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Digital Sports Training Exercises for Volleyball

BACHELOR THESIS

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Abstract

Within this research digital sports training exercises have been created for volleyball players. The exercises that have been created are aimed at supporting volleyball players from different levels in training their skills. During this research, a LED floor was used to create new and challenging exercises for volleyball players. First, the domain of digital sports training exercises was investigated. Both the commercial systems as the academic research in this domain were explored. Secondly, the information gathered from the related work was used to perform interviews with multiple volleyball trainers and players of different levels. From these interviews, it became clear which exercises that use a LED floor would really be an improvement for players to use during a training. These exercises were made into Lo-Fi prototypes, which were then tested and shown to a professional volleyball trainer. The prototypes that came out best were further developed into exercises for the LED floor. The design of these exercises was done in cooperation with a professional trainer. Finally, a user test and an expert review were done. These showed that the created exercises are capable of training a player's skills. The use of the LED floor was seen as innovative and can lead to further developments in volleyball and other sports.

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1. Introduction

The use of technology in sports has been rapidly growing over the past few years. Mainly in cycling and running numerous wearables and apps have been created to track a user's performances. Many people in today's society seem to be interested in knowing exactly how far they have run and how much calories they have burned. Therefore, a lot of companies are doing research in this field. The domain of digital sports training exercises, however, has not been explored that much yet. This domain focuses primarily on changing the way a certain sport can be trained by using new technologies. This domain is interesting for both sports trainers and researchers in the field of interaction design. Ludvigsen et al. [1, p. 412] state: "Merging the context of elite sport with the knowledge and experiences from HCI and interaction design is a promising domain for interaction design research."

The new exercises that can be created will push athletes in many different ways. This can result in faster skill training or having more fun while exercising. Using technology can help with making exercises better, more interesting and easier to understand. This is interesting for both beginning athletes as for professionals. Hopefully, this project and others will be the start of more investigating in this area.

In the remaining of this chapter, the motivation and challenges for this project will be described. Furthermore, there will be information about the client, the research goal with the corresponding research questions and finally the report outline.

For this project volleyball was chosen as the main sport to develop digital training exercises for. Volleyball is the fifth most popular sport in the world [12] and is played in at least 220 countries [13]. In volleyball, there are six players on either side of the net. The goal is to get the ball on the ground on the other side of the net. In volleyball, there is no physical contact between the teams. There are various skills needed to be a good volleyball player. Players need good reactions skills, hitting power, high jumping capabilities and a lot of ball control. Besides the physical skills, players need to be mentally strong as well and be able to make the right tactical decisions. Both physical skills and tactics can be trained by doing the right exercises. Therefore, the exercises that are developed should train the players in both these aspects.

The Human Media Interaction (HMI) lab is a group at the University of Twente that focuses on the interaction between humans and technology. One domain HMI works on is "Playful Embodied Interaction with Motivational Aspects", which is closely related to this research. However, this project focuses not just on playing games and having fun, but really on interactive sports exercises. HMI researchers see opportunities to make use of dynamic elements and so transform how sports are being trained and played. This project will be used as a starting point for a research done by this group.

As mentioned above the digital training exercises that will be developed in this project will be for volleyball. These exercises will be supported by the use of a LED floor. The LED floor that will be used during this project is currently located in the Design Lab at the University of Twente. This pressure sensitive floor with dynamic visualisations has never been used for a sport such as volleyball before. It will be interesting to see how this works out and if it will bring some alternatives to how a training is normally done. Therefore, the project involves making new interactive training exercises, games, or other types of playful interventions that address interesting developments of skills related to volleyball. All the testing will have to be done at the design lab, as the floor is not easy to transport. It has to be seen how precise the floor is and if it can measure someone jumping on it. To realise real size volleyball exercises on the relatively small floor in the design lab will be hard, however, parts of the exercises should be possible at least. If more testing needs to be done on a bigger service, the interactive playground at the design lab can be used as well.

The challenge of this project will be to develop genuinely good exercises, exercises that will really help in training a certain volleyball skill. As mentioned above not much is done in the domain of digital sport training exercises and especially not in the field of volleyball. So, it is a new field to investigate in and to make progress a certain direction will have to be chosen during this project. The aim of this project is developing an exercise that will improve a certain skill of a player. Ultimately an exercise will be developed that will improve different volleyball skills at the same time.

1.1 Research question

This bachelor thesis on sports exercises focuses on creating exercises that make use of a LED floor. These exercises should train the skills of volleyball players. Therefore, the main question that is answered in this paper is:

"What kind of digital sports training exercises on the LED floor are the most interesting and promising to develop for volleyball?"

To support the research question, different sub-questions will be answered during this research. These sub-questions help to determine what digital exercises are and how they can be used to support a training. The sub-questions are:

- "Which digital sports training exercises are already there?"
- "How can digital sports training exercises be useful?"
- "Where lie the possibilities of a LED floor in digital sports training exercises?"
- "What kind of interactive games, specifically made for the LED floor, can train the users' volleyball skills?"

1.2 Report outline

In this report, the research question and its sub-questions will be answered. Starting off in chapter two with the related work. In this chapter other projects that have a similar goal are discussed. Chapter three discusses the interviews and observations that have been done. Chapter four shows the ideation phase, the development of the first concepts and the evaluation of these concepts. In chapter five the best concepts are selected and further developed into exercises for the LED floor. Furthermore, user tests are done to see how people react on the exercises. In chapter six the conclusions from this graduation project are described. Chapter seven shows the discussion and finally, in chapter eight, recommendations and ideas for further work are presented.

2. Related work

In this chapter the related work is discussed, which will be divided into commercial systems and academic work. Here the questions of; "Which digital sport training exercises are already there?" and "How can digital sport training exercises be useful?", are answered.

2.1 Related work - commercial systems

First, an internet search for everything that has to do with sports combined with human media interaction is done to get some inspiration. The commercial systems that were found are used to understand what already exists in the field of sports and technology. They show how the combination of sport and technology is done with other sports than volleyball and how the interaction between them works. This internet research is not built upon any academic papers. All the commercial systems that are described here were either found by using Google or were heard off through conversations with others about this topic. The main key search words that were used are: Interactive AND sports-training AND games; sport OR interactive AND led-floor.

Nike Rise 2.0

AKQA has created the first reactive LED basketball court. This basketball court was called; House of Mamba. AKQA build this court in China and was meant for the Nike Rise campaign. In this campaign, Kobe Bryant taught young Chinese players the fundamentals of his Mamba Mentality. The court uses motion tracking and reactive LED visualizations to train, guide and challenge the players. It can be seen as a fully connected training ecosystem, which consists out of a coaching app, the tracking system, and the reactive LED court.¹ The coaches can measure, asses and elevate the performances of all the players. The coaches can draw running lines or see stats of all the players in the app. The House of Mamba system comes close to what will be created in this project as it shows in a great way how a LED floor can be used to train players and develop their skills. It also shows how personalized data can be of great use to coaches. In the House of Mamba system, the players are wearing sensors to make sure the motion tracking works well. In this graduation project, it is the goal to use almost no extra sensors besides the ones in the floor. Figure 2.1 shows a part of the House of Mamba system. This system will be used as inspiration for the graduation project and will be presented to people in the upcoming interviews. This system has only been used during the Nike Rise campaign as far is known.²



Figure 2.1 - The House of Mamba court, created by AKQA.

¹ ASB is a company that develops glass floors for sport purposes. ASB has created a basketball court as well. Websites last visited on: 12-07-2018 - <u>https://www.asbglassfloor.com/asb-glassfloor/?lang=en</u> & <u>https://asbglassfloor.wordpress.com/2018/06/25/3x3-pro-league-launched-on-glassfloor/</u>

² Websites last visited on: 30-05-2018 - <u>https://www.akqa.com/work/nike/rise-2015/</u> & <u>http://www.thevoted.com/sh/aoy2014/projects/houseofmamba/default.html</u>

TableTennisTrainer

The TTT is created by a group of developers and designers from Berlin. Their passion for table tennis resulted in creating this table. By using a table bat with NFC players can log in to their account by placing the bat on the table. All their statistics are shown, and different exercises can be played to further improve their skills. The table can see where a player hits the ball, by using a smart projector. Another player can log in as well at the other side of the table and now a multiplayer game can be played. During this game, the movement of the ball will be shown on the table. This system shows a great way of making a training more personal. By showing the player his statistics on different skills, the player will get motivated to improve these skills. This is a good way to train players and will be interesting to use in this project. In Figure 2.2 the system can be seen. 3



Figure 2.2 - TableTennisTrainer

Fun fitness rooms

A non-profit sports and recreation centre based in New York City has created a new gym for people that like to have fun while they work out. This gym, named AG6, has gamified their workout. This is done with a series of activities where you interact with lights that guide you through each section. It is a simple example of how technology can be integrated into sports to make things more fun or easier to do. The lights used will stimulate the users to act in a certain way and thereby performing the right exercise. Figure 2.3 shows a part of the fitness room.⁴



Figure 2.3 - Fun fitness rooms, AG6 New York.

Interactive squash

This project initiated by interactive SQUASH and ASB Squash can transform every regular squash court into an interactive one. They work with a smart projector that will change the wall of the court into a fun interactive wall. Players can play skill enhancing games and see their statistics on the wall. This information can be seen in the app developed by the team as well. Their companies also made some fun games to play against each other as can be seen in Figure 2.4. The interactive squash system is interesting because it shows how both skill training and fun can be combined with visual effects. Something that can be of interest for the LED floor as well.⁵



Figure 2.4 - Interactive squash by iSquash and ASB.

³ Website last visited on: 30-05-2018 - <u>http://ttt3000.de/</u>

⁴ Website last visited on: 30-05-2018 - <u>http://www.contemporist.com/this-new-gym-is-designed-like-a-video-game/</u>

⁵ Website last visited on: 30-05-2018 - <u>http://interactivesquash.com/</u>

Interactive climbing wall

The augmented climbing wall developed by ValoClimb makes climbing a more fun experience. It again uses a smart projector to show animations on the climbing wall which players can interact with. There are many different individual games and a few two-player games as well. This way climbing can be done together with others. See Figure 2.5 for such a two-player game. Same as with the interactive squash this system shows how skill training and fun can be combined by using only visual effects. The company says that people stop and watch how the interaction is going, sometimes they even shout instructions to the user. This shows that this system can get people more excited about exercising.⁶



Figure 2.5 - Interactive climbing wall by ValoClimb.

Yalp Sutu & Yalp Toro

The Yalp Sutu is an Interactive Football Wall, containing impact-sensitive panels which measure and react to ball impact. By using LED lights and audio speakers the system can give feedback to the players on their performance. These playgrounds can be found in different public areas in the Netherlands and the rest of Europe. In Figure 2.6 such a football wall can be seen. It shows how simple lights and pressure sensors can be used to create something that many people like and which makes them engage in doing an exercise.⁷



Figure 2.6 - Yalp interactive football wall.

The Yalp Toro is an interactive sports court. As can be seen in Figure 2.7 this system consists out of four areas with each their own goal. For the goals, the same impact-sensitive panels as with the Yalp Sutu are used. The court can be used by both hockey and football players. By using four goals instead of two the game gets more intense.

This company has created two interesting systems, that are helping with getting both children and adults to exercise more and to have fun while doing it.



Figure 2.7 – Yalp interactive sports court.

⁶ Website last visited on: 31-05-2018 - <u>http://valomotion.com/valoclimb/</u>

⁷ Website last visited on: 31-05-2018 - <u>https://www.yalpinteractive.com/sutu-football-wall/</u>

Interactive gym equipment

The systems that are described here are not that much different compared to normal gym equipment, but they do have some extra technology that is used in a great way. The systems make use of gym equipment with sensors to gather data on how the user is doing and to show this data a screen is used as well. Sometimes just a screen can already change a lot in how a training is perceived by the user. When the data is shown to the users in a motivating visual way, it can help them to get better results. Two examples of these systems are Skillrow Class by TechnoGym and the Tacx interactive bicycle. Both make use of gym utilities like an indoor bicycle and rowing machine, these are connected to a screen and show the user a graphical image of how they are performing. When this is done in the right way the users can get some extra motivation out of this. It is for example possible to battle against others in the gym, this is then shown on the screen. By using this simple but efficient technology, users have more fun while working out and can immediately see how they are performing. Figures 2.8 and 2.9 show these systems.⁸



Figure 2.8 – The Skillrow Class, created by TechnoGym.



Figure 2.9 - The Tacx interactive bicycle system.

Pool Live Aid

Pool Live Aid is a computer vision tool which is designed to help amateur snooker players to predict the ball trajectories. The system uses a Kinect camera and a computer program. The system detects the snooker table walls in real time, as well as the balls on the table, which are identified by colour and it will detect the position and angle of the cue. By using this data and a video projector, the ball positions and their trajectory will be projected in a visually attractive and interactive way. This way amateur snooker players can learn faster which angels they can use on the table to get a certain ball in. Showing a player where to aim in a visually attractive way can be interesting for volleyball and the LED floor as well. Figure 2.10 shows the Pool Live Aid system.9



Figure 2.10 – The Pool Live Aid system while being used.

⁸ Websites last visited on: 31-05-2018 - <u>https://www.technogym.com/int/line/skillrow-class/</u> & <u>https://tacx.com/nl/smart-trainers/</u>

⁹ Website last visited on: 20-06-2018 - <u>http://makerfairelisbon.com/en/2014/09/03/pool-live-aid.html</u>

Conclusion

These examples all have in common that they make sport exercises more fun. While they do this, some of them actually improve a player's skills as well. As said before this project will focus on improving the user's skills and not necessarily on having fun. Therefore, it is important to take these examples in mind when designing the exercises for this project. All these systems show how users can be motivated and intrigued to use the installation. These systems show that just a few sensors, lights or other visual effects can change how a sport was used to be trained and make it more interesting. The direct visual feedback that the users get is very important as well. For example, in the table tennis system, a player can see his statistics and movements on the table during his training. This can make a short training session way more efficient. Users can immediately see what went well and what they have to improve on. The data that is gathered this way is very important for both the player and trainer. It can, therefore, be said that the feedback provided by user data is important and that just some basic technological elements can change a lot for the user. Furthermore, the motivational aspects of these systems are interesting to see and the ways how skill training becomes easier are important.

2.2 Related work - Academia

In this section, the papers found from the academic research will be described. The search engines used to find these are: Google Scholar, Scopus, and ACM. The main key search words that were used are: Interactive AND sports-training AND games; sport OR interactive AND led-floor. However, most of the papers in this section were found by the HMI research department and were given to this research. Some papers were found through the use of snowball sampling, consequently, there are not that many key search words used during research.

For the purpose of training athletes, there have already been different kinds of digital sports exercises created. The paper of Jensen et al. [2] gives a clear description of these different sports exercises and divides them into categories. According to the authors, the different digital sports exercises can be divided into three categories: Exertion games, training systems, and interactive sport-training games.

Exertion games are not focused on training a sport, but often take a specific aspect from the sport and use it in a game. This can be something like Breakout for Two [3], which allows two players who are miles apart to play a physically exhausting ball game together. This paper shows that by using just one aspect of a sport a fun and entertaining digital game can be made. Exertion games are more about having fun and exerting, rather than training sport-specific skills. This is however still important for the design of digital sports exercises, as these games do a good job in engaging users to play the game.

Training systems are interactive systems that can be used to train more on sport-specific skills compared to exertion games. Interactive systems mainly use screens for the interaction. One of these interactive systems is described in the paper by Bideau et al. [4]. The authors test in this paper if handball goalkeepers will react the same in a made-up situation in virtual reality as they would in a real-life game. They concluded that this is indeed the case. Thereby proving that augmented games can be used to train a player for different situations in the real-life game. This is an important aspect for the eventual research because this means that sport specific skills can be trained by using just a screen. This is shown in a literature research by Miles et al. [6] as well. They state that there is enough evidence to prove that virtual environments (VEs) can improve motor control skills in ball sports and anticipation and decision-making skills as well. Furthermore, the level of difficulty can easily be alternated when using VE's as well as which skill needs to be trained. This is however only the case when all conditions are optimal.

As Miles at al. note:

A VE needs to provide realistic rendering of the sports scene to achieve good perceptual fidelity. More important for a sport-themed VE is high functional fidelity, which requires an accurate physics model of a complex environment, real time response, and a natural user interface [6, p. 714].

Not all of the systems discussed in this paper had positive results, this is primarily because the conditions described above were not optimal in these systems. Still, this paper shows that it is possible to improve motor control skills by using VE's, which is definitely noteworthy and should be considered when developing a digital sports training system.

Interactive sports-training systems, however, combine multiple elements to make a system. Jensen et al. [2, p. 2] define interactive sports-training games as "training systems that use game elements and mechanics in their design". An example of such a system would be the Digiwall [5]. Digiwall is an interactive climbing wall. The climbing holds are capacitive sensors and have LED's on the inside to be able to illuminate. By grabbing the holds, sounds will be played to enhance the experience and provide feedback to the users. This form of physical feedback is important to the player and is the aspect that makes interactive sports-training systems different from the other categories. Different games can be played on this interactive wall. These games will make training on this wall more fun and attractive for the users. Ouchi et al. [14] show a similar system which can recognize climbing patterns of children by using the same kind of climbing holds. Both systems use mechanics in their design.

These were the categories that are found in digital sports exercises. The last two categories, training systems, and interactive sports-training games are clearly the most interesting to use when developing a system that will improve sport-specific skills.

In this project, both training systems and interactive sports-training games will be used. The training system used during this project will be supported by the interactive playground, which is located in the design lab at the University of Twente. This playground can be seen as a big screen on the floor where the users can interact with the visuals they see. This interactive playground will be used to test some of the first concepts of this project. Later on, the LED floor will be used, that was described in chapter one, this LED floor is more of an interactive sports-training game and will be used to present the final concept on. The LED floor can be seen as an interactive sports-training game because it uses mechanics in the design. The LED floor with pressure sensors gives the user a more physical interaction with the system compared to the visuals from the interactive playground. First, some extra examples of both categories will be discussed, starting with training systems.

Besides Digiwall [5] there have been other systems that have been created for climbing. Augmented Climbing [7] by Kajastila and Hämäläinen shows a way of using a smart projector and body tracking software to create a sport-specific skill training. One of the games developed for this system is the endless route game. Climbers have to follow a projected route on the wall, this route can be as long as the user wants. This way an endurance training can be done. The paper shows that by using just a projector, still an interesting and challenging exercise can be made. In this system, there is no feedback provided to the player besides the changing visuals, as it only consists of a projector. Because just a projector is used, the system can easily be implemented in different climbing walls. It is a training system and not an interactive sportstraining system like Digiwall [5] because it has no mechanics in the design.

Hopwood et al. [8] describe in their paper a system that can train the decision-making skills of cricket players. One group of cricket players went through a six-week training program that consisted of on-field training and additional perceptual training in front of a life-size video projection. The other group that was formed did only the on-field training and was used as a

control group. In the end, there was a significant difference in the decision accuracy of the cricket players. The group that did the additional perceptual training clearly showed more improvements compared to the other group. Thereby proving that screens can be used to train a player's decision-making skills. This system is easy to implement and can be used in a lot of different locations.

In the context of training material arts, Hämäläinen et al. [9] show that feedback by video recording can improve a user's skills. In front of normal mirrors fast movements cannot be seen back, with the interactive video mirror this becomes possible. The system uses a computer, screen, and video camera. The movements can be watched back on the "mirror" in slow-motion or regular speed. This can be done by speech or gesture control. This paper shows that even just recording a training session and providing an intuitive way of showing it back to the user can be a way to train skills.

Second, the examples of interactive sports-training games are discussed. Jensen et al. [2] made a system on their own as well. This system, the bouncer, is developed to improve the throwing and decision-making skills of handball players. The first concept of the bouncer is an installation consisting of a 270x270 cm frame strung with wire which has the ability to return a thrown ball with 95% of its speed. By the use of eight piezoelectric sensors, a microcontroller can calculate the impact time and position. Behind the frame, there is a projection screen. To decide on the final design of the bouncer different trainers were asked to give feedback during a workshop of the system. In the final system, a touch plate is added to detect when a player jumps, it is placed on the ground, six meters from the projection screen. Six meters is the distance to the goal that is used in handball to indicate from where players should throw the ball. The moment someone jumps on the touch plate animations on the projection screen will start to move. The user should throw on one of the targets that are presented on the screen, by making them move around the moment the player jumps the system will train the player's skill to make decisions while being in the air. The system shows a good example of combining screens and mechanics to train multiple handball skills, as both throwing and decision-making skills are trained.

The TacTower system [1] is an interactive sport-training game developed for elite handball players. It consists of four towers with eight plastic balls stacked on top of each other and held together by a steel structure inside. All the balls have touch sensors on them and on the inside, there are RGB diodes. The lights can be either be turned on or off when you touch a ball. A few games are designed for this TacTower, most of them are reaction games. The games are played with two players at the same time to make it feel more like a real game of handball. This project really tried to not just develop a fun game, but to develop something that is capable of improving the skills of elite athletes. TacTower is an interesting concept of making an interactive sport-training game, it does a great job in practicing a specific skill. A problem with the TacTower is that reaction skill training is the only thing that can be done with it. It has no further options to implement during a handball training. The TacTower can only be used by two players at the same time. This is not a necessarily a problem of course but it makes it less of a team training. As it consists of four big towers it is not easy to set up, which makes it less desirable to use every training.

SmartGoals [11] is an embodied multi-agent system designed for soccer training.¹⁰ The two cones combined make an interactive soccer goal, which can be in an active or passive state. When a ball passes through a goal that was on will turn off and another goal will turn on. This is a really simple example of an interactive sports-training game. It helps soccer players with

¹⁰ The SmartGoals system is already used by professionals and amateurs during their trainings, see: <u>https://smartgoals.nl/nl/smartgoals/</u> - Website last visited on 15-07-2018

one specific skill and is easy to use. The system is a bit limited in the interaction possibilities but shows how some simple sensors can make an interesting system.

The examples described above show that interactive sports-training games are great ways of skill training as well. These systems can train multiple skills at the same time and make it possible to physically interact with the system, this is an important aspect that the training systems described earlier not have. These interactive sports-training systems, however, are much harder to implement in current training locations compared to the training systems. This is not always the case, see for example the SmartGoals system. However, in most cases, the interactive sports-training systems are harder to implement because of the added mechanics. The training systems only need a screen or maybe a projector. Therefore, it can be said that training systems that only use a screen can be implemented easier in certain locations and will be cheaper. This makes these systems a better option for amateur sports training, where money can be an issue as well. On the professional level, however, the interactive sports-training will be better. The reason for this is the added physical interaction. According to Sigrist et al., [10] augmented feedback that is supported by visual, auditory, haptic, and multimodal feedback will more effectively enhance motor learning. Therefore, using a physical aspect in the system to provide feedback can be very useful for players.

As mentioned before this graduation project will use the LED floor for the final concept. When enough research is done with this LED floor and it is proven to be useful it can be implemented in the floors of big sports centres. Thereby making it not only a suitable way to train skills but also a very convenient way because the floor is always already there.

Individual vs team exercises

As the graduation project will mainly focus on volleyball, it is interesting to see what normally is done during a training. Volleyball is a team sport and during a training most exercises are done in team form. When digital sports exercises are created for volleyball it is important to know which exercises actually make the team better. According to Hammami et al. [15], both team and individual exercises can be used to make a team better. Individual exercises are called small-sided games in this paper. These small-sided games can be focused on coordination, speed, strength, etc. The results of this paper show that increasing the training of specific skills of individuals is beneficial for the whole team. The team's sportrelated physical fitness will improve. Therefore, individual digital exercises can be made for team sports such as volleyball and still be of great importance to the team as well. This is an important point to keep in mind, as creating digital sports exercises for individuals might be easier to do compared to team exercises.

Conclusion

These papers all show different important aspects to keep in mind while developing a skill training system. The most important papers were the ones about interactive sports-training games. Keepin' it Real perfectly describes the design phase, this can be used as a good guideline for this graduation project. Their idea to train the player's late time decision making is very intuitive and can definitely be used for volleyball as well. Jensen et al. also showed that it is possible to train different skills with one system. TacTower is a physical system primarily focused on training one skill and therefore it is a slightly less convenient system. The system created for this graduation project should be able to train different skills as well. To be able to create a system that can train different skills there are not necessarily a lot of complicated sensors needed. Screens or other sorts of projections are proven to be very useful when it comes to creating these systems. By simply using screens, a lot of different skill training sets can be created. Another aspect that can be taken from this analysis is that having fun while doing an exercise is very important. Without fun, the users are less likely to use the system frequently.

3. Interviews and observations

To be able to design the beginning concepts for this project some interviews were done. For these interviews, the prior knowledge from the related work was used. The interviews were done both with volleyball trainers and players of different levels. Both the expertise of trainers and players was used during this project to make sure both perspectives were considered before creating the exercises. Because the exercises should be usable at different levels of volleyball, it was important to talk with both amateurs and professionals. The problems of an amateur team are of course very different compared to the ones of a professional team. However, some basic elements are the same and these should be present in the exercises. The first interview was done with local amateur trainers. The reason to start with local amateurs was because of convenience, the trainers were close by and easy to get in touch with. Furthermore, they give a broader view of all the problems and needs there are during volleyball training. Professionals will probably have more specific needs and problems during their training compared to amateurs. The second interview was done with two Eredivisie players, and the last interview was done with the trainer of the Dutch talent team. Both the sub-questions; "Where lie the possibilities of a LED floor in digital sport training exercises?" and "What kind of interactive games, specifically made for the LED floor, can train the users' volleyball skills?", are answered in this section.

3.1 Interview with local trainers -4^{th} of March

For this interview, three local volleyball trainers were asked. All three of the trainers have various diploma's in training volleyball and one of them for training other sports as well. Two of them have a gym teacher degree and all three of them have played or are playing volleyball themselves as well. These three trainers were asked to individually fill in a question form before they were told what the project precisely is about. This was done to make sure that they would answer the questions without having any prior knowledge. This question form can be found in Appendix A.

After answering these questions, the trainers were told about the project and they were shown a video of the House of Mamba system.¹¹ In this video a LED floor is used in combination with basketball, this system was already described in the related work section. The video about the system was used as inspiration for the trainers. After they had seen the video, the trainers were asked to think about which possibilities they saw for such a LED floor in combination with volleyball. The most interesting points from this interview will be described here, first, a short summary of the questions that were asked to the trainers will follow.

The question form consisted out of nine questions. The first six were asked prior to seeing the video. These questions were there to find out what difficulties trainers have while training their teams and what they normally do during a training. The last three questions were done together in a conversation, this way there was more of a discussion. These questions were asked after the trainers saw the video and were more focused on which possibilities they saw with the LED floor and for what purpose it could be used during a training.

Out of these first six questions, some interesting points were made by the trainers. First of all, they said that starting new exercises with a team is always difficult. Most players do not understand why they have to do a certain exercise or do not have the patience to learn it. Furthermore, the trainers had some difficulties in getting their players to defend on the right places in the field, as the more fanatic players tend to get more balls then they should have to. Because of this, they tend to defend in the wrong places, as they try to compensate for the lazier players and try to get the balls of them as well. The trainers want to get more out of their feedback to the players, primarily making them more aware of what they are able to do now

¹¹ See <u>https://www.youtube.com/watch?v=nGuOA_EJ8qk</u> for the video of the House of Mamba system.

and how they are progressing during a year. Exercises which are seen as difficult to train are the ones where techniques are combined with timing. As there are multiple aspects to these exercises that the players have problems with. During a training both individual skills as team skills are trained. The trainers mentioned that they want to get more out of the individual training parts. During these individual training parts, the trainers should pay attention to every individual and give them personal feedback. This is much harder to do compared to the team training parts. These are better to organize because giving tips to the whole team at once is easier compared to when you have to do that for every individual. Therefore, providing individuals with the feedback and attention they need is something the trainers would like to improve on. The following paragraph shows the discussion about the possibilities of the LED floor.

The first and most discussed possibility that the trainers saw was using the LED floor in a way of self-reflection. Players can get instant feedback after they performed a certain task. This can be attacking, defending, blocking, etc. The great thing about such a floor is that immediately after the exercise has been done, the player can see what he did and where he was standing. This is a much better way of getting feedback compared to filming the exercise. When the exercise is filmed it is often looked back later and shows a different perspective compared to when a player stands in the field. So, when a player is defending a certain ball, he can immediately see where he came from to get this ball. Therefore, seeing if his first position was good or not. This technique can be used during games as well and show how the players in defence were standing the moment the opponent was attacking. This way players can see themselves if they were standing at the correct spot at the right time. So, a lot of self-reflection will be possible with the floor.

Furthermore, the LED floor can be used as an explanation tool. Trainers can show how the exercise will work out in a more visual way. Thereby supporting the explanation of the trainer and making the exercise clearer to the players. The reason why a certain exercise is useful to do will be clearer as well.

All three trainers agreed that primarily the footwork can be improved when using the floor. Other techniques will be difficult because with volleyball this is primarily done with the hands of course. The footwork during an attack, block or defence move can be really interesting to show on the floor. To be able to show if the timing is good, the trainers said that it would be great if it would be possible to display a ball on the floor as well. If the footwork of the player(s) and the movement of the ball can be played back on the floor that will be a great way of getting the right feedback. This is something that is interesting for all three of the earlier mentioned techniques. Either for tactical reasons or individual skills.

The trainers thought that a LED floor can be used to motivate younger children as well. They can do some games on the floor which are related to volleyball. This can be with or without a ball, for example, the coordination, reaction time and speed of the children can be trained in a fun way. The statistics of every individual child can be presented on the floor to motivate them and to set clear goals. Also showing how the footwork of an attack or block is done on beforehand will be really useful for beginning players. This way they can try to imitate the steps while doing an exercise.

3.2 Interview with Eredivisie players – 13th of April

The second interview was done with two Eredivisie players from Coniche topvolleybal Zwolle HS1. One player is the trainer of a youth team in Zwolle and has a gym teacher degree. The other player has done a master's in human movement sciences and currently works as an Embedded Scientist at the NEVOBO. The NEVOBO is the Dutch volleyball federation. These two volleyball players were first asked to individually fill in a question form. This form is slightly different from the one the trainers got and can be found in Appendix A as well. After

the individual questions were answered, the video was shown again and there was a discussion about the possibilities of the LED floor. First, a short summary of the questions asked will be given here, and then the most important aspects of the interview will be described.

The questions that were asked to the players are slightly different compared to the questions for the trainers. The players were asked if they saw some shortcomings during training and if there were any aspects during a training that they would like to do more with. They were asked which techniques are hard to train and which exercises they do the most. Furthermore, they gave an overview of how a general volleyball training looks like and how much time they spend on volleyball specific exercises. Non-volleyball exercises are things like, coordination, speed, balance, strength, etc. The last three questions were the same as for the trainers and were asked after watching the video about the House of Mamba system. These questions were done together in a conversation to be able to get a discussion going.

One of the players gave some interesting insights on which aspects of their training can be improved. He answered on the question form that there should be a higher pace in training. So, the explanation before and the feedback after an exercise should go faster. He also mentioned that tips from a trainer that are meant for one person should be given more often and more efficient. Now it often becomes a group discussion while it was only meant for this one person. Both players want their training to be more efficient, so the time that they have should be used as optimal as possible. One of them mentioned that he would like it to be possible to see the video image of a training faster so that you get your feedback the moment you need it and not after the training. They both answered on the form that most training consists out of a lot of serving and passing, gameplay and defending with attacking. During a training, they are focused on training their own skills for about 70-75 percent of the time. The other 25-30 percent they give others tactical tips or work on their team performance. They both say that they are around 80 percent of the time busy with volleyball-specific exercises.

The video was shown to the players and a discussion about the possibilities of the LED floor followed. Both players said that professionals are working at such a high level that progress can only be found in the details. They mentioned that the direct feedback that was also described by the trainers of the prior interview would be very interesting to use. They said that if this direct feedback would be shown on the floor it should show the position of the steps with high accuracy. The accuracy is mainly important for professionals, as these players work at such a high level that improvements in techniques can often only be found in the small details. For beginners, it is not a big problem if the feedback on the floor is not precisely where it should be, as they are primarily just starting to learn how an attack or block works. For professionals though this should be really precise as they want to get the maximum out of their attack and block. For them it is not so much about learning a certain technique but more about making the movement perfect. So, if the system that will be created is made for professionals it should be precise. One of the players thought that the idea of making a player multitask during an exercise would be great as well. This could be with some lights on the floor, to let them defend a ball and then react to a light on the floor or the same as with the paper of Keepin' it real [1] and letting a player attack and hit something on the floor that started moving the moment he jumped. By using lights on the floor timing and reaction skills can be trained as well. Besides exercises that can help the players to get better, they thought of some other uses for the LED floor. One of their suggestions was that the floor could be used to make a volleyball game more interesting to look at for the audience. This can be done by showing different kinds of statistics of players on the ground or some other visuals. The statistics that will be shown can, for example, be the number of points a certain player has made, how high he jumps or how fast his serve goes. Another suggestion they made was to use the floor as a tool to help the referee. The floor could, for example, show the ball print on the floor and thereby making it immediately clear if the ball was in our out.

3.3 Interview with the coach of the Dutch Talent Team - 25th of April

The third interview took place at the Papendal sports centre in Arnhem and was done with the trainer of the Dutch Talent Team. This trainer has already trained and coached multiple professional teams before his current job and he has a gym teacher degree.

For this interview, a slightly different setup was used compared to the other two interviews. This time it consisted completely out of a conversation about how the trainings of the Dutch team go and what he thinks about the possibilities of a LED floor. To be able to arrange this interview the people that were emailed wanted to know about what it exactly would be. Which is why this time the trainer knew before the interview about the LED floor and what the idea of this graduation project is. This gave him some time on beforehand to think about the LED floor and discuss it with some colleagues. If this different setup was positive or negative is debatable. It can be said that because the trainer knew in what direction he had to think on beforehand, he could think more about the subject and discuss it with his colleagues. However, this may have caused the trainer to think in a certain direction on what the possibilities of the LED floor were for his trainings. Instead of first coming up with facets of his trainings that can be improved and then thinking about the LED floor. For now, the positive aspect of this setup was that he was able to discuss the problem with multiple professional trainers at the Papendal sports centre.

At the sports centre he explained which technologies they currently have in use. In their sports hall, they have multiple cameras setup, which are directed at the volleyball courts. Next to the courts, they have a big screen on which they can immediately see the camera footage. Most of the time they put a delay in the system of about eight seconds, this is done to let a player attack and then while walking back to attack again he can see his own attack. Furthermore, they use a jump height meter and a heart rate sensor to see how the players are performing. The trainer can make his exercises on an online platform and show them to the players prior to the training or at the start of the training. This is a way to make sure the players get a quicker understanding of how the exercises work. On this platform exercises of other trainers can be found as well.

According to the trainer and the colleagues he talked to the first and most important use of the LED floor would be to use it for direct feedback as a form of self-reflection for the players. The same as during the previous two interviews the idea of using the floor for direct feedback was one of the main points. This direct feedback can be used to train attacking, blocking and even defending. For a player, it can be very interesting to see his movements on the floor. The first steps towards defending a ball, for example, show a lot in how efficient a player is. The trainer mentioned that most of the time there are multiple people standing in the field. Therefore, it is important to provide each player's steps with an indication to be able to keep them apart. This could be done by using different colours or figures to present the steps of the players. These steps on the floor should be visible for a few seconds or longer when needed and then disappear again. Otherwise, there will be too many steps on the floor in just a few minutes. Therefore, it should be possible to change how long certain steps will be presented on the floor.

The trainer said during the interview that it would be great if the ball print could be seen on the floor. This way the attacker can see if he hit the ball in the right spot. Next to seeing where the ball was hit it would also be nice if the trajectory of the ball could be shown. One way of showing this on the floor would be by creating a shadow on the floor of this trajectory. This way the attacker or defender can see where he and where the ball was at a certain moment. Using this as a form of self-reflection for the players can be really interesting and help them improve further. The trainer said that the floor can also be used as an explanation tool during trainings or for game preparations. The trainer can for example easily draw some running lines on the floor or demonstrate how an exercise works by showing an animation of the exercise. Avatars can be used to represent the players on the field. This way the players can possibly understand the exercise quicker. The same can be done during game preparations, the opponents can be displayed on the field as avatars as well and their movements during a game can be shown. By doing this while standing in the field it is easier for the players to get a perspective of how it will be during the real game. This on-field perspective can be one of the benefits of the floor compared to a game preparation done in a room beside the field. This way the tactical systems that the opponent plays a lot can be shown and this will make it easier to understand for the players what to do about it.

The trainer mentioned that he thinks that currently, the most promising feature that should be realised on the LED floor is the direct feedback that was discussed earlier. Therefore, during the interview, there was already a bit of a discussion on how to realize it and what kind of exercises would be great to do with this. As a trainer, he knows his players and he knows what motivates them, so these insights were really useful. One of the games he would like to do with his players is letting a player attack as frequently as possible in a certain time span. A specified area at the other side of the field will show where the player should try to hit the ball on the floor. This area could even start to move the moment the player jumps, as is done in the paper described in chapter two by Jensen et al. [2]. During the exercise, there should appear information about the player's performances on the floor. The information that needs to be shown is the time that is left for the exercise, the number of times the player has hit the ball into the specified area and the number of performed attacks. By showing all of this data, players can get more motivated during the exercise. Especially when the players know each other's scores, they will probably try to defeat the other players with higher scores.

Another exercise could again be something with moving targets or showing were to hit a serve or attack at the last possible moment. To really dive into someone's abilities a system should be created that tracks all the player's attacks and saves them together with the information on where the ball was and then show it back on the floor to the player when he wants to see it. This way the best attack can be chosen to be shown on the floor. This attack can then be used by the player to train with and to further optimize his attack. To be able to save the best attack of a certain player and show it to him any time you want you will need a big database. One Other idea was to show the pressure distribution of a player's foot. It can be interesting to see if and when a player is shifting his weight forward to defend a ball in front of him. This is something that will not be possible to investigate during this project but is certainly interesting for future work. These were the most interesting points from the interview. Next to the interview, an observation of a training was done at the sports centre. This training will now be briefly described.

3.4 Training observation Dutch Talent Team – 25th of April

After the interview was done the training of the Dutch Talent Team started. This training was about three hours long. The first 45 minutes there was a conversation about the last game and some preparation for the next game. The players each got some information on paper for the next game. After this the players started doing their warming up, which consisted of jogging, sprinting, different movements for the arms and legs, core stability and stretching. This took about 35 minutes. They continued the training with some serving exercises for half an hour, then different sorts of game like exercises were done for the rest of the training. In these last exercises, a lot of defending, setting and attacking was done by the players. From this training, it can be learned that a lot of time is spent in talking about the tactics for the upcoming games. This time spent on tactics should become shorter and can be improved in some ways the trainer

and previously interviewed professional players already mentioned. There were multiple trainers walking around and giving individual tips to players during the exercises. In between the exercises the main trainer gave the whole team some tips and feedback on what went well and what went wrong.

Conclusion

From the related work and interviews, a few things can be concluded. It has become clear that there are a lot of different ways to train a player's skill. This can even simply be done with a screen as the related work pointed out. When screens are used it becomes easier to create multiple exercises for a certain sport. The more exercises there can be made the more skills can be trained. It is more efficient to build a system that can train multiple skills. Next to skill training, fun is an important aspect as well. Fun is something that needs to be in the exercises that will be made. By making the exercises fun, players are more motivated to do an exercise more than once. Showing information about the players' performances on the ground can be something to motivate them as well. The most interesting idea to start making concepts for is the direct feedback. From all the interviews this was the part that was seen as the most promising. This can be feedback to improve certain techniques or feedback on what the right positioning is for a defender during a game. So, both feedback on tactics as on techniques is interesting. For professionals, the technical feedback needs to be very accurate to be able to be of use. Meaning that the steps should appear on exactly the right spot after an attack has been done. For amateurs, the accuracy is of less importance.

Furthermore, the exercises the trainer from the last interview was talking about should be made into a concept. The idea of showing live statistics of a player on the ground is very interesting. It should be possible to save the movements and statistics of a player and use them again at a different moment. Both the professional players as the trainers mentioned in the interviews that they would like to see trainings become more time efficient and make it easier to give everyone personal feedback. The statistics on the floor are one way of showing personal feedback, but this is only the feedback that is generated by the floor and not the feedback from the trainer.

Therefore, another idea would be to let the trainer write notes or draw lines on the field next to the player's steps. An app should be made in which the trainer is able to select a player and see his attacking, blocking or defending steps that he made on the floor. The trainer should then be able to write notes and suggestions for improvements next to the steps. This can be done after or during the training. This can be a good way to realise more and better personal feedback for players. However, it would take a lot of effort for the trainer to do this for everyone during or after every training. Still, it is an idea that has potential and should be considered as one of the final products. This will, however, be too much to realise during this project, so it is an interesting point for future work.

Another feature that according to the interviews was interesting is being able to save the ball trajectory as a shadow on the floor together with the steps and personal data of the players. Showing the ball trajectory can be beneficial when training the timing skills of a player. Furthermore, making the players multitask with lights on the floor or by using moving objects is a good way to train as well according to the professional players from the interview. Training a player's late time decision-making skills is one of the possibilities to do this. As mentioned before in the related work, Jensen et al. [2] were able to make the user multitask and thereby train multiple skills. In the next chapter, the final ideas for the first concepts were chosen and developed further into Lo-Fi prototypes.

4. Lo-Fi prototypes

This chapter will describe the ideation and exploration of the first concepts. These concepts were made using the knowledge gathered in the earlier chapters. These concepts were then presented to a professional trainer. The feedback that followed from this, will be used to further optimize the concepts. Finally, user tests with the Lo-Fi prototypes were done. The result of this chapter will be a final idea of what will be developed for the LED floor. This idea is then further developed in the following chapters.

So, by using the information from the first two chapters some concepts were made. In the previous chapter there were already some ideas for the concepts and now the best concepts are presented and made into a Lo-Fi prototype. To be able to choose the best concepts the physical constraints of the platforms on which the user tests will take place are considered as well. More information about these platforms and their possibilities and constraints will be presented later. The first concepts will now be discussed in the following paragraph.

4.1 Design of the first concepts

Four concepts have been made as a starting point for the Lo-Fi prototypes. These concepts are exercises that were formed by either the related work or by the interviews. The first concept that is described below is one of the exercises that the trainer of the Dutch talent team wanted to see. The second concept plays with the idea of direct feedback, which has been mentioned during all the interviews as a promising idea. The third concept uses the idea from the paper Keepin' it Real [2] and challenges the players to work on their late time decision-making skills. The fourth and last concept was formed during the interview with the Eredivisie players that wanted something in which multitasking and reaction would be trained. The idea of how these reaction skills are trained comes primarily from the paper about the TacTower system [1]. The first concepts are:

- 1. An exercise in which a player will attack for a couple of times and then lets him choose the best one. The steps of this attack will then be shown on the floor. These steps can now be trained by following them on the floor. These steps should go faster and faster. The same can be done for blocking.
- 2. A game in which players have to attack as often as possible in a certain time span, the time and number of attacks will appear on the floor. The spots were the attacker has hit will be shown as well.
- 3. An exercise in which the attacker should hit a target. This target will start moving the moment when the attacker jumps. This can be done with a service as well.
- 4. An exercise that uses lights to guide the block on the net, the lights will represent the shadow of a ball. The starting point of the player is at the net in the middle and then lights will go either left or right. Different speeds can be chosen for the lights and a random option would be nice. This way the blocking steps, reaction skills, and the timing will be trained.

These concepts were made into Lo-Fi prototypes. The Lo-Fi prototypes are visualisations that can be controlled by a facilitator during the user tests. These visualisations contain animations, these animations were created in Adobe Animate CC. Only screenshots of the animations will be presented here. The four concepts are combined in 3 animation types, where small changes in playing the animation will create the four concepts. Figures 4.1 and 4.2 show the footsteps of an attack and of a block. In the animation, the footsteps will appear one by one, for now, the complete number of steps shown. The arrow shows in which direction the steps are taken and the line above shows were the net should be. These are examples of the Lo-Fi prototype for exercise one. As the direct feedback cannot be tested yet, the steps are just put on the right spots

prior to having done an attack. In Figure 4.3 a screenshot of the animation for exercises two and three can be seen. The attacking steps will be on the floor already and the user will have to hit the ball inside the area. The information about the user's performance will be shown on the floor as well. Because the performances cannot really be measured during the Lo-Fi user tests, the information that is shown on the ground will be fake. Exercise four is shown in Figure 4.4, the user should follow the direction of the ball. The steps will appear one by one in the right direction. These Lo-Fi prototypes were presented to a professional trainer to get some feedback on them.



Figures 4.1 & 4.2 - Footsteps of an attack (left) and a block (right) that are used for exercise one.



Figures 4.3 & 4.4 – Lo-Fi prototype of exercises two and three (left) and Lo-Fi prototype of exercise four (right).

4.2 Feedback on the first concepts

On the 23rd of May, a discussion about the first Lo-Fi prototypes took place. The feedback was given by a professional volleyball trainer. This trainer is one of the main NEVOBO trainers in Overijssel and has trained many selection teams. He has been a volleyball trainer for over twenty years. This is not one of the trainers from the previous interviews. His feedback showed some interesting new ideas for the prototypes. First of all, the direction of the feet is very important to show to the players. Therefore, it would be desirable if the LED floor would be precise enough to show the complete foot and thereby the direction of the foot. This will however not be possible by using only the LED as the floor is not precise enough to show this. Therefore, this will not be present in this project but is important to mention for future work.

Furthermore, some extra information on the floor next to the footsteps would be beneficial for the players as well. The distance between each step and the time between each step are very interesting to know. This way a player can attack a couple of times and immediately see the time and distance on the floor. This way a player can try again and improve either the pace or the distance between the steps. An example of this concept is shown in Figure 4.5. The measurements shown in this figure are not real and just an indication on how such a concept would look like. This is a good example of how direct feedback can be used to help players improve. When a player and a trainer think they have reached the best attack, they can save it and use it more often. For beginners, the footsteps can be shown on the floor already and be adjusted to their capabilities.

Some other ideas came to light as well during this discussion. Showing how much power a player puts into his jump would be interesting to show as well. This will however not be possible on the current LED floor. This will also be an interesting idea for future work. Another idea the trainer came with was simulating the movements of an opponent's defence. To train players on where to hit the ball, a visualisation of the opponent's defence could be shown on the floor when he is practicing his attack. Avatars can be used to represent the defenders on the other side of the field and they should start moving the moment a setup is given. Now the attacker should respond to this and hit the ball into the area where there is no opponent displayed on the floor. This is similar to the earlier idea of hitting the ball in the direction of a moving target, only now it is more of a game like situation. A screenshot of this idea can be seen in Figure 4.6. In the animation the avatars that represent the opponent's defence at the other side of the net will move around when the setup is given, the attacking steps are already shown on the floor to guide the user.

The feedback provided by the trainer was used to further develop the Lo-Fi prototypes. These new prototypes and the setup for the user tests are described in the next section. In section 4.4 the results of the user tests can be found.



Figures 4.5 & 4.6 - Footsteps of an attack with extra information about the distance and time between the steps (left). Attacking steps and the simulated movement of players while defending (right).

4.3 Final Lo-Fi prototypes and user tests

The final Lo-Fi prototypes are described here. By using the feedback from the trainer mentioned above the final prototypes have been created. Although most of the exercises have stayed the same, some small changes have been made. The final Lo-Fi prototypes are:

- 1. An exercise in which a player will attack for a couple of times and then lets him choose the best one. The steps of this attack will then be shown on the floor. These steps can now be trained by following them on the floor. These steps should go faster and faster. The same can be done for blocking. Next to showing the steps, the distance and time between each step are presented.
- 2. A game in which players have to attack as often as possible in a certain time span, the time and number of attacks will appear on the floor. The spots were the attacker has hit will be shown as well.
- 3. An exercise in which the attacker should hit a target. This target will start moving the moment when the attacker jumps. This can be done with a service as well.
- 4. An exercise that uses lights to guide the block on the net, the lights will represent the shadow of a ball. The starting point of the player is at the net in the middle and then lights will go either left or right. Different speeds can be chosen for the lights and a random option would be nice. This way the blocking steps, reaction skills, and the timing will be trained.
- 5. An exercise in which the opponent's defence starts moving the moment the attacker jumps. The attacker will have to hit the ball at the spot where there is no defender.

The Lo-Fi prototypes will be tested in the Design Lab at the University of Twente. In the Design Lab, both the interactive playground system as the LED floor can be found. More information about the Design Lab can be found in chapter one. The interactive playground that is located there will be used to do the user tests with, van Delden et al. uses this interactive playground in their research [16]. This paper holds an elaborate explanation of how the interactive playground works. For now, just a short explanation of the system is presented here. The interactive playground is a system that uses two computers, one for tracking the players and one for running the visualisation. The visualisation is run at 1920x2400 pixels using two wide angle projectors. The tracking is based on the depth channels of four Kinects. The tracking will however not be used during the user tests. Only the floor-projection will be used during the tests. Therefore, it will not be possible to test the all the exercises precisely as they are described now. Some of the exercises need the pressure sensors of the LED floor to work correctly. Especially exercises one and two are hard to realise on the interactive playground. For these exercises, the user tests will primarily be used to see what the users think of the design and the interaction the exercise will give on the LED floor. The interactive playground was chosen for the Lo-Fi user tests because it was easier to make the prototypes for this system compared to the LED floor. Therefore, it was more time efficient to use only the interactive playground for the Lo-Fi prototype tests. Also, since testing on the LED floor was only possible on a small sized floor, these midterm user tests were performed on this bigger surface to get the total overview of games that are possible.

The animations made in Adobe Animator CC were turned into videos which were then showed on the interactive playground. It was interesting to see how the participants reacted on the movements of the feet and the avatars. The user tests should show if the participants are able to concentrate on which steps they have to do in combination with a ball. Furthermore, it should show if people that have never played volleyball before will be able to learn how the attacking and blocking steps work. The Lo-Fi prototypes that were used during the user tests are shown below. The figures will only show screenshots, during the user test the footsteps and avatars were moving.



Figure 4.7 – Exercise four.



Figures 4.8 & 4.9 – Exercises one and two.



Figures 4.10 & 4.11 – Exercises three and five.

Figures 4.7 till 4.11 show the Lo-Fi prototypes that were used. In Figure 4.7 the steps are shown to the user one by one and the ball moves to the right at a certain speed. The user would have to follow the steps and jump where the ball stopped. The statistics that are shown in exercises one, two and three are made up and were only used to show the user the complete idea of the exercises. The exercise in Figure 4.8 shows the steps one by one and the moment the user jumps and throws the ball, the statistics and ball prints are shown. The same goes for exercise three in Figure 4.10. Exercise two will show the steps to the user one by one and the moment the player lands the statistics and all the steps will be shown to the player. Exercise five will show the steps on the floor already, so they will not appear one by one. The avatars on the other side of the line will start moving the moment the user starts with his attack. The place where the gap between the avatars will come is the spot where the attacker has to throw the ball.

4.4 Results of the Lo-Fi prototype user tests

The user tests described above were done over three days. In total sixteen participants have done the tests. From these sixteen participants, there were five that had some prior experience in playing volleyball, the other eleven did not. Because most of the participants had never played volleyball before only on the first day a volleyball was used while performing the exercises, on the other two days a tennis ball was used instead. This was done because it became clear after one day that testing with a volleyball that was played towards the user was too difficult for most of the participants. Furthermore, the room in which the interactive playground is located is not ideal for hitting volleyballs in different directions. There was not enough space and delicate objects surrounded the playground. Therefore, it was chosen to use a tennis ball instead. This tennis ball was given to the user at the start of the exercise. This way the user only has to jump and throw the ball in the right direction. The most interesting results from the tests will be described in the remaining of this section.

Most participants had a lot of difficulties with following the attacking steps. Because the steps would appear from nothing they felt that they were always too late. The blocking steps were easier to do as these were supported by the volleyball which moved at a certain speed. This way it was easier to follow the rhythm of the steps and to anticipate when the next one would appear. Other ways to make sure the user is in time for the next step is by using predictive alignment. This technique will analyse a user's steps and predict where and when the next one will be set. When this technique is properly visualized on the floor it can certainly be of use for beginning volleyball players. However, to implement this on the current floor will be too much for this project, therefore it is an interesting point for future work. Another way to make sure the users can follow the steps in the right rhythm is by showing all the steps from the start and light up the one that needs to be stepped upon. To make sure the light does not appear out of nowhere for the user, the light should gradually become more intense. A different way of doing this would be by slowly changing the colour from red to green.

Exercise five was done perfectly by most of the users. Because all the footsteps were already shown the users had no difficulties with following the steps. Even users that had never done volleyball before did a decent job in performing the attacking steps. Next to following the steps the users had to throw in the gap between the avatars that were moving. This part also went well. Most of the users threw the ball in the right spot while also performing the right steps on the floor. Thereby proving that multitasking is possible during this exercise. A side note may be that this exercise was made too easy by using the tennis balls. Because the tennis balls were given to the participants before the attack was done, they only had to focus on the steps and on where to throw. When people with no experience in volleyball are able to do this, it is not an exercise that experienced volleyball players will learn a lot from. However, when the avatars are moving faster and when the ball would have been thrown to them the moment they jumped, it would have become much harder to perform all the tasks in the best possible way. Because then they would have to separate their focus on their steps, their timing towards the ball and the moving avatars on the floor. So, if the exercise is done with a volleyball and with a setup towards the attacker it will be an interesting exercise for experienced volleyball players as well. By adjusting the speed of the avatars or the setup, the level of difficulty can be changed. Therefore, making it an exercise that can be used on different levels of volleyball trainings and that will train the late time decision-making skills of the players. In future work, this should be tested with either the interactive playground or the LED floor in a building with more space available.

Exercises one, two and three showed statistics on the floor after the exercise was done. The users were asked what they thought of these statistics and in what way it influenced them. Most responses were positive, especially the number of hits was seen as motivating. Some of the users pointed out that seeing how much time there is left can influence the performance of a player as stress may increase when the time is running out. Players who have difficulties with dealing with stress will be more likely to make mistakes at the end of the exercise. This is an important aspect to keep in mind and can be used to train these players mentally as well. It can be chosen to be left out as well because the goal of the assignment is to become better at aiming and not necessarily at dealing with stress. This, of course, depends on what aspect the player wants to work on. Furthermore, most users did not see the benefit of showing the distance between the steps. These were statistics that had no meaning for these users. Professionals know what the right distance is and can use this information, but it might not be as interesting for amateurs. The time between each step, however, was seen by most users as important. This statistic made more sense to them, they understood that doing the steps faster would eventually help with jumping higher.

From these user tests the most important aspects will be taken to the final designs of the exercises for the LED floor. Starting with the steps that appear one by one. These steps are too hard to follow for most users and therefore all the steps will be shown from the beginning of the exercise. It will still be possible to try and do the steps faster and faster, only now this will be shown by colours that will slowly turn to green when the user needs to set a step. Furthermore, the speed of the avatars should be able to be changed during the exercise. As the players that will use the exercise will have different levels of performance. The blocking exercise works well and the multitasking during the exercises was no problem for most of the users as well. The statistics that are shown on the floor can work motivating, but it can have its downsides as well. People can get frustrated by the statistics or feel stress because of them. Therefore, it should be easy to change which statistics are shown to certain users and which are not. In the exercises that are developed during this project the statistics that should be visible on the floor can be chosen, however, there will be no difference between users. Changing the settings per user will be something for future work. From the Lo-Fi prototypes discussed in this chapter two were chosen to be made into exercises for the LED floor. The next chapter describes the selection of the exercises and the designing process.

5. Realisation & Evaluation

In the previous chapter, the designs for the Lo-Fi prototypes were presented and user tests were done on the interactive playground. This chapter focuses on the realisation of the exercises on the LED floor. First, it is described how two of the discussed Lo-Fi prototypes are selected and turned into exercises that can be done on the LED floor. This is then followed by the design of these exercises and, finally, user tests and an expert review were done.

5.1 Selection

To select the final exercises for the LED floor out of the Lo-Fi prototypes, the physical constraints of the LED floor were considered. The LED floor that is used for the final design is located at the Design Lab and cannot be moved to another space. The size of the LED floor is a little less than three by three meters. Therefore, the exercises two, three and five were already no option for the LED floor. These exercises need more space to be able to work. Exercises one and four do not have this problem and are possible on the LED floor. However, some alternations were done to make them better fitting for the LED floor.

As a reminder the five Lo-Fi prototypes from the previous chapter are shown here once more:

- 1. An exercise in which a player will attack for a couple of times and then lets him choose the best one. The steps of this attack will then be shown on the floor. These steps can now be trained by following them on the floor. These steps should go faster and faster. The same can be done for blocking. Next to showing the steps, the distance and time between each step are presented.
- 2. A game in which players have to attack as often as possible in a certain time span, the time and number of attacks will appear on the floor. The spots were the attacker has hit will be shown as well.
- 3. An exercise in which the attacker should hit a target. This target will start moving the moment when the attacker jumps. This can be done with a service as well.
- 4. An exercise that uses lights to guide the block on the net, the lights will represent the shadow of a ball. The starting point of the player is at the net in the middle and then lights will go either left or right. Different speeds can be chosen for the lights and a random option would be nice. This way the blocking steps, reaction skills, and the timing will be trained.
- 5. An exercise in which the opponent's defence starts moving the moment the attacker jumps. The attacker will have to hit the ball at the spot where there is no defender.

Exercise one stayed the same as the Lo-Fi prototype described above. Exercise four, on the other hand, needed to change a little bit as there is not enough space to start in the middle of the floor and perform a full blocking pass to either the left or right. Therefore, the player should start at one side of the floor and perform the blocking steps towards the other side. Unfortunately, the surprise element is eliminated in that way, as the player cannot go either left or right. The player can, however, still train his timing skills and his blocking steps.

During the remaining of this chapter, the exercises are called exercise one and exercise two, with one still being the attacking steps and two being the blocking exercise. All of the features from both exercises are now described.

5.2 Final description of the exercises

Exercise one

During exercise one, the user can attack as many times as he wants. Every time the user performs his attack, the steps will be shown on the floor and afterwards the option is given to either erase them or to keep them on the floor. Both the distance as the time between each step are shown as well. The user has the option to show both statistics, only one or none. When the user is satisfied with his attacking steps, he can choose to keep the current steps on the floor and use them to train further. From now on, no new steps are drawn on the floor. For future work, it should be possible to save the steps in a database and link them to the user's profile. This way multiple sets of steps can be saved and used again during a future training. The goal of the exercise is to improve the user's attack by providing the right feedback instantly.

Exercise two

In exercise two, the user starts either on the left or the right side of the floor, depending which direction of blocking steps he wants to train. From the starting position, the user can see a volleyball on the floor and the line of the net. When the exercise starts the ball moves to the other side of the floor and the user needs to follow it at the same speed. For this exercise, three different speeds were chosen and a random option that picks one of the three. Before the exercise starts the user can choose to see pre-programmed blocking steps on the floor, so he can use them to practice with. The user can also choose to show no steps on the floor at the start and to use the direct feedback that was used in exercise one as well. This way the user can see the actual steps that he performed on the floor including the distance and time between each one. This option would be for the more experienced players.

When the pre-programmed blocking steps are shown on the ground the user can see if he stepped on the footstep or not. When the user has stepped on the footstep it will turn from black to green. This way the user can see if he performed every step correctly. As mentioned before, the ball moves at a certain speed towards the other side. If the user arrives at the other side later than the ball does, the words: "Too late!" will be shown on the floor. When the user arrives at the other side the same time as the ball, the word: "Perfect!" will be shown on the floor and when the user is too fast and arrives earlier than the ball at the other side the text will say: "Too early!". Sounds will be used to mark the start of the exercise, this way the user is ready to start and focused on the ball. Depending on the outcome different sounds will be played. A positively received sound will be used when the user is doing the exercise right. A negative sound is heard when the user is either too late or too early. All of this feedback is used to help the user in training his timing skills and his blocking steps. The goal of the exercise is to improve both the player's timing and blocking skills. By using the sensors of the floor, the users get instant feedback on their performance and are able to train individually certain aspects that they find difficult.

5.3 First designs

The first designs of both exercises for the LED floor are described here. First, the setup of the system is explained. The information gained from this setup makes sure that the possibilities and limitations of the LED floor are clear before the start of the designs.

Setup

As mentioned before the LED floor is located in the Design Lab at the University of Twente. In Figures 5.1 and 5.2 the LED floor that was used during this project can be seen. Besides the LED floor a computer was used. This computer received the data of the floor via a network cable. The data of the floor was sent using the UDP protocol. For every tile, the x and y coordinates and the weight of the centre of the mass (z) were calculated. This data was only

sent to the computer when one of the three values (x, y, z) changed. The programming of the exercises was mostly done in Xcode, using C++ with openFrameworks, as the laptop of the researcher uses macOS. The computer in the Design Lab, however, uses Windows, so on this operating system, the programming was done in Visual Studio, using C++ and openFrameworks as well. On the computer, the openFrameworks app was running, interpreting the UDP data and running the exercises. The LED floor was connected to the computer as a second screen while showing the openFrameworks app.



Figures 5.1 & 5.2 – The LED floor located in the Design Lab.

Code

As multiple points are triggered when a complete foot touches the LED floor, all the weight points within a distance of fifteen centimetres of the first point that is measured are combined into one. This way the floor would only show one point for each foot.

Exercise one

Figures 5.3 and 5.4 show the first design that was made for exercise one. The circles represent the position of the user's steps and the lines are drawn to show which distance is measured. The distance is shown on the floor next to the steps, the letter "D" is used to indicate this. The distance is shown in centimetres.

The computer that is located next to the LED floor can be used to change what is seen on the floor. The user can choose if he wants the statistics and lines to be visible on the floor or not. The statistics, which in this case is the distance, can be made visible or invisible with the 's' key on the keyboard. The same can be done for the lines by using the 'l' key. The data output of the floor that is sent to the computer can be stopped and started by using the space bar on the keyboard. When the input is stopped, the last performed steps will stay on the floor and can be used to train further with. A reset key was implemented to erase all the previously taken steps when needed, this is done with the 'r' key. Mouse clicks can be used to simulate footsteps on the floor, this way the trainer can be the one to decide how the attacking steps of the player should look. An algorithm automatically calculates the distance between the steps and makes sure that for every foot that enters the floor only one point is shown on the floor by gathering the data points as mentioned above.



Figures 5.3 & 5.4 – Pictures of the first designs of exercise one. On the left there is a picture of the design on the LED floor and on the right a screenshot made in Xcode is shown.

Exercise two

Figures 5.5 and 5.6 show the first design that was made for exercise two. The footsteps show where the user should place his feet during the blocking action. The volleyball indicates the side where the player should start the exercise and will move to the other side. The white line is a representation of the net in a volleyball field.

Again, the computer next to the LED floor can be used to arrange the interaction on the floor. The keys: 'l' and 'r' are used to select in which direction the user wants to train his blocking steps. The 'l' key is used to train the blocking steps to the left and thereby will show the ball on the right in the starting position and the 'r' is used to train the blocking steps to the right and consequently, the ball will start on the left side. The user can choose three different speeds for the ball to move to the other side, these speeds are put under the keys: '1','2' and '3'. Key '4' will randomly pick one of the three speeds to move the ball to the other side. A reset button was implemented to move the ball back to the starting position, this is done with the 'b' key.

Mouse clicks can again be used to draw steps on the floor, this way the trainer can be the one to decide how the blocking steps of the player should be done. An algorithm automatically calculates the distance between the steps and makes sure that for every foot only one point is shown on the floor as mentioned above. Figures 5.7 and 5.8 show screenshots of the blocking exercise while using the direct feedback option. This option can be turned on or off by using the 'd' key. Figure 5.7 shows the steps with statistics and Figure 5.8 shows only the steps that were taken. The statistics, which in this case is the distance, can be made visible or invisible with the 's' key on the keyboard.



Figures 5.5 & 5.6 – Pictures of the first designs of exercise two. On the left there is a picture of the design on the LED floor and on the right a screenshot made in Xcode is shown.



Figures 5.7 & 5.8 -Screenshots of exercise two made in Xcode. The direct feedback option is chosen here.

5.4 First evaluation

First, user tests were done to see how the design of the exercises was perceived by the participants. Secondly, an expert review with the same professional trainer as from the interview at the Papendal sports centre was done.

Setup of the user tests

The first round of user tests was done to see what the participants thought of the design and what they thought of the exercises. A total of seven participants did the user test. Three of them had prior volleyball experience. During the user tests, the users were instructed to start on the floor and to do both exercise one and exercise two. The researcher sat behind the computer, using the keys to control the exercises. Afterwards the participants were asked what they thought about the exercises and filled in the question form.

The informed consent and information brochure that were used for this research can be found in Appendix B. The question form used for this research can be found in Appendix C. The results from the user tests will be described now.

Results

The participants did exercise one quite well, they tried to do the attacking steps and played around with the feedback option. Most of the users tried to make the biggest possible jumps on the floor. However, the biggest problem of the exercise was that there was no goal to reach during the exercise. Therefore, most users became quite bored with the exercise after a few tries. They did mention that the statistics could be seen as motivating, but this would only be the case when you have a certain real goal you want to reach. When this exercise is done on its own, it was too boring for most of the users. The three users with a volleyball background, did like the exercise a bit more compared to the others. As they knew what the importance is of the right placements of steps and which distances are good.

Exercise two also went well and was perceived with more enthusiasm by the participants compared to exercise one. This was mostly because now there was a clear goal for the participants to reach. Trying to improve timing while getting instant feedback on how you performed was seen as an interesting aspect. The used sounds in the design were perceived as positive. Overall this exercise offers more compared to exercise one. There is more feedback presented and the users were more motivated to use the exercise for a longer period of time. The exercise was quite hard to do, but they had the feeling that if they used the system more often they would be able to do it better. So, probably skills can be trained with this exercise.

Expert review

As mentioned above, the professional trainer of the interview at the Papendal sports centre was asked for his opinion on the designs. The pictures shown above and a short video of both exercises while being used on the floor were sent to him. His response was very positive, he immediately said that he would like to try it out sometime with his players. Especially the direct feedback option in both exercise one and two took his interest. However, to be able to really give something extra to a training the system needs to be very accurate. So, he wanted to know how accurate the floor exactly is? How accurate are the distances that are given between the steps and how accurate are the positions of the circles that are drawn on the floor? These questions will be checked and answered during the final evaluation in section 5.6.

Furthermore, he said that the feedback presented in exercise two was more interesting because it offered more than only the statistics. However, making a system decide when something is good or bad can be dangerous when techniques are being learned. The system will have to be set up really accurately by specialist to be able to make sure the right feedback is given to the users. This is why the direct feedback with the statistics is, for now, the best feature of the floor. As it does not make suggestions on its own but gives the user information to think about and to work on. Now the final designs and final evaluation will be described.

5.5 Final designs

By using the results from the first user tests and the expert review the final designs have been made. Figures 5.9 - 5.12 show the design of exercise one, both in screenshots as on the actual floor during tests.



Figures 5.9 & 5.10 - Screenshots of exercise one made in Xcode. Both figures show the attacking steps of a player.



Figures 5.11&5.12 – Exercise one while being used on the LED floor (left) and exercise one after a set of steps is chosen and with a tape measure on the floor to check the accuracy.

As can be seen in these figures the design has not changed a lot compared to the first design. The biggest difference is the time function that is added. Now players can see the time between each of their steps in milliseconds. The time is shown on the floor after the letter "T". A new font was used as well for this design. The font Futura was chosen to be used for the exercises since the text was recognisable in normal letters as well as in caps. Furthermore, the colour of the circles was changed to black. Both grey and black lines were used as can be seen in Figures 5.9 and 5.10. The grey lines were used to make the distance between the steps easier to measure. While the black lines were less distracting and the better choice to be part of the final design.

Figures 5.13 - 5.16 show exercise two, again both in a screenshot and while being test on the floor.



Figure 5.13 & 5.14 – Exercise two while being used on the LED floor.



Figure 5.15 & 5.16 – Screenshots of exercise two made in Xcode. Option with the direct feedback (left) and the pre-programmed blocking steps (right).

Also, in this design, there were no major differences compared to the first design. As with exercise one the time statistic is added to the design. Furthermore, the steps are turned green when the user steps on them, see Figure 5.16. In Figures 5.13 and 5.14 the floor can be seen while being used. Two situations are shown, in Figure 5.13 the user is on time, all the footsteps are turned green, and the user was perfectly on time as is shown on the floor. Figure 5.14 shows a user that is too late, which is then also showed on the floor. As mentioned above, sounds are played depending on the outcome of the exercise. Positively perceived sounds are heard when the timing is perfect and negatively perceived sounds can be heard when the timing was too early or too late. These designs are now tested during the final evaluation.

5.6 Final evaluation

First, measurements were done to see how accurate the floor is. Both the distance between the drawn points was checked as the average distance that was between the actual position of the foot and the drawn position on the floor. Also, the accuracy of the measured time between each step is checked. Secondly, final user tests were done to see how the design of the exercises was perceived by the participants. Thirdly, the professional trainer mentioned above was asked to give feedback on the final design.

The measurements were done with measuring tape for the distance and a stopwatch was used to check the time between each step. For the measurements, one participant was used. The setup of the user tests was the same as described above and the question form that was used at the end of the tests can be found in Appendix C.

Setup measurements

Following from the feedback from the first expert review the floor was checked to see how accurate it is. One participant was walking over the floor and first the distance between the drawn points was checked. Figure 5.12 shows the tape measure being used on the floor. Secondly, the time between each step was checked. To be able to check different situations, the participant moved around at different paces. Finally, the accuracy of the positioning of the floor was checked. This was done by slowly walking over the floor and checking the distance between the actual position of the foot and the drawn position of the foot for every step.

Results measurements

From the measurements, it became clear that the distance between the drawn points was very accurate. Every time the floor showed a distance between two steps, it was exactly the same as the measured distance of the measuring tape.

The measurements of the time between each step seemed to be correct as well. These were, however, quite hard to measure with the stopwatch. The measured time from the stopwatch was either the same or almost the same as the one of the floor. So, it seems that the floor measures the time accurately as well.

The last measurements were done to check how accurate the floor was when it came to drawing the position of the footsteps. This gave a different result compared to the previous two measurements. The results pointed out that on average the floor is 8.1 centimetres off. This seems like a high number for something that is needed to be accurate to work, according to multiple trainers. However, this number gets so high because of a few outliers. The distance was measured fifty times and for 35 times the distance was either two, three or four. The other fifteen times, the distance was around twenty centimetres. Therefore, it can be said that around one out of every four steps was not accurately drawn on the floor.

User tests

The user tests were done in the same way as mentioned above. This time there were five participants of which there were again three which had prior volleyball experience. The designs had not changed that much so just a few remarks were interesting. The added colour change of the footsteps from black to green in exercise two was seen as a helpful extra part of feedback. The time between the steps, however, did not make much sense to the participants. The use of milliseconds caused for some troubles. The participants did like the option and think that it can be useful when it is used over a longer period of time. Exercise two was still perceived as the more interesting exercise, but the added statistic of time between the steps did make exercise one more interesting compared to the first designs.

Expert review

The trainer had been sent the new designs and was asked for feedback once more. This time he was still very positive about the direct feedback possibilities. There were not many comments on the design as not much had changed. The use of the coloured footsteps in exercise two was seen as an improvement. He mentioned that the time statistic was hard to interpret at the moment. This was mostly caused because of the use of milliseconds, which is because of its accuracy desired but also outputs numbers that are hard to put in perspective at first. The trainer did mention that the milliseconds will probably make more sense for the users after a while. One of the things the trainer mentioned was that averages of the time and distance will probably work better to see improvement over time. When after each training the average distances and time between the steps are calculated and shown to the user he can see if he is improving. When only the statistics of single attacks are shown it is hard to be certain about the overall improvements. By using averages, outliers that are caused by the floor can be filtered out as well.

6. Conclusion

By using the information from the related work, the interviews and observations, the user tests and the expert reviews it was possible to develop digital sport exercises for volleyball that are capable of training a player's skills.

So, what kind of digital sports training exercises on the LED floor are the most interesting and promising to develop for volleyball? From the related work, it became clear that good training systems should contain a bit of fun, should be easy to integrate into trainings, and should provide the user with the right feedback to understand his progress. From these already existing systems, it became clear how digital sports training exercises can be useful during trainings. It became clear that the floor should present the user with helpful information and indications of how the exercise is going.

So, now it was clear how the problems in volleyball trainings should be solved, but which problems were there actually? After the related work, interviews and observations were done to get an understanding of the problems, but mostly, the opportunities for improvements in volleyball. These interviews presented lots of interesting information about current trainings in volleyball and their shortcomings. They showed how the LED floor could be used and which improvements it could help to realise. From these interviews, it became clear that there are many different aspects of a training that need improvements. However, just a few points could be chosen for this project and the most promising ones were chosen. Primarily the direct feedback was seen as a promising feature of the floor, next to using the floor as an explanation tool and using the floor to make players multitask.

The Lo-Fi prototypes helped with getting a focus on the most interesting and promising exercises. The selection of exercises was also partly made because of the physical constraints this project had. Eventually, the selected exercises were further developed and made for the LED-floor.

Following from the research that has been done, it can be said that the most interesting and promising kind of digital sports training exercises on a LED floor is providing direct feedback to the players. Using the LED floor to show the user directly what he has done is a good way to support self-reflection. It is believed by the trainers and players from the interview that a lot can be learned from this self-reflection. Combining this with statistics that were generated by the floor and other feedback makes the exercises a good instrument for improving skills.

The floor is used in the developed exercises to make it possible to see the steps of the user and to measure time and distance between the steps. This makes it possible for the user to receive direct feedback on their performance, while still being on the field. On normal floors, this would not have been impossible. Filming could have been done, but this would have been less desirable, as the users will not be able to see what they did with the same accuracy as on the floor and the feedback will probably come later at a different location instead of directly at their feet. The accuracy of the floor was quite good during this research, the time and distance between each step were always correct. The accuracy of the drawn steps did have some bugs and showed that one out of every four steps was not accurately drawn.

From the evaluation, it became clear that the exercises that were made during this research were interesting to use, especially when there was a clear goal for the exercise. Exercise two was in that sense the better exercise, as it was perceived as more motivating. Exercise one was interesting because of the direct feedback that was presented and for professionals, this was proven to be very insightful and helpful. For beginners, however, more feedback from the floor is needed to commit to the exercise over a longer period of time.

As stated above, it is important that the floor can be used on different levels. At the beginner's level, the floor is used to show how attacking, blocking or defending steps should be performed. At a higher level, these visualisations are not necessary anymore and players will only compare their own movements on the floor to see where improvements can still be made. By doing this, the different levels were able to use the exercises for their own improvements. The sensors of the floor were used to show the direct feedback as well as to show how the users were doing the exercise. This showed that direct feedback can improve a player's skills and is a promising feature that can be used for many other exercises as well. To find out if the system can actually improve skills over time, more research should be done with volleyball players over a longer period of time. Now the discussion will follow and elaborate on this.

7. Discussion

From the conclusion, it has become clear that the most promising exercises that can be developed for volleyball on a LED floor are focused on direct feedback. This was concluded after the interviews and observations were done, and these assumptions were tested with the Lo-Fi prototypes and the exercises made for the LED floor.

These tests, however, could have been done differently to have more certain results. In future research, the exercises should be tested over a longer period of time. Players should use the system regularly during training for a certain period of time. A control group that does not use the system during this period of time should be checked as well. This way the improvements of players can really be measured over time and it will become clear if the floor really helped with improving the skills of the players.

The tests should also take place in bigger rooms compared to the ones that are available at the Design Lab. The best location for testing would be a sports hall, as this is the place where the players are normally training as well. This way the tests can be done with no limitations of the room and it gives a realistic view of how the system would work if it was implemented in a sports hall. Also, more participants could have been used for testing, however, this would not have changed much in the sense that the improvements of players should be tested over time.

The tests and the expert reviews that were done show that there certainly is a lot of potential in these exercises. They show that direct feedback really can be used to improve a player's skills in a more efficient way. The use of live statistics on the floor was seen by most users as motivating, however, it was also mentioned that these statistics could be felt as pressure and thereby have a negative consequence on the results of the player. This is a feature that depends from person to person and therefore it should be easy to control these settings. Furthermore, the visuals and sounds used during the exercises were received as motivating as well.

During the user tests of exercise one, there were a lot of bugs in the system. At random places on the floor, there were points drawn sometimes. These bugs could not have been solved during this project because the LED floor itself caused these random points to appear and this was the only floor that could be used. The reason that one out of every four drawn points was a bit off can also be explained by the floor as it was not calibrated well during the research. New floors have been made and these are supposed to be more accurate. Exercise two, however, did not have that many difficulties with the bugs. This was mainly because this exercise did not show all the points that were measured directly on the ground. Only specific areas were of interest. When the direct feedback option was used during exercise two, however, there were random measured points to be found as well.

The design used for the exercises is very basic. There are not a lot of animations, images or vivid colours used in the design. The main point of the project was to create an exercise that can train a user's skills. Fun is an important aspect of this, as was proven in the related work section. Therefore, more vivid visualisations could have been used during this project. However, because of time restrictions, it was decided that the main goal was to make sure that exercises actually worked in the way that was meant. In the end, the designs of the exercises were changed a bit to make them more inviting to use. When more colours, animations or images are added to the design, it has to be tested if those extra design choices do not distract the users from their main goal of skill improvement. The design choices made should guide the user in this learning process and not distract him. It can be concluded that the exercises can still improve on these aspects.

Finally, the floor has proven to be useful for both amateur and professional volleyball players. This research will hopefully inspire others to do more research in this field as well, as this is a domain with still lots of unexplored possibilities.

8. Future work

Two good exercises have been made during this project, however some optimisations and extra tests were left out due to time constraints. Throughout this research all sorts of ideas and suggestions for future work came to mind as well. An overview of this will be given here in the form of a bullet point list:

- Using extra sensors to show the pressure distribution of a player's foot. It can be interesting to see if and when a player is shifting his weight forward to defend a ball in front of him.
- Another idea would be to let the trainer write notes or draw lines on field next to the player's steps. An app should be made in which the trainer is able to select a player and see his attacking, blocking or defending steps that he made on the floor. The trainer should then be able to write notes and suggestions for improvements next to the steps. This can be done after or during the training. This can be a good way to realise more and better personal feedback for players. Although, it would take a lot of effort for the trainer to do this for everyone during or after every training.
- A LED floor that is precise enough to show the complete foot and thereby the direction of the foot. This should either be done with a better floor or with extra sensors. The direction of the foot is desirable to know for self-reflection and is an important part of a player's technique.
- Showing how much power a player puts into his jump can be very interesting to know. This data can easily show the player his improvements in his jumping. This should be done by using extra sensors or the new LED floor should be capable of measuring this.
- Developing the predictive alignment technique for the LED floor. This technique will analyse a user's steps and predicts where and when the next one will be set. If it notices that the next step is going to be too much to the right, for example, the technique can let the player know by visualisations to correct slightly to the left. When this technique is properly visualized on the floor it can certainly be of use for beginning volleyball players.
- It should be easy to change which statistics are shown to certain users and which are not. In the exercises that are developed during this project the statistics that should be visible on the floor can be chosen, however there will be no difference between users. So, it would be a good idea to make personal accounts on which users can decide which statistics they want to see on the floor and which techniques they do not want to see on the floor. The floor should be capable of noticing who currently is on the floor, this can be done by using RFID tags that are put in the player's shoes. By using the RFID tags the system will know who is using the floor and what his or her preferences are.
- In future systems of the LED floor it should be possible to save the steps of a player in a database and link them to the user's profile. Referring back to the point above, the RFID tags should be used to link a player's footsteps to a profile. By using an ordered database, multiple steps can be saved and used again during a future training. When the steps can be saved the user can choose to use a certain set of steps in a training and use them to further develop the attacking steps. On these "old" steps, new steps can be shown. This way the user can see if he comes close to his previous steps, only the time between each step is now important and should be shown. The distance will stay the same, but the time can be used to improve.

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Appendix A – Question forms interviews

Dutch Version:

Vragenlijst trainers

Naam: Leeftijd: Niveau training geven (hoogste):

Vragen:

- 1. Waar loop je als trainer zowel tegen aan tijdens een training? Zijn er bepaalde dingen/oefeningen die moeizaam lopen?
- 2. Waar zou je tijdens een training nog meer uit willen halen?
- 3. Welke technieken zijn het lastigste om te trainen?
- 4. Welke oefeningen doe je vooral tijdens een training?
- 5. Hoe veel ben je met de individuele prestaties van spelers bezig om ze beter te maken ten opzichte van het team als geheel? (Percentage + toelichting)
- 6. Hoeveel ben je daadwerkelijk met volleybal specifieke oefeningen bezig tijdens een training? (Percentage) Vergeleken met coördinatie, balans, kracht, snelheid, etc.
- 7. Welke voordelen zou zo'n ledvloer kunnen hebben tijdens een training? Wat voor een oefeningen zouden hierop handig zijn?
- 8. Zou je het vooral als side-game (spel/oefening naast de gebruikelijke oefeningen) willen gebruiken tijdens een training of als analyse materiaal tijdens de training/wedstrijd?
- 9. Waar zie je de mogelijkheden voor de vloer? Terug refereren naar vraag zes. Sub vraag van vraag seven.

English Version:

Question form trainers

Name:

Age:

Level of trained volleyball teams (highest):

Questions:

- 1. What are generally the difficult parts of a training?
- 2. Which parts of a training would you like to see improve?
- 3. Which techniques are the most difficult to train?
- 4. Which exercises do you generally use during a training?
- 5. How much time of the training is spent on making the individuals of the team better and how much is spend on training the team as a whole? (Percentage + explanation)
- 6. How much time of the training is spent on volleyball specific exercises? (Percentage) Compared to: coordination, balance, strength, speed, etc.
- 7. Which benefits would a LED floor have during a training? What kind of exercises would be useful on the floor?
- 8. Would you like to use the floor primarily as a side-game (game/exercise beside the normal exercises) during a training or as a way to get feedback during a training/game?
- 9. Where do you see the most possibilities for the floor? Refer back to question six. Sub question of question seven

Dutch Version:

Vragenlijst spelers

Naam: Leeftijd: Niveau van speler (hoogste):

Vragen:

- 1. Zijn er bepaalde dingen/oefeningen die moeizaam lopen tijdens een training?
- 2. Waar zou je tijdens een training nog meer uit willen halen?
- 3. Noem van elke techniek een aspect dat lastig te trainen is. (Bovenhands, onderarms, aanval en blokkering)
- 4. Welke oefeningen zitten altijd standaard in een training? (Top drie)
- 5. Hoe veel ben je met je individuele prestaties bezig om deze beter te maken ten opzichte van het team als geheel? (Percentage + toelichting)
- 6. Hoeveel ben je daadwerkelijk met volleybal specifieke oefeningen bezig tijdens een training? (Percentage) Vergeleken met: coördinatie, balans, kracht, snelheid, etc.
- 7. Welke voordelen zou zo'n ledvloer kunnen hebben tijdens een training? Wat voor een oefeningen zouden hierop handig zijn?
- 8. Zou je het vooral als side-game (spel/oefening naast de gebruikelijke oefeningen) willen gebruiken tijdens een training of als analyse materiaal tijdens de training/wedstrijd?
- 9. Waar zie je de mogelijkheden voor de vloer? Terug refereren naar vraag zes. Sub vraag van vraag seven.

English Version:

Question form players

Name: Age: Level of player (highest):

Questions:

- 1. What are generally the difficult parts of a training?
- 2. Which parts of a training would you like to see improve?
- 3. Mention for every technique what the most difficult aspect to train is from that technique? (setting, passing, attacking and blocking)
- 4. Which exercises do you almost always do during a training? (Top three)
- 5. How much time of the training do you spend on self-improvement and how much on improving as a team? (Percentage + explanation)
- 6. How much time of the training is spent on volleyball specific exercises? (Percentage) Compared to: coordination, balance, strength, speed, etc.
- 7. Which benefits would a LED floor have during a training? What kind of exercises would be useful on the floor?
- 8. Would you like to use the floor primarily as a side-game (game/exercise beside the normal exercises) during a training or as a way to get feedback during a training/game?
- 9. Where do you see the most possibilities for the floor? Refer back to question six. Sub question of question seven.

Appendix B – Informed consent & Information brochure

Informed consent

I hereby declare that I have been informed in a manner which is clear to me about the nature and method of the research as described in the aforementioned information brochure 'Digital Sport Training Exercises'. My questions have been answered to my satisfaction. I agree of my own free will to participate in this research. I reserve the right to withdraw this consent without the need to give any reason and I am aware that I may withdraw from the experiment at any time. If my research results are to be used in scientific publications or made public in any other manner, then they will be made completely anonymous. My personal data will not be disclosed to third parties without my express permission. If I request further information about the research, now or in the future, I may contact Niels Dikken. (Contact information can be found at the end of this page)

If you have any complaints about this research, please direct them to the secretary of the Ethics Committee of the Faculty of Electrical Engineering, Mathematics and Computer Science at the University of Twente, J.M. Strootman-Baas.

Signed in duplicate: Name subject Signature

I have provided explanatory notes about the research. I declare myself willing to answer to the best of my ability any questions which may still arise about the research.'

Name researcher

Signature

Contact information:

Researcher: Email: <u>n.dikken@student.utwente.nl</u> Telefoonnummer: +31610097674

Adres: het Egbertink 20, 7582DE, Losser

Secretary of the Ethics Committee of the faculty of EEMCS: Name: J.M. Strootman-Baas Tel: 053-489 6719 E-mail: <u>ethics-comm-ewi@utwente.nl</u>

Information brochure

In this letter, we would like to inform you about the research you have applied to participate in. The experiment will take place on **dd-mm-yy**, in the design lab located in the gallery building. For this bachelor thesis Digital sport training exercises were developed for volleyball. These training exercises are meant to train a player's volleyball skills by using new technologies. The exercises are created for a LED floor which is basically a touchscreen on the floor. It can show dynamic visualisations and interact with the users by using its pressure sensors. For the research these exercises will be tested with participants on the LED floor.

In the proposed research, entitled "Digital sport exercises", movements of the participants on the LED floor are analysed. The exercises created on the LED floor for volleyball will show the steps a user takes on the floor and provide them with some extra information. This can be the time and distance between each step. The participants will try out this exercise and give feedback on the experience.

The purpose of the research is to find out how the participants will react to the visualisations on the floor and how the floor reacts to the movements of the participants.

The anonymity of the subjects participating in the research is guaranteed and the data will not be disclosed to third parties without the permission of the subject.

The participation remains voluntary at all times, so without giving any reasons, subjects may refuse to participate in the research. Subjects may also end their participation at any time and may refuse afterwards (within 24 hours) to allow their data to be used for the research.

Contact information of the researcher leader:

Name: Niels Dikken Tel: +31610097674 E-mail: <u>n.dikken@student.utwente.nl</u>

Contact Information for Questions about Your Rights as a Research Participant. If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee of the department of EEMCS.

Name: J.M. Strootman-Baas Tel: 053-489 6719 E-mail: <u>ethics-comm-ewi@utwente.nl</u>

Appendix C – Question form user test

Question form user tests

Name: Age: Prior volleyball experience: Yes/No If yes, which level:

Questions:

- 1. What do you think of the design of the exercises?
- 2. Did you think the data showed on the floor (distance/time) worked as motivating?
- 3. Did you think the sounds that were used during exercise two were a positive addition?
- 4. Did you like to do the exercises?
- 5. Did you manage to do the exercises correctly?
- 6. Do you think that by using these exercises, you will improve your volleyball skills?