Interaction Technology in Improving Learning of Sports Tactics: A Novel Way of Teaching Adult Novice Players the Volleyball Side-out Rotation with an Interactive LED Floor

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ABSTRACT

This research is part of a bigger project called Smart Sports Exercises, which aims to incorporate Interaction Technology into volleyball training. According to previous research of the project, it has been learned that novice players tend to struggle to learn the side-out rotation rule. Besides that, most previous interaction technology research in sports has been focusing on teaching (sets of) skills, and little is known about interaction technology applied in teaching tactical principles such as side-out rotation. This research used the Design Thinking methodology to investigate how an interactive LED floor can be integrated into volleyball training, improve the learning experience of this rule in novice players, increase the learning speed, and make the sport more engaging. The research proposed a Design Space that can be used by Interaction Designers when developing and deciding on solutions to sports tactical knowledge improvement and gives an exemplar of how a prototype that tackles this problem could look like. The results indicate that the interactive LED floor can be exerted in different phases in various ways to support the tactical knowledge acquirement and has many potentials that need to be further researched.

Keywords

Interaction technology; Volleyball; Sport; Training; LED Video Floor; Interaction Design; Novice Players; Pedagogy

1. INTRODUCTION

All sports have their pros and cons, and volleyball is no exception, however, it can be rather a challenging sport as it has a steep learning curve and it requires players to practice hard until they achieve proper techniques (Demers, 2019). With such a demanding sport, it can be challenging to engage novice players in the sport for a long enough period to become proficient rather than dropping out. One of the most critical reasons players give up on their current team sports is the conflict of interests or lack of enjoyment or interest, and since volleyball can take a lot of time to train and compete, players can lose interest, and the sport can coincide with player's other interest (Perry, 2013).

This research is part of a bigger project called Smart Sport Exercises. The project focuses on an interactive volleyball court and aims to develop "novel ways of training through the design of interactive digital-physical exercises" (Postma et al., 2019, p. 620). The initial research was mainly focused on the interaction technology aspect, and this research will be built on that and further delve into the pedagogy aspect of the project.

In previous research of the Smart Sports Exercises project, it was learned that novice players struggle with learning the side-out rotation rule. In volleyball, there are six positions on the field, and players need to rotate through each of these positions in a game. After every time a team wins a point while being on the serve-receiving side, that team needs to rotate clockwise and start serving. The tricky part of this rotation system is that each player has a specific specialisation and they play the best in their position of specialisation, therefore, every time they rotate, they need to switch places on the court to achieve the most optimal spot while still in the correct relative position (see Background section for more detailed information). The conventional way to learn it is to keep participating in volleyball games, which is not always accessible and can take a significant amount of time.

This is where Interaction Technology can come in and help. Interaction technology has been proven to improve sports experience such as levels balancing (F. Mueller et al., 2012), high enjoyment (Marshall, Mueller, Benford, & Pijnappel, 2016) and eliminating practical boundaries (Mueller & Gibbs, 2007). This leaves a lot of room for research and development on ways to integrate Interaction Technology in volleyball training, especially to facilitate the learning and teaching process of complicated rules like rotation. Some previous research has been done regarding integrating Interaction Technology in teaching sports such as substituting the traditional relationship teacher-student in choreography with interaction technology (Drobny & Borchers, 2010), training throwing skills in basketball when lacking close and constant guidance (Helmer, Farrow, Lucas, Higgerson, & Blanchonette, 2010, p. 2985) and gamification of skills practice like trampoline and climbing (Kajastila & Hämäläinen, 2015). However, the research so far is mainly on improving motor skills and lacks focus on sports tactical skills.

This research will focus on investigating ways of implementing a next-generation, high-resolution, interactive LED video floor to improve the learning experience of the side-out rotation rule in novice players, analyse if the learning speed would increase and make the sport more engaging to novice players. The two main objectives are:

- Explore possibilities of alleviating the current problems that volleyball coaches and novice players face while teaching and learning the side-out rotation rules with the help of the interactive LED floor.

33rd Twente Student Conference on IT, July. 3rd, 2020, Enschede, The Netherlands.

- Make the first stride at closing the gap of knowledge of how Interaction Technology can be implemented to help athletes understand tactics better and how tactical knowledge can be taught more effectively, efficiently, and dynamically.

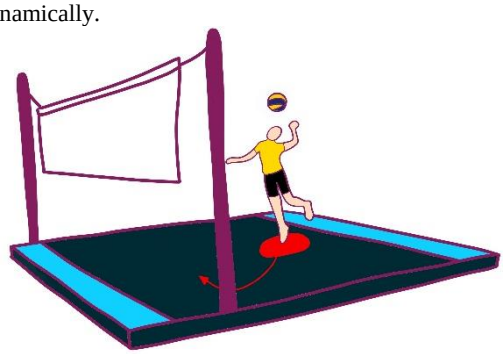

Figure 1-1 This illustration depicts the interactive LED floor set up as half a volleyball court. The red circle indicates the player's current location and the red arrow indicates the player's next move.

2. RESEARCH QUESTIONS

To fulfil the Research Objectives from the Introduction section, the research needs to answer these questions:

- **RQ1:** What are the strengths and shortcomings of the current teaching and learning technique of the volleyball side-out rotation? What are the difficulties that players or coaches meet while learning or teaching this rule?
- **RQ2:** How can the potential of Interaction Technology in the interactive LED floor leverage to facilitate the learning of sports tactical knowledge, in comparison to current uses in motor skills knowledge?
- **RQ3:** How would the proposed novel training technique tackle the shortcomings of the existing conventional training technique of volleyball side-out rotation?

3. BACKGROUND

Each volleyball team has six players playing at a time, and they stand on six different positions on their half of the field. After the team win a point off the opposing team's serve (side-out), the team rotates clockwise. All players need to stay in rotation after rotating. This means that each player needs to take into account the position of the players in front or behind them and player(s) next to them. This means in a rotation, if player A needs to stand in front of player B, where ever player B moves, player A still needs to stand closer to the net than player B.

There are six different standard players' specialisations: setter (S), outside hitter (H1, H2), middle blocker (M1, M2), and opposite (O). Each of these players has a specific role, and each plays the best in a specific position. This is not always easy because after each rotation, the position of each player changes. To play in their best position, all players need to shift and adapt so that all players can be as close to their optimal position as possible without breaking the rotations.

This can be illustrated in Figure 3-1. On the left is the abstracted ideal version of the positions and on the right is where all players need to stand in rotation 2. All players have moved to the positions that are easiest for them to move to the optimal positions, without breaking relational position in the abstracted ideal positions.

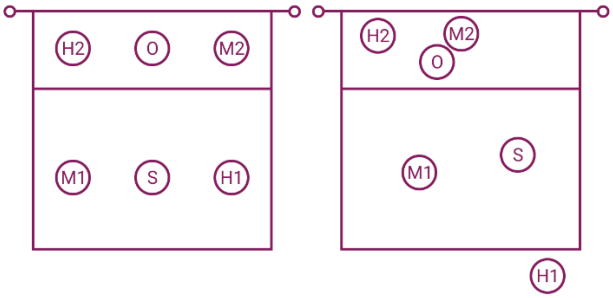

Figure 3-1 Rotation 2: Abstracted Ideal Position (left) vs Optimal Position for Attacking (right) (Adapted from MIT Women's Volleyball Club, n.d.)

The positions are different for every rotation, and there are also different strategies each team could use; therefore, it is easy to imagine how difficult this can be to grasp for a novice volleyball player. More detailed information about this rule can be read in MIT Women's Volleyball Club (n.d.).

4. LITERATURE REVIEW

4.1 Interaction Technology in Sports

Interaction Technology has been shown to be very promising and has a lot of potential in sports (Marshall et al., 2016). A lot of research has been done around this topic, and they can range from eliminating the physical boundary of a sport (Mueller et al., 2012), transform sports experience (Mueller & Gibbs, 2007) or tailored to teaching a sport (Drobny & Borchers, 2010). This research's focal point is the implementation of Interaction Technology in teaching sports tactical skills; therefore, this aspect will be further discussed.

Most sports are still being taught by human trainers nowadays, and sometimes technology can intervene to help the trainers. However, Interaction Technology can also be used as a substitute for the traditional teacher-student relationship with verbal instructions, demonstrations, and guidance (Drobny & Borchers, 2010). In 2011, Rauter et al. provided some arguments on why human trainers can be quite limited. Among other factors, two things stood relevant to the research: a human cannot hold the same level of attention and concentration over a long period of time, and human trainers can hardly provide augmented concurrent feedback.

While playing a sport, athletes usually rely on specific sets of skills; therefore, it is important to learn, practice and perfect them to improve their overall performance. For instance, in basketball, it is crucial to be capable of throwing the ball into the basket. Some examples of how Interaction Technology has been developed to help human practice specific skills in sports are explained below.

Throwing skill in Basketball. "Early skill development often occurs without the presence of a skilled instructor, or in settings where the skilled mentor is unable to provide prolonged one-to-one instruction and guidance" (Helmer, Farrow, Lucas, Higgerson, & Blanchonette, 2010, p. 2985). And therefore, Helmer et al. found it was important to help novices overcome the lack of guidance when learning one of the basic skills required in basketball – throwing technique. They did this by providing auditory biofeedback along with the interactive throwing sleeve so that learners can adjust their throwing action, and therefore, learn and improve their technique.

Real skills in video games contexts. In 2015, Kajastila & Hämäläinen introduced two approaches that can make practising real skills more motivating. By augmenting on top of the existing practice, they were able to transform the practice experience into

a video game, immerge the user into the game and make practising more empowering and engaging.

Firstly, implementing interaction technology into sports training can not only replace traditional learning relationship between student and teacher or facilitate this relationship, but it can also help overcome some of the limitations traditional training have and make training more engaging and empowering.

Secondly, there is much more research that has been done regarding this topic such as Godbout & Boyd (2010), Fogtmann Grønbæk, and Ludvigsen (2011), however, these research have been focused on solely technical skill and nothing like the volleyball side-out rotation rule – a tactical principle. The volleyball rotation rule is not a straightforward skill that can be practised over and over; it is a complex systematic plan that either needs to be practised repeatedly through games or learned by heart. This lack of research in Interaction Technology in learning tactical and strategical insights calls for attention, and this research will make the first attempt at closing this knowledge gap.

4.2 Smart Sports Exercises

This research is built on and adds to the on-going project Smart Sports Exercises; therefore, it is necessary to learn from what has already been done. The Work-in-Progress provided some great insights on what should be considered while designing the training concepts (Postma et al., 2019, pp. 622-623).

A coach is also a designer for training programmes. They teach, support, give feedback and adjust the training to the skills and needs of the players and team. Thus, it is crucial to incorporate them to the design of the solution. Therefore, empathising with not only volleyball players is essential but also with the coaches.

Age is an important factor in designing training schemes, and for adult players, it is typical of them to focus on technique and tactics, to gain a sense of accomplishment and get engaged to the sport. It is essential to succeed in conveying the knowledge to keep adults interested in the sport.

Level of expertise – for novices, it is more important to focus on the basic prerequisites, and the rotation is a fundamental principle of the sport.

Therefore, while designing the solutions, these factors should be considered: the role of the coach, focus on making the training informative as this is geared towards adult players and focus on successfully conveying the rules to the novice players.

As mentioned before in the Introduction, in previous studies of the Smart Sports Exercises, novices tend to struggle to learn the technicality demanding rule which is the side-out rotation. This suggests a need in an investigation into novel ways of teaching or learning it and Interaction Technology could be developed further to accommodate this.

4.3 Tactical Knowledge

It has been established that further research into the volleyball rotation rule is necessary; however, to understand how to improve the teaching technique of this tactic, it is essential to understand what tactical knowledge is. "Tactical knowledge is fundamentally for us "knowledge in action", because, for a player, tactical awareness and performance are strongly linked" (Gréhaigne & Godbout, 1995, p. 495). The correlation suggests a deep understanding of what tactical knowledge is. Tactical knowledge in team sports consists of three categories: action rules, play organisation rules and motor capacities (Figure 4-1) (Gréhaigne, 1992; Malglaive, 1990, as cited in Gréhaigne & Godbout, 1995).

The side-out rotation can be considered a play organisation rule as play organisation rules cover these four themes (Gréhaigne & Godbout, 1995, p. 498):

- The logic of the activity (1)
- The dimensions of the play area (2)
- The distribution of players on the field (3)
- Differentiation of roles (4)

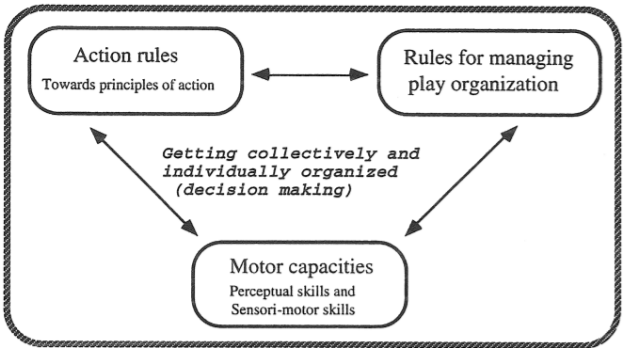

Figure 4-1 System of Knowledge in Team Sports (Gréhaigne & Godbout, 1995, p. 496)

In order to fully understand the side-out rotation, players would need to understand all four themes – rotating positions clockwise after a side-out (1) while remaining in rotation (correct relative position) (2, 3) and still in a position that can show full potentials of the role specialisations (4). Therefore, in order for players to fully establish an understanding of this rule, the novel teaching technique needs to cover all four themes.

To fully understand how to help players learn and memorise this knowledge, it is important to realise that knowledge can be split into two different classifications (Anderson, 1976, as cited in Gréhaigne & Godbout, 1995, p. 499):

- Declarative knowledge: factual information
- Procedural knowledge: conceptualised information (if-then scenarios)

Anderson (1982) and Chin and Rees (1983) (as cited in (Gréhaigne & Godbout, 1995, p. 499) "suggest that the acquisition of declarative knowledge provides the foundation for the development of procedural knowledge such as what to do in a specific game situation". Moreover, to build a secure and robust foundation, it is essential to practice procedural knowledge. Therefore, the novel teaching technique of the side-out rotation should lay down the foundation of declarative knowledge, then evoke and strengthen this knowledge with learning situations, if-then scenarios (procedural knowledge). This is usually done with participating in matches; however, matches are not always accessible and can take a significant amount of time; therefore, the novel teaching technique should have a systematic method that makes this process faster and more accessible.

5. METHODOLOGY

This research will be conducted based on the Design Thinking approach, which is a human-centred iterative process that looks at the problem(s) from the users' eyes, challenge alternatives and look for alternatives. Some great resources for Design Thinking can be found in IDEO (2019), Dam and Teo (2020) and Liedtka (2018). The Design Thinking methodology is an iterative process with five different phases which can be gone back to as many as times needed. Since this research project mainly focuses on the interaction technology and pedagogy aspects, this is suitable as it allows a deep understanding of the learning/teaching process of side-out rotation from the learners' and coaches' perspective and discovers new ways the LED screen could improve the learning experience. This research will be primarily qualitative. How this should be achieved will be explained below.

5.1 Empathise

Individual interviews were arranged with ten different coaches and eleven players to find the answer for RQ1.

- The ten trainers come from different backgrounds with 1 to 40 years of coaching experience between the Youth Entry Level to the Highest Division for Adults. All the trainers teach the 5-1 rotation formation.
- The 11 players' volleyball experience span from less than a year to 17 years. They participate in levels from recreational up to the Second National Division. Most of the players use the 5-1 rotation formation, and the recreational player uses 4-2.

The interviews were conducted online within the first two weeks of the research except for ten players whose information were collected via a survey with the same questions as the interviews. The interviews duration span from 20 minutes to 90 minutes. The interview questions were regarding the trainer's or player's personal experience with volleyball in general and learning, teaching, and practising volleyball rotation rule in particular. In the last 10 minutes, after provided with information about the capabilities of the interactive LED floor, each interviewee was given the freedom to brainstorm on how they would use it to teach the volleyball rotation rules to novice players. They were also asked to rank the most important principles for the new teaching technique from this list: visually stimulating, learning speed, quality of tactical insight, engagement and other.

The phase "Empathise" was gone over again when the first prototype was done. The prototype was presented on a physical LED floor to a Sports Scientist annexe Interaction Designer, a Professional Volleyball Player annexe Human Movement Scientist and a Student Creative Technology annexe Avid Volleyball Player and an informal think-aloud feedback session was conducted to examine if the concepts are aligned with volleyball trainers' and players' needs.

5.2 Define

The interviews from the previous phase were transcribed, and thematic analysis was conducted to identify the players' and coaches' views, opinions, and experiences with side-out rotation. The interviews were both video recorded and noted down; the videos were gone over again to complete the transcription. This data was then coded in two different topics: current learning techniques and their difficulties.

Common themes from both topics were then realised, and they were ranked based on how frequent they appeared in different interviews. Insights about the difficulties with learning the side-out rotation were used to define the research problems, and insights from the current learning techniques were used to understand the origin of the problems and how they could be eliminated with the help of an interactive LED floor.

5.3 Ideate

From the defined problems, brainstorm sessions were arranged to determine different possibilities on how to tackle them. For each problem, a "How Might We" question – a Design Thinking technique that supports launching ideation (Hasso Plattner Institute of Design, 2018, Card 13) was proposed to initiate the brainstorming process. A time constraint of 15 minutes was put on each question to achieve an intense and high creativity session. The platform Mural was used for collaborative and high visual brainstorm sessions with the supervisor.

Some lo-fi prototypes were made to demonstrate how each idea could work. These included more elaborated drawings and animations.

5.4 Prototype

A few of the best ideas from the Ideate phase were chosen based on how well they tackle the problems presented by following these steps:

- From all the ideas, different emergent themes were realised. These themes were based on the type of guidance given by the interactive LED floor and how the floor is used in that teaching technique.
- A Design Space was then devised to plot the themes on, supporting the decision of ideas that should progress to the next phases. More details are revealed in the Results section (Figure 6-1).
- The aim is to focus more on Procedural Knowledge while trying to test the full potential of the interactivity of the floor, so the themes were chosen based on high interactivity and higher focus on procedural knowledge.

The higher fidelity prototype was programmed with a flexible software sketchbook called Processing which is built for electronic arts and visual design. This programme was used because it is centred around the visual context and suitable for quick visual prototyping with a high level of customizability. The prototype was programmed to illustrate how the programme that controls the interactive LED floor could look like and how the trainers and the volleyball players could interact with the floor in real life.

After the second empathise session, the prototypes were adjusted to improve accordingly and finalised for the final phase.

5.5 Test

Six different individual testing sessions were arranged with the trainers and players from the first phase. Each session was conducted online via the platform Zoom as it allows screen sharing and remote control. These functions enabled me to share the prototype via the screen, let the testers directly interact with the prototype via screen sharing and allowed me to take control over the screen again whenever needed.

Each session lasted from 50 minutes to 2 hours. The testers were assigned with five different tasks which aligned with four different modes of the prototype. During each task, the tester was required to think-aloud – describe their actions, their emotions and reasonings behind each action, while interacting with the prototype. After each task, three sets of questions were asked:

- Usability of the mode and what did they wish the mode would have to understand how to improve the prototype further.
- What the overall impression of the tester is regarding the mode and how they think the mode could impact on the training to answer RQ2.
- How the mode could impact on different aspects of learning such as quality of learning, engagement and dynamic, and speed of learning to answer RQ3.

6. RESULTS

6.1 Empathise & Define

The interviews with both volleyball players and coaches provided great insights into the current teaching technique of the volleyball rotation rules and what is causing the failure to teach this rule to new players.

Learning Techniques

The most common way that volleyball players are being taught the rotation rules at the moment is through practice and training exercises. The trainers would tell the players where they need to stand for each rotation, and the players just practice by

participating in games. When there is a change, the trainers would give verbal instructions and feedback or go in the court and move the players to the correct positions physically.

The second most common way to learn the rotation rules is by getting visual illustration such as drawings on the whiteboard, a paper, or PowerPoint presentations. One coach mentioned that he created animations and uploaded them to YouTube so his students could watch and learn the rules from home. These visual illustrations are often paired with verbal explanations.

Some of the less common tactics are theory and scenario exercises (e.g. "Where do you need to stand when the setter is in the position 5?", "What does a middle hitter need to do when there is a free ball?", etc.); self-study by sourcing from YouTube or books; or being guided by other more experienced teammates during the games (e.g. "Go to the left of me now.", "Move back", etc.). In the cases of more recreational teams or young teams (under 12 years old), this rule is not focused and simplified.

Though there are similarities between the training techniques between the different coaches and players, there are drastic differences between them. For example, some trainers refer to the rotations by the order it comes while others refer to them by the position of the setter in the court; some trainers strictly guide the players to the correct position per rotation and scenario, while some leave the players more open to exploring different positions; and so on.

It is also important to consider that the teaching technique of the rotation rules has changed quite drastically within at least the last 40 years. The way the current trainers were taught this rule was often more passive as they just followed the instructions without being given much explanation, and current players learn more actively as they get a better overall picture by learning more visually and getting more explanations of the different positions and scenarios.

Difficulties

One of the most common difficulties the players face while learning the rotation rules is that they do not get an overall picture of the positions of all the players. Players usually only learn where they as an individual need to go on the court and in relation to the other 2 or 3 players whom they need to be aware of not to break the rule when rotating. However, they are not given the full picture of all the players and how their position relates to others in the tactical context.

An as common difficulty is that players mix up the rotations together, especially after a long rally, they can get too into the game and forget which the last rotation was and where they need to go next.

Other difficulties are players can rely too much on autopilot, and this requires them to practice a lot in the court to memorise all the rules. This can be due to the lack of explanation and understanding of reasonings behind where each player needs to stand and move to in each scenario. There is also currently no standardised way of teaching this rule; therefore, it can become an obstacle when switching teams. The training exercises specifically for this rule is also repetitive and lack dynamic, resulting in demotivation to practice it.

Ranking of Measures

All 21 interviewees ranked these measures based on what they thought were the most important. These measures will be used to compare the effectiveness of traditional and novel teaching techniques.

1. Engagement
2. Quality of Tactical Insight
3. Visually Stimulating
4. Learning Speed
5. Other (practicality, understanding of basics, feedback, analytics, adaptability, customizability, explanation)

6.2 Ideate

Ideation

From the insights of the interviews, seven How Might We (HMW) questions which represent the most pressing problems were realised. These questions took the challenges and difficulties that players and coaches meet with the conventional teaching technique and break them down to smaller actionable bits. 47 ideas stemmed from these questions[1]. A few ideas were turned into lo-fi prototypes[2]. The seven HMW questions and some example ideas that came from these questions are:

- HMW give the players an overall picture of the team's positions?
  Each team has six players on the court, and all their positions are recorded and shown on both the LED floor and the controller programme. There will be another player outside of the court and controlling one of the players via the programme. This "puppet" player on the court would need to follow the order of the "puppeteer". This gives the outside player a better overview of the game and the rule while still being able to participate and immerse in the game.
- HMW make it clear where and when players need to go? All the positions and moves are preprogrammed. Before each rally, the floor displays all the positions that all six players need to be in. After the ball has been served, arrows stemming from each player's positions directing them to new positions whenever appropriate are displayed.
- HMW facilitate the understanding of the reasoning behind each position and tactical decisions? Players are allowed to explore and design their own position formations that follow the rule. These designed are put into the programme and displayed on the floor for the players to follow. After each game, the players can reflect on how their game performance is affected by this formation. From doing this, the players will understand the impact of stacking and switching positions and find out what the most optimal positions are and understand why.
- HMW make the training more engaging? The relative positions rules are turned into a game of tag. One player will be chosen as the tagger, and there will be two horizontal lines and two vertical lines around him. The goal of the game is for this player to try tagging other players by making the (relevant) players cross these lines. Whoever crosses the line become the new tagger and the game continues.
- HMW make the learning of side-out rotation more accessible for players with less practice time? Two teams play against each other, and every rally, one player from each team need to be swapped around as quick as possible and continue the rally immediately.
- HMW help players disambiguate the side-out rotation? In the middle of the floor, a rotation number appears, and all players need to run to their positions in this rotation as

[1] https://app.mural.co/t/qfwfq7288/m/qfwfq7288/1590749408662/undefined

[2] https://app.animaker.com/animo/v47abhS7lDo3TBgj/

https://app.animaker.com/animo/CsvRFtI2GCmqqMlI/

quickly as possible. After everyone has gone to their positions, the game repeats.

- HMW help the players automate the skills? At first, the floor will indicate all six positions of all six players per rotation. The players need to keep switching their positions throughout the six rotations. After some rounds, the indication of one player disappear, and they need to find their positions by themselves. The game repeats until all players can find their positions without the help of the floor.

Emergent Themes & Design Space

From all the 47 ideas that came from the ideation process came five emergent themes:

- Visual Demonstration
- Strict Visual Guidance
- Loose Visual Guidance
- Practice by Repetition
- Strategic Games and Puzzles (Trainer Role)

To illustrate how the prototype themes might help with different learning stages, serving different aims and with different Interactive Technology solutions, the Design Space has been devised (Figure 6-1).

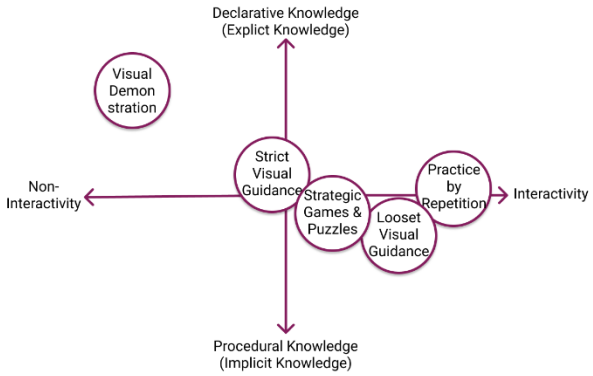

Figure 6-1 Knowledge - Interactivity Theme Matrix

As the aim is to focus more on Procedural Knowledge while trying to test the full potential of the interactivity of the floor, so the two themes “Loose Visual Guidance” and “Practice by Repetition” were chosen for the Prototype phase. A combination of 4 most breakthrough ideas from these two themes were chosen to be tested.

6.3 Prototype

Among all the ideas, four concepts were chosen – two games and two modes. The prototype is an interactive representation of how the programme would work on a computer or a tablet where the coach could control the interactive LED floor (Figure 6-2). The different buttons correspond to different games or modes (Musical Chair, Setter Choose, Show Lines and Draw Modes). The floor has pressure sensors so it would be able to sense where all the players are standing, therefore, on the interface if this controller programmer there are indications of where the players in real life are standing, the letters on each player indicates their specialisation in the team. For each game or mode, whatever is displayed on the court in the programme is what is displayed on the physical LED floor.

The first game is called *Musical Chair*. As the name suggests, the game is inspired by a kid’s game called musical chair. When the game starts, all six players are summoned to the centre, each player is assigned to a colour, and there would be a countdown. After the time turns to zero, the chosen rotation number would be displayed in the middle of the court of the team, and six

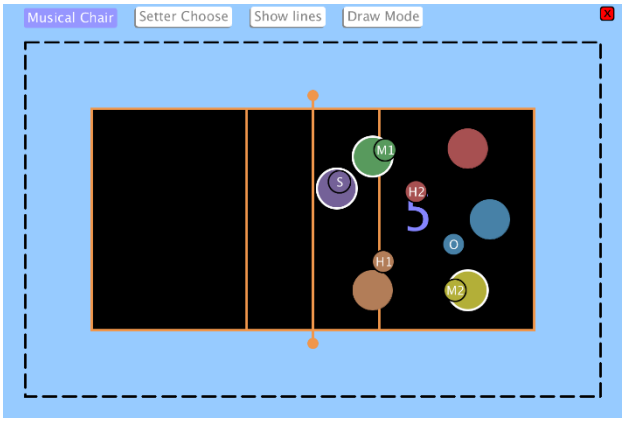

Figure 6-2 Interface of the Prototype; The Game Musical Chair has been started

colour-coded positions are displayed on the court. Players need to quickly find their corresponding coloured position and get there as quickly as possible. When each player gets to their correct position, their circle will light up.

The second game is called *Setter Choose*. This game will start with displaying all the positions the setter could have in the six rotation formations their team has in circles, and each position is corresponding to one of the rotations. The setter can choose one rotation by running into one of the circles, and as soon as they does this, all other circles disappear, and other players need to run as quick as possible to their positions. When each player gets to their correct position, their position will light up. This game is based on how the setter is usually assigned as the leader of the team, and most of the time, the players would need to "stack" around this player.

The first mode is called *Lines Mode.* Since the rule requires all players to be conscious of 2-3 other players (this rule is explained more in details in the Background section) such as one player might need to stand behind one player and to the right of another player. When a rotation gets tricky, the coach can choose to use this mode and choose one player who is in a particularly difficult position, and the LED floor would display two horizontal lines and two vertical lines around the player. This is to show that if other (relevant) players have crossed their lines or not. For instance, player A needs to stay behind player B, therefore player A cannot cross the horizontal lines of player B.

The second mode is called the *Draw Mode.* As the name suggested, allows the trainers to draw on the LED floor via the programme. This lets the trainers transfer from how they usually draw on papers or whiteboards to a life-size court. By drawing "directly" on the court, players could see more precisely the directions in real-time.

6.4 Test

6.4.1 Musical Chair

The general response of this game concept was positive. This game gives clarity by showing all the positions of the players on the court itself. This lessens the amount of description of the positions the trainer needs to say, and instead, the trainer can focus more on explaining why the positions are arranged like that and how it can be interpreted. This game also gives a new perspective of the positions and encourage the players to be more aware of other players' positions and movements.

The game makes the learning experience of this rule more rapid and requires more movement than the traditional teaching technique; therefore, the practice becomes more engaging and

fun. The live feedback also makes the success experience more tangible, and students would become more engaged in it.

This game is especially valuable for new players or players who are just learning the rotation rules as this game can bring more focus on this rule which is often brushed through now. However, to increase the quality of learning, the game would need more customisation to fit each teams' tactics.

This game would also increase the speed of learning as the teacher can spend less time explaining, and the players can spend more time on practising it. This will also allow the teachers to have more time to practice other skills.

There are also some limitations to this game, as to how it currently stands, the game does not give any incentives other than lighting up. One suggestion was to make it even more rapid with time countdown or points calculated based on the speed and accuracy of each player. The next suggestion was to add the positions after the serve and adjust them based on different balls they receive and where the ball would land. A few testers also mentioned that this concept might not fit in the form in relation to the target audience.

6.4.2 Setter Choose

This game received more mixed opinions, but overall, still positive. The game gives less guidance than Musical Chair and lets the players think and openly explore more. However, there is still live feedback which gives more structure and guidance for the players to learn the rotation rule. Besides that, this game is helpful since it simulates what usually happens in real games when players look at the setter to adjust their positions.

The game would help with the engagement to the training with the rotation rules as it provides powerful live feedback. It would also make learning the rotation rules or more complex tactics more accessible to new players.

Setter Choose's impact on the quality of learning is quite similar to Musical Chair; however, the effect would be more sustainable, and players would get a deeper understanding of the rules and tactics as they need to think more rather than just following instructions of the floor. However, this game might not increase the quality of learning for the setter themself.

This game also gives more structure on how to learn this rule so consequently make the process of learning it quicker. However, some testers said that this game requires quite some thinking and exploring, so it will slow down the process, but the sustainable effect balances it out.

This game's limitation was also the fact that it does not teach the players the next moves for after the serve. Moreover, the correct positions' areas should be more flexible by making them reflect on the relational positions to other players as well.

6.4.3 Lines Mode

The overall response to this mode was neutral. This mode does provide a bit more insight, but not much. This somewhat is due to the fact that the prototype does not have the live feedback function implemented. Most of the testers suggested implementing logic into this mode.

However, when asked to try this mode out in combination with the previous two games, this mode was received better as this mode can support explanation and gives an extra layer of information on top of the games. The Lines Mode could also be improved if the lines could indicate who is affected by which lines.

6.4.4 Draw Mode

The Draw Mode was received well as it provides a lot of different possibilities and most trainers and players are familiar with drawing out the tactics. Moreover, by drawing "directly" on the court, the trainer could give direction in real-time and waste less time on directing the players and spend more time on explanation.

This mode can also replace how trainers now use cones for practice. What could make this mode even more powerful is to add standard shapes such as arrows, circles, or even effects such as celebrations, fireworks, etc.

When asked to combine this mode with the two games, the feedback was similar to combining the lines mode with the games. This mode can be used to give more context to the games, allow more clarifications and explanations. Overall, it would make the impact of the games more reliable and more powerful.

One important trend seen while testing all the games and modes is that a lot of the testers wondered if they can be used along with the movement tracking functionality of the floor. They suggested that these teaching techniques would become even more powerful if it could be used to record the players' movements and compare them to the right movements indicated by the floor. This way, the players could visualise their faults and fix them.

6.5 Experimental Design

This section will describe how the prototype would have been tested with a physical LED floor if offline testing was an option.

Materials

Testing in real life would require a built interactive LED floor. The floor is 5x5-meter and is built out of 0.5x0.5-meter tiles. Each tile has four pressure sensors, one on every corner, and a high-resolution grid of LED's that effectively make the floor one large video display. Information about players and team behaviours, derived from embedded pressure sensors, can be used as input to provide rich and augmented visual feedback through the video display capabilities of the floor. An example could be viewed in Figure 1-1. A monitor to control the LED floor is also required.

A video recorded should be used to record the live interaction between the testers and the floor and informal interviews with the testers throughout and after the testing session.

Participants

Each testing session should require one volleyball trainers with experience of teaching novice players the side-out rotation rule and six people with limited to no volleyball experience.

Multiple trainers should be arranged for the testing sessions, and the same quality of teaching needs to be ensured. Before the testing phase starts, this trainer should be taught how to use the LED floor, how the prototype works and familiarise themself with working with the floor and the programme.

The players should be recruited and split into two groups randomly: one group is tested with the traditional teaching technique and one group with the novel teaching technique.

Test

A strategic puzzle test should be created to test players' knowledge regarding the side-out rotation rules. The test would show different scenarios of rotations when some players are standing on the court, and the testers should be able to complete the puzzle by describing where the rest of the players should be standing on the court for an optimal attacking formation.

Process

Both groups of testers would be taught and given practice for the side-out rotation by the same volleyball trainer in groups of six. Both groups will be filmed to show how each group reacts to the training.

Both before and after the lesson with the trainer, the testers are given the test. The before and after results will be used to compare and measure how much they have learned from the training. These results then should be analysed and compare which teaching technique yielded more significant growth in knowledge. There would also be a short quiz that let the testers grade on different levels of engagement to compare the engagement between the two teaching techniques.

7. DISCUSSION

7.1 Interaction Technology & Tactical Knowledge Acquirement

The results indicate that besides the wide range of possibilities to integrate Interaction Technology in motor skills training, it also has great potential in improving tactical skills training. It can be exerted in both phases of tactical knowledge acquirement: Declarative Knowledge and Procedural Knowledge. However, from the test results, the testers also suggested using the floor to analyse mistakes. This implies another phase in tactical knowledge acquirement: "Reinforcement & Advanced Knowledge". Analysing games and tactics are already done by sports coaches; however, by integrating the interactive LED floor, we could use it to record game behaviours and make it more accessible for players to do analysis and get more in-depth tactical insight. All three phases can be seen in figure 7-1.

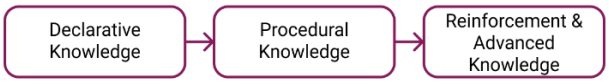

Figure 7-1 Three Phases in Knowledge Acquirement

Beside the Tactical Knowledge Acquirement phases, there is also the Interactivity dimension. The results indicate that the interactive LED floor could be used with different levels of interactivity depending on the purpose of the training.

The potentials of the interactive LED floor in tactical knowledge could be summed up in the Design Space in figure 6-1. This Design Space helped to decide on the most suitable ideas to test for the key goals in this research and could facilitate other Interaction Designers in their design process for different sports tactical knowledge teaching method.

7.2 Interactive LED Floor & Volleyball

The interview results suggest that the side-out rotation rules are currently not focused on and hence not being taken too seriously by the players, hindering the full potential of the team. Just like how the current Interaction Technology research has mostly been focused on training motor skills, the coaches also mainly train these skills and train the tactical skills just as a side-lesson.

The prototype in section 6.3 is an exemplar of how a prototype that tackles sports tactical performance could look like. The prototype gives a structure to how the side-out rotation rules could be taught and learn and separate this rule to be its own lesson. Consequently, this both gives more focus on this rule and decrease the responsibility of the trainers to teach this rule and allow them to put more focus on other skills.

Moreover, instead of replacing the teacher in the traditional teacher-student relationship, the interactive LED floor can empower the trainers to explain more in-depth about the rules and tactics. This solves the problem of players relying on muscle memory and autopilot too much. Besides that, the players can all see each other's positions and their relations to each other, giving them not only an overview of all positions but also an understanding of each of the position with regard to others.

The interactive LED floor could also create a more engaging and immersive learning experience of the rule, as the trainers do not need to interrupt in the middle of the training for feedback and the visuals on the floor can replace the cones and tapes which can disrupt the practice experience.

8. CONCLUSION

8.1 Insights

RQ1. Strength & Shortcomings of the Conventional Teaching Technique

The interview results indicate that even though the current teaching technique of the rotation rules has evolved compared to how the coaches used to learn it, there are still a lot of rooms for improvements.

The coaches now help the players have a better and more in-depth understanding of this rule and the tactics that stemmed from it; however, they still fail to teach the players to look at it from a broader perspective and see the importance of it. This creates a barrier for players to understand these rule and tactics fully.

The current teaching technique also encourages players to rely mostly on muscle memory and autopiloting skills, which is not necessarily a bad thing, however, it restrains the players from reaching their fullest potentials tactical wise.

RQ2. Leverage Brought by the Potential of the LED Floor

The results suggest that the interactive LED floor could be exerted in all three phases of sports tactical knowledge acquirement, can have different levels of interactivity with the players and in each of these phases, can have different positions in relation to the traditional teacher-student relationship. The summary of the potentials of the LED floor in different dimensions is in figure 6-1.

On the linear scale of sports tactical knowledge acquirement phases, the LED floor can serve different roles – in Declarative Knowledge, it can provide as a visualisation tool in order for a more seamless knowledge transfer; in Procedural Knowledge, it can be used as a medium for practice and training, providing an immersive learning experience; and in Reinforcement & Advanced Knowledge, it can serve as a tool that makes tactical analysis more accessible to the players.

Besides serving different roles in the sports tactical knowledge acquirement phases, the LED floor can also bring different experiences of interactivity with the users. This can be seen in figure 6-1. The floor can act purely as an illustration tool or transform the whole learning experience of the players by letting them directly interact with it throughout the training.

Last but not least, the LED floor can be positioned differently in the traditional teacher-student relationship throughout these knowledge acquirement phases and level of interactivity. It can either be used as an assistant of the teacher to overcome difficulties the teacher usually meets, or as the primary "teacher" to practice with the players, or even replace the teacher completely in things that require more precision and accuracy.

RQ3. Novel Training Techniques Tackling Shortcomings of the Conventional Teaching Techniques

The proposed games and modes serve as a good starting point for teaching novice players the rotation rules. They show some limitations in complexity; however, it is enough not to get new players overwhelmed. They give both players and trainers a new perspective of the rules and how to learn and teach tactical knowledge and decrease the size of the knowledge gap between the trainers and the players. The players can now see the rules

and tactics more from the trainer's perspective and develop more sophisticated tactical insights.

The prototype still needs more improvements and iterations to tackle the problems in RQ1 fully, and more testing needs to be done. This matter will be addressed in the Limitations and Recommendation sections. However, this prototype serves as a foundation for future research and designs for sports tactical performance.

8.2 Limitations

Even though this research is on an interactive LED floor, everything has been done online via a computer screen. Instead of interviewing, learning, and observing volleyball in real life, everything has been done entirely online. Though this has some disadvantages in the first and last stage of the research (Empathise & Test), this circumstance enabled the research to focus more about creating different concepts of how to use this technology, encouraged thinking outside of the box and eliminated the physical and technical boundaries.

The generalisability of the results can be limited by the small sample size for both the Empathise and Test phase, and this can lower the reproducibility of the results. However, it had a high diversity level (section 5.1), and this research can serve as a foundation to further research into this topic. This research can also be reproduced easily due to the Design Thinking methodology's flexibility.

8.3 Recommendation

The reasonable next step would be to reiterate the prototype according to the feedback received in the Test phase and implement them to test on the physical LED floor as described in Experimental Design (section 6.5). This would allow the testing to be more focus on the usability instead of the concept.

This research also only focused on the side-out rotation, however, with similar methods, this research could provide a foundation on how to replicate for defensive rotations rules and go even further with different moves and tactics during a rally. Notably, the Design Space (Figure 6-1) can be used to determine the direction of further research regarding volleyball tactical knowledge and sports tactical performance.

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