. Substantiated by the found literature and the evaluation results, this choice was found suitable for training offensive decision-making. Although these dimensions are supported by the literature read, other dimensions could also have been used to represent the multidimensional construct of offensive decision-making. Dimensions such as age category or gender could also have been used. By going with the gender dimension, the developed exercises could respond more to the strength of each gender. For example, research comparing women and men shows that men make more use of their power, whether in jumping, attacking, or serving. Women are more tactical, although the attack plays are slower, the rallies are longer and more complex than with the men [123, 124]. Capitalising on these differences can make for very customised exercises. By using an age category dimension, the exercises become more age-oriented and skill-oriented than what they are

now, because the developed exercises do not target the age of the player but the level of the player. As a result, the current system is not suitable for the youngest volleyball players, but more for volleyball player starting from the C-youth (12 years and older).

Another consideration that has been made regarding the developed exercises, is the trainings context of the Touching Colours exercise. The focus of the Touching Colours exercises is on improving a player's reaction time by using visual cues. However, there is some scepticism around researchers about training reaction time by means of vision systems, as some studies show that the context of the sport is not sufficiently included in these types of systems [125-129] and some studies indicating that vision training does improve reaction time [130-132]. It is therefore not possible to say with certainty that the systems work in the context of the volleyball sport. Because the opinions about the reaction time training by means of vision systems are divided, I decided to put this exercise in the context of a preparatory exercise. The player will thus become acquainted with training the reaction time by keeping his or her concentration, the context of the volleyball sport is therefore less considered.

To train the multidimensional construct of offensive decision-making, the choice was made to use a suite-of-games approach. In section 2.2 the choice and why a point design approach was not chosen was explained. In this explanation, the different approaches are presented as if they were two extremes in the field of design approximation. However, this is not the case with real-life implementations. There are interactive sport-training systems that have implemented a single application but have the potential for many other applications. An example of such an application is The Bouncer interactive handball training installation. The Bouncer now uses a point design approach, the structure of the system is not expandable, and the developed exercises cannot be tailored to the level of the player. Still, The Bouncer has the potential to be converted into a suite-of-games structure, as the handball sport also uses a multidimensional construct. The application has the potential to use a suite-of-games approach by breaking down the exercises so that every element is trained and by making the exercises more player specific by using different levels. Looking at this example, it is not self-evident that a point design approach does not have the potential to evolve into a suite-of-games approach.

7.2. Research Question 2

7.2.1. Answering Research Question 2

Research Question 2 stated:

How is interaction technology viewed in general by trainers and players?

Looking at the results of the thematic analysis, it emerges that the use of interactive technology in general is seen as an added value to training. Trainers and players, regardless of whether they use technology or not, expressed their enthusiasm for the integration of technology in sports. As a result, the concept of the interactive floor was quickly embraced as a new way of training that promotes player motivation, creates more insight into player performance and takes pressure off both trainer and player.

7.2.2. Discussion of the Evaluation Results

The results of the evaluation showing that the participants are enthusiastic about the integration of interactive technology is not entirely surprising; the preliminary research on technology use in the volleyball world already showed that trainers and players are open to technology integration [10]. Offering more and new insights appeals to both trainers and players according to the results. However, it cannot be said with certainty whether all volleyball players and trainers will make use of this interactive technology. Although everyone is positive about the use of technology, there will probably only be a certain group of trainers/players who will use interactive technology. From the results of the interviews, it repeatedly emerged that trainers of smaller clubs and lower playing teams will probably not make use of advanced interaction technology soon because there is not enough

money available. For trainers and players of bigger clubs this does not seem to be a problem, the interviewed trainers of the higher-level teams indicated that they already use different technologies and that they are orienting on new technology for training purposes. What can be said is that there is potential in the use of interactive technology in volleyball. Trainers and players are willing to incorporate technology in training sessions and matches. Therefore, it is not unlikely that through for example subsidies or sponsorships, smaller clubs will also start integrating technology.

The costs for purchasing an interactive floor are currently still too high for clubs. Volleyball clubs also do not have the sports hall under their own management and therefore the placement of an interactive floor will have to be done in consultation with the several parties such as the municipality. The future will show whether LED technology and pressure-sensitive technology will become cheap enough to install such a floor in a sports hall so that several clubs can train on it.

7.3. Research Question 3

7.3.1. Answering Research Question 3

Research question 3 stated:

Are the developed suite-of-games exercises suitable for training the attacking subdomain in volleyball when using an interactive floor?

All participants found the developed exercises suitable for training the subdomain offensive decision-making. Some exercises were considered more appropriate than others, but in general there is a willingness among the participants to include the exercises in their current training sessions. This willingness to use the exercises also has to do with the integration of the interactive floor with the exercises, participants experienced this integration very positively. This positivity stems from the use of gamification in the exercises, the gamification made the exercises visually very attractive and motivating according to the participants. Furthermore, the similarity with existing exercises and therefore expected facile integration with existing training sessions, the data-driven analyses, and the versatility in exercises and levels contributed to the suitability of the developed system according to the participants.
Not all exercises were found suitable for higher level playing teams, certain levels and exercises need to be more challenging and dynamic to be considered suitable for higher level playing teams. The current exercises and levels are considered most suitable for youth and senior teams playing below league level.

Finally, the evaluation results showed that the participants found the established structure of dimensions and aspects logically and therefore obvious for training the subdomain. The division of offensive decision-making into different dimensions corresponded to the division trainers use in their own training sessions. Because of this similarity, the conceptual structure was considered a proper way to train the subdomain.

7.3.2. Discussion of the Evaluation Results

The positive view regarding the developed system seems to be mainly due to the provision of a new way of training. With the use of interactive technology, the developed system provides a modern form of training that allows for new ways of learning a skill. The variety and versatility offered by the developed training exercises reinforces the suitability of the developed system and the integration with existing training courses. Most of the participants (7 out of 9) did not know what the concept of an interactive floor for training purposes entailed. However, it does not seem to have influenced the positive reactions towards the developed system. The participants who knew the least about the interactive floor were the most critical of the system because they were not inhibited by possible limitations of the floor. They also spoke the most about the levels within the exercises being too static. Especially at a higher level there is much more dynamic playing and training happening because a higher performance of the players is required.

Determining the suitability of the exercises is now done based on the characteristics added value to the existing exercises, variety, readiness for use and facile integration. These characteristics have been chosen by own interpretation of the word suitableness within the context of the evaluation and are also mentioned in the interview data. The use of these characteristics can be disputed as other people may associate other characteristics with the word suitableness, because of this the results may differ on the suitability of the exercises to train the offensive decision-making subdomain. In addition to using other characteristics, adding emotions to the dataset could also have provided new or more complete results.

7.4. Limitations

During the thesis project some limitations emerged, these limitations will be discussed in this section.

7.4.1. Limited Published Work

There is limited knowledge of designing interactive sport-training games. A few papers [2, 21] have been written about giving advice on what to look for when designing games within an interactive sports-training environment. The papers state what the design sensitivities and challenges are during the design phase and do not serve as guidelines. The reason for naming them as design sensitivities instead of universal guidelines is because the essential features of interactive sport-training games differ to a great extent. The training games are dependent on their objective, the type of sport that they aim to train and the level of their target group. When designing the exercises for this system, in addition to considering the design challenges and design sensitivities, own interpretation was also used.

7.4.2. Transferability

Even though the developed system is based on a design process involving volleyball experts, design literature, and the participants of the evaluation related the developed exercises to their regular training. It cannot be ensured that a players' offensive decision-making abilities will improve over time by using the developed exercises. Transferability is a challenge when designing digital training exercises [2, 5], because the risk of introducing inexpedient behaviour exists when simplifying or altering the context characteristics of a game situation in order to focus on training a specific skill. Furthermore, because the determination of the aspects has been done by iterative design (start designing, look at what has been designed, talk about the design, and spar with the supervisors and then go back to the drawing board) aspects or dimensions could be missed. This is because it is not possible to determine with certainty that all the aspects within the mentioned dimension cover all the elements of that dimension. For example, while writing this chapter, it emerged that the aspect of endurance is missed under the physical skills dimension, as endurance is an important aspect in being able to perform different actions for a long time within a short time frame.

7.4.3. Evaluation Method

A limitation with the performed evaluation, and a discussion point towards the result, is the inability to conduct a usability testing study due to COVID-19. The participants have based their opinions on the shown exercises digitally, which is not entirely representative as standing on the interactive floor in real life. Standing on the floor creates a completely different experience than seeing the exercises on a screen. By conducting usability testing, it would be possible to find out even better how the exercise is performed from a trainers and players perspective. Unfortunately, due to COVID-19 it was not possible to test the exercises with the participants on the real floor.

7.4.4. Participants

Another limitation that may have affected the results is having participants on women's teams. None of the participants is active in a men's team, neither player nor trainer. This limitation is also partly due to the reduction in the number of participants because no new results were received. Another possible reason for the absence of men's teams is the over-representation of women in volleyball.

Volleyball is a very popular sport among women, but among men not so much. It would have been nice if the participants had also included players or trainers from men's teams. By having both genders in the data set, the results are more representative of the suitability of the exercises. With the current data set, only the female perspective is considered, therefore it cannot be said with absolute certainty whether the results are valid for the entire volleyball population. It is possible that men's teams focus on other aspects than women's teams, or that they find other components of the exercises more important than their female counterparts.

The limitation could perhaps be avoided if specific requests were made for men's teams. In this project, clubs were approached that have several men's teams, but none of them responded to the invitation for an interview.

7.5. Recommendations

This section describes the future research directions and recommendations for the work described in this thesis. The section is divided into two parts. The first section provides research directions for future work and the second section provides some explicit suggestions for future work on the developed system.

7.5.1. Future Work

In their current set-up, the developed exercises classified under different aspects that together as a whole train the subdomain offensive decision-making. Each exercise is conceptually designed to focus on training a single dimension, be it tactical, technical, or physical. However, certain exercises contain elements that are both tactical and technical or explosive and tactical, these exercises require the player to combine several dimension or aspects to execute the exercise. The Panel Attack exercise is one such exercise, although unintentional, that contains tactical and technical elements. The tactical element is to find the right panel and the technical element is to use the different spike techniques to get the ball there. Thus, the player makes use of the aspects: reading opponents, cognitive processing speed, execution variability and accuracy for the execution of the exercise.
For future work it would be interesting to design exercises that cover this mid-spectrum, exercises that combine multiple aspects to train a particular subdomain. The current suite-of-games implementation already does this unconsciously with various exercises (Panel Attack, Take Aim and Touching Colours), but it would be interesting to see how structures could be designed for that.

Another interesting research for future work is a field study that looks at the influence on team spirit when players know each other’s playing level within an exercise. Most coaches and players indicated that being able to see at what level a player is training within an exercise can create friction within the team and reduce the team spirit. By conducting a small field study on this, it can be found out whether these statements are correct and whether this has consequences for the use of the different levels within the exercises.

In addition to conducting a study on the influence on team spirit, it is also interesting to see whether the used suite-of-games approach with an interactive floor can also be used for other purposes. Like other domains within volleyball; serving or setting, or for other sports such as football. Finally, it could also be examined how the suite-of-games framework holds up in another system with a different sport than volleyball.

Finally, future research will have to look at where the developed exercises fit into a training program. Because although the exercises designed, implemented, and tested by me were found to be suitable for training the subdomain, it has not been concluded where in the training program the exercises will perform at their best. Some participants indicated that they saw the Sprint exercise as a warm-up exercise, therefore this exercise could be performed at the beginning of the training. With the other exercises it was less clear where the participants would like to place the exercises in a training.

7.5.2. System Improvements

This section provides a list of suggestions that can be considered to improve the developed system. The suggestions mainly concern the extension of the developed exercises, many of these suggestions emerged during the interviews.

Customisation exercises

One of the suggestions that was frequently made is to make the exercises more dynamic and thus more challenging, especially for players and trainers of a higher level. Making the exercises dynamic means that the trainer can provide input regarding the difficulty of the exercises by, for example, determining the layout of the Sprint exercise via a second screen, adding more blocks or by using the Panel Attack exercise to add more panels. This customisation is also important when training on opponents, currently the training is adjusted at a higher level to the opponent against which the team will play the upcoming weekend. By giving field players the opportunity to participate in the various exercises, the trainer can better prepare his players for the next match.

Multiple player detection

Another improvement for the developed system is the detection of multiple players on the floor. This detection was deliberately left out in this project because the floor was not yet accurate enough to detect multiple people. For future work, this is recommended to implement because it offers many more possibilities for the entire team to train on the floor. In the interviews it also emerged that it was a pity that the exercises can mainly be performed by a single person, their preference was that several people could work on the floor at the same time to prevent the players from getting cold and getting injured.

Smart devices integration

Finally, the suggestion was made to let the interactive floor work together in combination with smart devices so that an even more targeted result emerges that helps the player to improve its performance. The combination of interactive floor and smart devices is expected to provide trainers and players with more precise feedback. In addition, more exercises could be developed, such as the 4-step attack approach.

8. Conclusion

This thesis aimed to explore the possibility of developing an interactive sport-training games system that together with the integration of an interactive floor offers an addition to traditional volleyball training. The developed system has achieved this goal by accommodating the multidimensional construct of volleyball using a suite-of-games approach. Although the research done shows that a suite-of-games approach is not as straightforward as initially thought, the first steps have been taken. Therefore, I think that this thesis offers at least an illustration of how one could design a framework for multidimensional sports constructions. In addition to providing a design illustration, the evaluation regarding the developed system has shown that people are open to integrating this technology in today's training sessions and the developed exercises are suitable for training offensive decision-making. There will still need to be some refinements to the exercises, such as the complexity and dynamics, to make them appropriate for higher-level teams, but most of the participants wanted to integrate the exercises directly into their training as they are now.

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Appendices

Appendix A: Research Protocol Sprint Exercise

Appendix B: Information Brochure

Appendix C: Consent Form English

Appendix D: Consent Form Dutch

Appendix E: Interview Questions English

Appendix F: Interview Questions Dutch

Appendix A: Research Protocol Sprint Exercise

Research Protocol Sprint exercise

Purpose

This research protocol evaluates whether there is less cognitive load in volleyball players during a sprint exercise when visual cues are presented.

Participants

People from the age of 18 who are holding a volleyball trainer or player position. The participant must also have no injury as he/she must perform sprint exercises.

Study Design

Type of study. For this research, a cross-sectional study is conducted. The observation of the participants executing the sprint exercise is done at a single point in time. The participants must perform the exercise on the day of conduction. Subsequently, the result of this research protocol will be mainly based on the opinions that arise during the performance of the exercise.

Recruitment. The trainers and players are randomly recruited by contacting different volleyball associations. An email will be sent to the volleyball clubs asking if there are trainers or players available who want to participate in the study. When participants report to the researcher, an information brochure is distributed containing more information about what exactly is expected of participants during the research. If participants are still enthusiastic, they are asked to sign a consent form, when this form is signed, the participant can participate in the research. A time and date are agreed with the participant to carry out the survey, the location of the survey depends on where the interactive floor is located. The aim is to recruit 10-15 participants for this study.

Measurement. The participants are asked several questions before they perform the sprint exercise. They are asked at what level they currently train or give training at and how they currently train the sprint. After answering the questions, the concept of the interactive floor and the purpose of the sprint exercise will be explained, then the participants will perform the sprint exercise. During the practice of the sprint exercise, the participant is observed. The participant provides then immediate feedback on their experiences with the floor and its sprint exercise. When all levels of the sprint exercise have been completed, a short interview session is held with the participant in which he or she could share experiences they have not voiced before. With all the data from the objective observations and interviews, the hypothesis can be answered. All the interviews and observations will be done by the assigned researcher.

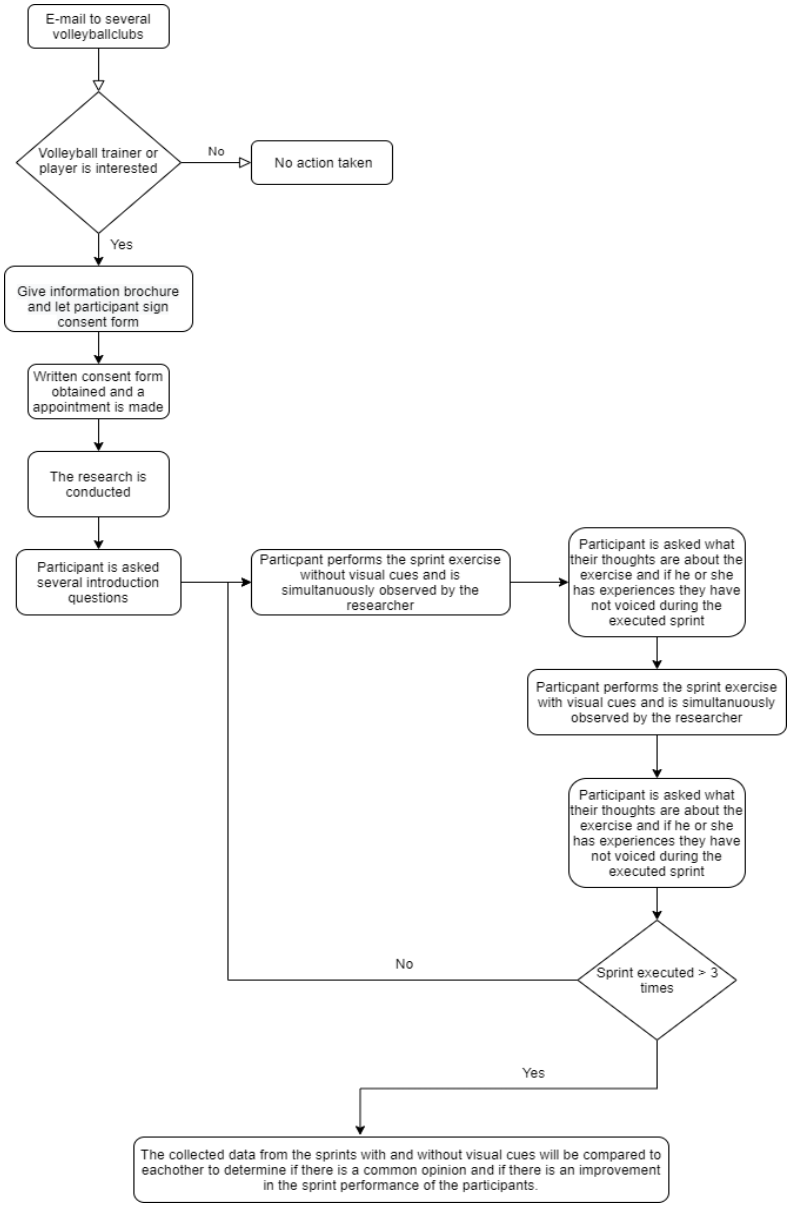
Sprint exercise. The sprint exercise consists of two parts, one part with and one part without visual cues. The player starts the first level of the sprint exercise without visual cues, the player is told how to run the sprint and then the player will be asked to perform the sprint. The time of the sprint is recorded and the accuracy of the player in taking the sprint is looked at. After the sprint is completed the player is asked how he or she experienced the sprint, for example what difficulties there were. After performing this sprint, the player will do the same sprint again, only now there are visual clues, the entire sprint parkour is shown entirely on the floor so that the player knows exactly where he or she must run. The same observation is performed again, and the player is asked about his or her experience with the sprint exercise now that the visual cues are present, including whether the player could now focus more on himself now that the parkour was visible in its entirety. This series of observation and questioning afterwards is done six times in its entirety, three times without visual cues and three times with visual cues. With each round a new level is shown, so for example the second time a player must do a sprint without visual cues, the second level of the sprint exercise will

be shown. During the exercise, the participant is free to give his or her opinion about the exercise at any time. The research will take about an hour and a half per participant.

Data analysis. The data resulting from the different sprints are compared, for example, it is compared whether the speed of the player has improved compared to the sprints without visual cues, if the footwork of the player is performed neater and the difference in posture of the player during the different sprints. In addition to comparing this dataset, the unstructured interview data is divided into themes to draw conclusions about the data. All the analysed data is then combined and compared with the data of the other players, differences and similarities between datasets will be written down. Finally, with the written results the research question can answered.

Expected results. The expected result is that the cognitive load becomes less and therefore the footwork of the volleyball players during the sprint exercise will be performed more tightly because the entire parkour is shown by means of visual cues. It is expected that showing the entire sprint parkour decreases the cognitive load of the volleyball player because he/she does not have to memorise the exact route of the sprint parkour, this has the advantage that the player can focus more on him- herself and therefore improve his/her footwork and speed.

Study Outline



Appendix B: Information Brochure

Achtergrond
Technologie speelt een steeds grotere rol in ons leven, het helpt ons beter te presteren en gezonder te leven. Ook tijdens het sporten wordt er steeds vaker gebruik gemaakt van technologische innovaties: van slimme digitale sporthorloges tot doellijn technologie voor de videoscheidsrechter in voetbal.

Aan de Universiteit Twente, in samenwerking met het Windesheim Zwolle en LedGo BV, doen we onderzoek naar sport en technologie. Op het moment zijn we bezig met de ontwikkeling van toepassingen voor een 'slimme' sportvloer voor volleybal, waarmee meer mensen beter en leuker zouden kunnen sporten.

Dit interactieve volleybalveld maakt gebruik van druksensoren en LED-technologie om spelers in real-time van visuele feedback te voorzien over hun sportprestaties. Zo kan de vloer bijvoorbeeld direct informatie in het veld tekenen over hun sprongkracht, timing, en spelinzicht.

Het huidige onderzoek, geleid door de Universiteit Twente, is erop gericht om volleybaltrainers- en spelers in aanraken te laten komen met de 'slimme' sportvloer om vervolgens in kaart te brengen wat de acceptatiegraad onder de trainers en spelers is bij het gebruik van zo'n vloer met bijbehorende oefeningen voor trainingsdoeleinden.

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ZonMw

Windesheim
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INNOVATIE IN BREEDTESPORT

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INFORMATIEFOLDER
PROJECT: SMART SPORTS EXERCISES
(INTERACTIE-TECHNOLOGIE IN VOLLEYBAL)

In deze brochure staat informatie over het onderzoeks-project: *Smart Sports Exercises in Volleybal*. De brochure helpt je beslissen of je mee wil werken aan het onderzoek.

Sharon Engbers – s.f.engbers@student.utwente.nl

Onderzoeksprocedure
Door middel van interviews zal informatie verzameld worden over de acceptatiegraad van de 'slimme' sportvloer.

In deze folder zal uitgelegd worden wat het voor u betekent om aan het onderzoek mee te doen. U beslist zélf of je deel wilt nemen. Voor vragen kunt u contact opnemen met Sharon Engbers, contactgegevens op de voorkant.

Deelname
Deelname is geheel vrijwillig. U kan op ieder moment, zonder opgaaf van reden, aangeven dat u niet meer wil meedoen.

Wat gebeurt er tijdens het interview?
Het interview is met name bedoeld om de acceptatiegraad onder volleybaltrainers- en spelers in kaart te brengen met betrekking tot het gebruik van de 'slimme' sportvloer met de ontwikkelde oefeningen voor trainingsdoeleinden, met de gedachte dat geld geen rol speelt. Er zijn diverse oefeningen met verschillende spelniveaus ontwikkeld voor de sportvloer, deze oefeningen zullen gedurende het interview digitaal uitgevoerd en getoond worden door de onderzoeker. Vervolgens wordt na het laten zien van deze oefeningen om uw mening gevraagd over de intuïtiviteit, het design en de moeilijkheidsgraad van de oefeningen. Voorbeelden van oefeningsvormen die worden getoond tijdens het interview zijn: sprint, reactievermogen, spelinzicht en sprong.

Welke gegevens worden er verzameld?
Tijdens het onderzoek worden er schriftelijke notulen gemaakt van de gegeven antwoorden op de interviewvragen en zal het interview opgenomen worden.

Hoe worden de gegevens bewaard?
De data wordt veilig bewaard en anoniem verwerkt volgens AVG-richtlijnen. Onderzoeksgegevens worden volgens VSNU-richtlijnen minimaal 10 jaar bewaard.

Wie heeft er toegang tot de data?
De interviews zijn enkel toegankelijk voor mensen betrokken bij dit onderzoek. Een lijst met namen van mensen die toegang hebben tot het materiaal is beschikbaar en kan worden opgevraagd bij Sharon Engbers.

Hoe worden de gegevens gebruikt?
De gegevens worden geanalyseerd voor wetenschappelijk onderzoek. Dit wordt gepubliceerd in wetenschappelijke artikelen en in de 'gewone' media, waarbij volledig *anonieme* resultaten op basis van de gegevens gepresenteerd worden. Hoogstens zal er een anonieme interview quote gebruikt worden in een artikel. De gegevens worden mogelijk ook gebruikt door de onderzoekers van dit project voor vervolgonderzoek, passend binnen de kaders van deze brochure. Verder worden de resultaten gebruikt als inspiratie voor het ontwikkelen van nieuwe trainingsvormen met slimme technologie.

Worden er gegevens van mij publiek gemaakt?
Onderzoeksmaterialen waar je op te herkennen bent worden nooit publiek vertoond, ook niet voor demonstratie, promotiedoeleinden, of media.

Kan ik mijn gegevens laten verwijderen?
Als je tijdens of direct na het interview besluit dat je niet (meer) wil meedoen worden al je gegevens van die sessie verwijderd. Als de onderzoeksmaterialen eenmaal anoniem gemaakt zijn kunnen ze niet meer aan jou gekoppeld worden en kunnen ze dus ook niet meer verwijderd worden.

Meer informatie en onafhankelijk advies.
Wil je graag onafhankelijk advies over meedoen aan dit onderzoek, of een klacht indienen? Dan kan je terecht bij Petri de Willigen, secretaris van de Ethische Commissie (tel. 053-489 2085, ethics-comm-ewi@utwente.nl). Deze commissie bestaat uit onafhankelijke deskundigen van de universiteit en is beschikbaar voor vragen en klachten rondom het onderzoek.

Voor vragen kan je verder terecht bij de onderzoeker, contactgegevens op de voorzijde van deze folder.

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Appendix C: Consent Form English

INFORMED CONSENT FORM

Purpose of the research
This research, led by the University of Twente and the Windesheim University of Applied Sciences, aims to develop a suite of smart sports exercises that can be used with a next-generation interactive floor in volleyball.

Research: Interaction Technology in Volleyball
I hereby declare that I am fully informed about the purpose of the research, the research procedure and the relevant research methodology. I have read and I understand the provided information and have had the opportunity to ask questions. I give my consent for the collection of anonymized data, the kind of which has been described in the information brochure. I give my consent for recording audio and video for research and evaluation purposes.

Any (video) data will solely be accessible to researchers affiliated with this research and will never be made public. None of the research data will be used for promotional purposes without explicit consent. All data will be treated and stored according to the rules and regulations of the AVG and the GDPR. All data will be stored for a minimum of 10 years, conform the NVSU-guideline. You have the 'right to be forgotten', which means that you can request your data to be erased from the research database if you wish. Your consent will be valid for the remainder of the academic year (until 31-08-2019).

I understand that my participation is voluntary and that I am free to withdraw at any time, without giving a reason and without cost.

☐ Hereby, I also grant permission for sharing the video recordings with my trainer / coach. Other data, like interviews and sensor data, may also be shared but only after consultation.

City:

Date:

Full name:

Signature:

.....

Principal investigators:
Dennis Reidsma[1], Robby van Delden[1], Dees Postma[1], Sharon Engbers[1], Bert-Jan van Beijnum[2], Fahim Salim[2], Ivo van Hilvoorde[3], Jeroen Koekoek[3] and Wytse Walinga[3]
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[2]University of Twente | Electrotechniek, Wiskunde en Informatica | Biomedical Signals and Systems
[3]Windesheim University of Applied Sciences | Human Movement, School and Sports

Contact information
If you have any questions concerning this research, please contact Dennis Reidsma (d.reidsma@utwente.nl), any of the researchers on site or the secretary of the Ethics Committee (ethics-comm-ewi@utwente.nl). The Ethics Committee is composed of highly trained research-professionals affiliated with the University of Twente. The Ethics Committee is available for any questions or complaints you might have regarding the research.

Appendix D: Consent Form Dutch

TOESTEMMINGSVERKLARING (INFORMED CONSENT)

Betreft
Onder leiding van de Universiteit Twente en het Windesheim wordt er in dit project onderzoek gedaan naar de inzet van 'slimme' technologie voor het verbeteren van training- en sportprestatie voor volleybal.

Onderzoek: Interaction Technology in Volleyball
Ik verklaar hierbij dat ik volledig geïnformeerd ben over het onderzoek. Het doel van het onderzoek en de daarbij behorende methodes zijn mij uitgelegd, waarbij ik de ruimte heb gehad om vragen te stellen. Ik geef toestemming voor het verzamelen van geanonimiseerde onderzoeksmaterialen zoals beschreven in de bijgeleverde informatiebrochure. Ik geef toestemming voor het maken van video-opnames voor onderzoek en evaluatie.

Enig beeldmateriaal wordt enkel door betrokken onderzoekers bekeken en zal nooit openbaar gemaakt worden en/of vertoond worden aan derden voor demonstratie of rapportage. Al het onderzoeksmateriaal zal verwerkt en opgeslagen worden conform de regels en richtlijnen van de AVG en de GDPR. Alle data wordt voor een minimum van 10 jaar opgeslagen, conform de NVSU-richtlijn. U heeft het 'recht om vergeten te worden', wat betekent dat alle eerder verzamelde gegevens van u verwijderd kunnen worden als u dat wilt. De hierbij verleende toestemming hoeft slechts eenmalig verstrekt te worden en is geldig voor de rest van het academisch jaar (tot 31-08-2019).

Ik begrijp dat ik mijn deelname op ieder moment, zonder opgaaf van reden, mag en kan beëindigen zonder dat hieraan enige consequenties verbonden zijn.

☐ Ik geef tevens toestemming voor het delen van ten minste de videodata met mijn trainer/coach. Overige data, zoals interviews en sensordata, worden enkel beschikbaar gesteld met expliciete goedkeuring.

Plaats:

Datum:

Naam:

Handtekening:

.....

Hoofdonderzoekers:
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Contact informatie
Mocht u vragen hebben over dit onderzoek, dan kunt u contact opnemen met Dennis Reidsma (d.reidsma@utwente.nl), een onderzoeker ter plaatse of bij de secretaris van de Ethische Commissie (ethics-comm-ewi@utwente.nl). De Ethische Commissie bestaat uit onafhankelijk deskundigen van de universiteit en is beschikbaar voor eventuele vragen en klachten rondom het onderzoek.

Appendix E: Interview Questions English

- How would you divide the game insight into dimensions during the attack?
- What exercises do you use when training the offense with your players?
    - Which exercises do you use the most?
    - Do you use any tools in those exercises, and if so, what is used?
    - Do you focus on certain aspects of the offense or do you train the offense as a whole?
    - Which exercises do your players like the most?
- What did you notice first when showing the exercises?
- What is your opinion regarding the execution of the exercises?
    - Are they too difficult to understand or not and why?
    - Are the exercises not related enough to training the offense?
- How do you look at the integration of different game elements in the exercises? (E.g., lights, time, or sounds)
    - Does having for example a competitive atmosphere in an exercise add value?
    - Do you find the game elements distracting? Why or why not?
- How do you view using the different game levels to teach a skill?
    - Does having multiple levels give the player a better starting position in learning the skill in your opinion?
- Do you see added value in using the exercises shown to train the offense?
- Does any of the exercises correspond to exercises you use yourself in training?
    - Yes
        - What kind of exercise? What is the purpose of that exercise? What is the similarity?
    - No
        - Does it appeal to you to include such an exercise and why not?
        - In what ways are your exercises different from the implemented exercises?
- Are there any exercises that you do not find appropriate for training the attack? And why not?
- Are there any exercises that you would have expected in training the attack that were not mentioned?
- Looking at the exercises shown, how do you view the use of the interactive training floor for training purposes?
    - Positive:
        - What exactly appeals to you about the floor? (Game element-new way of training)
    - Negative:
        - What do you find disappointing? (Not trustworthy, difficult to understand, requires too many extra steps)
- What do you think about the fact that several dimensions are considered to train the attack?
    - Do you think this has an added value?

In addition to the interactive floor being used to teach players skills by having them perform exercises, the floor can also be used as a support for the trainer. The attacking jump exercise showed this by displaying various statistics on the floor and thereby giving the trainer an insight into the player's jumping power.

- How do you see the supporting role of the floor?
- Do you think it has an added value in training or not?

Trainer:

- If money were no object, would you include the interactive floor in your training program?
    - Yes:
        - Based on what points would you like to use such a floor?
        - Would you also include the exercises shown in your training program and why or why not?
    - Not:
        - What reason(s) do you have for not using such a floor?

Player:

- Would you like to use such a floor to train offense?
    - Yes:
        - Based on what points would you like to use such a floor?
        - Would you also like to use the exercises shown during training and why or why not?
    - Not:
        - What reason(s) do you have for not using such a floor?

Appendix F: Interview Questions Dutch

- Hoe zou u het spelinzicht gedurende de aanval opdelen in aspecten?
- Welke oefeningen gebruikt u bij het trainen van de aanval bij uw spelers?
    - Gebruikt u bij die oefeningen ook hulpmiddelen, en zo ja wat wordt er gebruikt?
    - Legt u de focus op bepaalde aspecten van de aanval of traint u de aanval in zijn geheel?
- Wat viel u het eerste op bij het tonen van de oefeningen?
- Hoe kijkt u naar de uitvoering van de oefeningen?
    - Zijn ze te moeilijk te begrijpen of juist niet en waarom?
    - Zijn de oefeningen niet genoeg gerelateerd aan het trainen van de aanval?
- Hoe kijkt u naar de integratie van verschillende game-elementen in de oefeningen? (E.g. Lichten, tijd of geluiden)
    - Heeft het hebben van bijvoorbeeld een competitieve sfeer in een oefening een meerwaarde?
    - Vind u dat de game-elementen afleiden? Waarom wel of waarom niet?
- Hoe kijkt u naar het gebruiken van de verschillende spelniveaus om een vaardigheid aan te leren?
    - Geeft het hebben van meerdere niveaus de speler een betere uitgangspositie bij het leren van de vaardigheid volgens u?
- Ziet u meerwaarde in het gebruik van de getoonde oefeningen voor het trainen van de aanval?
- Komt één van de oefeningen overeen met oefeningen die u zelf ook gebruikt in trainingen?
    - Ja
        - Wat voor een soort oefening? Welk doel heeft die oefening? Wat is de overeenkomst?
    - Nee
        - Spreekt het u aan om zo'n oefening op te nemen en waarom wel/niet?
        - Op welke manier zijn uw oefeningen anders dan de geïmplementeerde oefeningen?
- Zijn er oefeningen die u niet vindt passen bij het trainen van de aanval? En waarom niet?
- Zijn er nog oefeningen die u had verwacht bij het trainen van de aanval die niet genoemd werden?
- Gezien de getoonde oefeningen, hoe kijk u naar het gebruik van de interactieve trainingsvloer voor trainingsdoeleinden?
    - Positief:
        - Wat spreekt u precies aan bij de vloer? (Game-element/nieuwe manier van trainen)
    - Negatief:
        - Wat valt u tegen? (Niet te vertrouwen/te moeilijk te begrijpen/vergt te veel extra stappen)
- Wat vindt u ervan dat er meerdere aspecten worden gepakt om de aanval te trainen?
    - Heeft dat een meerwaarde volgens u?
- Naast dat de interactieve vloer ingezet wordt om spelers vaardigheden aan te leren door oefeningen uit te laten voeren kan de vloer ook als ondersteuning gebruikt worden voor de trainer. De getoonde aanvalssprong oefening liet dit zien door op de vloer verschillende statistieken weer te geven en daarbij de trainer een inzicht te geven in de sprongkracht van de speler.
- Hoe kijkt u naar de ondersteunende rol van de vloer?
- Heeft dit een meerwaarde in het training geven volgens u of juist niet?

Trainer:

- Zou u, als geld geen rol speelt, de interactieve vloer willen opnemen in uw trainingsprogramma?
    - Wel:
        - Gebaseerd op welke punten zou u zo'n vloer willen gebruiken?
        - Zou u ook de getoonde oefeningen willen opnemen in uw trainingsprogramma en waarom dan wel of niet?
    - Niet:
        - Welke reden(en) heeft u voor het niet gebruiken voor zo'n vloer?

Speler:

- Zou u met zo'n vloer willen gebruiken om de aanval te trainen?
    - Wel:
        - Gebaseerd op welke punten zou u zo'n vloer willen gebruiken?
        - Zou u ook de getoonde oefeningen willen gebruiken tijdens de training en waarom dan wel of niet?
    - Niet:
        - Welke reden(en) heeft u voor het niet gebruiken voor zo'n vloer?