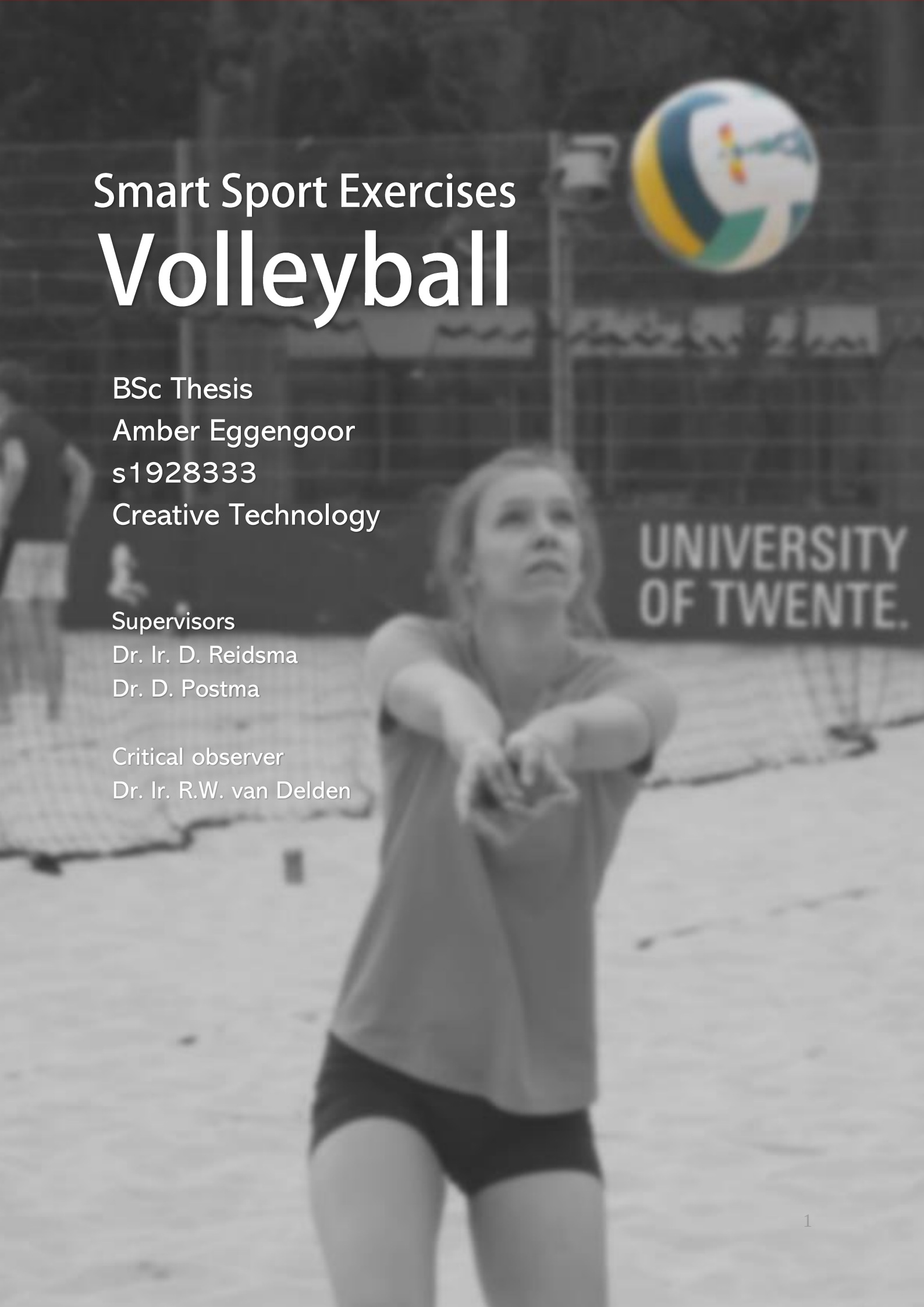

Smart Sport Exercises
Volleyball

BSc Thesis

Amber Eggengoor
s1928333
Creative Technology

Supervisors
Dr. Ir. D. Reidsma
Dr. D. Postma

Critical observer
Dr. Ir. R.W. van Delden

Abstract

This thesis presents the work that creates and tests novel ways to train volleyball with the use of an interactive system. This thesis is part of the Smart Sports Exercises project, which investigates the potential for interaction technology in creating rich learning environments for interactive sports exercises.

The goal of the work is to find the potential of an interactive LED-floor in volleyball practice and to come up with meaningful digital-physical exercises that add to traditional volleyball practice. Related work and insights from other researchers, volleyball trainers, and volleyball players are discussed, and this information is used to construct a design space to map the opportunities of the interactive floor in a volleyball practice. Several lo-fi prototypes are tested to gather more insights into the desired digital interactive exercises related to volleyball. Later, several hi-fi prototypes were used to see how the created exercises turn out on an interactive floor. Finally, an experimental research study is proposed to experimentally study the merits of the interactive floor to improve upon traditional training approaches.

This work showed that the interactive floor is promising in a volleyball practice. Next, this research is an important practical step towards integrating an interactive floor with volleyball practices. After finding the potential in volleyball practices, it is recommended to look at other (team) sports to make the interactive floor more appealing and economic feasible.

Table of contents

Acknowledgements

Foremost, I would like to thank my supervisors Dr. Ir. Dennis Reidsma and Dr. Dees Postma for the support, motivation, enthusiasm, knowledge, and time. Both supervisors helped me writing my thesis and I cannot imagine having better supervisors.

Besides my supervisors, I would like to thank my critical observer Dr. Ir. Robby van Delden. He helped me to get in contact with the rest of the Smart Sport Exercises Team, and this helped me a lot during the testing phase.

My sincere thanks to all the participants that helped me during this project. This project would not have ended like this without the expertise and knowledge of the participants.

Last but not least, I would like to thank everyone who listened to me while I was quite ‘too’ enthusiastic about this project.

1. Introduction

The use of technology raise enormously over the past few years [1]. Almost everyone seems to be interested in and obsessed with knowing exactly how many steps we took today. Therefore, many companies are researching the subfield of interactive technology. However, such systems, for example, smart watches or step counters, are often focussed on the health obsession. However, the domain of interactive digital sports exercises has gotten little attention from the scientific community. That domain focuses on creating novel ways to train a particular sport with the use of an interactive system, which is interesting for athletes, trainers, and researchers. Those systems have the potential to develop exercises that are more productive, enjoyable, and easier to understand [2].

This thesis is part of the Smart Sports Exercises project of a research group within the domain Human Media Interaction (HMI). This research group works on "Playful Embodied Interaction with Motivational Aspects." The research group focusses on the context of interactive sports exercises and sees the opportunity to make use of dynamic elements to transform how sports are being trained and played.

The Smart Sports Exercises project focuses on volleyball to investigate the potential for interaction technology in creating rich learning environments for volleyball. The technology used for this thesis is the LED floor or the interactive playground, both located in the Design Lab of the University of Twente. Both the LED floor and interactive playground make use of dynamic visualizations, which can be alternatives for in a volleyball training. However, the LED floor makes use of pressure-sensitive capabilities, which is helpful during interactive digital exercises.

The main research question for this thesis is: *What is the potential of the interactive LED-floor to improve upon traditional (existing) training approaches, and how can this be implemented in a volleyball practice?* This question is answered throughout this thesis.

The goal of this thesis is to come up, test and evaluate meaningful digital-physical exercises that add to traditional volleyball practice. The ideation of 150 concepts is a tool used in this thesis to achieve that goal. The design space, created for this thesis, guides the ideation phase. Insights from other researchers, volleyball trainers, and volleyball players are gathered to create a design space. This design space is filled with related work to see whether and where there is room for new digital-physical exercises. The finished design space can guide the brainstorm session and can help to generate 150 ideas. Later, the 150 ideas are translated into 7 lo-fi prototypes which are tested and evaluated. The lo-fi testing phase also functions as inspiration for improving the lo-fi prototypes into hi-fi prototypes. The hi-fi prototypes help to see how the created exercises work on an interactive floor. Suggestions for improvements will follow. Next, this thesis proposes an experimental research study to prove that the interactive floor can help to explain the volleyball system. In the end, the conclusion, contributions, limitations, implications, and future work are discussed.

2. Context Analysis

First, the capabilities of the LED-floor and the aspects of a volleyball practice have to be discussed to be able to find the potential of an interactive LED-floor in volleyball practice. These is done with literature research, interviews and observations.

2.1 Research question

The main research question of this section is:

> **How would an interactive LED-floor be useful in a nowadays volleyball practice?**

To answer this broad research question, multiple sub-questions are made:

1. How do volleyball athletes train nowadays?
2. What kind of team sport exercises exists?
3. What factors influence motivation in sports practice?
4. What are the current difficulties in volleyball practice?
5. What kind of interactive digital-physical exercises exists?
6. How can an interactive system be implemented in a volleyball practice?
7. What factors influence the outcome of an exergame?
8. What are the technical aspects of the interactive floor?

2.2 Approach

Multiple approaches are used to find a detailed answer to the sub-questions. Ethnographic methods, interviews, and literature research are used in this thesis. Questions categorized to the ethnographic approach will be answered by observing real-time practices and videos. Questions categorized to the interviews will be answered through interviews that are prepared, held, and discussed. Questions categorized to literature research will be answered through discussing research papers.

Literature research

Questions 1, 2, 3, 5, 6, 7 and 8 can be answered with literature research. The research will be done using searching engines like Google Scholar, Scopus, and the University of Twente library. First, the study will be about related work, where exergames and interaction technology in sports are discussed. Second, the study will be about the interactive floor itself and his technical specifications. Lastly, the study will be about volleyball practice, where small-sided games are discussed since they are the most popular exercises used in a team sport practice.

Interviews

Questions 1, 2, 3, and 4 can be answered with interviews. P.E teachers who teach volleyball. Volleyball trainers and volleyball players are asked to participate in an interview.

Ethnographic approach

Questions 1, 2, and 3 can be answered by observing real-time practice.

2.3 Literature research

2.3.1 Related work of exergames

Exergames are games that rely on technology that tracks body movement and reaction. Many exergames make use of an interactive floor. Yoonsin Oh and Stephen Yang [3] explored the various terms used for exergames in other literature. Exergames are defined as videogames that require physical activity in order to play, by Yoonsin. Yoonsin reviewed the work of Caspersen et al. [4], who discussed the difference between exergames and physical activity. A new definition of exergaming is made; "*an experiential activity in which playing exergames or any videogames that require physical exertion or movements that are more than sedentary activities and also include strength, balance and flexibility activities."* The definition created by Yoonsin [3] is used in this thesis to review related work of exergames. Exergames differ from each other and can be divided into different categories. All the exergames discussed in this thesis makes use of an interactive surface (floor/wall). In order to discuss the exergames in a structured way, the exergames are categorized based on their implementation. There are three categories used in this thesis.

- Exergames with LED light and touch sensors
- Exergames with projections of colorful graphics
- Exergames with a physical object and an interactive surface

Different examples of related work are discussed below in the thee just mentioned categories. This information functions as background knowledge while creating the design space (chapter 3). Next to that, looking at existing work inspires the brainstorm sessions in the ideation phase (chapter 4).

Exergames with LED lights and touch sensors

Pavigym Prama[1] is an intelligent interactive floor with LED lights that are controlled by touch-sensitive sensors. The Pavigym Prama enables the athlete to design and track their performances. Pavigym Prama supports and guides the athlete to step in a particular place at a specific moment. Working out on the Pavigym Prama provides a method of distraction and helps the athletes to give a regular exercise such as push-ups, meaning, and an end goal. The Pavigym Prama is visible in figure 2. Another example of an exergame that uses LED lights and touch sensors is the LEDflex[2]. The exergames with LED lights and touch sensors is skill-related and can teach individual skills without its context. For example, reaction time and movement speed. However, the disadvantage is that these exergames are not in a real-game context. So, the intensity of the exergame differs from the real-game. Next to that, the athlete has a smaller movement area compared to a real game. During the exergame, feedback is given to motivate the athlete to push harder or take that extra step.

[1] https://www.motionfitness.com/Prama-Fitness-Platorm-p/prama.htm
[2] https://www.paviflexgymflooring.com/ledflexen

Figure 2: Pavigym Prama

Exergames with projections of colorful graphics

The interactive floor can be placed vertically or horizontally, as a wall or as a floor. Lumo Play[3] is an example of an installation that can project exergames on both a vertical and horizontal surface. Lumo Play can be seen in figure 3, where it is placed vertically.

Figure 3: Lumo Play

Lumo Play is an interactive display software that can turn walls and floors into engaging, motion-reactive environments in order to create an interactive experience. Other examples of those installations are Luminvision[4], Beamwall[5], MotionMagix[6], BubblePopper[7]. Those installations are often called virtual playgrounds because it allows multiple players to interact with playful, colorful graphics and sounds, and there is a wide range of games/environments. The exergames that make use of projections with colorful graphics allow more players since the interactive floor is the only equipment needed and can be used by multiple players at the same time. These exergames can also be used as a playground. The players can just walk over the floor to see what happens instead of using the floor as an intensive exercise.

Exergames with an interactive surface and a physical object

Exergames can also be combined with a physical object. In the example of Smartjump[8] the interactive wall is combined with a trampoline that is connected to sensors. The character in the game jumps virtually when the player jumps physically. Smartjump is shown in figure 4.

[3] https://www.fitness-gaming.com/news/events-and-fun/lumo-play-transforms-walls-and-floors-into-immersive-motion-reactive-environments.html
[4] https://luminvision.com/
[5] https://www.exergamefitness.com/products/active-wall-games/eyeplay-wall/
[6] http://www.motionmagix.com/
[7] https://exertiongameslab.org/projects/bubble-popper
[8] https://www.sportinnovator.nl/nieuws/smart-jump-trampoline-via-nsp-van-leisure-naar-topsport/

The player can get points when he jumps at the right moments. Different games can be connected to the trampoline. The player has to exercise with the physical object to be able to achieve the goal of the virtual game. Another example of an exergame that uses a physical object is Hanging on a bar[9].

Figure 4: Smartjump

The exergames that make use of an interactive surface and a physical object can be played with the number of players equal to the number of physical objects or equal to the number of players that can share the same physical object. For example, if there are two trampolines, two players can play the game at the same time. The interactive surface is used as a visualization of the movement of the player. In the example of the trampoline, if the player jumps, the character in the game jumps too. This feedback stimulates the athlete to keep jumping; otherwise, the athlete fails the game (game over) and has to start again.

2.3.2 Interaction technology in sports vs. exergames

The use of technology enlarged enormously over the past few years [1]. Nowadays, we seem interested in and obsessed with knowing exactly how many steps we did today. There is much research in the field of interactive technology, but the domain of interactive digital sports exercises has gotten little attention from the scientific community so far. The domain of interactive digital sports exercises focuses on creating novel ways to train a particular sport with the use of an interactive system, which is interesting for athletes, trainers, and researchers. Those interactive systems have the potential to develop exercises that are more productive, enjoyable, and easier to understand [2].

Interaction technology in sports is not the same as exergames. Exergames have significant potential in improving physical activity and reduce obesity [5]. Exergames mostly focus on physical movement and are, therefore, relatively easier to come up with [5]. Coming up with ideas for interaction technology in sports has more constraints because the focus of interaction technology in sports lies in the development of skills in a particular context. Therefore, the context of the sport has to be emulated in or with the technology. An example of interaction technology in sports is the TacTower [6]. The TacTower is visible in figure 5.

[9] http://www.exergamelab.org/2010/05/exergame-pullup.html

Figure 5: TacTower

The TacTower is designed to motivate the athlete by challenging their psychomotor skills. Psychomotor skills help the athletes to get to know their environment by movement tasks, for example, throwing a ball. The TacTower was made for handball and basketball players. The tower exists of eight plastic 'balls' and is 2,25 meters tall. Hitting a ball on the TacTower with flat hands is similar to how handballs and basketballs are hit in blocks and dribbles. Other examples of interaction technology in sports are SmartGoals[10], Nike Rise 2.0[11], ValoClimb[12] , and T-T-T[13]. These set of interaction technology in sports are examples that goes beyond the existing training techniques. This way of using technology in sports is proved to be promising [5, 6]. The volleyball practice of today has to be investigated to determine where interaction technology and exergames can fit.

2.3.3 The interactive floor

This thesis does not focus on the technical implementation but more on the ideation. Nevertheless, it is essential to consider the technological constraints and limitations of the existing technology as not to stray too far from what is feasible today and the near future.

The current existing technology used in the project of Smart Sport Exercises is the interactive LED-floor with pressure-sensitive tiles and the Inertial Measurement Units (IMU). The interactive floor has four pressure sensors embedded per tile, one sensor in every corner. The pressure-sensitive tiles of the interactive floor can be used to recognize the location of the athletes. Next, it can give insights into the number of people on the floor. An IMU sensor is capable of assessing and monitoring a particular movement. The IMU sensors can be easily attached or strapped around the body of the athlete. The Smart Sport Exercises project makes use of those IMU sensors to classify the athlete's movement as a volleyball specific movement. Those volleyball related movements are attacking, serving, passing, or blocking. The data from the IMU sensors is sent to the interactive floor. Together with the data coming from the pressure-sensitive tiles and the IMU sensors, an athlete can be recognized based on location and movement.

[10] https://smartgoals.nl/nl/smartgoals/
[11] https://www.akqa.com/work/nike/rise-2-0/
[12] https://valomotion.com/valoclimb/
[13] https://ttt3000.de/

The goal of volleyball is to ground the ball on the opponent's court, and to prevent the ball from being grounded on its own court[14]. Therefore, it might be essential to be able to detect the ball if it hits the ground but also if the ball is in the air. The ball could be detected if it hits the ground by the pressure-sensitive tiles of the interactive floor. Ball tracking can be used to detect the ball while it is in the air. Kamble [7] reviewed the different ball detecting techniques based on their performance, advantages, limitations, and their suitability for a particular sport. Kamble claims that using a trajectory-based method for ball detecting has the best prospects of success in a dynamic sport such as volleyball. Chakraborty [8] proved that this trajectory-based method for ball detecting indeed works for volleyball. Chakraborty claims that ball-tracking can help to analyze the game better.

Based on this information, it is assumed that the Smart Sport Exercises project is or will be able (soon) to identify the position of the athletes and their movements and to detect the ball. General volleyball practice is perused to understand where this technology could help to improve a volleyball practice.

2.3.4 Volleyball practice according to literature research

Small-sided games are the most popular exercise game used in team sports training [9-11]. The literature about small-sided games is gathered and discussed because the information on what those games are, how to use them, the advantages, and disadvantages are significant to consider before designing exercises for the same target group. This literature review is written for the subject of Academic Writing in module 11 of Creative Technology. The full literature review can be found in Appendix D: Academic Writing literature review. It gave insights about how volleyball athletes practice nowadays, and this can help to create the gradient lines in the design space of this thesis, which is discussed in the next chapter.

Small-sided games

Small-sided games are considered the most common exercise used in team sports training [9-11]. The literature on small-sided games is gathered and discussed to be able to create interactive digital sport exercises related to volleyball. Volleyball is chosen as the main focus of this paper because there are currently no interactive exercises available for volleyball, and it is the sixth-largest sport in the world [12].

A small-sided game is defined as a game that is a smaller adapted version of the formal team sport, where athletes spent more time with the ball and can develop multiple skills at the same time [9, 11, 13]. Six variables contribute to the intensity of those small-sided games and must be taken into account when designing new small-sided games [9, 11, 13-15].

1. The field dimensions
2. The number of players
3. Rule modifications
4. Coach encouragement
5. Training regimens
6. Game duration

With the definition and the list of six variables in mind, the next step was to research the impact of small-sided games. Small-sided games have an impact on the development of volleyball-

[14] http://www.fivb.org/thegame/Fundamentals.htm

specific skills, physical and cognitive performance [16-18]. However, if the level of the players carrying out the small-sided games makes a difference in skill development has not been thoroughly researched yet.

To be able to see the potential of small-sided games, the advantages and disadvantages are compared. Small-sided games are time-efficient, an effective transfer to match play, and increases the enjoyment level of youth players [9-11]. Nevertheless, small-sided games ask for more guidance to prevent athletes from getting injured and do not work for every group of athletes [9, 11]. In conclusion, the trainer of a team sport has to weigh the advantages and disadvantages for every team he trains, to be able to consider whether or not it would work for his athletes.

This research provides information about the aspects of small-sided games. The interactive floor is capable of visualizing the field dimensions, number of players, rule modifications, coach encouragement, training regimens, and game duration. Therefore, the interactive floor might be a helpful asset in a small-sided game. The interactive floor can help to implement small-sided games in a volleyball practice. The next chapter will use the information on small-sided games while creating the design space. Later, a careful process of designing, testing, and validating is recommended in order to precisely examine which small-sided game works for what kind of group of athletes.

2.4 Interviews and observations

Interviews are held, and observations are done to gather more information and opinions about volleyball exercises in practice nowadays. The interview questions are kept open because the author of this thesis has much experience with volleyball. The open questions help to open up the horizon of the author to prevent her from only following her feelings and thoughts.

2.4.1 Volleyball practice according to volleyball trainers and P.E. teachers

The main goal of this interview was to find out how volleyball is taught nowadays, what exercises are used nowadays and how we can improve those practices. There were 12 participants, seven volleyball trainers and 5 P.E. teachers (Physical Education teacher) who teach volleyball. This interview was focused on children from 4 to 12. Children from that age are the focus of this interview because they learn volleyball step by step, and this pre-knowledge is useful when designing volleyball exercises that can develop volleyball-related skills. The interviews are semi-structured and held in a comfortable environment, at home, or in the volleyball hall. The consent form for adults and the interview protocol one is used and can be found in Appendix A: Consent form adult and Appendix B: Interview protocol 1.

Results

The first two questions are asked to gather information about the behavior of the children while explaining the volleyball rules. According to both the trainers and P.E. teachers, children from 8 to 12 years concentrate longer and understand the rules better than younger children.

Volleyball trainers added to this question that children need much variation during the practice. Next to that, children are more excited when they play a game where they can get points or win a prize. P.E. teachers added that the rule of changing positions is often not considered as useful by the children, and this results in children who standstill at the same spot for a while. Volleyball trainers and P.E. teachers agree on the fact that the volleyball technique is hard to

learn within one practice or lesson, which results in grumpy children who have lost their interest after not seeing any result.

After a short explanation of what an interactive floor is and what it can do, question 3 is asked. The volleyball trainers and P.E. teachers are asked to think of possible games that are played right now and in what way the interactive floor can assist. The collection of games and their strong and weak points are visible in table 1.

Game	Strong points	Weak points
Playing tag	The player who has to tag moves a lot.	Some players do not move and stand in a corner.
Dodgeball[15]	Playing with a ball.	The player who is in the middle does not like it anymore after a while.
Smash ball[16]	Easy to learn the circulation of volleyball.	Not as exciting if the children feel that they understand the rules, but practicing it is still needed.
Serving	Win points for serving on a specific object.	Serving cost a lot of muscle strength.

Table 1: a collection of games mentioned by volleyball trainers and P.E. teachers

Volleyball trainers and P.E. teachers added to this question that games are fun for the children but require much guidance from the assistant to make sure the game works as intended.

According to trainers, movement patterns are learned at a later age because explaining them is hard for children from a young age. The volleyball trainer thinks that this is the case because teaching the rules in the air to the children can be confusing and is too hard to process. The trainers are positive about the idea of having an interactive floor that can teach the children movement patterns in a playful and understanding way. Lighting up certain areas on the field to show where the ball should be caught or thrown can already erase much confusion during practice, according to the trainers. Next to that, learning the volleyball system at the age of 12 is hard. Nowadays, children are asked to watch YouTube videos and read the written instructions of the system before they go to practice. During the practice, the trainers try to keep all the players in the right place, but because everyone is confused, the trainer has a hard time too. The trainers imagine that the volleyball system could be explained by the interactive floor; this imagination makes them immediately enthusiastic.

The P.E. teachers come up with the idea of lighting up the volleyball lines to decrease the confusion of the size of the field. Many sports are practiced in a gymnastics hall. Each sport has different dimensions of the field, and this can be confusing.

Next to that, P.E. teachers and volleyball trainers are enthusiastic about an extra assistant during the training. According to all of the participants, personal attention is essential, especially with younger children. The interactive floor can help to decrease the discussions during practice, and this might result in a higher level of joy during the volleyball training or P.E. lesson, according to the trainers and teachers.

[15] https://www.rulesofsport.com/sports/dodgeball.html
[16] https://www.topendsports.com/sport/new/smash-ball.html

Conclusion

Using an interactive floor while practicing volleyball is received positively, according to both the volleyball trainers and P.E. teachers. The interactive floor can assist the trainers and teachers in explaining the rules, in visualizing the rules, and in giving personal feedback per athlete.

The discussions during training can be removed by the interactive floor if the interactive digital exercises are designed clearly. It is essential to take into account that the exercises need to be designed so that it is easy to understand, in order to prevent other discussions from happening. Replacing the time lost of discussions by new exercises might result in a higher level of joy and a higher level of skill-development during volleyball practice.

The volleyball trainers mentioned that the theoretical approach of teaching the volleyball system these days can be improved when using an interactive floor. This idea seems of great importance, according to the trainers. Therefore, this idea will be kept in mind through this thesis.

2.4.2 Volleyball practice according to volleyball players

The main goal of this survey was to find out what volleyball athletes think of their practice. This survey expands the information about how volleyball is taught nowadays, what exercises are used nowadays and how we can improve those practices.

A survey is sent to volleyball players of Harambee, the volleyball association of the University of Twente. 16 Volleyball players responded to the survey. The survey can be found in Appendix C: Survey for volleyball players. The survey consists of 5 open questions to gain insights into their volleyball practice. The answers to the open questions are more detailed and allow an infinite number of possible answers. Besides that, it does take more time to process the answers, but it encourages creative answers and self-expression [19]. All the participants fall in the same age-group of 18-25 years.

Results

According to the answers to the first question, every participant is a volleyball player. One participant has an injury right now and cannot play volleyball. However, the injured participant is still considered a volleyball athlete since he has the same knowledge as the other participants.

The second question asks for difficulties/struggles during the volleyball practice. Some difficulties/struggles cannot be solved with an interactive floor. For example, not having enough balls, or that the height of the net is uneven. However, there are some difficulties/struggles named by the participants that can function as inspiration when ideating for new interactive digital volleyball exercises. According to the participants, today's practice lacks in personal feedback. Next to that, participants stated that some techniques are hard to train because the situation happens so fast. The participants also mention that the learning process when learning the system of volleyball takes time and is not exiting. The last thing mentioned by the participants is that volleyball is a dynamic sport where it is hard to do a specific situation twice.

The third question is about what kind of exercises are done in every practice. All the participants mention the same exercises. They listed different exercises that can be categorized into groups. All the participants mention the categories in the same order.

- Warming-up
- Attacking
- Serving
- Defense
- Match

Before asking the next question, a figure of the interactive floor is given. Some examples of the interactive floor are given to explain the figure, to make sure the participants understand the interactive floor and to give them some inspiration.

The fourth question is about the advantages of the interactive floor in volleyball practice. The participants are asked to think about the interactive floor and to wonder what advantages an interactive floor might have in their volleyball practice.

- Show attacking steps
- Positions before serve (system)
- Defense positions
- Where to attack
- For staying low
- Make exercises clearer
- Warming up games
- Serve locations
- Mark of where the ball landed
- Feedback of the feet afterward
- Consistency in setting
- Pushing to work harder
- Making exercise more fun
- Supports to develop skills

The fifth question is about the disadvantages of the interactive floor in volleyball practice. The participants are also asked to think about the interactive floor and to wonder what disadvantages an interactive floor might have in their volleyball practice.

- Distraction
- Can the floor be fully trusted?
- Technology errors
- Becoming too dependent
- Not focussed on the ball
- Expensive
- Lose the team feeling
- Looking at the floor all the time
- Fake, does it become a new sport?
- Can cause confusion

In the sixth question, the participants are asked to come up with an idea for an interactive digital exercise. Many participants answered with the same content as in question four but with different words. Only a few participants answered with an example of a real exercise. This might have to do with the question as it was probably not clear enough. However, some exercises are given, which will help in the ideation process.

1. Digital beer pong as a serving game.
2. Visualize footsteps on the floor, which an attacker should take.
3. Lighting up a certain place on the floor, where to defend/attack.
4. Warming up game where you have to run as hard as the colored bar.
5. Moving target that should be hit by the ball when attacking.

The participants are thanked after filling in the survey.

Conclusion

Equal to the interviews with the volleyball trainers and P.E. teachers is that the interactive floor is received positively by the volleyball athletes.

Volleyball athletes claim that situations during training happen so fast that the trainer is often not able to give proper feedback on that specific situation. For example, the middle blocker has to close the block with the out-side attacker; this is a matter of seconds. Therefore, it is hard to

give feedback afterward because it happens so fast. The interactive floor can generate feedback on this situation, and this can help the trainer as well as the athlete.

Nowadays, the volleyball system is explained by the trainer, who has a handout of the different rotations of the system. The trainer makes sure everyone is in his or her place before the opponent serves. Understanding and learning the volleyball system causes much frustration, according to the participants. The interactive floor might be a solution to this struggle.

There is another struggle that is brought up by the athletes, which seems essential to keep in mind. The athletes claim that setting up the same ball for an attacker is not doable since all the volleyball actions are related to each other. Especially in a combination routine, it is hard for a setter to give the same ball every time. The interactive floor might have the potential to solve this issue since it can add continuity in an exercise.

The imaginable advantages given by the volleyball athletes will be taken into account when designing the interactive digital volleyball exercises, this also applies to the disadvantages.

2.4.3 Observing real-time practice

The goal of this observation is to see how volleyball practice is done nowadays, to gather more information but also to get the feeling of the volleyball environment. On the 2nd of March, a real-time practice of Harambee (volleyball association of the University of Twente) was observed.

Results

The training had different exercises. The athletes first started with warming up exercises. Then they started with attacking exercises. After that, serving and defending were trained in the same exercise. The practice ended with half an hour of gameplay, where the trainer threw two extra balls in before the athlete may serve again. Using extra balls made sure that the athletes were not standing still for a while.

The trainer used different groups during the training. The warming up with the ball was in pairs. The attacking exercise was without a group. The serving and defending exercises were trained in groups of four athletes, where one person served on three defenders. During all the exercises, the trainer walked around to give feedback where needed. During the observation, it was clear that 13 athletes were a lot for the trainer to give feedback. Therefore, he focussed on a few athletes, gave feedback, and then went on to another hand full of athletes to give feedback. It was interesting to see that the athletes were also willing to help each other by giving feedback.

The trainer used a turn cabinet to stand on when throwing balls in the court during the gameplay. Pylons and hoops were used during the warmup. The athletes had to lay down the ball in the hoop and zigzag through the pylons to get back to the line. A noodle was used to divide the field into two during the serving and defending exercise. The practice had a duration of 120 minutes, where 10 minutes of the training was used for some (private) discussion. This discussion took place at the beginning of the training.

Conclusion

Every exercise needed an explanation from the trainer. Therefore, the athletes were standing still for quite a while. Of course, moments of rest is also essential, but this can maybe be improved by the interactive floor.

There is are potentials for the interactive floor to give feedback to help both the trainer and the athlete. The discussion time at the end of the training can maybe be replaced by a simulation on the interactive floor, where the athletes get a visualization of a specific situation. The athletes might find this more attractive than listening to a speech of their trainer. However, if this is a potential for the interactive floor in volleyball training is not clear yet.

2.5 Interpretation of the context analysis

The goal of this chapter was to find the answer to: How would an interactive LED-floor be useful in a nowadays volleyball practice?

- First, related work of exergames are discussed in order to understand what is possible. Next to this, discussing exergames can help to find some inspiration.
- Second, the difference between exergames and interaction technology in sports is discussed in order to understand the extra constraints interaction technology in sports gives. This difference is essential to keep in mind during the ideation phase.
- Third, the volleyball practice nowadays has been researched based on the literature of small-sided games, interviews with trainers, P.E. teachers, and volleyball players, and observations of a real-time practice. This information will also be incorporated into the design space of this thesis.

According to the information of this chapter, the interactive floor is promising in volleyball practice and can help to improve the skill development of the athletes. Next to that, the interactive floor can help to avoid discussions and unclarities in practice, and that seems to make the interviewees enthusiastic.

Before the ideation process starts, the design space has to be created based on the information from this chapter.

3. The design space

The previous chapter answers the research question: *How would an interactive LED-floor be useful in a nowadays volleyball practice?* The main focus of this section is on how that usefulness can be translated into a design space.

The design space of this thesis is created to design interactive digital-physical exercises in a structured way. The design space is used as a tool in this thesis to guide the ideation process, which is presented in the next chapter. The design space that is created here is inspired by the concept of Florian Mueller [20].

Florian Mueller [20] researched exergames that support physical movements. Mueller presents a set of design cards that can support the designer in designing those exergames. The Exertion Framework [19] consists of four lenses.

1. The responding body – how the body responds
2. The sensing body – how the body experiences the world
3. The relating body – how the body and people relate to one another
4. The moving body – how the body parts move concerning one another

This framework is turned into design cards by Mueller. He created different domains with a gradient that is proven to be helpful when designing exertion games. One aspect on the left side, and the second aspect (often the opposite of the first aspect) on the right side. An example of such a gradient line is visible in figure 1.

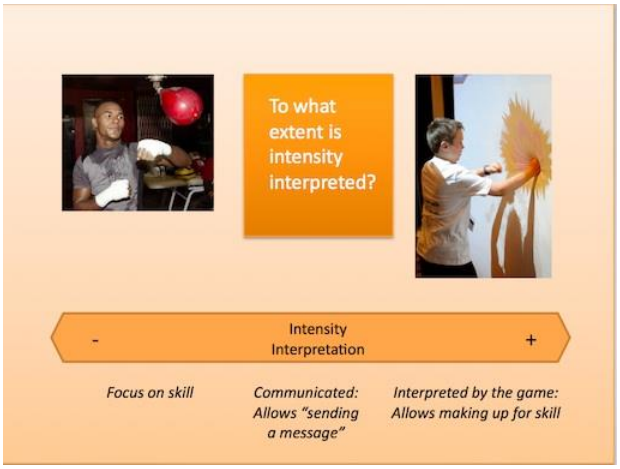

Figure 1: an example of a design card made by Florian Mueller

Mueller researched the effect of using his design cards while designing exergames. The result of his research was positive. The design cards helped the designers to expand their horizons and to consider areas they usually do not consider. The design cards are considered useful and support the creative process of designing exertion games.

In this chapter, different gradient domains will be created based on each subject of the context analysis. Second, the total of gradient domains will be considered and narrowed down by searching the compatible gradient lines. The process narrowing the gradient lines down will help to make the design space more manageable for this thesis. At the end of this chapter, the design space is finished and can be used throughout the ideation phase.

3.1 The gradient lines

Small-sided games are a popular exercise used in team sport training, according to the literature research in section 2.3.1 is that. Section 2.3.1 discussed the different aspects of small-sided games and what has to be taken into account when designing those exercises for team sports. The aspects that are considered significant, according to section 2.3.1, are translated into domains for the design space and are visible in figure 6.

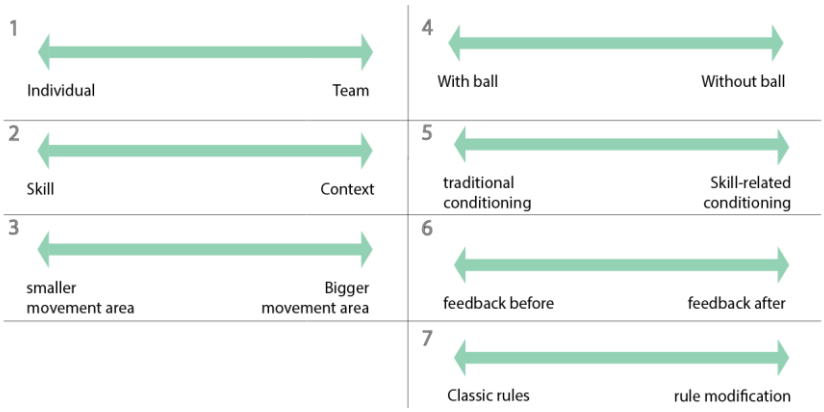

Figure 6: Gradient lines based on small-sided games aspects

Section 2.3.2 discussed the exergames. Florian Mueller [20] created exertion cards that can support the designer when designing exertion games. His exertion cards, in combination with the existing exergames, are considered and translated into lines for the design space of this thesis. The lines based on the exertion cards are visible in figure 7.

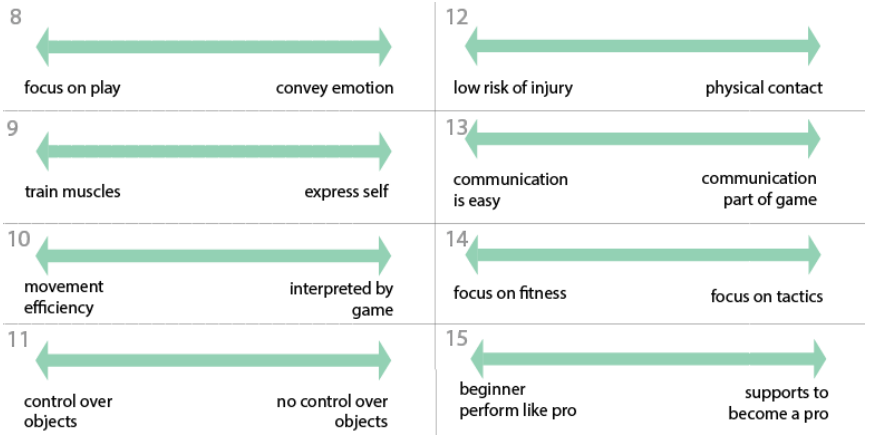

Figure 7: Gradient lines based on the research of Mueller [20] and the exergames

Volleyball trainers, volleyball athletes, and P.E teachers gave more insights about the current volleyball practice in section 2.4. The volleyball trainers and athletes gave insights into what kind of exercises are used in training. They mentioned cooperative and competitive exercises, coactive and interactive exercises, (non)-sport specific exercises, and open and closed exercises. The P.E teachers added to this that children find it hard to use the volleyball theory in a practical exercise. Next to that, it is mentioned that children are more into volleyball if they could play at their skill level. These results are translated into domains and are also added to the design space. Figure 8 shows the lines based on the interviews and observations of section 2.4.

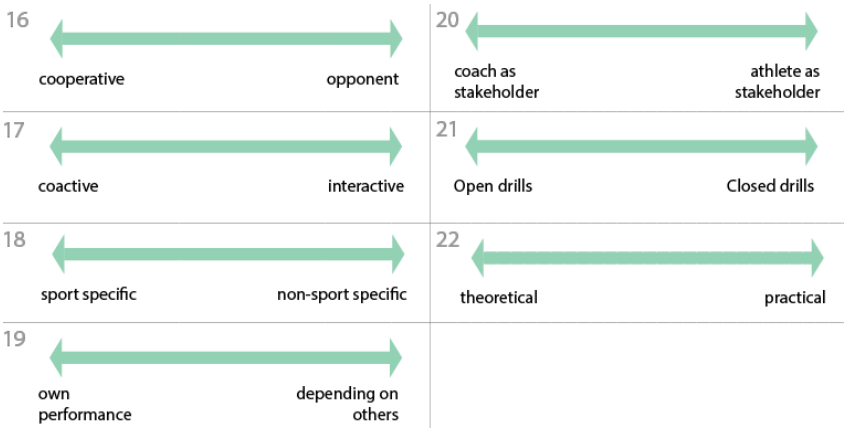

Figure 8: Gradient lines based on interviews and observations

3.2 Narrowing down the 22 gradient lines

The current number of gradient lines is 22. The 22 gradient lines will be considered and narrowed down. This process of narrowing down is discussed in this section. Figure 9 visualizes the narrowing down process. The ten gradient lines (blue) are created based on the 22 gradient lines (green) from the previous section.

Figure 9: Narrowing down the 22 gradient lines into ten gradient lines.

Gradient lines 3 and 7 fall under gradient 18 because they both deal with the gradient line sport-specific / non-sport specific. Gradient line 8 is intertwined in gradient line 21 because this is a more detailed version of open drills / closed drills. Gradient 4 is a binary line and falls instinctively under gradient 22 because practicing volleyball related skills with a ball are practical. Gradient line 2 is the more abstract version of gradient line 5, 13, and 14 together. 'Skill-related conditioning,' 'communication is easy,' and 'focus on fitness' fall under the 'skill' side of gradient line 2. 'Traditional conditioning', 'communication is part of the game' and 'focus on tactics' fall under the 'context' side of gradient line 2. Gradient line 15 is a disguised gradient of line 6. An amateur user can perform like a pro if the installation gives

him the feedback to do so. Some exercises can be completed by any user if the user has a specific movement efficiency, like cycling. While other exercises cannot be completed by anyone because that exercise requires a particular skill, like climbing a mountain. Adjusting the required skill-level of a particular exercise can be done by the stakeholder. The stakeholder can be either the coach or the athlete in terms of this thesis. If an exercise is played alone, the athlete is only dependent on his performance. The same applies as the athlete has to complete an exercise together with other players; the athlete is dependent on the performance of him/herself and the others. Gradient 9 is connected to gradient 11 because expressing itself is easier when the user can make use of objects. Gradient 16 and 17 are combined to a new gradient line, cooperative/interactive. This is done because, throughout this section, it seemed more logical to create a new gradient line to cover the content of both lines 16 and 17 better.

The ten gradient lines (blue) are used in the final design space.

3.3 Translating the ten gradient lines into a design space

The ten gradient lines that are created in the previous section will be translated into a design space. The goal of this section is to consider the ten gradient lines and to translate those into a 2-dimensional (2D) space. Creating a 2D design space helps to see the relation between two lines and to see the possible gaps that still exist throughout the brainstorm. Before two lines are superimposed on each other, three categories are made.

Interactive digital exercises exist of content that should be carried out by the athlete. The athlete has to be motivated to achieve the desired result of the exercise. During the exercise, interactions happen between the player, the technology, and the environment. Therefore, the three categories are made.

1. Content
2. Motivation
3. Interaction

The remaining gradient domains are categorized in the three above mentioned categories. Besides that, two gradient lines are superimposed on each other. Skill/context is superimposed on theoretical/practical because it seems interesting to think of a theoretical exercise that is played in context since this is not yet done according to the related work of section 2.3. Low-risk injury / physical contact is superimposed on cooperative/competitive because those are indirectly related. There will be a lower risk of injury and less physical contact if athletes have to reach a common goal.

This 2-dimensional space is used to see where the open places in the design space are. The open places can remind the designer to expand his horizon and can support the creative process. The result of the design space is visible in figure 10.

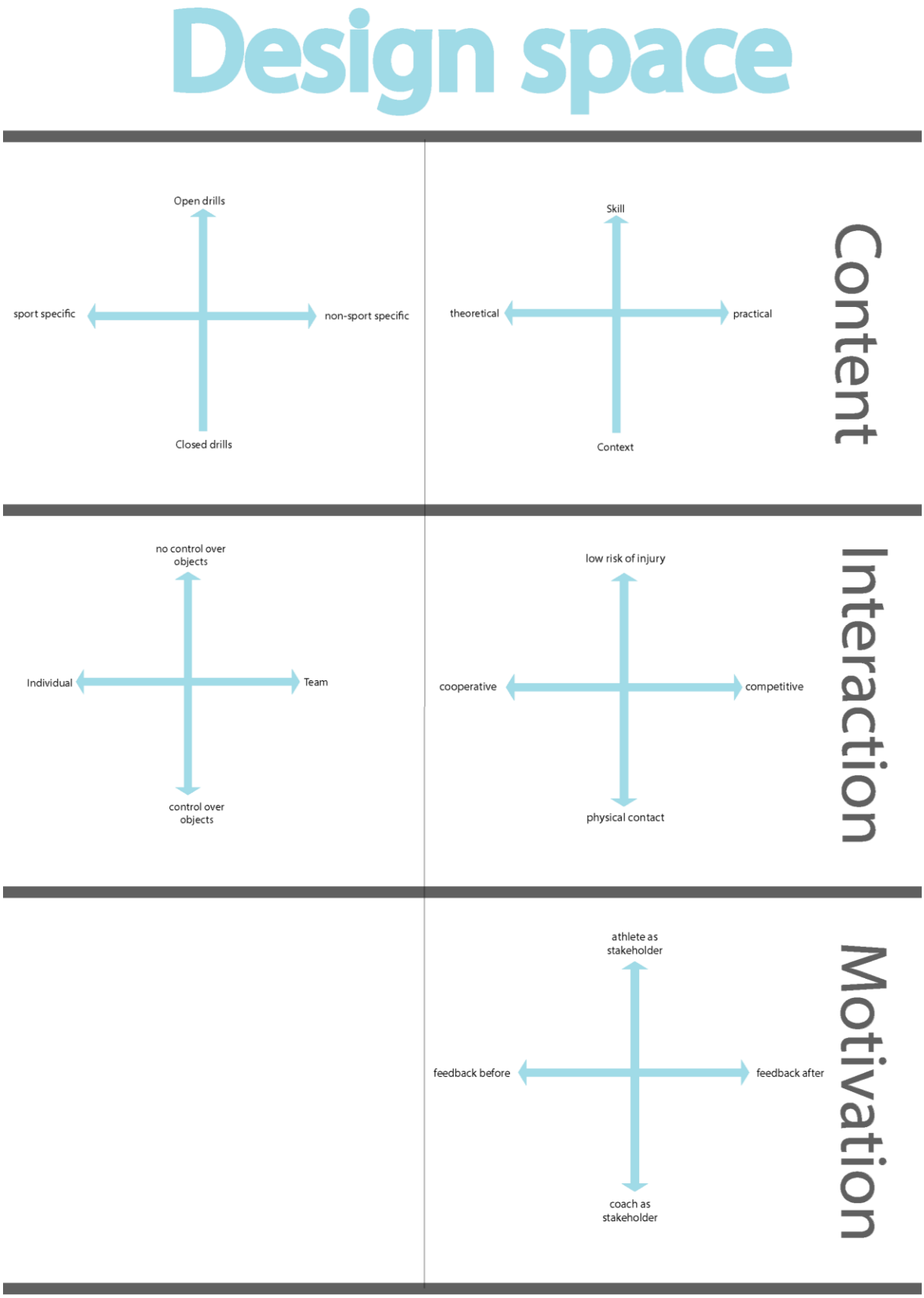

Figure 10: The design space

3.4 Connecting the related work to the design space

The related work that is discussed in section 2.3 is connected to the final design space and can be seen in figure 11. This result can provide the brainstorm from inspiration. For example, if one corner of the design space is not yet filled, the related work that does fill that corner can be an inspiration for creating more ideas in that specific corner. Next to that, the distribution of the related work in the design space is visible in figure 10 to helps to get insights into what corners have not been filled by the related work.

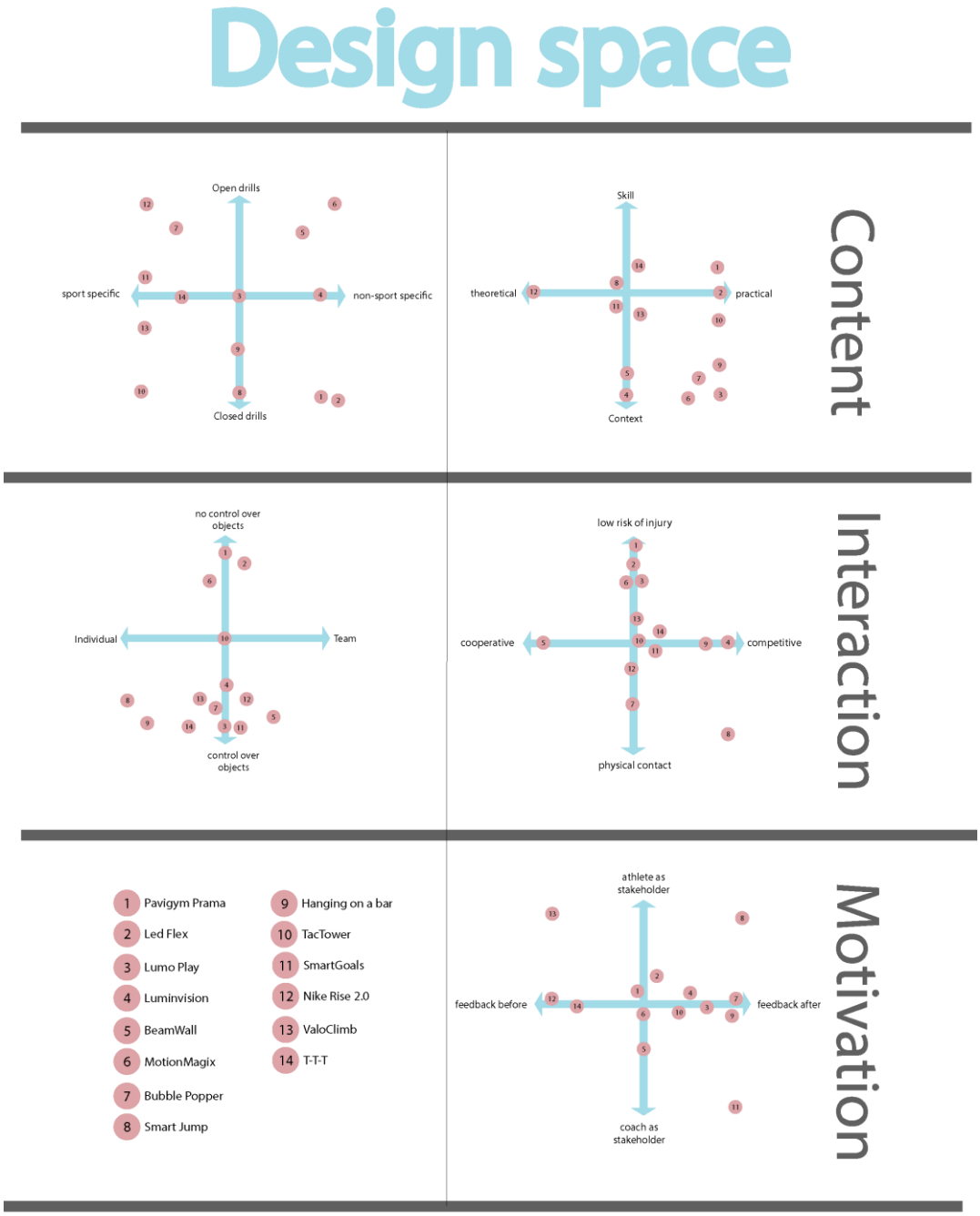

Figure 11: Related work connected to the design space

Analysis

The category of 'Content' has related work in almost every corner. However, the corner of 'skill' is not yet filled. Therefore, it means that the related work does not focus on single skill

development. There might be a potential for the interactive floor in improving the skill development of athletes since this is not done yet.

The related work shows a broad range of different interactions that is possible when using an interactive floor. The related work can function as an inspiration to brainstorm about how the interaction can be implemented in the smart sport exercises. Different ways of providing feedback can help to motivate athletes. Giving feedback can be done either before, during or after. The different way of giving feedback is visible in the related installations discussed in section 2.3.

Almost all kinds of interactions and motivations are used in the related work. However, some combinations of content, interactions, and motivations have not been made yet. This thesis tries to find one or more of those combinations to create interactive digital exercises that can improve upon traditional volleyball training.

4. The ideation

The goal of this first ideation section is to end up with around 150 ideas during a structured brainstorm. The literature research, related work, interviews, and observations are used as inspiration in the brainstorm. The design space is used as guidance through the brainstorm to be able to create more ideas. A list of categorized ideas will be created.

At the end of this section, ideas will be combined into different lo-fi prototypes. The ideas for lo-fi prototypes made in this section will be used and further designed in the lo-fi testing phase (chapter 5). In the lo-fi testing phase, potential users (volleyball athletes and trainers) will be asked to play around with the lo-fi prototypes.

4.1 150 ideas

The brainstorm session is performed by one person, the researcher. The researcher has experiences with ideation tools and has a background as a volleyball athlete. The context analysis and the researcher's background and experiences function as inspiration. The design space of the previous chapter helps to expand the horizon of the researcher, so the researcher does not only think from a volleyball athlete's perspective. Besides that, the design space is used to see the 'empty' areas in the ideation. Seeing these gaps in the design space can stimulate the researcher to consider areas she normally does not consider.

The ideas of the brainstorm session are categorized into different groups, so it easier to find them back and to read through them. The distribution of the ideas is visible in figure 12. The complete list of the 150 ideas can be found in Appendix E: 150 ideas. Each idea is covered in one of the lo-fi prototypes, this will be explained later. The lo-fi prototype that fits the idea is visible between the brackets, for example (LP1) means lo-fi prototype 1.

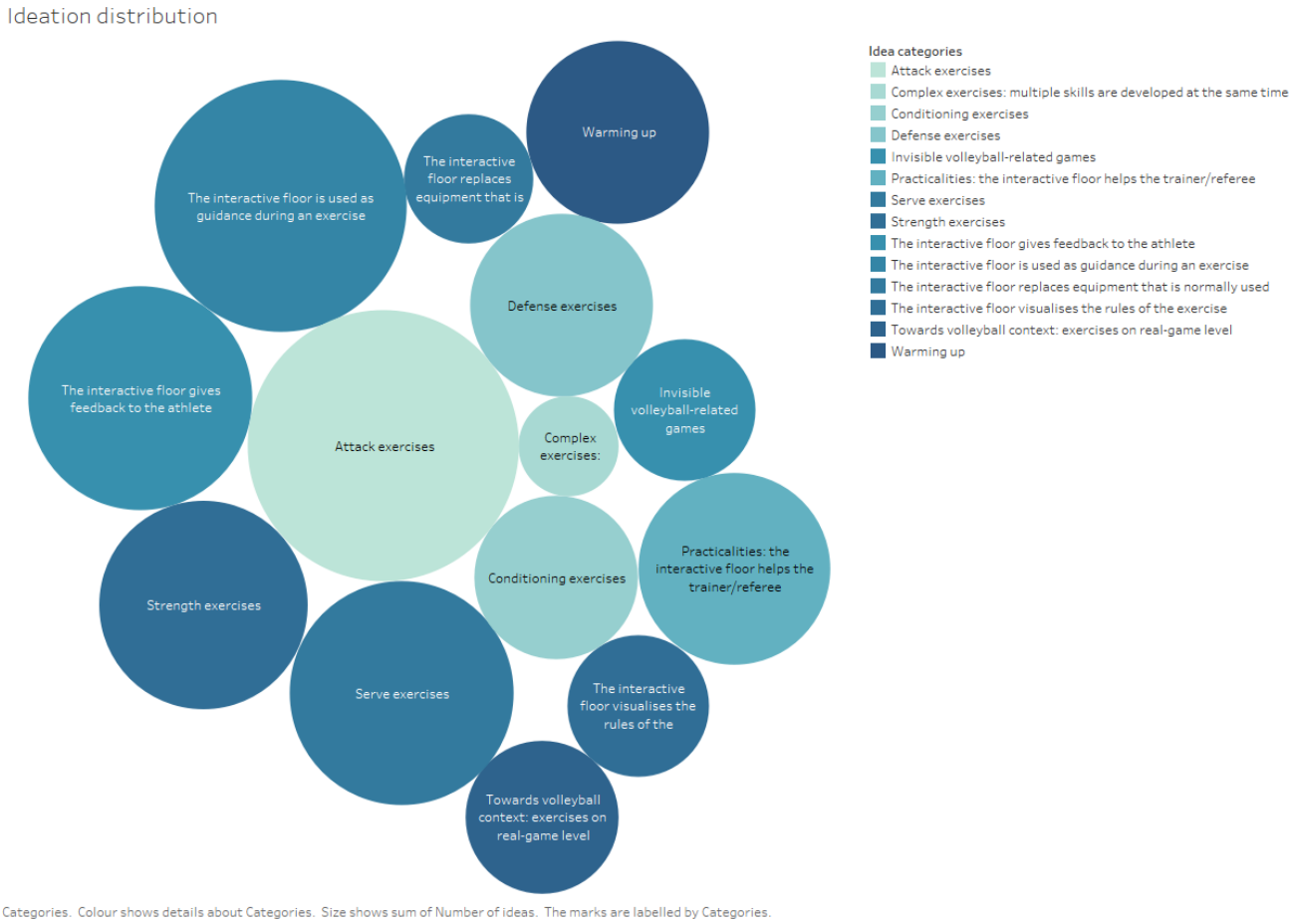

Figure 12: Ideation distribution

4.2 Translating the ideas to lo-fi prototypes

150 ideas are created in the first ideation session. The ideas are categorized into different groups to make them more manageable. However, there is also a connection between the ideas based on how to create and design them. For example, only one lo-fi prototype has to be created to explain the idea of visualizing replays. Visualizing the replay of a block, attack, defense, serve or last played match, can all be explained by making only one lo-fi prototype that explains that replays are possible. So, one lo-fi prototype can be used to explain and demonstrate the concept of other ideas.

Seven lo-fi prototypes are made to illustrate the central concept of every idea of the first ideation phase. Each lo-fi prototype covers many ideas. Using one lo-fi prototype while explaining other ideas might result in an open brainstorm where the participant can think of ideas that come to mind.

5. lo-fi testing

The goal of this lo-fi testing section is to review the ideas that are created in the ideation phase and create more ideas based on the input delivered by the participants.

5.1 The seven lo-fi prototypes

An explanation of the lo-fi prototype will be given with their research questions. Every prototype has his research questions because it could be that a participant does not have the time to evaluate all the lo-fi prototypes. Therefore, the lo-fi prototypes are kept separate. Every prototype is programmed with the program Processing with Java as a coding language.

Lo-fi prototype 1: Block Shadow

This prototype represents an interactive floor that shows a block shadow. If the attacker walks towards the net to attack a ball, the athletes of the opponent will try to stop that ball. The opponent does this with first a block and second with the defense. The interactive floor will trace the attacker and the block. Based on that information, a block shadow will be generated. The block shadow can be used by the attacker, so he/she knows where to attack. The shadow can also be used by the defense, so they know where to defend. This lo-fi prototype can also be used to explain other concepts such as idea 1, 11, and 13. All the ideas that can be explained by this lo-fi prototype are marked with LP1 in the first ideation list. The Block Shadow game is visible in figure 13.

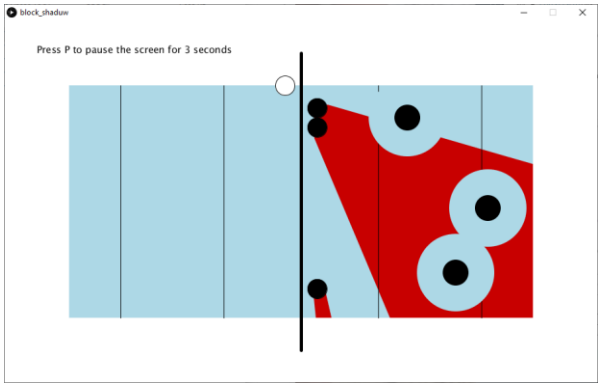

Figure 13: Block Shadow

This lo-fi prototype is made to show the participant that it is possible to light up parts of the field. Next to that, it is also possible to generate a reaction based on a particular situation. So, for example, the block shadow is generated based on the positions of the attacker and block. The block shadow is explained by showing this lo-fi prototype. Research questions have been made that will be answered through the use of the lo-fi prototype: Block Shadow.

Research questions:

- In what ways is the Block Shadow beneficial for showing the block shadow?
- What is the initial reaction of the participant about being able to light up parts of the field?
- What kind of problems can be solved by using the block shadow in a volleyball practice?
- What kind of disadvantages has the block shadow in a volleyball practice?

Lo-fi prototype 2: Random Attack

This prototype represents the interactive floor where random spots can appear. This prototype explains the idea where a random spot appears when the attacker jumps. The attacker has to anticipate on the virtual object and has to try to hit the spot with the ball. This idea can also be used to train the defender because if the defender follows the spot and the attacker is trying to hit the spot, the defender should be in the right position. This lo-fi prototype can also be used to explain other concepts such as ideas 27, 38, and 69. All the ideas that can be explained by this lo-fi prototype are marked with LP2 in the first ideation list. The Random Attack game is visible in figure 14.

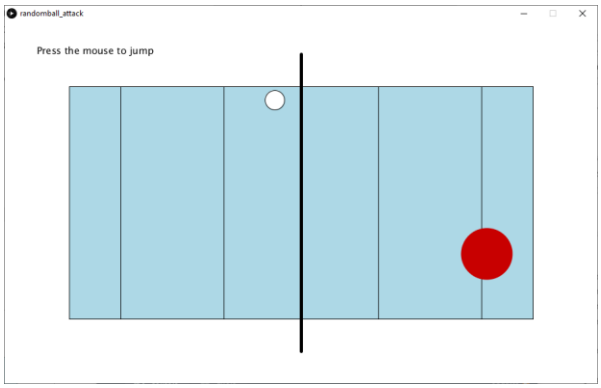

Figure 14: Random Attack

This lo-fi prototype is made to show the participant that the floor can help during exercises, with, for example, a random dot that appears. This dot can also be transformed into another shape or another idea. Research questions have been made that will be answered through the use of the lo-fi prototype: Random Attack.

Research questions:

- What do the participants think of this exercise when training reaction speed?
- What equipment from the existing traditional training can be replaced by this system?
- What is the initial reaction of adding a random object in a traditional training?

Lo-fi prototype 3: VolleyCup

This prototype represents an interactive floor that can be used as a fun non-sport specific game. This prototype explains the idea of volleyball pong. The volleyball pong exercise can be used as a serve exercise where the ball has to hit one of the cups. This idea explains a concept where the interactive floor makes a game more fun and visualize the rules. This lo-fi prototype can also be used to explain other concepts such as ideas 65, 66, and 72. All the ideas that can be explained by this lo-fi prototype are marked with LP3 in the first ideation list. The VolleyCup game is visible in figure 15.

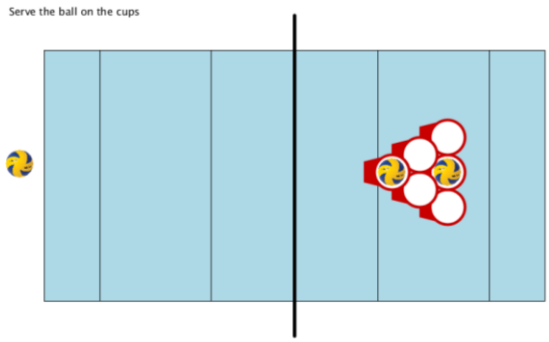

Figure 15: VolleyCup

This lo-fi prototype is made to show the participant that exercises can be made more fun with the interactive floor. This serving exercise is turned into a game. More games like this can be made. Showing this example can help to stimulate the thoughts of the participant while brainstorming about other ideas. Research questions have been made that will be answered through the use of the lo-fi prototype: VolleyCup.

Research questions:

- What is the first reaction when seeing a non-sport specific game translated into a training exercise?
- What are other ideas of games that come up while the participants play with the lo-fi prototype?

Lo-fi prototype 4: Volleyball System

This prototype represents an interactive floor that can be used as guidance while athletes are learning the volleyball system. The interactive floor can explain how the system works while the athletes are playing. This concept helps the athletes to learn while doing. This lo-fi prototype can also be used to explain other concepts such as ideas 2, 21, and 35. All the ideas that can be explained by this lo-fi prototype are marked with LP4 in the first ideation list. The Volleyball System game is visible in figure 16.

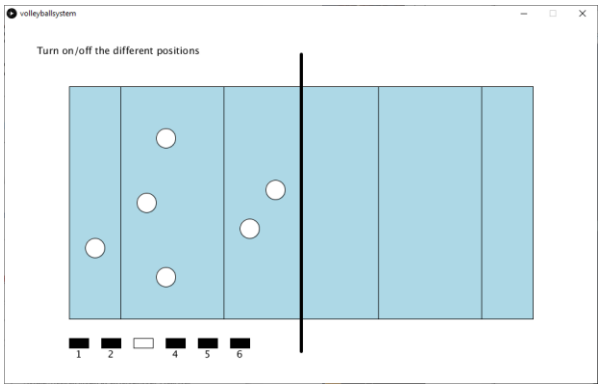

Figure 16: Volleyball System

The lo-fi prototype is made to show the participant that it is possible to use the interactive floor as guidance. This example shows that the interactive floor can function as guidance while learning the volleyball system. Research questions have been made that will be answered through the use of the lo-fi prototype: Volleyball System.

Research questions:

- To what extent understands the user the idea and the use of the system?

- To what extent is this concept clear to the participant?
- What characteristics of this system are indispensable?

Lo-fi prototype 5: Attack steps and defense hands

This prototype represents an interactive floor that stimulates the athlete to move more or to do a small exercise. This prototype shows that, for example, hands or footsteps can be visualized on the floor to explain where to step, jump, walk, or where to touch the ground. This lo-fi prototype can also be used to explain other concepts such as ideas 9, 14, and 73. All the ideas that can be explained by this lo-fi prototype are marked with LP5 in the first ideation list. The attack steps and defense hands concept is visible in figure 17.

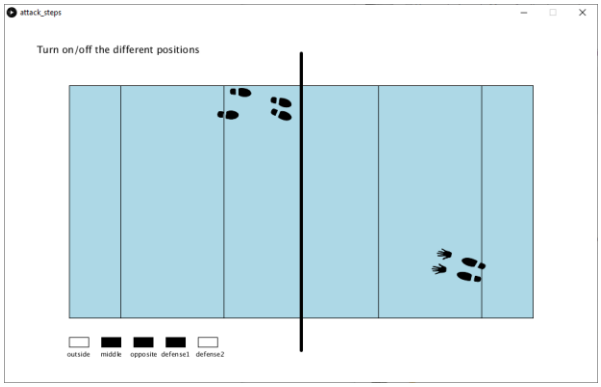

Figure 17: Attack steps and defense hands

This lo-fi prototype is made to show the participant that the interactive floor can help to give feedback before and after a particular situation. In this example, the attack and defense footsteps are visualized. This example can also be explained by showing the footsteps on the interactive floor after the situation occurred; this can help the athlete and the trainer to reflect on a particular situation. Research questions have been made that will be answered through the use of the lo-fi prototype: Attack steps and defense hands.

Research questions:

- To what extent can this concept be adjustable on the level of the athlete?
- To what extent can this concept be translated into the way the steps of the attack are trained nowadays?
- How do the participants react to the idea of letting the defender touch the floor before he defends?

Lo-fi prototype 6: The Trainer Assistant

This prototype represents an interactive floor that can help the trainer during his practice. The interactive floor could show the trainer if the ball is in or out. Next, it could show if the athlete steps over the serving line. Next, the floor can visualize a replay of a particular situation to see what has gone wrong. This lo-fi prototype can also be used to explain other concepts such as ideas 59, 63, and 95. All the ideas that can be explained by this lo-fi prototype are marked with LP6 in the first ideation list. The Trainer Assistant concept is visible in figure 18. The left picture visualizes a line error during the serve. The picture on the right visualizes the ball that goes of the court.

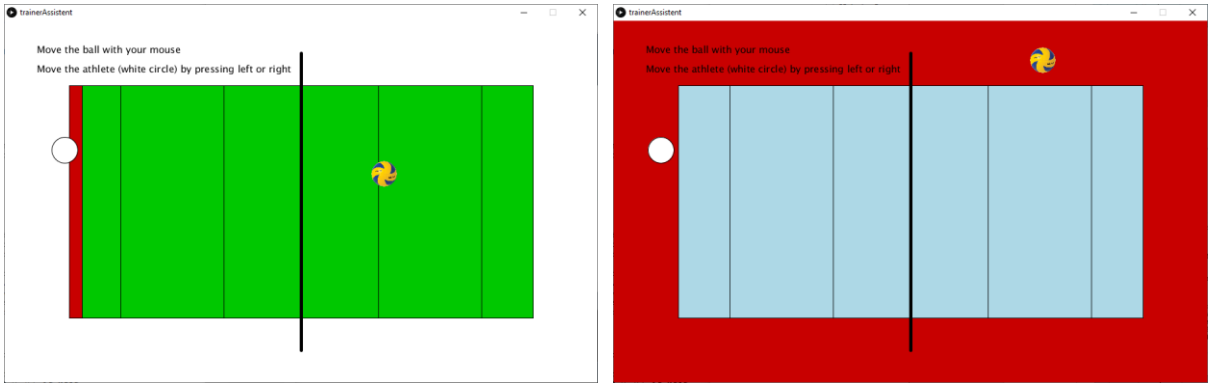

Figure 18: The Trainer Assistant

This lo-fi prototype is made to show the participant that the interactive floor can help the trainer during the training. Research questions have been made that will be answered through the use of the lo-fi prototype: The Trainer Assistant.

Research questions:

- To what extent can this concept help the trainer in training?
- What does the participant think about where the opinion of the assistant should be visualized?
- How do the participants respond to being able to train with an extra referee?

Lo-fi prototype 7: Follow the Floor

This prototype represents an interactive floor that can show visualizations that the athletes have to follow. For example, how hard the athlete has to run, where he/she has to jump, and where he/she has to dive. This lo-fi prototype can also be used to explain other concepts such as ideas 32, 39, and 48. All the ideas that can be explained by this lo-fi prototype are marked with LP7 in the first ideation list. The Follow The Floor game is visible in figure 19.

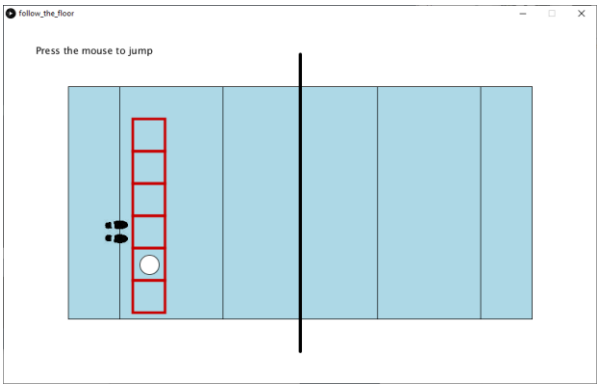

Figure 19: Follow the Floor

This lo-fi prototype is made to show the participant that the interactive floor can be pre-programmed, which means that the trainer can pre-plan his training. During the training, the interactive floor can take over the training, and the trainer can focus on giving feedback, instead of planning the training. Research questions have been made that will be answered through the use of the lo-fi prototype: Follow the Floor.

Research questions:

- To what extent can this make the volleyball athlete more independent in training?
- What does the participant think of the fact that the trainer might have more time to give feedback if he could send the exercise to the floor?

- How do the participants react to the idea of showing footsteps and the layout of the ladder in the exercise?

5.2 Testing with the lo-fi prototypes

The next step is to test with the lo-fi prototypes that are explained and visualized in the previous chapter. The lo-fi prototypes are tested in two set-ups. Set-up 1, the participants see the facilitator playing around with the lo-fi prototypes on the touchscreen monitor via skype, the touchscreen monitor represents the interactive floor. Set-up 2, the facilitator sees the participants playing around with the lo-fi prototypes on their laptop via screensharing on skype.

Every lo-fi prototype has its research questions because every lo-fi prototype is different. However, there are also common research questions. Each prototype addresses the same set of standard questions but will probably have a different answer because the prototypes differ.

Standard research questions

- What characteristics from the lo-fi prototype are liked?
- What improvements can be made for the lo-fi prototype?
- What is the initial reaction of the participant when they encounter the lo-fi prototype?
- What is the initial reaction of the participant about the context the prototype can be used in?
- How do people behave on the given instructions?
- How can the design of the exercise be improved?
- What ideas does the participant come up with while playing around with the lo-fi prototype?

The setup

The participants are split up over the two setups used during the lo-fi testing.

The first set-up uses a touchscreen monitor, a laptop with a webcam and skype running, and plastic puppets. The set-up is visible in figure 21.

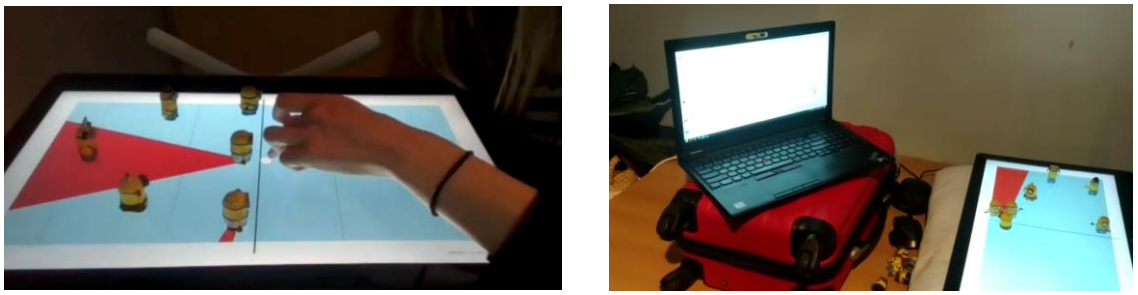

Figure 21: set-up 1: Touchscreen monitor and a laptop with a camera and skype running.

First, the participant is getting to know the interactive floor by showing him the touch screen monitor with plastic puppets on it. The participant sees the touch screen monitor through skype. The touch screen monitor represents the interactive floor. This could stimulate the imagination of the participant on how the interactive floor will look like. The facilitator sees and hears the participant and can observe and analyze the reaction of the participant. The plastic puppets represent the volleyball athletes on the interactive floor. After that, the facilitator shares his screen via skype. The participant can see the software and can hear the facilitator. The seven lo-fi prototypes are shown and explained via screen sharing and audio on skype. After showing

one lo-fi prototype, the lo-fi prototype-specific questions are asked. After all the lo-fi prototypes are shown and explained, the general questions are asked.

The advantage of using the touch screen monitor in this setup is that the concept of using an interactive floor is demonstrated by puppets to provide a better imagination on how the interactive floor will be used in the future. By contrast, the participant cannot move the puppets/lo-fi prototype by himself, and this might result in reluctance by the participant. The advantage of using screen sharing in this setup is that the participant might forget that the facilitator is there because the participant cannot see the facilitator. Besides, this might decrease the nervousness of the participant as well as it might let the participant speak freely.

The second set-up is the opposite of the first set-up. The software is running on the laptop of the participant instead of on the laptop of the facilitator. The participant is asked to share his screen while he is playing around with the lo-fi prototypes. In this set-up, the facilitator is fully visible and hearable for the participant. The participant can be heard but not be seen by the facilitator. The participants are asked to use the lo-fi prototype while continuously thinking aloud. This can help the facilitator to gain insights into the thoughts of the participant. Using the thinking aloud method is of crucial importance in this set-up since the facilitator cannot see the participant, so the verbalizing thoughts are of greater importance than in the first set-up. The lo-fi prototype-specific questions are asked after each time the participant is finished playing with a lo-fi prototype. The general questions are asked after the participant has played with every lo-fi prototype. The lo-fi prototypes are sent as an executable file where the participant only has to double click on the file. An instructional document will be included in the zip-file that the participant receives in order to make sure that the participant understands what he has to do to open the lo-fi prototypes. The advantage of this lo-fi prototype is that the participant can play around with the lo-fi prototype and can test and try anything that comes to mind. However, this way of lo-fi testing might take more time than the other two set-ups because the facilitator only has control with his voice during the test. Next to that, the facilitator cannot see the face and expressions of the participant. This makes it hard for the facilitator to analyze the reaction of the participant.

All the set-ups have their advantages and disadvantages. All the five participants are randomly addressed to one of the two set-ups, to minimize the effects of the advantages and disadvantages on the outcome of the test. In the end, every participant has used one set-up, and every set-up is used two/three times. The results of the questions, together with the observations of the participants, are gathered and discussed.

Participants

The seven lo-fi prototypes are tested with both volleyball trainers and volleyball athletes. The demographics of the participants are visible in figure 20. Each participant is randomly added to one of the two set-ups.

Participant 1	
Gender	Male
Relation to SSE volleyball	Trainer/Researcher
Lo-fi testing set-up	Set-up 1

Participant 2	
Gender	Male
Relation to SSE volleyball	Athlete/Researcher
Lo-fi testing set-up	Set-up 2

Participant 3	
Gender	Female
Relation to SSE volleyball	Athlete
Lo-fi testing set-up	Set-up 1

Participant 4	
Gender	Female
Relation to SSE volleyball	Athlete
Lo-fi testing set-up	Set-up 1

Participant 5	
Gender	Female
Relation to SSE volleyball	Athlete/P.E. teacher
Lo-fi testing set-up	Set-up 2

Figure 20: Demographics of the participants

The evaluation set-up

Two participants do the lo-fi testing in the first set-up and three participants with the second set-up. The participants have to agree with the consent form before the testing can start. The consent form can be found in Appendix A: Consent form adult. During the lo-fi testing, the thinking aloud method will be used in both setups [21]. This method asks the participants to think aloud while using the lo-fi prototype. This method fits online lo-fi testing because there is no other equipment needed.

The question list, Appendix F: Lo-fi testing question list, is used as a checklist during the lo-fi testing. The question list is used as a checklist to keep the lo-fi testing unstructured and open for unexpected thoughts that arise while the individual participates in the lo-fi testing. The checklist is made to make sure that the lo-fi testing gives at least the answers to the desired questions during the lo-fi testing. The ideal situation is that the participants come up with ideas that are not yet in the ideation section and/or provide novel insights on strengths and weaknesses of each idea. Next to that, it would be ideal if the participants help to elaborate on the ultimate requirements for implementations of the ideas.

One part of the question list is asked before the testing starts. The middle part of the questions is split up in 7 parts; each lo-fi prototype has its part. The lo-fi prototype-specific questions are asked each time the participant finished using one of the lo-fi prototypes. Splitting up the questions is done to prevent the participants from forgetting about the lo-fi prototype after seeing seven of them. Next to that, splitting up the list of questions helps to create variety during the testing to make sure the participant does not get bored. After the participant has tested all the lo-fi prototypes, the rest of the question list is asked. The question list can be found in Appendix F: Lo-fi testing question list. The questions from the list are asked by the facilitator. The participant can respond with speech, to make it as easy as possible for the participants.

Content analysis of the results

After the 5 lo-fi tests, many results were gathered. However, the results of the lo-fi test were different per person since the lo-fi test was unstructured and open. Therefore, the content of the results per participant is analysed and summarized (a content analysis) in order to analyze the results in a structured way. When all results were processed, four categories came forward. These four categories are named below and are later explained in more detail.

1. Aesthetics

2. Functionality
3. Interaction
4. Purpose

Those four categories will be discussed in more detail in order to find the desired characteristics for the smart sport exercises.

Aesthetics

The coherence of the lo-fi prototype is complimented by the interviewees since the prototypes follow the same style. The interviewees think that indicating 'wrong' with the color red and 'right' with the color green is clear. One interviewee brought up that the block shadow should not be red because the shadow is not wrong or right. Next to the color, the visibility of the moving block shadow is doubted by three interviewees. The interviewees suggested freezing the visualization on the moment that the attackers jump. Since the block shadow also consists of a tip-zone, other shapes or colors should be used in order to clarify the difference.

Two interviewees suggest making the dots distinguishable and, therefore, recognizable. This can be done by adding numbers, letters, colors, or shapes. According to the interviewees, the athletes need to understand what the dots mean. Therefore, it is useful to use empty white dots as long as the dots do not belong to a specific athlete.

All the objects/targets used in the lo-fi prototypes can be reshaped. This reshaping can give new dimensions to an exercise. One interviewee mentioned that attacking a ball on a round shape requires more control than attacking a ball in an angular shape. This also applies to the size of the targets, where a smaller target is more difficult to hit than a bigger target. The trainer should be able to control the size and shape of these targets to make the exercise challenging for every skill level. Next to that, for example, using fun and appealing visualizations for small children might improve the level of enjoyment in an exercise according to the interviewees. The visualizations can be changed easily per age-group.

Other aesthetics were mentioned by the interviewees. One interviewee claimed that adding a timer or scoring table to a target could trigger the motivation of the athlete. Another interviewee added to this that changing colors could help the athlete to prioritize the targets unknowingly. Next, it could help the trainer to stimulate the athlete to prioritize a corner of the court over another corner.

Functionality

According to the interviewees, the interactive floor can be used as a replacement for practicalities. Pylons, hoops, tape, gymnastic cabinets, chairs, and noodles are the equipment that is often used in generic training according to the interviewees. The interactive floor can easily replace this equipment because the interactive floor is capable of visualizing a specific object anywhere. Usually, physical equipment is moved by hand by the trainer if the exercise needs an adjustment or if the exercise is completed. This effort and time can be erased if the trainer could move the digital objects on extern technology, for example, on a tablet or smartphone. One interviewee mentioned that the trainer prefers cancelling an exercise over adjusting it because it takes a lot of time and effort to change all the pylons.

Next to that, the interactive floor can be explanatory and can offer guidance to the athletes. The interviewees were enthusiastic about the lo-fi prototypes, where the interactive floor was used as a guide. For example, the guidance in the attack steps, the defense steps, or the ladder

exercise. The trainer should be able to adjust the level of guidance, according to the interviewees. The interviewees consider this of great value because the intention of the guidance should be to help the athletes rather than think for them. It can help the athletes, but it could also help the trainer to prepare the training at home and press the play button at the training. This might give the trainer more time to give feedback during the training since he/she does not have to focus on explaining the exercises.

The interactive floor can also be used as a visualization. The visualization can be chosen by the trainer and athletes. Some interviewees imagined that the visualizations should be different per age-group. For example, using a cartoonish jaguar for children and using abstract shapes for adults. However, this is, of course, subjective. Therefore, it would be useful to have a database with different visualization, so the trainer can choose which visualization fits bets. The visualizations could help to remind the athletes to do something. For example, visualizing a jaguar when the children should defend and stay low (just like a jaguar).

Two interviewees brought up that the interactive floor can also be used as a control mechanism. Since the interactive floor can trace athletes, a situation can be frozen. This frozen visualization can be used as a grounding for feedback that is given by the trainer. So, for example, what steps the attacker took before he/she hit the ball. The trainer could give feedback on his/her steps while showing the taken steps with the interactive floor. The interviewees imagine that this could decrease much discussion, and this may be of genuine value.

Interaction

Some interviewees were mainly enthusiastic about the floor that visualized the interaction between the athletes. This interaction was mainly visible prototype 1, where the block shadow was dependent on the positions of the blockers and attackers. The interactive floor could be used to show the relationship between athletes in a particular situation. According to interviewees, this would add an extra dimension to the training. Next to the block shadow, the interactive floor could help to divide the field into certain defend areas. This could offer more clarity in the defense-line. This direct feedback should be designed without any great fuss. Otherwise, it might be too difficult for the athletes to understand the direct feedback in a glance.

Next, the interviewees recognized an interaction between the athletes and the floor itself. This interaction was mainly explained based on the second and the seventh prototypes, where the athlete should hit or jump on a target visualized on the floor. This interaction was useful for motivating athletes to reach the desired goal, according to the interviewees. The interviewees believe that it would be more fun if the floor reacts upon the athlete if he/she, for example, hit a target. The athletes are more motivated to hit something if the hitting has a result. The interaction between the floor and the athlete might give more feeling of achievement during the exercises.

Purpose

According to the interviewees, the interactive floor can be used in the skill-development process. The interviewees claim that random practice improves the skill-development process. Changing the target on the interactive floor can quickly be done by hand or can be pre-programmed. This offers many opportunities to create an exercise that involves randomness.

The interactive floor can be used as a tool and can help the trainer to make training more effective. The interviewees imagine that the interactive floor could offer more opportunities in

creating more complex exercises. More complex exercises could result in a better skill-development or at a higher level of enjoyment. The floor could give feedback in such a way that the level of discussion decreases and where the training can entirely focus on the development of skills. Some interviewees mentioned that the interactive should not replace the trainer since the interviewees think that the social part of a team sport should not be removed.

5.3 Conclusion

The content-analysis analyzed the results of the lo-fi testing interviews in a structured way. After the content-analysis, the desired requirements are listed in the four categories (aesthetics, functionality, interaction, and purpose). According to interviewees, multiple characteristics are created. These characteristics will be used to improve upon the existing lo-fi prototypes.

Aesthetics

- ✓ There should be coherence in the design style between the different exercises.
- ✓ The visualizations should be visible from the position of the athlete.
- ✓ The object/targets/dots should be distinguishable and recognizable.
- ✓ The shape/size of the objects/targets should be chosen based on skill level.
- ✓ Visualizations should be adjustable per age-group.

Functionality

- ✓ The interactive floor should be able to visualize objects anywhere preferred.
- ✓ The trainer should be able to change a pre-programmed exercise by hand.
- ✓ The trainer should be able to change the level of guidance per exercise/athlete.
- ✓ The trainer should be able to freeze current positions of the athletes on the floor.

Interaction

- ✓ The interactive floor should be able to visualize the relation between athletes.
- ✓ The interaction between the athletes and the floor should be visualized.

Purpose

- ✓ The interactive floor should help in the skill-development process.
- ✓ The interactive floor should help in volleyball training as a tool.

5.3 Revised prototypes

Lo-fi prototype 1: the block shadow and lo-fi prototype 4: The Volleyball System will be improved based on the content analysis. Prototype 1 and 4 are seen as two lo-fi prototypes that need to be further tested. The concepts of the other five prototypes are sufficiently clear by the interviewees, so testing those ideas on a bigger scale probably does not give more insights about the concept at this point. Therefore, lo-fi prototype 1 and 4 will be revised based on the content analysis. The revised prototypes will later be tested as a prototype that is further developed (hi-fi prototype).

Revised lo-fi prototype 1: Block Shadow

The lo-fi prototype Block Shadow was received positively by the interviewees but could still use some improvement. The strong and weak points of the lo-fi prototype are listed below based on the feedback the interviewees gave during the lo-fi testing.

Lo-fi prototype 1: Block Shadow

- ✓ The interactive floor visualizes the positions of the athletes.

- ✓ The position visualizations could be used in other exercises.
- ✓ The interactive floor visualizes the relation between athletes by a block shadow.
- ✗ The dots are distinguishable and recognizable.
- ✗ The level of guidance is adjustable.
- ✗ The visualization is evident in the moment of action.
- ✗ The field is divided, so all the defenders know where they have to defend.

Colors, text, and shapes can be added or adjusted to make the dots distinct and recognizable. Since a volleyball team exists out 6 to 12 players [22], using a different color per athlete might not be as distinguishable as wanted. Therefore, numbers will be used to identify a dot and make it recognizable for the athletes. Using numbers also makes sense since the athletes already have a jersey number in a real-time match; the numbers are therefore easy to remember.

To be able to adjust the level of guidance, a scale of guidance has to be made. Three levels of guidance are suggested by the interviewees. The first level is where the interactive floor only gives guidance when the athletes struggle with the rules and do not know where to stand. This first level lets the athletes think for themselves. If the athletes cannot figure it out independently, the interactive floor will help. The second level is where the interactive floor gives a bit of guidance for the whole time and gives only more guidance if the athletes make mistakes. The third level is where the interactive floor thinks for the athletes. The athletes are fully instructed by the interactive floor. This third level might be necessary for athletes that face the volleyball system for the first time. Later the level of guidance can be switched to level 2 or level 1. If the athletes are familiar with the volleyball system and the guidance in level 1 does not show anymore, the interactive floor can also be switched off.

Lo-fi prototype 1: Block Shadow visualized the radius where the defender should defend. However, according to the interviewees, visualizing the radius of the defender would also be helpful outside the block shadow. Therefore, the defend-radius of the defender should be clear at any time. Next to this, the field can be divided based on the position of the defenders. Since there is much discussion about which defender should defend the ball, the field will be divided according to the number of defenders ‘available’ (ready to defend).

Revised lo-fi prototype 4: Volleyball System

The lo-fi prototype Volleyball System was a static concept where only the theory of the volleyball system was shown to the users. The strong and weak points of this prototype are listed below based on the feedback the interviewees gave during the lo-fi testing.

Lo-fi prototype 4: Volleyball System:

- ✓ The interactive floor visualizes the positions of the athletes.
- ✓ The position visualizations could be used in other exercises.
- ✓ The interactive floor prevents athletes from rotation faults.
- ✗ The dots are distinguishable and recognizable.
- ✗ The level of guidance is adjustable.
- ✗ The interactive floor visualizes the reasoning behind the positions of the athletes.

Since making the dots distinguishable and recognizable was also a requirement in the previous revised prototype, it is not explained again. This also applies to the requirement of making the level of guidance adjustable.

The positions of the athletes are based on the theory of the volleyball system. The most commonly used volleyball system is the 5-1 system, one setter, and five defenders/attackers. According to section 7.4.3 in the rulebook of the Nevobo ("Nederlandse Volleyball Bond," the Dutch volleyball association) [22], there are two types of volleyball rotation faults in the 5-1 system. The two rotation errors are visible in figure 22.

1. Row position faults: stay left/right of the athlete left/right next to you.
2. Back row/front row position faults: stay in front/behind the athlete in front/behind you.

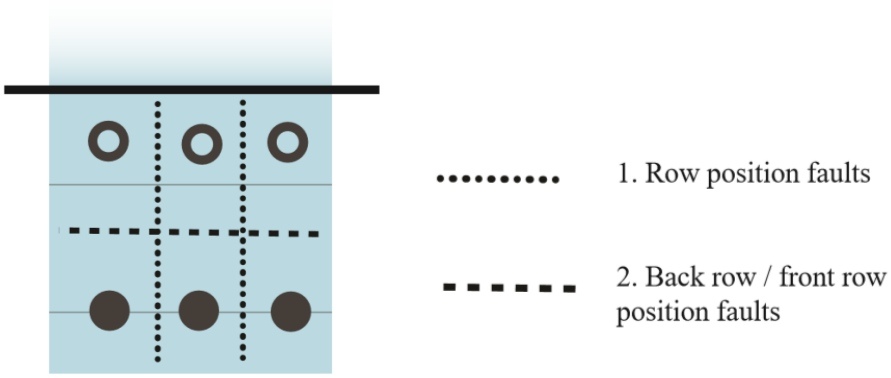

Figure 22: The two types of rotation faults

The athletes need help in why they are standing there instead of where they have to stand. The lo-fi prototype shows the athletes where they have to stand by visualizing a dot in the right position. The two rules that cause rotation faults have to be implemented in the next iteration of the prototype. That can help the athletes to understand the relation between the different positions. When the reasoning behind the positions is clear, the athletes can customize the positions in such a way that it works best for their team but is still correct according to the rotation rules.

6. Formative hi-fi testing

The goal of this formative hi-fi testing phase is to see how the prototypes turn out on a ‘full’ size interactive floor. This concerns opportunities that can easily be realized, so participants in the future are not distracted by small design flaws and can focus on the content of the exercises, in more extensive experiments. This type of formative hi-fi testing is more informal and allows more communication between the moderators and participants. The focus lies on how the user perceives the interface and not on how well the user completes the task.

The technical constraint during this hi-fi testing phase is the interactive floor. The interactive floor that is currently built and used by the project has a surface of 6 times 5 meters. It is ideal if the interactive floor could cover at least one side of the field since the whole team is standing in that area during a real-time match. Since the interactive floor (6 times 5 meters) is smaller than the original court size (9 times 9 meters), the court size is adjusted to the size of the interactive floor. The interactive floor comes under the net of the other side of the field with a width of 1 meter. A sketch of the measurements is visible in figure 23.

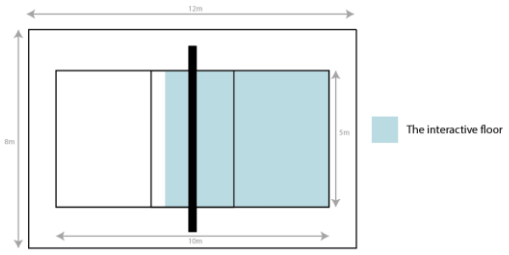

Figure 23: Measurements of the current built interactive floor

6.2 Research questions

The aspects of the hi-fi prototypes are translated into research questions to be able to reflect on the hi-fi prototypes. Some research questions can be answered by one, two, or by all three the hi-fi prototypes. A structure is created to see what prototype can answer which research question. The research questions are written below, and the structure is visible in figure 24.

General questions

1. What characteristics of the hi-fi prototype are positively received by the participants?
2. What improvements can be made for the hi-fi prototypes?
3. How well are the visualizations visible from different angles?
4. How can the design of the exercises be improved?
5. What are other technical difficulties that should be taken into account when designing digital-physical exercises for an interactive floor?

Class of prototypes

6. How well are the visualizations recognizable?
7. How do the participants behave on the instructions given by the interactive floor?
8. How well are the visualizations fully understood?

Prototype specific

9. When does the block shadow has to pause?
10. How large should the defend circle be?

11. How does the volleyball system help to understand the theory?
12. How well do the participants keep a distance?
13. How dependent are the participants on the dots?

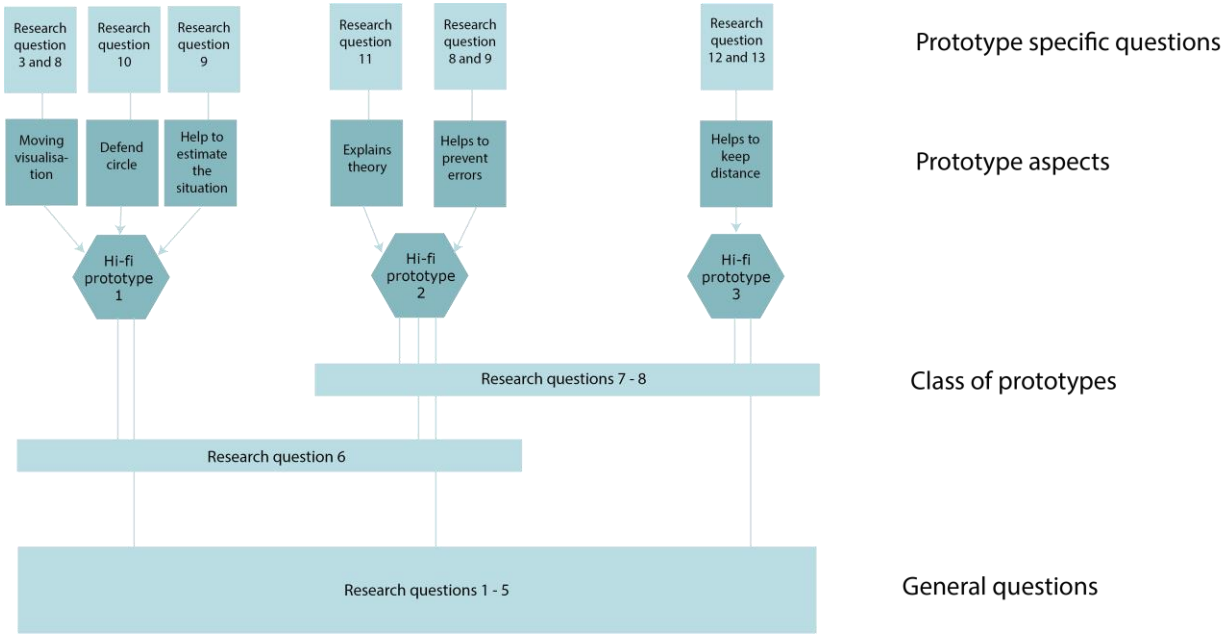

figure 24: structure of the research questions

6.3 The Hi-fi prototypes

This hi-fi testing focusses on the design flaws, the functionality, and tries to gather insights on the performance of the exercises on a real interactive floor. The results of the lo-fi testing phase suggested improving upon lo-fi prototype 1: block shadow and lo-fi prototype 4: volleyball system. Those two prototypes where the least static and are considered most likely to give more insights when testing those concepts in a hi-fi testing environment compared to testing them in a lo-fi testing environment.

The Rijksinstituut voor Volksgezondheid en Milieu (RIVM) set up rules to control the impact of the Corona disease. One of those rules is the 1.5-meter distance. The third hi-fi prototype is made to test if the interactive floor could be a helpful tool during the times of the 1.5-meter rule.

The interactive floor that is used for this hi-fi testing is 5 times 6 meter. There are 256 pixels located per meter. This means that the interactive floor has a size of 1536 times 1280 pixels. Therefore, the programs have to be adjusted to the pixel resolution of the floor to get the best result.

Hi-fi prototype 1: Block Shadow

This hi-fi prototype presents the concept of lo-fi prototype 1: Block Shadow of chapter 5. The concept of the lo-fi prototype was liked by the interviewees. The suggestions of the interviewees are incorporated in the design of the first hi-fi prototype: Block Shadow.

The defend radius that is used in the hi-fi testing is 2 meters. It could be true that this is too big or too small. The hi-fi testing can give more insights about the right size of the defending radius. Every athlete has his/her radius. The defend radius can help the athletes to understand where they have to stand to cover the desired area. The defend radius has to visible at any time to be helpful. Therefore, the radiuses are translucent white; this makes sure that the radiuses of multiple players can overlap but stay visible.

The dots of the athletes have numbers, to make sure all the athletes can recognize their dot. The block shadow is not red anymore since the block shadow is not considered as a 'bad' thing. Most people associate the color red with something wrong, therefore the color of the shadow is changed to a translucent dark grey to represent an actual shadow.

The results of testing with hi-fi prototype 1 will give insights into the design of the visualizations. If the visualizations are visible from any angle and if the athletes understand what the visualizations mean.

The design of hi-fi prototype 1: Block shadow is visible in figure 25.

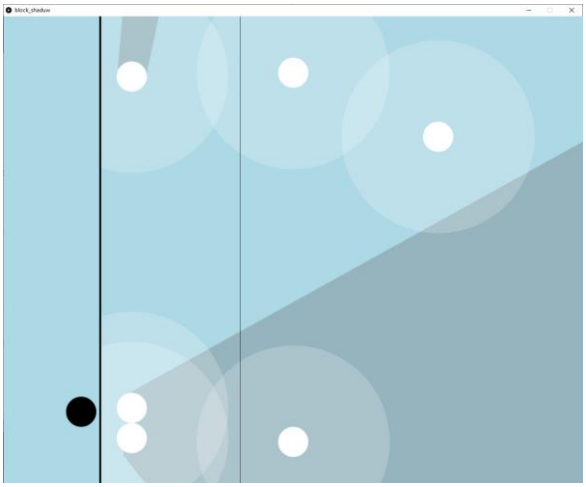

Figure 25: Hi-fi prototype 1: Block Shadow

Hi-fi prototype 2: Volleyball System

This prototype is based on the lo-fi prototype 4: volleyball system from chapter 5. The concept is generally the same. However, the way of presenting the concept is different.

The dots of the athletes are marked with numbers. This number can be customized per team/athlete. Since the concept of the prototype is about explaining and teaching the volleyball system, rules and visualizations had to be added to the lo-fi prototype 4. The position rules are programmed in the hi-fi prototype so that a positional error is directly visible to the athletes. A positional error is visualized by a red area that connects all the athletes. If two athletes cross/overlap each other where they may not. The dots of those two athletes turn bright red to makes sure the athletes understand who is in the wrong position. Not only the dots turn red, but also the area between all the players turns red. If there are no positional errors, the area between the athletes turns green. Connecting all the athletes by an area is done to involve all the players if two or more players make a positional error. The whole team needs to feel 'responsible' for every positional error, even if they are not directly involved. In the end, the whole team is affected by a positional error.

The results of testing with hi-fi prototype 2 will give more insights about teaching the volleyball system. The visualizations that are used need to be able to explain the different positions and the rules behind it. Except for only giving the rules, the interactive floor helps the athlete to understand why and where they may stand.

This hi-fi prototype 2: Volleyball system is visible in figure 26.

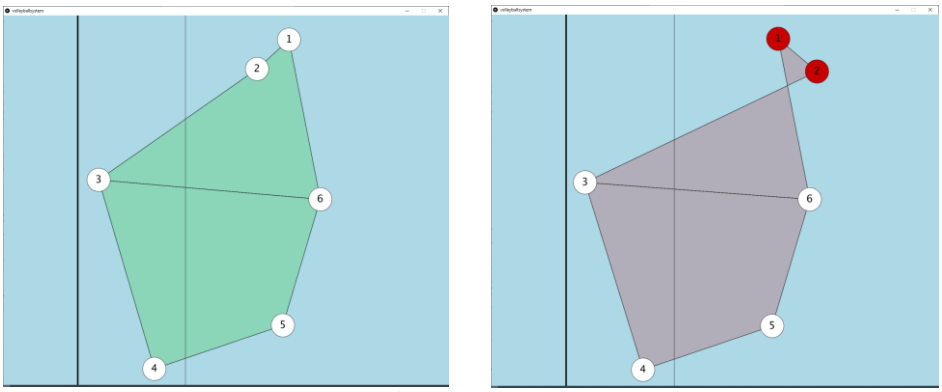

Figure 26: Hi-fi prototype 2: Volleyball System

Hi-fi prototype 3: Corona-proof volleyball

Volleyball is a team sport in which two teams of six players are separated by a net. The volleyball court is 9 times 9 meter at each side of the net and needs to be divided over the athletes where the athletes can keep the 1.5-meter rule in mind. However, when playing volleyball, it might be hard to keep looking at the other players to see if the distance is long enough.

There are two solutions possible to solve the problem of the 1.5-meter rule while playing volleyball. The first solution is dividing the court in different circles. Each circle has a radius of 0.75 meter, which means that two circles next to each other keep the 1.5-meter in mind. The athletes may go to another circle if that circle is free. The circles can be drawn on the court with tape, stickers, or markers. However, this means that the athletes still have to think if they may go to the circle nearby. According to the 1.5-meter rule, there needs to be at least one circle between the athletes, to be entirely safe

The second solution uses the capabilities of the interactive floor. Since the interactive floor locates the position of the athletes, it is possible to keep track of the distances between the players and can alarm the athletes when the distance becomes too small. To be entirely safe according to the 1.5-meter rule, the 1.5-meter circles may not touch other 1.5-meter circles. The two solutions are visible in figure 27.

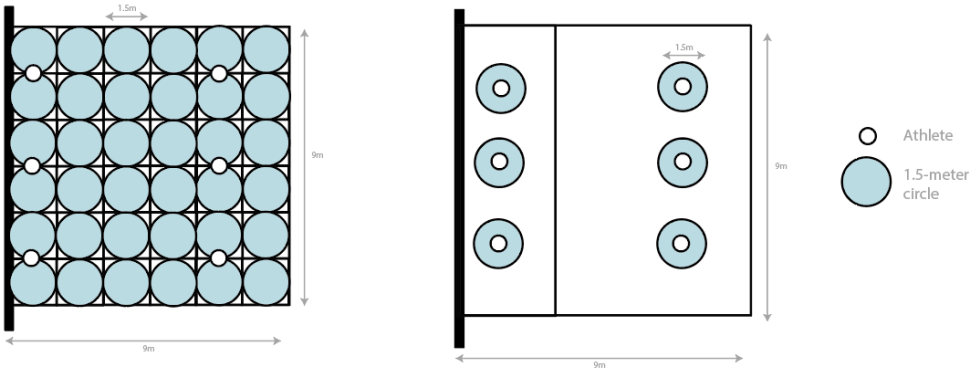

Figure 27: solution 1 (left) and solution 2 (right) to keep a distance of 1.5 meter

Since this thesis focusses on the interactive floor, solution 1 can use the interactive floor as a visualization of the circles. However, visualizing the circles can also quickly be done with tape or other marking equipment. Solution 2 uses the interactive floor as visualization, but next to that, it uses the technology in the interactive floor to track the athletes. Solution 2 is chosen to be further tested during the hi-fi testing because the capabilities of the interactive floor are better used compared to solution 1. Next to that, testing solution 2 as a hi-fi prototype can give insights into what visualizations are most suitable for volleyball practice.

The interactive floor that is used for the hi-fi testing phase is 5 times 5 meter instead of 9 times 9 meters. Therefore, the prototype is adjusted according to those technical constraints. The 1.5-meter is just as crucial during the hi-fi testing as during the volleyball practice. Therefore, the circles still have a width of 1.5 meter (384 pixels) and look, therefore, a bit large compared to figure 27. Hi-fi prototype 3: Corona-proof volleyball is visible in figure 28.

As visible in figure 28, the 1.5-meter circles are translucent, to help the athletes to understand where there is not enough distance (the overlap of the circles). Next to that, the color red is used since keeping not enough distance is, in this case, definitely a bad thing. The boundaries of the circles should go out of the court because it is also essential to keep a 1.5-meter distance with the coach and the opponent.

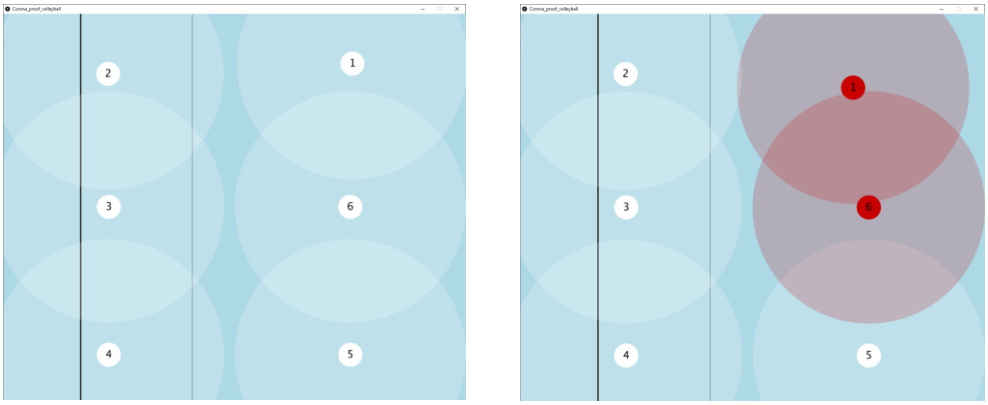

Figure 28: Hi-fi prototype 3: Corona-proof volleyball

6.3 Testing with the hi-fi prototypes

Participants

In total, there are 2 participants and 1 moderator attending due to the Corona restrictions. It would have been better to test the hi-fi prototypes with more participants than is currently done,

but the safety of the participants and moderators is the priority. The participants are carefully chosen based on their professional background. This is done to make sure that the result will be as good as possible. Both the participants have experience with doing research and work on the Smart Sport Exercises project. Next to that, one of the participants has experience playing and teaching volleyball. This gives the moderator more in-depth feedback on the hi-fi prototypes compared to participants who see the interactive floor for the first time. However, it could be true that the participants are not able to be as objective and independent as participants who are not familiar with the interactive floor. So, we should not be surprised if the follow-up research still finds some flaws in the designs since the participants in this research stand too close to the project. Due to the circumstances, this is the best thing the project can do.

Tasks

The participants are asked to do one or two tasks to get familiar with the hi-fi prototypes before they give their opinions. During the tasks, it is visible if the participants understand the hi-fi prototypes and if they can work with it.

Hi-fi prototype 1: Block shadow

1. One participant walks towards a chosen position as an attacker. The other participant walks towards the position he/she thinks is most valuable to defend. The participant explains based on his/her position, which player has to stand there.
2. The block shadow is paused in a particular position. The participants have to discuss/agree on where the ball can land without a defender defending it.
3. The participants may play around with the block shadow.

Hi-fi prototype 2: Volleyball System

4. The moderator causes a positional error by changing positions until a red area occurs. The participants have to explain why the error occurs and what they have to do to prevent the error from happening.
5. The moderator places defender 6 out of the passing line. The goal is to have at least 3 defenders in the passing line. They have to come up with a solution to do this.

Hi-fi prototype 3: Corona-proof volleyball

6. The participants have to stand on their circle and discuss how this distance is visualized. There are asked to think out loud about this use of 1.5-meter circles.

Visibility test

The visibility of the visualizations was a common worry during the lo-fi testing. The question if the visualizations are visible is valuable to know when improving these specific hi-fi prototypes. However, when creating new smart sport exercises, it would be helpful to know what sizes are visible from where. Therefore, a visibility test is done where the participants have to stand in different positions and have to score the visibility of the visualizations from 1 (not visible) to 5 (visible). In this task, 7 different sizes of circles are used (5, 10, 20, 30, 50, 70, 100 cm). Besides the size, color also has its influence on the visibility of the circles. According to Holtzschue [23], there are 4 underlying color harmonies: complementary, analogous, triadic, and tetradic color schemes. This thesis has chosen #ADD8E6 as a background color for the volleyball court. However, since the visibility test will test which of

the four colour harmonies are most useful to use, the result will be also applicable to other background colors.

A color-calculator[17] can help to find the color harmonies. The four harmonies of #ADD8E6 are visible below.

Complementary Analogous Triadic Tetradic

Since some colors occur in multiple color harmonies, only five colors have to be tested to be able to conclude on the color harmonies. The colors that are used for the visibility test are visible in figure 29.

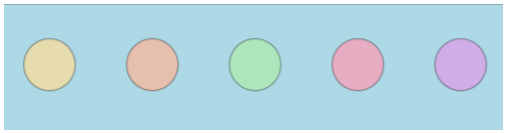

Figure 29: Colour for the visibility test

However, this thesis has chosen a pastel color scheme, which is low in color saturation. Therefore, also the primary colors (red, green, blue) and the colors black and white are brought to the hi-fi testing to see the difference between pastel colors and more bright and saturated colors.

The visibility test is the sixth and last task for the participants.

7. The participant is asked to stand on a distance of 9 meters and rank all the dots per color. Then, the participant is asked to choose its favorite size and color and note this in the scheme. After that, the participant is asked to stand on a distance of 7.5-meter and later on a 5-meter distance. The scheme that the participants are asked to fill in is visible in figure 30.

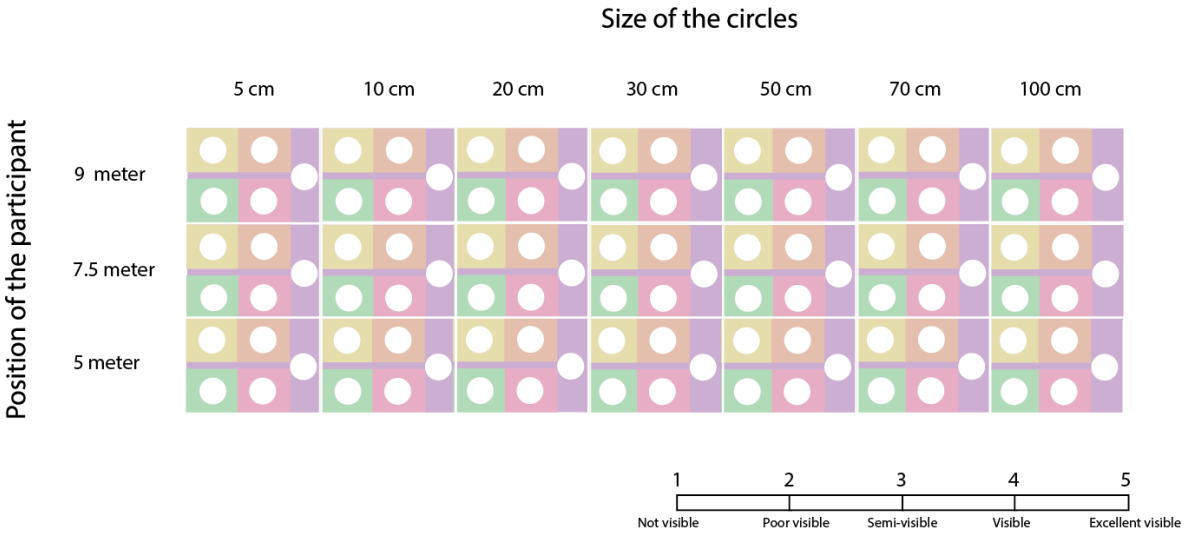

Figure 30: 5-Likert scale for the visibility test

[17] https://www.sessions.edu/color-calculator/

Collecting data

An observational scheme and a questionnaire are made to collect qualitative data. Both the questionnaire and the observational scheme are scaled from strongly disagree to strongly agree. This five Likert scale is used to translate qualitative data (opinions/behavior/expressions) into quantitative data (numbers). This quantitative data can be analyzed with relative ease. The questionnaire and the observational scheme can be found in Appendix G: Questionnaire Hi-fi testing. The observational scheme is visible in table 2.

	Strongly disagree	Disagree	Neutral	agree	Strongly agree	Notes
The participant understands the exercises.						
The participant enjoys the exercises.						
The participant finds errors.						
The participant needs time to react on the interactive floor.						
The participant carries the exercises out according to the plan.						

Table 2: Observational scheme.

The questionnaire is handed over to the participants after the formative hi-fi testing. The observational scheme is used by the project team while the participants are using the interactive system. This observational scheme can help the project team to collect data on the opinions, behavior, and the expressions of the participants.

The evaluation procedure

Before the hi-fi testing starts, the participants have to sign the consent form. The consent form can be found in Appendix A: Consent form adult. After the consent form is signed, the participants are allowed to participate in the hi-fi testing.

The moderator of the hi-fi testing explains to the participants the six different tasks they have to do. The moderator is available through the whole experiment for questions. The six different tasks are visible below, together with the explanation that the participant will receive when participating in the hi-fi test.

Task	**Explanation**
1	One participant chooses an attacking position. The other participant has to estimate where he/she should defend. After he/she chooses, he/she has to explain which position should be on that location to defend.
2	Both participants have to stand next to each other with a suitable distance (1.5 meters). The block shadow will be simulated by the moderator, and the participants have to agree on where the scoring options are.
3	The moderator will cause a positional error, and the participants are asked to come up with a solution to solve the positional error.
4	The moderator places defender 6 out of the passing line; the participants are asked to replace the players in such a way that the passing line consists out of 3 passers without the use of athlete number 6.
5	The participants have to stand on one of the circles and have to get the feeling of the 1.5-meter circle. They are asked to talk out loud about the visualization of the 1.5-meter circle.
6	The participants are asked to fill in the visibility test scheme. The moderator clicks through the sizes of the circles.

In this moment of time, the locations of the athletes cannot be tracked through use of the interactive floor. Therefore, the choice has been made to track the positions of the athletes by hand. Replacing the technical interface by a human is also known as a Wizard-of-Oz approach. The Wizard-of-Oz approach is used to meet the needs of this hi-fi testing. The 'magic' in the Wizard-of-Oz approach that makes the demo work is performed by a human. The Wizard-of-Oz approach enables to test the interface without full implementation of the technology. The truth would typically not be revealed to the participants until the end of the experiment. However, the participant can see the moderator during the experiment. Therefore, it is likely that the participant witnesses the Wizard-of-Oz method carried out by the moderator. To prevent this from happening, the moderator will be honest and explains the Wizard-of-Oz method. The Wizard-of-Oz is the most suitable way of testing with this not yet finished interactive floor. However, it has its limitations. The moderator would likely make human errors while following the position of the athletes with the computer mouse. Therefore, it might be challenging to control the independent variable to achieve the desired condition. The observations on the participant are done in a structured way to make sure the result of the experiment does not suffer under the technical constraints and the Wizard-of-Oz approach. The interactive floor that is used during the formative hi-fi test is visible in figure 31.

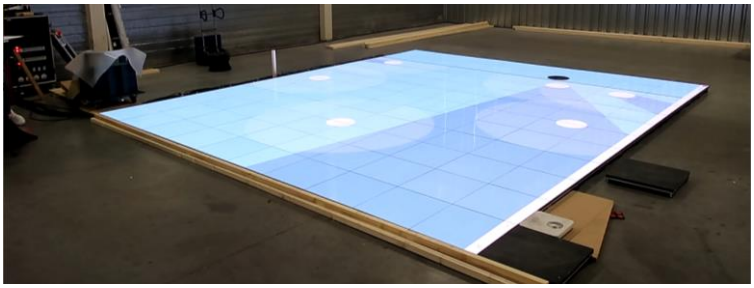

Figure 31: The interactive floor

The observational scheme (table 2) will help the moderator to observe the participants in a structured way. At the end of the hi-fi testing, the questionnaire of Appendix G: Questionnaire Hi-fi testing and a pen is handed over to the participant. The questionnaire and the visibility test sheet are printed so that no technical problems can occur.

6.3 Results

Aesthetics

Both participants were satisfied with the design of the system. The consistency in design in the three exercises (Block Shadow, Volleyball System, and Corona-proof Volleyball) is liked by the participants. According to the visibility test, the analogous color harmony is least visible from all the different distances. Besides that, the participants claim that the higher the contrast between the colors, the better the visibility. Based on the visibility test, it is recommended to use circles of at least 20 centimeters to make sure the circles are visible from any angle/distance.

Before the prototypes were turned on, it became clear that the interactive floor has lots of detail. Together with the participants, a new idea came up. The interactive floor is detailed enough to show videos and, therefore, it might be possible to show the athlete a replay of his/her previous action(s). Showing a replay might help the athlete to understand their previous action better. Next, showing a replay is a fast way of giving feedback, since it does not require further explanation. However, to be able to play a replay, cameras should be added to the system that

can record the athlete's action and can send the recordings to the interactive floor in a matter of seconds.

Functionality

The participants both agree that the main functionality of the prototypes is to decrease the discussion during a volleyball exercise. The current interactive floor can show visualizations that are sent to the floor by using an HDMI-cable. The sensing part of the floor is not yet working. Therefore, the current primary functionality of the floor in this hi-fi testing is to show visualizations. Showing these visualizations can help decrease the discussions between athletes or between an athlete and the trainer. Next to that, the participants claim that the visualizations can also function as a guide or as an explanation.

Interaction

During the visibility test, the participants claim that the circles with a high color contrast are visible. However, when the participants are asked to throw a ball on that specific circle, it was not that easy. The participants claim that it is hard to estimate the location of the circle because the shape of the circle is different per distance. The circles that are currently used are single-colored and do not have a pattern. Therefore, it might be hard to see the perspective as an athlete. The participants claim that a lined or dotted pattern on the circle might help to estimate the location of the circle from any perspective.

Purpose

During the hi-fi test, it became clear that there are three main purposes for prototypes.

1. Theory explained beforehand

This purpose fits by the hi-fi prototype Volleyball System, where the theory is explained before the opponent serves. The theory has to be explained beforehand because positional errors cause direct scoring for the opponent.

2. Theory explained during

This purpose fits by the hi-fi prototype Block Shadow and Corona-proof volleyball since the interactive floor explains the theory during these exercises. According to the participants, the Block Shadow can help the defenders to estimate where they have to defend. Next to that, the participants agree that the block shadow is not visible enough for the attacker since it is hard to focus on other things than the ball. The Corona-proof volleyball can remind the athletes of the 1.5-meter rule. However, the circles of this prototype have a diameter of 1.5-meter. Therefore, it is already too late if an athlete gets a warning. The prototype works better if the diameter of the circles is, for example, 2-meter, according to the participants.

3. Theory explained afterward

The idea of showing a replay to the participant explains the theory afterward. The athlete can watch the replay of his/her previous action to learn from it before he/she goes to the next action. However, according to the participants, this might only work in drill-exercises, where the athlete has to wait in line before he/she may go again since the athlete then has time to watch his/her replay. On the game-level, it might take too much time to watch a replay after each action. However, if the trainer/coach has control over the replays, the replay can be shown as additional feedback while the trainer/coach provides feedback.

6.4 Conclusion/recommendations

The design of the hi-fi prototypes is tested on a 5 times 6-meter size interactive floor. The designs on the interactive floor are liked and are pleasant to see. Bernhard researched color design for the color vision impaired, and suggest to use colors with a high contrast since that is most visible [24]. Next to that, he advises against using red together with green since the difference between those two colors is hard to tell for someone who is color vision impaired. The participants in the hi-fi test agree with Bernhard. When designing accessible digital-physical exercises for anyone, it is recommended to use colors with high contrast and to avoid using red and green in the same design.

The Corona-proof volleyball prototype is tested to see if the warning is helpful for the athletes. However, warning the athletes when they violate the 1.5-meter rule is too late. Therefore, it would be better to warn the athletes already when they pass a 2-meter distance so that the athletes know that they are in a 'dangerous' zone. Instead of making existing exercises Corona-proof, new exercises (from origin Corona-proof) can be made. The idea of creating such an exercise came up during the hi-fi test and is visible in figure 32.

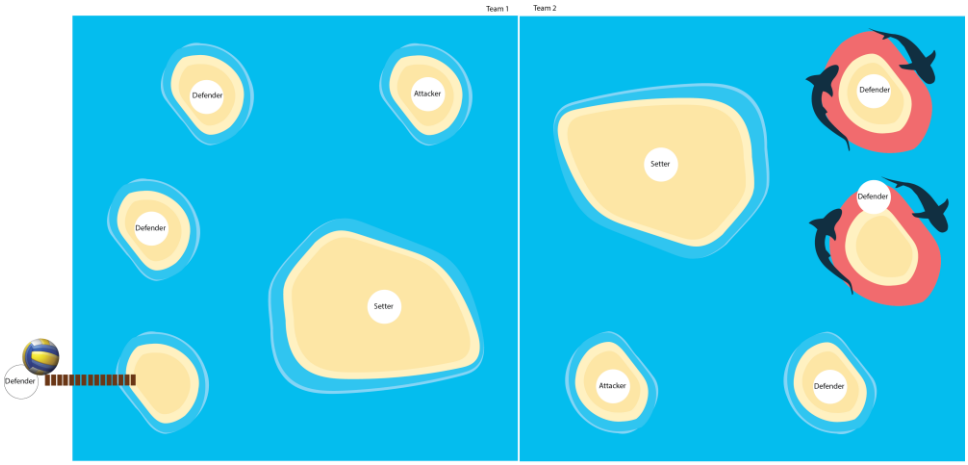

Figure 32: The Island game

The Island game is Corona-proof and can be played with ten players (two teams of five). On the left in figure 32, a defender is serving. A bridge is drawn between the athlete and his island. After the serve, the defender has to go back to his island via the bridge. The bridge prevents the s defender from violating the 1.5-meter rule. On the right of figure 32, it is visible that one defender almost left his island. Sharks swim around his island to 'scare' him and force him back to his island. An additional red marking around the island appears to warn the athlete. The defender that is close to the defender that is leaving his island is also warned by a red marking and the sharks. The defender who leaves his island will keep one shark around him for one minute. If the athlete does not leave the island again within this one minute, the shark will disappear; otherwise, the shark will stay for another minute. The island of the setter is bigger than the islands of the defender/attackers to give the setter more options and space to set the ball. The task of the attacker is to attack the islands of the defenders of the opponent. If the ball ends up in the water or on the island of the setter, no scoring point is given. In the end, the total score is the scoring points minus the number of visible sharks. The defenders and attackers can switch islands when the trainer prefers. This Island game is an example of a game where the 1.5-meter rule is fully integrated. The interactive floor can trace the athletes and can visualize islands and sharks as in figure 32. The interactive floor has a significant value in these games

since the general equipment (pylons, hoops, gymnastics cabin) cannot warn the athletes as the interactive floor can. Especially in times of Corona, the interactive floor has much potential in these Corona-proof exercises since the 1.5-meter rule must be maintained.

This formative hi-fi testing is done with participants that have experience with the used user interface (interactive floor). Therefore, the participants are experts in the field. These experts can give in-depth feedback and identify potential usability problems. However, testing with the target audience (volleyball athletes, coaches, and trainers) could give more or different results. Therefore, it is recommended to test these hi-fi prototypes again with the target audience, before the final concept is made.

7. Plan of experimental research study

The goal of this phase is to set up an experimental research study that can be done when the corona-constraints are over. The goal of the experimental research study is to find out whether or not the interactive floor can help to teach the volleyball system. After this test, it is possible to improve upon the hi-fi prototype: Volleyball System, as become clear through user interaction. The Volleyball System is designed with the idea that volleyball athletes get the opportunity to learn the volleyball system while getting direct feedback from the interactive floor. Next to that, the interactive floor can be used as guidance for both athletes and trainers. This can help to decrease discussions and to make a volleyball practice more enjoyable.

7.1 Research questions

A research question is made to test whether the interactive floor is useful while learning the volleyball system.

> **Is the exercise Volleyball System on the interactive floor helpful while learning the volleyball system?**

7.2 Recruitment and the selection of participants

Two main requirements are made before the participants are selected. The participants must comply with the two main requirements to make sure the results of the experimental research study are unbiased.

1. The participant is in the age group of 18-30 years.
2. The participants practice his/her volleyball skills at least twice a week.

The participants are contacted via advertisements for the experiment. The advertisements are sent to the volleyball teams that are competing in the annual Nevobo (Dutch volleyball association) competition by email. According to the board of Harambee, all the volleyball teams that compete in the annual competition have the opportunity to train twice and play one match a week from September till April.

Since the advertisements are only sent to the volleyball teams that compete in the annual competition, it is plausible that all the participants practice their volleyball skills at least twice a week. Applying to Harambee as a non-student is more expensive than applying as a student or applying as a non-student to a general volleyball club. Therefore, it is also plausible that all the participants are between 18 and 30 years. Despite this, the age of all the participants has to be confirmed, preferably by ID or driving license.

The experiment will be conducted in the Sports Centre, preferably in room 1 or 2 since all the volleyball practices of Harambee usually are in one of those two rooms. The experiment will be done in only one location. Even though this might mean that the installation is only tested in one specific Sports Centre room, it is the only way to ensure that the general participant is similar in all experiments, so the individual differences are effectively isolated. The experiment takes 10 weeks to make the results of the experiment more reliable. The volleyball competition has a Christmas break from mid-December till mid-January. Therefore, the experiment of 10 weeks is preferably conducted before or after the break, to make sure the 10 weeks are continuous. The testing will be done over some time (10 weeks) to reduces the effects of confounding variables such as sickness, inadequate sleep, or stress.

The participants will be recruited in the field. The recruiters will ask the volleyball athletes if they want to join the experiment. If the participants like to join the experiment, they are asked if they agree with not practicing volleyball outside the 10-weeks experiment (except for the matches from their annual competition). The recruiters will bring the participants to the project team if the participants still agree with the experiment. The age of the participant has to confirm. Next, the participant has to confirm how many times he/she practices volleyball per week. If the participant complies with the requirements, he/she is allowed to participate in the experiment. After the experiment is explained once again, the participant has to fill in the consent form. This consent form can be found in Appendix A: Consent form adult. After signing the consent form, all the participants are equally divided over group A or B by a randomization software. The maximum number of athletes per volleyball team is 12 since only 12 athletes may compete in the annual competition matches. The board of Harambee confirmed that they strive for 12 athletes per volleyball team and ensure that the maximum number of athletes per team is 12. Therefore, the desired number of athletes for groups A and B is 12. The experiment groups are of equal size, even if less than 24 participants are willing to participate to ensure similar conditions,

7.3 Method

A between-subject design will be used to test if the interactive floor is helpful while learning the volleyball system. This means that the participants are divided equally over the two experimental groups. Only experiment group A may practice with the interactive floor. Experiment group B practices the volleyball system without the use of the interactive floor.

Conditions

This experimental research has two test conditions. Condition 1, where the interactive floor is turned on during the 10-weeks practice (group A). Condition 2, where the interactive floor is turned off during the 10-weeks practice (group B). The effect of condition 1 and condition 2 on the dependent variable will be compared.

Set-up

The interactive installation is created for volleyball practice. Therefore, the experiment will take place in the volleyball environment. The interactive floor will be integrated into the floor of the volleyball court. This ensures that both experiment groups practice on the same floor-material. Next, both experiment groups make use of the same volleyball and volleyball net.

The project team has access to laptops and cameras to work as efficiently as possible. The project team is not visible for the participants to ensure that the participant does not behave differently compared to being alone. The project team can watch the participants via screens and can observe and write down remarkable things.

The interactive floor explains to the athletes of group A what they have to do and when. The interactive floor can define the location and movement of the athletes and can define the location of the ball. This information is translated into feedback. The feedback is given to the athletes by the interactive floor. Group B does not have access to the interactive floor, and therefore, the floor is turned off during their practice. Group B does the same exercise as group A, but the explanation and the feedback are provided by the trainer in words. This makes sure that group A and group B practice the same exercise for the same time.

All the athletes have to fill in a consent form before the experiment starts. After signing the consent form, the athletes are aware that the project team is watching them, and they permit using their data for the research. Before the 10 weeks start, all the participants have to fill in a questionnaire about the theory on the volleyball system, so that the project team can analyze their knowledge on the volleyball system beforehand.

During the experiment, the exercise Volleyball System needs to be carried out for 20 minutes per training. The project team observes the athletes and writes down the remarkable things. After 10 weeks, the same questionnaire, which is mentioned above, is filled in by the participants once again. The results of before and after the 10-weeks experiment will be cross-checked and analyzed. The participants may not practice the volleyball system outside the 20 minutes per training to make sure that all participants practice the volleyball system for the same time. The Volleyball System exercise is the measuring tool for this experiment and being 'good' in this exercise is not the goal.

Hypothesis

It is expected that the participants in condition 1, group A improve their knowledge on the volleyball system faster than group B. If that hypothesis is correct, the exercise Volleyball System on the interactive floor is helpful while learning the volleyball system. The experimental research study will test the null hypothesis. If the null hypothesis is rejected, the alternate hypothesis is correct. The null and alternate hypothesis is visible below.

H_0: *The exercise Volleyball System on the interactive floor is not helpful while learning the volleyball system.*

H_a: *The exercise Volleyball System on the interactive floor is helpful while learning the volleyball system.*

Variables

This experimental research study has both dependent and independent variables. The dependent variable is the improvement of the knowledge on the volleyball system. The independent variable is the type of practice the participants use (practicing with or without the interactive floor). This independent variable is controlled by the project team. The dependent variable will be measured during the experiment. Other influencing factors than the (in)dependent variables are the confounding and the controlled variables. The confounding variables that play a role in this experiment are, for example, sleeping time, stress, eating habits, or use of alcohol. The participants are randomly assigned to group A or B to minimize the effects of those potential confounders. Despite, groups A and B might still differ in the level of confounding variables by chance. The randomization of the participants to group A or B minimizes these differences. The controlled variables are added to the experiment to reduce the effects of the confounding variables. This experiment is controlled for age (18-30 years), and the average number of practices per week (>2).

Measurements

During the test session, there are two types of data collection done.

Quantitative data

The quantitative data that is collected in this experiment is the knowledge on the volleyball system while using a questionnaire. This quantitative data is collected to calculate the

improvement over a specific period. This calculation helps to compare the level of improvement over 10 weeks.

Qualitative data

The qualitative data that is collected for this experiment is done via interviews, surveys, and observations. The expression, reaction, and sayings are written down, recorded, and saved in the database, to get insights about the design and functionality of the product.

Protocol

The information brochure will be handed over to the participants before they sign the consent form. The brochure offers information about the Smart Sport Exercises project. The information brochure can be found in Appendix H: Information Brochure. The project team offers more information on what is expected from the participants if that is needed.

To make sure the experiment goes according to the plan, the project team will be available at all times during the experiment. However, the project team will disturb the athletes as little as possible to prevent influencing the results of the experiment.

Instructions for the participant

The participants are not allowed to study the volleyball system outside the 10-weeks experiment except for the Nevobo matches. The participants are asked to listen to the interactive floor or to the trainer (dependent on their experiment group) so that the project team gets the most out of the experiment. The project team is available at any time, and this is clearly explained to the participants.

7.4 Analysis Plan

After the 10-weeks experiment, the project team has gathered many data. This data includes qualitative data and quantitative data. The measurements from before, during, and after the experiment are saved to the database and are analyzed.

Reliability of the results

This experiment strives for high reliability. However, testing with humans can result in many errors. This makes it hard to duplicate or redo the experiment, and it might bias the outcome of the experiment. Therefore, the fluctuations in the experimental results have to be considered and understood.

Random errors

The random errors in this experiment can have a significant impact on the results because the sample is relatively small. Both experiment groups A and B consist of 12 participants. If the sample is small, the random errors might not offset each other. It is ideal to use more participants and to test over a more extended period. However, this experimental research study is made to be executed in the near future, with a feasible number of participants.

Systematic errors

Next to random errors, there are probably systematic errors in this experiment. Random errors can cause variation in both directions of the actual value. Systematic errors can only cause variation in one direction. The systematic errors are harder to offset because they do not offset themselves as random errors do.

This experiment uses the interactive floor as the primary technology. If the technology fails, it could cause a systematic error. For example, the feedback on positional errors should appear when the two athletes cross each other while they may not. However, if the position of the athletes are not accurate, the interactive floor may give positional feedback too late. This could bias the functioning of the exercise.

Written documents are made to decrease the bias caused by the experimental procedures. The written documents will entail a detailed instruction for the participants and a detailed procedure for the experiment. The written documents will be given or read out loud to the participants and the moderators to make sure everyone gets the same instructions.

The bias caused by the participants is decreased be recruiting the participant carefully. Next to that, the volleyball practice environment is used to cause the least stress to the participants. The participants have the chance to ask the moderator when they have questions, and this might decrease the stress level of the participants.

Independent-samples t-test

The *t*-test is considered the most common statistical procedure used to compare two means, according to Rosenthal [25]. The two experiment groups A and B are not related since the groups are created by randomization software. Therefore, an independent-samples *t*-test is used as a statistical procedure for this experimental research study.

Statistical software, such as SPSS, uses the data from the experiment to calculate the value *t*. The more significant *t* is, the higher the probability of the null hypothesis being false. In other words, the more significant *t*, the higher the probability that there is a significant difference between the mean of group A and B, and the interactive floor improves upon traditional existing training approaches.

Significance tests help to determine if the results observed can be generalized to the entire population; in this case, the population of volleyball athletes. Significance testing determines the likelihood that the null hypothesis is correct [26]. There are two risks involved in significance testing.

- Type I error, rejecting the null hypothesis while it is true.
- Type II error, not rejecting the null hypothesis while it is false.

In this experimental research, a type I error occurs when it is decided that the Volleyball System exercise on the interactive floor is helpful while learning the volleyball system but this is not the case on the general population. A type II error occurs when it is decided that the exercise is not helpful while it is. According to Lazar [26], it is believed that type I errors are worse than type II errors since type I errors might result in a condition worse than the current state. A low p-value (0.01) is adopted to control the occurrence of type I errors.

Conclusion

The experiment is held in a comfortable and known environment, the participants are equally divided over group A and B by randomization software (between-subject design), and the experiment will be held in 10 weeks to reduce the confounding variables.

The predicted bias has to be taken into account when analyzing the results of this experiment. However, the experiment is designed in such a way that the level of bias is manageable. Despite, the theory needs to be tested in practice before any conclusions can be drawn.

The *t*-test compares the two means of groups A and B. If the null hypothesis is rejected, the result of the experiment proves that there is a significant difference between the two means of the two experimental groups. After rejecting the null hypothesis, there is sufficient evidence to conclude that the exercise Volleyball System on the interactive floor is helpful while learning the volleyball system.

8. Conclusion and discussion

The main research question of this thesis this thesis is:

> ***What is the potential of the interactive LED-floor to improve upon traditional (existing) training approaches, and how can this be implemented in a volleyball practice?***

In order to answer this question, information from related work, interviews, and observations were collected. The collected information was used to create a design space. This design space guided the ideation phase, where 150 smart sport exercises were created. The 150 exercises were translated into seven lo-fi prototypes, which were created, tested, and evaluated. Later, three hi-fi prototypes were created, tested, and evaluated. Together with this information, one prototype was selected and is used in the plan for an experimental research study.

According to the findings of this thesis, the interactive floor can improve upon a traditional existing training approach by erasing the discussion between athletes or between the trainer and the athletes and by offering more guidance. In addition, the athletes and volleyball trainers that participated in this research think that the interactive floor could help to make the training more fun and engaging.

8.1 Contributions

This thesis has many findings, and those are discussed throughout this report. However, four significant contributions are worth to look at once again.

The created design space can help other researchers while brainstorming about more smart sport exercises related to volleyball. The structure of the design space is grounded in literature, interviews, and observations. Next to that, the idea of creating a design space can be used as a tool in other research to guide their ideation process. This thesis was not the first that used a design space during the ideation phase. However, this thesis showed that using a design space is a effective way to generate new ideas. This is not (yet) often seen in projects that focus on interaction technology in sports.

Second, the lo-fi testing phase proved that it is feasible to create simple interactive prototypes that show the central concept of the ideas. Besides that, the method of lo-fi testing showed that it is possible to do user testing at a distance. Next to that, the lo-fi prototypes showed that there is a wealth of smart sport exercises that can be used in volleyball practice. The lo-fi testing section also came up with a requirement list that is recommended to take in mind while creating (new) prototypes.

Third, the evaluation of the lo-fi and hi-fi prototypes showed that the interactive floor has potential in volleyball practice. The positive reaction of the participants in the lo-fi and hi-fi testing proved that the created smart sport exercises work for the user (user acceptance).

Fourth, the plan for an experimental research study has stated how the prototype Volleyball System can be tested. This research study can easily be conducted by a future researcher.

8.2 Limitations

Besides the contributions of this thesis, there were also limitations. Other choices could have been made that may have led to another outcome of this thesis. These limitations are discussed

here. More than 150 ideas could have been made during the ideation phase. The lo-fi and hi-fi tests could have been conducted with more participants in order to gain more insights about the tests. The results could have been different if the hi-fi prototypes were tested on an interactive floor with a size equal to a volleyball court in order to make the test more realistic. However, these are just minor limitations, other limitations probably have had a more significant impact on the results of this thesis. These limitations are discussed below in more detail.

- The lo-fi tests haven been carried out through use of video chat programs online, due to the Corona restrictions. During online testing, it is harder to observe the user since the user is only visible by the camera. Next to that, online testing is more distant, and this can cause that the participant is less talkative compared to testing in person. Therefore, it could be true that lo-fi testing in person would have given more or different results, and this has to be taken into account when looking at the results.
- The interactive floor's technology has not been fully implemented yet by the manufacturer. Therefore, The Wizard of Oz method has been used in the hi-fi testing to 'fake' that the hi-fi prototypes were interactive exercises. During the test, there were no wizarding problems. Therefore, it is assumed that the Wizard of Oz method has not stood in the way of the results of the hi-fi testing. However, the technology of the interactive floor should be able to execute the prototypes on its own in the future. Therefore, sensing should be added to the interactive floor before the prototypes can be further tested and developed.
- The hi-fi prototypes were tested with experts of the Smart Sport Exercises Project instead of the target audience. The tested experts might have a higher user acceptance since the experts are above the average interested and are already used to using the interactive floor. Therefore, it could be true that the hi-fi testing phase would have given different results if it was tested with the target audience. It is recommended to redo the formative hi-fi test with the target audience to make sure all the usability problems are identified.
- During the test with the hi-fi prototype, a new idea was created. However, more research on maintaining the 1.5-meter rule should be done in order to create more Corona-proof exercises.

8.3 Implications

During this thesis, many choices have been made in executing the research efforts. However, what does that mean for future research?

The first implication of this study derives from the targeted user group. This thesis was focussed on young volleyball athletes that want to improve their (existing) volleyball skills. Another user group could be children from 6-12 years old who play Cool Moves Volley (CMV). CMV teaches children volleyball related techniques in a playful matter[18]. This means that the children learn to play volleyball step by step. In contrast to children, young athletes are more focused on the result of the game (win or lose)[19]. Therefore, generating different exercises per user-group should be considered in the next iteration of this study since their main goal might differ.

[18] https://www.nevobo.nl/wedstrijdsport/zaalvolleybal/cmv-competitie/
[19] https://www.fivb.org/TheGame/Fundamentals.htm

The second implication stems from the choice of using the interactive floor as the main technology. Besides the interactive floor, other technology such as smart sensors, augmented reality, or virtual reality could have also been used as the primary technology. Each technology has its advantages and disadvantages. According to this thesis, the interactive floor can make more flexible learning environments and can make volleyball more fun and engaging. On the other hand, the volleyball trainers and athletes have to learn how to get along with the interactive floor, and the interactive floor is already expensive for only the technology, not yet talking about the implementation costs. This study found the utility of an interactive floor as the primary technology, future research should evaluate the landscape of available technologies and exercise judgment on the viability of alternatives.

The third important implication of this study is the chosen design (color or shape). These design choices are based on the expertise of the author of this thesis. Later the taste of the lo-fi and hi-fi testing participants was taking into account and was used while improving the prototype designs. However, from the start, the color scheme was equal in all the prototypes. It takes more time, effort, and skill to improve upon a design compared to choosing between two design options. Therefore, it might be true that the opinion of the participants will differ if they have the chance to choose from a selected number of designs.

The last and fourth implication derives from the used ideation method. The ideas have been generated during a brainstorm that was performed by one individual, in this case, the researcher. This has not limited the ideation phase as 150 ideas have been created. However, the diversity and applicability during a volleyball practice might be inhibited by the lack of co-design with experts. Nevertheless, it is also possible that more diverse and more creative ideas have come forward due to the author's experiences with ideation tools and having a background as a volleyball athlete. The benefits of co-design (also called; participatory design) are extensively discussed in the literature. Multiple papers claim that using co-design improves the creative process and the knowledge on the user needs and is more efficient in decision making [27-30]. Therefore, co-design with volleyball trainers is recommended in the future since their habit of re-designing volleyball exercises on the spot and focus on applicability might bring new ideas to light.

8.4 Future work

The topics of the context analysis of this thesis could be further explored. Especially the effects and the implementation of the small-sided games could be more detailed. Furthermore, future research can expand on the list of 150 ideas and can implement this is in new prototypes. Regarding the interactive floor, in-depth research on the technical possibilities is helpful while designing digital-physical exercises that can be carried out soon.

Besides that, many unexplored possibilities are left for future research. This thesis was mainly focussed on the team sports volleyball. However, the results of this thesis might also apply to other (team) sports. Some ideas came up during this research outside the scope of this thesis that are worth pursuing through testing and further research.

1. Create a planning tool and a database of exercises. So, the trainer can easily see what exercise can be done when. The planning tool can be used to pre-program a practice. The planning of a specific day can be attached to the interactive floor and can be used as extra help for the trainer.

2. Research the economic feasibility for a sports club to purchase such as technology as an interactive floor. It might not be feasible for a sports club to purchase an interactive floor since the technology is expensive. However, if more avenues of funding or profiting from the interactive floor can be found, the interactive floor can become more appealing.
3. The vision of this thesis is limited by looking at volleyball and learning this game in a digital environment. However, this vision can also be erased to allow ideating on new (team) sports where the interactive floor is an indispensable part of the sport.

Finally, the interactive floor has much potential for volleyball practice. The ideas that are tested in this thesis came out positively and show promise to be an asset for volleyball practice. Furthermore, if more sports could benefit from the interactive floor, it will be more plausible that the interactive floor will be purchased by a (diverse) sports club. The author hopes with the findings in this thesis to encourage others to realize the potential of new technology in the context of sport.

References

[1] M. Roser and H. Ritchie, "Technological progress," *Our World in Data*, 2013.

[2] A. E. Staiano and S. L. Calvert, "Exergames for physical education courses: Physical, social, and cognitive benefits," *Child development perspectives*, vol. 5, no. 2, pp. 93-98, 2011.

[3] Y. Oh and S. Yang, "Defining exergames & exergaming," *Proceedings of Meaningful Play*, pp. 1-17, 2010.

[4] C. J. Caspersen, K. E. Powell, and G. M. Christenson, "Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research," *Public health rep*, vol. 100, no. 2, pp. 126-31, 1985.

[5] J. Sween, S. F. Wallington, V. Sheppard, T. Taylor, A. A. Llanos, and L. L. Adams-Campbell, "The role of exergaming in improving physical activity: a review," *Journal of Physical Activity and Health*, vol. 11, no. 4, pp. 864-870, 2014.

[6] M. H. Fogtmann, K. Grønbæk, and M. K. Ludvigsen, "Interaction technology for collective and psychomotor training in sports," in *Proceedings of the 8th International Conference on Advances in Computer Entertainment Technology*, 2011, pp. 1-8.

[7] P. R. Kamble, A. G. Keskar, and K. M. Bhurchandi, "Ball tracking in sports: a survey," *Artificial Intelligence Review*, vol. 52, no. 3, pp. 1655-1705, 2019.

[8] B. Chakraborty and S. Meher, "A trajectory-based ball detection and tracking system with applications to shot-type identification in volleyball videos," in *2012 International Conference on Signal Processing and Communications (SPCOM)*, 2012: IEEE, pp. 1-5.

[9] J. Halouani, H. Chtourou, T. Gabbett, A. Chaouachi, and K. Chamari, "Small-sided games in team sports training: a brief review," *The journal of strength & conditioning research*, vol. 28, no. 12, pp. 3594-3618, 2014.

[10] C. B. Harrison, A. E. Kilding, N. D. Gill, and T. Kinugasa, "Small-sided games for young athletes: is game specificity influential?," *Journal of sports sciences*, vol. 32, no. 4, pp. 336-344, 2014.

[11] S. V. Hill-Haas, B. Dawson, F. M. Impellizzeri, and A. J. Coutts, "Physiology of small-sided games training in football," *Sports medicine*, vol. 41, no. 3, pp. 199-220, 2011.

[12] K. U. Mughal, "Top 10 most popular sports in the world," *Retrieved March*, vol. 22, p. 2016, 2020.

[13] F. M. Clemente, "Small-sided and conditioned games in basketball training: A review," *Strength and Conditioning Journal*, vol. 38, no. 3, pp. 49-58, 2016.

[14] E. Rampinini *et al.*, "Factors influencing physiological responses to small-sided soccer games," *Journal of sports sciences*, vol. 25, no. 6, pp. 659-666, 2007.

[15] M. P. Cruz, G. M. Lage, P. C. Ribeiro-Silva, T. F. Neves, C. d. O. Matos, and H. Ugrinowitsch, "Constant and random practice on learning of volleyball serve," *Revista Brasileira de Cineantropometria & Desempenho Humano*, vol. 20, no. 6, pp. 598-606, 2018.

[16] M. C. Lopes, R. T. Magalhães, L. B. F. Diniz, J. P. A. Moreira, and M. R. Albuquerque, "The influence of technical skills on decision making of novice volleyball players," *Revista Brasileira de Cineantropometria & Desempenho Humano*, vol. 18, no. 3, pp. 362-370, 2016.

[17] D. Formenti *et al.*, "Volleyball-Specific Skills and Cognitive Functions Can Discriminate Players of Different Competitive Levels," *The Journal of Strength & Conditioning Research*, 2020.

[18] B. Piggott, S. Müller, P. Chivers, A. Cripps, and G. Hoyne, "Small-sided games can discriminate perceptual-cognitive-motor capability and predict disposal efficiency in

match performance of skilled Australian footballers," *Journal of sports sciences,* vol. 37, no. 10, pp. 1139-1145, 2019.
[19] F. F. Mueller *et al.*, "Designing sports: a framework for exertion games," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 2011, pp. 2651-2660.
[20] F. Mueller, M. R. Gibbs, F. Vetere, and D. Edge, "Supporting the creative game design process with exertion cards," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 2014, pp. 2211-2220.
[21] J. Nielsen, "Thinking aloud: The# 1 usability tool," *Nielsen Norman Group,* vol. 16, 2012.
[22] *Officiële Spelregels Volleybal 2019-2020, 1e divisie en lagere divisies c.q. klassen* Rule Book NeVoBo, 24 mei 2019 2019.
[23] L. Holtzschue, *Understanding color: an introduction for designers*. John Wiley & Sons, 2012.
[24] B. Jenny and N. V. Kelso, "Color design for the color vision impaired," *Cartographic perspectives,* no. 58, pp. 61-67, 2007.
[25] R. Rosenthal and R. L. Rosnow, *Essentials of behavioral research: Methods and data analysis*. McGraw-Hill New York, 1991.
[26] J. Lazar, J. H. Feng, and H. Hochheiser, *Research methods in human-computer interaction*. Morgan Kaufmann, 2017.
[27] M. Steen, M. Manschot, and N. De Koning, "Benefits of co-design in service design projects," *International Journal of Design,* vol. 5, no. 2, 2011.
[28] P. Díaz, I. Aedo, and M. van der Vaart, "Engineering the creative co-design of augmented digital experiences with cultural heritage," in *International symposium on end user development*, 2015: Springer, pp. 42-57.
[29] C. Spinuzzi, "The methodology of participatory design," *Technical communication,* vol. 52, no. 2, pp. 163-174, 2005.
[30] M. J. Muller and S. Kuhn, "Participatory design," *Communications of the ACM,* vol. 36, no. 6, pp. 24-28, 1993.

Appendix A: Consent form adult

TOESTEMMINGSVERKLARING (INFORMED CONSENT)

Ptcpt no.

Betreft
De Universiteit Twente en het Windesheim doen onderzoek naar naar de inzet van 'slimme' technologie voor het verbeteren van training- en sportprestatie voor volleybal, zoals uitgelegd in de informatie-brochure "Smart Sports Exercises" die bij dit formulier is gegeven.

Hoofdonderzoekers:
Dennis Reidsma[1], Robby van Delden[1], Dees Postma[1], Amber Eggengoor[1], Bert-Jan van Beijnum[1], Fahim Salim[1], Ivo van Hilvoorde[2], Jeroen Koekoek[2] en Wytse Walinga[2]
[1]University of Twente [2]Windesheim University of Applied Sciences

Contact informatie
Mocht u vragen hebben over dit onderzoek, dan kunt u contact opnemen met onderzoeker Amber Eggengoor (), haar Begeleider 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.

Onderzoek: Smart Sports Exercises in Volleyball
Ik verklaar hierbij het volgende voor het seizoen 2019'2020:

☐ Ik verklaar hierbij dat ik volledig geïnformeerd ben over het onderzoek. Het doel van het onderzoek en de methodes zijn mij uitgelegd, waarbij ik de ruimte heb gehad om vragen te stellen.

☐ Ik begrijp dat ik mijn deelname op ieder moment, zonder opgaaf van reden, mag en kan beëindigen zonder dat hieraan enige consequenties verbonden zijn (ook later in het seizoen).

☐ Ik geef hierbij vooraf toestemming voor mijn deelname aan onderzoek tijdens seizoen 2019'2020 en voor het verzamelen en gebruik van anonieme gegevens zoals beschreven in de informatie folder.

☐ Ik geef toestemming voor het maken van video-opnames voor onderzoeksdoeleinden

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. Alle data wordt voor een minimum van 10 jaar opgeslagen, conform de NVSU-richtlijn.

☐ Ik geef tevens toestemming voor het delen van de videodata met mijn trainer/coach. Overige data (bv interviews) worden niet op basis van enkel dit formulier beschikbaar gesteld.

Datum: Plaats:

Naam: Handtekening deelnemer:

……..……
……
The extra copy of this consent form is for you to keep.

Appendix B: Interview protocol 1

#	Phase	Description	Minutes	Materials
1	Welcome and Introduction	I am a student of the University of Twente, our projects we have done so far are mostly about combining technology with the society. In this project I am researching the potential of using an interactive floor in volleyball practice. The goal of using an interactive floor in volleyball practice is to make an practice more easy to understand, more enjoyable and more efficient and effective.	10	Photos of an interactive floor.
2	Informed consent	Participant fills out informed consent form.	2	Informed consent form and a pen.
3	Semi-structured interview	Interview outline: After showing pictures of several types of technology such as an interactive floor and wearables: Question 1: What age group has the hardest time with understanding the volleyball rules? Question 2: How do the children react on a long explanation? *After explaining what an interactive floor is and what it can do:* Question 3: Can you think of a game that is played nowadays and where an interactive floor can assist? Question 4: What do you think of using an interactive floor in practice? What comes to your mind? In and around the interview outline, more questions will be asked about topics that will come up. End: Thank you for your participation, this has been very helpful to us.	45	The interview outline
4	Closure	Thank the participant once again. Tell the participant what is going to happen with their information. Ask if the participant is willing to participate again if needed.	5	
	total		62 min	

Appendix C: Survey for volleyball players

You are being invited to participate in a research study titled Smart Sport Exercises Volleyball. This study is being done by Amber Eggengoor from the UT Twente. The purpose of this research study is to get insights into volleyball practice and will take you approximately 5 minutes to complete. The answers you give are anonymous and will not be published. When you click on yes, you agree on participating in this research. Your participation in this study is entirely voluntary and you can withdraw at any time. You are free to omit any questions.

1. Are there any struggles/difficulties during your volleyball practice?
2. What exercises are done in (almost) every volleyball training?

figure 1: example of an interactive floor

An interactive floor is a LED-screen used as a floor, where different graphics/colors can be used to guide the athletes. An example of an interactive floor is visible in figure 1. The interactive floor can also show/do other things. For example, a red dot can guide the athletes through an exercise. For example, the interactive floor can light up the field dimensions of a certain exercise. For example, the interactive floor can light up a certain area in the field to show where the attacker can or have to attack (or where to defend).

3. What kind of advantages do you think that the interactive floor has in volleyball practice?
4. What kind of disadvantages do you think that the interactive floor has in volleyball practice?
5. Can you think of another example where the interactive floor could help in practice?

Thank you for your participation!

Appendix D: Academic Writing literature review

Small-sided games in volleyball practice

The use of technology enlarged enormously over the past few years [1]. Nowadays, we seem interested in and obsessed with knowing exactly how many steps we did today. There is a lot of research in the field of interactive technology, but the domain of interactive digital sports exercises has gotten little attention from the scientific community so far. The domain of interactive digital sports exercises focuses on creating novel ways to train a particular sport with the use of an interactive system, which is interesting for athletes, trainers, and researchers. Those systems have a lot of potential to develop exercises that are more productive, enjoyable, and easier to understand [2]. Small-sided games are considered the most common exercise used in team sports training [3] [4] [5]. The literature on Small-sided games is gathered and discussed as pre-knowledge to be able to create interactive digital sport exercises. The main objective of this paper is to get an insight into how to apply small-sided games in the context of volleyball practice. Volleyball is chosen as the main focus of this paper because there are currently no interactive exercises available for volleyball, and it is the sixth-largest sport in the world [6].
This paper contains two parts leading to the conclusion. The first part regard related work, this first part discusses aspects of small-sided games that are needed to make training efficient and effective. The second part criticizes the use of small-sided games. Lastly, the conclusion provides a clear and concise answer to the question raised in this paper.

For this research, it is a prerequisite to define Small-sided games and what it is influenced by. In this paper small-sided games are compared to generic training, where generic training is defined as training without the use of small-sided games. According to Hill-Haas, Dawson, Impellizzeri, and Coutts [5], Small-sided games refer to skill-based conditioning games or game-based training [5]. Halouani, Chtourou, Gabbett, Chaouachi [3], and Clemente [7] define small-sided games as games that are smaller and an adapted version of the formal team sport. Hill-Haas [5] claims that small-sided games train a specific movement pattern and physiological demand of the sport. His research concludes that small-sided games are more time-efficient compared to generic training because it is possible to develop more than one skill within one small-sided game concurrently. Halouani [3] supports Hill-Haas [5] and states that small-sided games allow more time spent with the ball under real match conditions compared to generic training. Additionally, small-sided games maintain the physical demand of a generic training and the level of enjoyment increases, which encourages youth athletes in particular, according to Halouanis research [3]. In conclusion, different synonyms for small-sided games are used. This paper uses the term small-sided game with the definition of a game that is smaller and an adapted version of the formal team sport, where athletes spent more time with the ball and allows for development of multiple skills at the same time.

There are six main factors that influence the intensity of small-sided games. Clemente [7] and Hill-Haas [5] researched the heart rates of the athletes while doing different kinds of small-sided games. Research has found that field dimensions, the number of players, rule modifications, coach encouragement, training regimens, and game duration contribute to the intensity of small-sided games. Rampinini et al. [8] and Halouani [3] agree on this statement and add that if the athletes do not reach the wanted level of intensity, rule modification is the most important factor. Adding rules can increase the motivation of the athletes but can also increase the cognitive load required to fulfil the smallsided games. Therefore, the right balance of additional rules is needed to assure that the athletes are not bothered by their cognitive level in completing the small-sided game. In situations where the athletes have a difficult time with the cognitive part of the exercise, direct supervision and verbally coaching have been shown to help the athletes. Coach encouragement can improve the intensity of the small-sided game, especially when the goal is to reach a high-intensity level, according to Hill-Haas [5]. Expanding on Hill-Haas [5],

Herbert [9] researched the difference between constant and random practice. Herbert concludes that only random practice improves the learning of a volleyball skill. According to Clemente, Hill-Haas, Rampinini, and Halouani is this 'random' practice the same as the factor called training regimens. In summary, all the authors [8] [3] [7] [9] [5] agree on the six main factors. The field dimensions, number of players, rule modifications, coach encouragement, training regimens, and game duration contribute to the intensity of small sided games. In conclusion, each of these factors must be taken into account when designing new small-sided games.

Small-sided games can help to develop three skills concurrently. Albuquerque [10] agrees with Formenti [11] that volleyball players play in complex and dynamic environments during real matches. "The game develops in relatively unpredictable and changing contexts where players have to maintain their focus on the ball and to plan and execute their response while observing teammates and opponents", Formenti [11]. According to Piggott, Müller, Chivers, Cripps, and Hoyne [12] are small-sided games more effective than generic training because small-sided games are played in the same complex, and dynamic environments as in real-game environments. According to Albuquerque [10] volleyball-related skills such as setting, passing, and spiking are trained in a drill (without context) and in small-sided games (with context). Formenti [11] agrees with Albuquerque [10] and adds that small-sided games can also be used to develop the physical and cognitive performance of athletes. The main findings of Formenti [11] were that players competing at higher levels are better in performing small-sided games than lower-level peers and therefore develop more skills. Albuquerque [10] research the same as Formenti [11] but concluded that future studies should investigate further to get a concise answer. In the end, it is proven by research that small-sided games contribute to the development of volleyball specific skills, physical and cognitive performance. If the level of the players carrying out the small-sided games makes a difference in skill development is not yet proven and asks for more research.

Small-sided games are perfect practice exercises. According to Hill-Haas [5], small-sided games are more time-efficient, as volleyball-related skills, physical and cognitive performance can be developed concurrently. Haliouani [3] agrees with Hill-Haas [5] and adds that practicing with small-sided games can help the athletes to develop game-specific conditions, and this is assumed to be a valid transfer to match play. Harrison, Kilding, Gill, and Kinugasa [4] researched the effects of small-sided games on young athletes. Research has found that using small-sided games in training encourages young athletes. Asier [13] did similar research and claims that small-sided games promote a high level of enjoyment in youth players, which incentivizes youth athletes to push themselves to their limit. Haliouani [3] agrees with Harrison [4] and Asier [13] and sees the importance of motivating athletes at a young age to encourage them and concludes that enjoyment during sports can result in better skill development. So, research has found that using small-sided games gives his benefits. Small-sided games are time-efficient, an effective transfer to match play, and increases the enjoyment level of youth players. The skill development of athletes can benefit when choosing small-sided games over generic training.

When using small-sided games, there are a few constraints as well. Haliouani [3] and Hill-Haas [5] note that the intensity of a small-sided game is not similar to the intensity of a real match. The change in field dimensions can result in unrealistic running/shooting/spiking distances. Haliouani [3] states that the skill level of the players needs to be high to achieve an appropriate small-sided game intensity. Haliouani [3] explains that if the players do not have the required level of skills, then the players are not able to perform in a smaller area. Hill-Haas [5] agreed to this and said that indeed playing a small-sided game in a smaller area is harder than in a small-sided game where the area is larger. Furthermore, when the athletes play in a smaller area, the risk of contact injuries is higher. To prevent the athletes from getting injured, more coaches should be available to control and monitor this type of training according to both Haliouani [3] and Hill-Haas [5]. So, using small-sided games also has its down-sides. The

intensity of small-sided games is not similar to real match intensity. Only athletes with a higher skill level are likely to accomplish a small-sided-game.
Furthermore, small-sided games ask for more guidance to prevent the athletes from getting injured. Small-sided games do not work for every group of athletes, and this has to be considered before using them.

The goal of this research was to get an insight into how to apply small-sided games in the context of volleyball practice. Using a systematic review of relevant sources, small-sided games is defined as a game that is smaller and an adapted version of the formal team sport, where athletes spent more time with the ball and allows for development of multiple skills at the same time. After defining small-sided games, a list of six variables that contribute to the intensity of small-sided games has been established. The field dimensions, number of players, rule modifications, coach encouragement, training regimens, and game duration must be taken into account when designing new small-sided games. With the definition and the list of six variables in mind, the next step was to research the impact of small-sided games. Small-sided games has impact on the development of volleyballspecific skills, physical and cognitive performance. If the level of the players carrying out the small-sided games makes a difference in skill development has not been thoroughly researched yet.

To be able to see the potential of small-sided games, the advantages and disadvantages are compared. Small-sided games are time efficient, an effective transfer to match play, and increases the enjoyment level of youth players. Nevertheless, small-sided games ask for more guidance to prevent the athletes from getting injured and do not work for every group of athletes. In conclusion, the trainer of a team sport has to weigh the advantages and disadvantages for every team he trains, to be able to consider whether or not it would work for his athletes.

In summary, small-sided games are discussed in detail. This research provides information that can help with the design and the implementation of small-sided games. A careful process of designing, testing and validating is recommended in order to precisely examine which small-sided game works for what kind of group of athletes.

Further studies should explore the potential of an interactive floor in small-sided games. If the potential is found, lo-fi testing can be done to prove if and how the interactive floor can be an asset for volleyball training in the future.

References

[1] Roser, M., & Ritchie, H. (2013). Technological Progress. Our World in Data. https://ourworldindata.org/technological-progress

[2] Staiano, A. E., & Calvert, S. L. (2011). Exergames for Physical Education Courses: Physical, Social, and Cognitive Benefits: Exergames for Physical Education Courses. Child Development Perspectives, 5(2), 93–98. https://doi.org/10.1111/j.1750-8606.2011.00162.x

[3] Halouani, J., Chtourou, H., Gabbett, T., Chaouachi, A., & Chamari, K. (2014). Small-sided games in team sports training: A brief review. Journal of Strength and Conditioning Research, 28(12), 3594-618. doi:10.1519/JSC.0000000000000564

[4] Harrison, B., Andrew, E., Nicholas, D., & Taisuke, K. (2014). Small-sided games for young athletes: Is game specificity influential? Journal of Sports Sciences, 32(4), 336-344. doi:10.1080/02640414.2013.824600

[5] Hill-Haas, S., Dawson, B., Impellizzeri, F., & Coutts, A., Dr. (2011). Physiology of small-sided games training in football : A systematic review. Sports Medicine, 41(3), 199-220. doi:10.2165/11539740-000000000-00000

[6] Anon. 2020. 'Top 10 Most Popular Sports in The World [Updated 2020]'. Sportsshow.Net. Retrieved 9 March 2020 (https://sportsshow.net/top-10-most-popular-sports-in-the-world/)

[7] Clemente, F. (2016). Small-sided and conditioned games in basketball training: A review. Strength and Conditioning Journal, 38(3), 49-58. doi:10.1519/SSC.0000000000000225

[8] Rampinini, E., Impellizzeri, F., Castagna, C., Abt, G., Chamari, K., Sassi, A., & Marcora, S. (2007). Factors influencing physiological responses to small-sided soccer games. Journal of Sports Sciences, 25(6), 659-66.

[9] Herbert, U., Cíntia, D., Thiago, F., Guilherme, M., Patrick, C., & Madson, P. (2018). Constant and random practice on learning of volleyball serve. Revista Brasileira De Cineantropometria E Desempenho Humano, 20(6), 598-606. doi:10.5007/1980-0037.2018v20n6p598

[10] Albuquerque, M., Diniz, L., Lopes, M., Magalhães, R., & Moreira, J. (2016). The influence of technical skills on decision making of novice volleyball players. Revista Brasileira De Cineantropometria & Desempenho Humano, 18(3), 362-370. doi:10.5007/1980-0037.2016v18n3p362

[11] Formenti, D., Trecroci, A., Duca, M., Vanoni, M., Ciovati, M., Rossi, A., & Alberti, G. (2020). Volleyball-specific skills and cognitive functions can discriminate players of different competitive levels. Journal of Strength and Conditioning Research, 2020 Jan 16. doi:10.1519/JSC.0000000000003519

[12] Piggott, B., Müller, S., Chivers, P., Cripps, A., & Hoyne, G. (2019). Small-sided games can discriminate perceptual-cognitive-motor capability and predict disposal efficiency in match performance of skilled australian footballers. Journal of Sports Sciences, 37(10), 1139-1145. doi:10.1080/02640414.2018.1545522

[13] Asier, L., Juan, S., Juan, M., Javier, L., Felipe, S., Federico, V., & Javier, J. (2015). Effects of small-sided games vs. interval training in aerobic fitness and physical enjoyment in young elite soccer players. Plos One, 10(9). doi:10.1371/journal.pone.0137224

Appendix E: 150 ideas

Interactive floor as guidance

1.	Light up the field dimensions.	(LP1)
2.	Explain the volleyball system.	(LP4)
3.	How to rotate in the field.	(LP4)
4.	How to do an exercise.	(LP4)
5.	Light up the different available attackers for the setter.	(LP2)
6.	Light up where to defend.	(LP2)
7.	Light up where to attack.	(LP2)
8.	Light up where to serve.	(LP2)
9.	Visualize steps for attack.	(LP5)
10.	Visualize steps for defending.	(LP5)
11.	Divide field in areas where that person has to get any ball.	(LP1)
12.	Show the position numbers, 1 till 6.	(LP4)
13.	Show the combination of the opponent, to train the block.	(LP1)
14.	Replace the hoops / pylons.	(LP5)
15.	Tell the referee who own the point.	(LP6)
16.	Show the duration of the exercise.	(LP6)
17.	Trainer can premade the outline of the training and show it.	(LP6)
18.	Trainer can premade his last game feedback and show it.	(LP6)
19.	Tell the trainer where the rally ball should go	(LP6)

Interactive floor visualizes the rules

20.	Show the rules for level 2 of volleyball (CMV).	(LP4)
21.	Show the rules for level 3 of volleyball (CMV).	(LP4)
22.	Show the rules for level 4 of volleyball (CMV).	(LP4)
23.	Show the rules for level 5 of volleyball (CMV).	(LP4)
24.	Show the rules for level 6 of volleyball (CMV).	(LP4)
25.	Volleyball system for the youth (C, B, A) and seniors.	(LP4)

Interactive floor replaces equipment

26.	Replace pylons.	(LP2)
27.	Replace hoops.	(LP2)
28.	Replace noodles.	(LP2)
29.	Replace gymnastics cabinet.	(LP2)
30.	Replace tape on the ground.	(LP2)

Conditioning exercises

31.	Random balloons, every balloon needs a ball on it.	(LP7)
32.	Relay race, visualize the speed of the opponent	(LP7)
33.	Follow the dot and place the ball on it.	(LP7)
34.	Beach game, 2x2, half the size of the field.	(LP4)
35.	Run with the moving line, if the line goes faster, do so too.	(LP7)
36.	Tennis, 1x1, whole size of the field.	(LP4)
37.	Really ball in sync.	(LP2)
38.	Run as fast as the line on the floor, wanted distance of trainer.	(LP7)

Strength exercises

39.	Visualize an agent that tells you what exercise you should do.	(LP5)
40.	Timer how long it takes and the next exercise.	(LP6)
41.	Training schedule made by the trainer.	(LP6)
42.	Trainer can see progress.	(LP6)
43.	Assistant for the trainer to be able to focus on giving feedback.	(LP6)
44.	Block, every time the visualization changes from a circle to a rectangle, jump.	(LP5)
45.	Dive, every time the visualization changes, dive.	(LP5)
46.	Run, block, dive. Do what the floor does.	(LP7)
47.	Guidance with the first steps of the ladder, team can do it at the same time.	(LP7)
48.	Shuffle exercise, shuffle with the block on the floor.	(LP7)
49.	Visualize hands, if the hands are shown touch the hands.	(LP5)

50. Combination run without a ball, how to return to an attack from the block. (LP5)
51. The ladder exercise but in a different shape, snake or a round shape (LP7)

Attack exercises

52. Visualize the steps of others to prevent collision. (LP5)
53. Visualize when to jump. (LP5)
54. Colour the area where to attack. (LP1)
55. Random place on the floor, where to attack. (LP2)
56. Visualize where the block is. (LP5)
57. Visualize the steps to take for an attack. (LP5)
58. Show the setter where the attacker is. (LP5)
59. Pre-made combination by the trainer. (LP6)
60. Attack for example 5 times in a row, show the number. (LP6)
61. Give positive feedback to feel more confident. (LP6)
62. Replay the situation. (LP6)
63. Replay part of the situation. (LP6)
64. Show the open places, where no defender is standing. (LP1)
65. Score a point if you hit the random dot. (LP2)
66. Part of the field is light up, score a point if you hit it (LP2)
67. Show where it is the smartest to attack (LP2)
68. Show a dot, it only disappears if someone hits it, more dots over time (LP2)
69. Show a dot, it disappears if someone hits it, It gains a point. (LP2)
70. Show where the free space is to attack. (LP2)
71. Combinations of attacking can be visualized on the floor (LP2)
72. Do not hit the target, attack everywhere else (LP2)
73. Tip in the block shadow (LP1)

Serve exercises

74. Tic tac toe (LP3)
75. Field full of ‘dead’ fish, someone should stand on a fish, red fish, red team. Etc. (LP3)
76. Beer pong (volleyball pong) (LP3)
77. Art by paint, paint dots where ball landed. (LP3)
78. Show the steps of serve with jump (LP2)
79. Replay your steps to see if your steps crossed the line. (LP5)
80. Give a note that athlete stepped over the line. (LP6)
81. Hit the mole rat (or another object). (LP3)
82. Moving animal, hit it. Moves faster if he is hit. (LP3)
83. Darts (LP3)
84. Collect ‘lives’, hit the hearts and gain a live. Loose hearts over a certain time. (LP3)
85. Collect coins, if you hit the monsters, loose coins. (LP3)
86. Serve on an object over certain time, if you hit you get +5 sec. (LP3)
87. Serve till the cup made of glass (visualized) is broken (LP3)
88. Risk, conquer the land by serving on the land (bombs) (LP3)

Defense exercises

89. Visualize hands that the defender has to touch. (LP5)
90. Visualize where the serve would end. (LP2)
91. Colour the floor if the defender has to dive and stand up really quick. (LP7)
92. If the floor turns green, turn around and pass the ball. (LP7)
93. Visualize for the defender if the ball ends out or not. (LP2)
94. Touch the object till it is gone, run towards another object (LP2)
95. Let him follow feet steps, to keep moving. (LP7)
96. Show the shadow of the block (LP1)
97. Show the range of the defender, are you close enough to the line? (LP1)
98. Keep moving, move the place of the defender by moving his dot (LP2)

Invisible volleyball-related games

99. Playing tag. Fast moving. (LP7)
100. De floor is lava, keep moving (LP7)
101. Jump over the shark when it comes by. (LP7)
102. Dive to catch apples or another object. (LP7)
103. In the back is the jaguar, stay down, at the net, giraffe, be ‘long’ (LP7)

104.	Collect coins by touching the coin (on the floor) now and then (for kids)	(LP7)

Warming up

105.	Knee lift over the snakes (or another object.	(LP7)
106.	Heel to buttocks over the snakes.	(LP7)
107.	Turning exercises, turn otherwise the clown catches you.	(LP7)
108.	Dribble with the ball on the mouse, otherwise he runs away.	(LP7)
109.	Warming up with attack routines.	(LP2)
110.	Warming up with butterfly routine.	(LP2)
111.	Planking count down	(LP7)
112.	Motivational sentences or music (rhythm) to keep going	(LP7)
113.	Defender has to touch the random appearing dot on the ground	(LP2)
114.	Two players in the field, one dot, first one how touch is owns the point	(LP2)

Feedback

115.	Provide tips if mistakes are made.	(LP6)
116.	Give more points if done perfectly.	(LP6)
117.	Go back to the basics and the players does not understand.	(LP6)
118.	Provide positive feedback to encourage the players.	(LP6)
119.	Replay the situation, so everyone can see where it went wrong.	(LP6)
120.	If the player done it perfectly three times, provide less instructions to train him.	(LP6)
121.	Show afterwards how the athletes were standing on the moment of serve	(LP4)
122.	Visualize line where the athletes have to stand in between, to prevent system errors	(LP4)
123.	Visualize when the serve started, the setter and middle players can start running	(LP4)
124.	Show shapes/colours where the athlete should be standing (on/off)	(LP4)
125.	Show feedback before or after if they did it right or not.	(LP1)
126.	Show footsteps of the athlete after attacking, what did he do, reflect on it	(LP5)
127.	Show footsteps of the athlete after serving what did he do, reflect on it	(LP5)
128.	Show footsteps of the athlete after defending, what did he do, reflect on it	(LP5)
129.	Encourage the athletes before he attacks, be explosive, go for it!	(LP7)

Complex exercises

130.	2 balls, interactive floor shows and guides the rhythm	(LP7)
131.	Keep the ball in the rally till the interactive floor says: SCORE, then score	(LP7)
132.	Ladder exercise, do it with multiple people at the same time.	(LP7)

Practicalities

133.	The trainer can pre-plan his training with the software of the interactive floor	(LP7)
134.	Show the athletes a summary of the upcoming training	(LP7)
135.	Show the athletes a summary of the last match	(LP7)
136.	Show line errors for the back players in their attack (3-meter line).	(LP7)
137.	Show line errors for the block players in the block (middle line)	(LP7)
138.	Show who owns the point	(LP7)
139.	In/out	(LP7)
140.	Foot error while serving	(LP7)
141.	Personalization of the exercises.	(LP7)
142.	Let the coach focus on giving feedback instead of explaining the exercises	(LP7)
143.	Time out	(LP7)

Towards volleyball context: game level.

144.	If the team scores, make the field smaller and if it fails twice, make it bigger again	(LP2)
145.	In a rally ball, the team can only score in the part that is light up by the floor	(LP2)
146.	Visualize more defenders, if the ball is attacked on the fake defender, still defended	(LP2)
147.	The floor rotates with the kids on for example a wheel, makes it clearer	(LP5)
148.	Let the substitute player touch the floor on the coin to keep him busy.	(LP5)
149.	Replace a passer in the pass line, make sure the system is correct	(LP3)
150.	Divide the field into different areas with colours, every passer defends his colour	(LP1)

Appendix F: Lo-fi testing question list

Questions before the lo-fi testing

1. What is your age?
2. How are you related to volleyball?

Questions after lo-fi prototype Block Shadow

1. How and when do you think that this game can be beneficial?
2. What else can be done with this block shadow game?
3. You can light up parts of the field, what would you light up?
4. What kind of problems do you think are solved when this system is used in a volleyball practice?
5. What kind of disadvantages do you think this game could give?
6. What do you think of the design?
7. How can this game be improved?
8. What instruction should be given before athletes can play this game?
9. In what context can this game be used?

Questions after lo-fi prototype Random Attack

1. How do think this can help when training reaction speed?
2. Can you imagine other situations where this game can be useful?
3. What equipment used in a practice can be replaced with this interactive floor?
4. What is your opinion of adding more randomness to the training?
5. What do you think of the design?
6. How can this game be improved?
7. What instruction should be given before athletes can play this game?
8. In what context can this game be used?

Questions after lo-fi prototype VolleyCup

1. What do you think of this game?
2. Can you imagine other games that has the same goal but with other content?
3. What do you think of the design?
4. How can this game be improved?
5. What instruction should be given before athletes can play this game?
6. In what context can this game be used?

Questions after lo-fi prototype Volleyball system

1. What do you think that this game/concept is?
2. What do think of this concept?
3. Have you ever encountered problems that can be solved by this floor? What kind of problems?
4. What do you think of the design?
5. How can this game be improved?
6. What instruction should be given before athletes can play this game?
7. In what context can this game be used?

Questions after lo-fi prototype Attack Steps and Defense Hands

1. How can this game be adjusted on the level of the athletes?
2. How are attack-steps trained nowadays and how can this concept help in that process?
3. What do you think of letting the defender touch the floor before he defends the ball?
4. What do you think of the design?
5. How can this game be improved?
6. What instruction should be given before athletes can play this game?
7. In what context can this game be used?

Questions after lo-fi prototype Trainer Assistant

1. How can the floor help the trainer?
2. Where should the floor visualize his 'opinion'? (in/out, line-error. Etc.)
3. Do you think the interactive floor can help the athletes to train independently? How?
4. What kind of discussions can be erased from the training if the interactive floor would be used?
5. What do you think of the design?
6. How can this game be improved?
7. What instruction should be given before athletes can play this game?
8. In what context can this game be used?

Questions after lo-fi prototype Follow the Floor

1. How can this concept help the athletes to become more independent?
2. Do you think that this concept can help the trainer to prepare the training beforehand, so that he has more time for feedback during the training? How?
3. Do you think that explaining exercises with footsteps can help to decrease the time needed for explanation in practice? How?
4. What do you think of the design?
5. How can this game be improved?
6. What instruction should be given before athletes can play this game?
7. In what context can this game be used?

Questions after the seven lo-fi prototypes

1. What exercise did you like most and why?
2. After you have seen the examples of the interactive floor, what else comes to your mind?
3. Do you think that the interactive floor has a potential in a volleyball practice?
4. What did you think of the lo-fi testing?

Thank you very much for participating. Your opinion means a lot to this research.

Appendix G: Questionnaire Hi-fi testing

1. Overall, I am satisfied with the design of this system.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
❑	❑	❑	❑	❑

2. I felt comfortable using the system.

❑	❑	❑	❑	❑

3. I found the various functions in the system were well integrated.

❑	❑	❑	❑	❑

4. I needed to learn a lot of things before I could get going with this system.

❑	❑	❑	❑	❑

5. I found the visualisations unnecessarily complex.

❑	❑	❑	❑	❑

6. I am satisfied with the colors that are used in the system.

❑	❑	❑	❑	❑

7. I am satisfied with the shapes that are used in the system.

❑	❑	❑	❑	❑

8. The visualizations given by the system were enough for me to understand the exercise.

❑	❑	❑	❑	❑

9. I thought there was too much inconsistency in the design.

❑	❑	❑	❑	❑

10. I can imagine this system could help volleyball athletes.

❑	❑	❑	❑	❑

11. List the most negative aspect(s)

1.	
2.	
3.	

12. List the most positive aspect(s)

1.	
2.	
3.	

13. Do you have any remarks or comments left?

Appendix H: 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 aanwijzingen in het veld tekenen over hun positiespel, timing, en techniek.

Het huidige onderzoek, geleid door de Universiteit Twente en het Windesheim, is erop gericht om passende trainingsmethoden te ontwikkelen voor deze nieuwe vorm van sporttechnologie. Om dat te kunnen doen, brengen we in kaart hoe een 'standaard' training eruitziet; ontwikkelen we interactieve trainingsvormen en testen we deze bij de doelgroep. Zo ontwerpen we, samen met jullie, de training van de toekomst!

SSE3.0 – lt.ac.rc – 19'20 – v1

ZonMw

Windesheim
UNIVERSITY OF APPLIED SCIENCES

UNIVERSITY OF TWENTE.

sport service veenendaal

LED GO

INNOSPORTLAB
SPORT & BEWEEG!
INNOVATIE IN BREEDTESPORT

Human Media Interaction.

BIOMEDICAL SIGNALS AND SYSTEMS
UNIVERSITY OF TWENTE.

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.

BSc Amber Eggengoor – a.eggengoor@student.utwente.nl
dr. ir. Dennis Reidsma – d.reidsma@utwente.nl

Onderzoeksprocedure
Door middel van interviews, observaties en video-opnames zal informatie verzameld worden over relevante trainings-, sport- en spelsituaties waarin de 'slimme' sportvloer bruikbaar kan zijn.

In deze folder leggen we uit wat het voor jou betekent om aan het onderzoek mee te doen. Je beslist zélf of je deel wilt nemen aan het onderzoek. Voor vragen kunt je contact opnemen met de Amber Eggengoor of de begeleidende docent Dennis Reidsma, contactgegevens op de voorkant.

Deelname
Deelname is geheel vrijwillig. Je kan op ieder moment, zonder opgaaf van reden, aangeven dat je niet meer wil meedoen met het onderzoek. Toe-stemming voor deelname hoeft slechts eenmalig verleend te worden en is daarna geldig voor de rest van het Seizoen (tot 31-08-2020). Daarna word je opnieuw gevraagd toestemming te verlenen.

Wat gebeurt er tijdens de activiteiten?
De activiteiten zijn met name bedoeld om te begrijpen hoe volleybaltraining werkt. Dit wordt gedaan om de meerwaarde van de 'slimme' sportvloer in kaart te brengen. Onderzoeks-activiteiten zullen onder andere bestaan uit observaties, interviews, video opnames, sensormetingen (bijvoorbeeld met geavanceerde bewegings-sensoren) bij de training.

Daarnaast zullen sommige teams en trainers betrokken worden bij het testen van interactieve prototypes van training-, sport- en oefenvormen.

Welke gegevens worden er verzameld?

Tijdens het onderzoek worden er video opnames gemaakt, ook kunnen er vragenlijsten afgenomen worden en wordt er misschien sensordata (bijvoorbeeld bewegings-data) verzameld.

Hoe worden de gegevens bewaard?
De data en video worden 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 video-opnames, interviews en vragenlijsten 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 Amber Eggengoor.

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. De gegevens worden mogelijk ook gebruikt door de onderzoekers van dit project voor vervolg-onderzoek, 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.

Wat als mijn kind tijdens een sessie niet meer wil?

De onderzoekers zijn alert op signalen dat een kind echt niet wil. Zo nodig wordt de sessie afgebroken. De leerkracht heeft veel ervaring met de kinderen en kan ook als dat nodig is tegen de onderzoekers zeggen dat een sessie met een kind niet doorgaat. Als het kind zelf tijdens de activiteit niet meer wil kan het op elk moment weggaan, al zijn/haar gegevens van die sessie worden verwijderd. Als de onderzoeksmaterialen eenmaal anoniem gemaakt zijn kunnen ze niet meer aan hem/haar koppeld 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 de Ethische Commissie (ethics-comm-ewi@utwente.nl). Deze 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 onderzoekers, contactgegevens op de voorzijde van deze folder.

SSE3.0 – lt.ac.rc – 19'20 – v1