Keepin' it Real: Challenges when Designing Sports-Training Games

Mads Møller Jensen[1], Majken K. Rasmussen[1], Florian 'Floyd' Mueller[2], Kaj Grønbæk[1]

[1]Dept. Computer Science
Aarhus University, Denmark
{mmjensen, mkirkegaard, kgronbak}@cs.au.dk

[2]Exertion Games Lab
RMIT University, Melbourne, Australia
floyd@exertiongameslab.org

ABSTRACT

Using game elements and mechanics in sports training holds great potential for increasing player enjoyment, but also introduces a risk of reducing training relevance. This paper describes a novel training installation for individual handball training, called "The Bouncer", and the design process behind three training games. In order to investigate how game elements can affect the training experience, we conducted a study with 10 experienced amateur handball players, eliciting responses regarding the training relevance of the games. Based on the study and our design insights, we propose three challenges that designers of interactive sports-training games need to consider: 1) Maintaining relevance when translating physical elements into digital representations. 2) Choosing an appropriate level of sensing as game input. 3) Introducing points in training exercises without reducing sport relevance. For the three challenges, we propose strategies to help future designers of training games.

Author Keywords

Interactive sports-training games; exertion interfaces; sports; handball; exergames; human-computer interaction;

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

Most players recognize the importance of training, but would readily agree that playing the actual sport is significantly more fun and engaging, than training for it. Using technology to support sports training has received interest from both the sport science and HCI community, where a range of different examples of using technology to aid training in sport have been developed (e.g. [6,21]). However, few have addressed increasing the engagement in training by adding game elements as a way to motivate players to carry out the necessary training. We believe that designing training as games can motivate players to train, and shift training from being repetitive and boring to being engaging and fun. However, as pointed out by Jensen et al. [10], designing training as games requires designers to be sensitive to elements from the sport, as design decisions can lead to inexpedient behavior. By inexpedient, we mean actions that are inappropriate, undesirable or illegal in relation to the sport. Thus, designers of training games are faced with the challenge of utilizing game elements in an appropriate way that balances the use of engaging elements to make the training interesting, while keeping it real and relevant to the sport.

Our research seeks to add to the limited knowledge of designing interactive sports-training games by providing insights on how game elements can be used to increase engagement in sports training and how they affect sport relevance. In this paper, we articulate characteristic challenges that designers of training games will encounter, and propose strategies for approaching them.

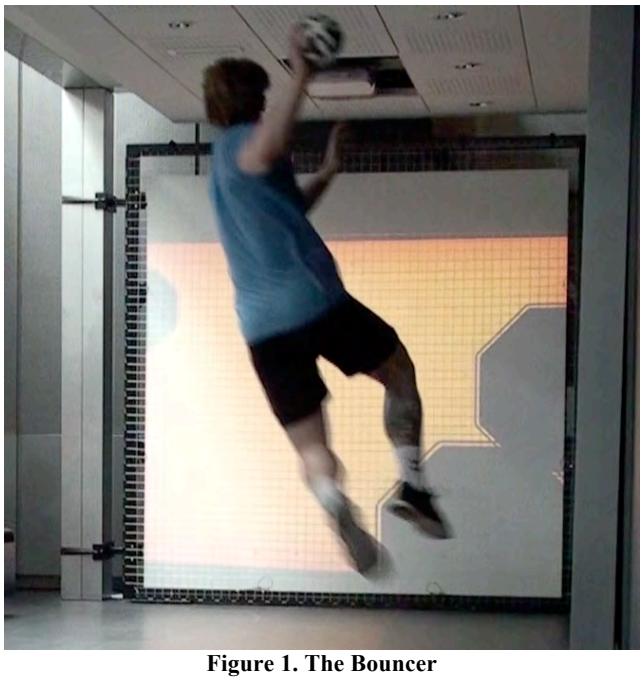

Figure 1. The Bouncer

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The paper is structured as follows: We start by looking at related work that combines technology and sport. Then we present the Bouncer, an interactive training installation, and the design process behind three training games. We present a study with 10 experienced amateur handball players, resulting in findings regarding the handball relevance of the training games. Based on the study and our design insights, we propose three characteristic challenges that designers of interactive sports-training games need to consider: 1) Maintaining relevance when translating physical elements into digital representations. 2) Choosing an appropriate level of sensing as game input. 3) Introducing points in training exercises without reducing sport relevance. For each of the three challenges, we propose strategies aimed at helping designers to create training games with a high relevance to sport training.

RELATED WORK

Three specific areas that combine sport and technology have informed our research: Exertion games, training systems, and interactive sport-training games. These areas focus on encouraging physical engagement, training sport relevant skills, and combining games and training, respectively. We have limited our scope of exertion games and training systems to screen-based examples, as we have used a screen-based approach in our work.

Exertion games: Focus on physical engagement

Exertion games refer to games that use bodily activity as input to facilitate engagement. Exertion games are not focused on training a sport, but often use elements from sports in their design. Within exertion games, screens have been used to facilitate physical games between multiple players, who are either distributed in different location, e.g. Table Tennis for Three [17], Breakout for Two [14], and Remote Impact [15], or playing in the same space, e.g. Splashball [8]. In these games, players interact through a screen, using a ball or their body, and the game provides a virtual space where the players' physical actions have an impact, e.g. by awarding points to players for smashing virtual bricks. Exertion games have also been popular at sports museums, enabling visitors to situate themselves in a sports context, such as shooting a soccer penalty (National Sports Museum, Melbourne), or scoring a goal in hockey (Hockey Hall of Fame, Toronto). While the setup of these installations might resemble a training situation, they are not training visitors' sport abilities. However, by applying game-like settings, the installations engage visitors in sports-related experiences. These examples of exertion games illustrate different ways of transferring physical elements into a virtual space in order to create an engaging experience.

Training systems: Focus on sport relevance

Training systems refer to interactive systems that facilitate training of different sport-specific skills. An example is using a large screen as a video mirror for training martial arts, thereby allowing athletes to perform and evaluate spin kicks; a move that is difficult to practice using a regular mirror [6]. Several systems explore using screens to create virtual environments for athletes to train their perceptual and decision-making skills isolated from the sport [13]. An example is the decision-making training system for cricket by Hopwood et al. [9], where cricket players are placed in front of a life-size video projection of batters striking virtual balls from different fielding positions. Similar examples exist from handball training [1,22], where goalkeepers' reactions are trained by using a virtual space and virtual ball-throwers. This enables goalkeepers to train important decision-making and reaction skills. Examples of screen-based training interfaces also include the numerous variants of golf simulators, e.g. [23], where screens are used to display a digital golf course that the players hit actual golf balls towards, allowing training of swing technique in a controlled environment. These training systems illustrate various ways of training specific skills, e.g. decision-making, using virtual environments.

Interactive sports-training games: Combining engagement and sport relevance

Interactive sports-training games focus on training systems that use game elements and mechanics in their design. Examples of interactive sport-training games, include the trampoline training games presented by Holsti et al. [7]. The system mixes jumping-height training on a trampoline with controlling a virtual character on a screen. The player's movements are tracked and displayed on the screen, enabling a platform style game where the player has to jump higher and higher to succeed. Football Lab is a football-training installation that trains players' ball-handling skills [10]. A player is placed in a small football field surrounded by sensor-mounted rebounders that call for the ball using lights and sound, and players are rewarded with points depending on how many passes they make during a game. TacTowers [4] is an example of an interactive handball-training game, which embeds the training of micro tactics and kinesthetic empathy in an interactive context through different games. The games aim to train the players' ability to "read" each other's intensions, and are played by two players without a ball. These interactive sports-training games illustrate different ways of combining relevant skill training and engaging gameplay, often by focusing on isolated skills, e.g. micro tactics or ball handling.

THE BOUNCER: TRAINING GAMES FOR HANDBALL

Inspired by existing work, we developed an interactive installation, supporting individual handball training, called "The Bouncer". We decided on screen-based interaction as the outset for our design, as 1) existing work indicate that using a screen supports the training of perception and decision-making skills (e.g. [1,9,13]), and 2) a screen enables a virtual space for incorporating game elements and mechanics (e.g. [14,15,17]).

Handball was chosen, as it is a popular team sport in Europe. Handball is a fast paced, high scoring game that is played by two teams of six court players and one goalkeeper. The game is played between two 3x2 meter goals, which are surrounded by a 6-meter zone, where only the defending goalkeeper is allowed. Players can score by throwing the ball past the goalkeeper and into the goal.

Technical description of The Bouncer

The Bouncer installation consists of a 270x270 cm frame strung with wire (called an M-station [24]) that has the ability to return an impacting ball with 95% of its speed. The M-station is fitted with 8 piezoelectric sensors that provide signals to a positioning algorithm running on an Atmel Xmega microcontroller. The algorithm detects the impacting balls and calculates the impact time and coordinates using a best-fit approach with an accuracy of approx. 10 cm. The micro controller sends data to a computer, and the computer's screen is projected onto a surface placed behind the M-station (see Figure 1).

THE PROCESS OF DESIGNING A TRAINING GAME

The following section presents the design process behind three games for The Bouncer. The aim of the design process was to design an engaging handball-relevant training game that would allow players to train individually.

In order to ensure handball relevance of our training games, we invited three graduate students in sports science to a brainstorming workshop. The students had theoretical and practical knowledge about coaching and playing various sports, two of them specifically in handball. The workshop lasted 2 hours and took place in front of The Bouncer, enabling the participants to explain and externalize their ideas by acting them out, using the installation. Three simple demo games were designed to kick-start the ideation process, and exemplify some of the possibilities offered by the installation, such as training handball penalty shots, hit accuracy and reaction time.

Especially two findings from the initial workshop influenced alterations to the installation and the design of the training games: First, the game should be more than target shooting training, and second, the installation needed additional sensing to encourage relevant movements.

Increasing handball relevance: beyond hitting a target

The workshop suggested that a training game should go beyond hitting targets and include other aspects, e.g. changing direction, reaction time, or decision-making, supported by previous research, emphasizing that aspects such as decision-making and cognitive skills should be addressed in training situations [11]. The demo games focused primarily on static target shooting, and our participant found that approach too simplistic for handball training. This is in line with the idea of balancing training between *part practice* and *whole practice* [12], as focusing on a specific and isolated part of a sport helps to limit stimuli of the players' senses, but too narrow a focus can complicate the process of implementing the learning outcomes back into the actual game. The most prevalent idea that arose during the workshop was the prospect of training decision-making abilities while being in the air during shot execution. Many handball players, especially when pressured, revert to their *habitual shot*, instead of surveying the situation in order to make a shot decision. A habitual shot is the shot that players like the most and often tend to shoot in stressful situations. Furthermore, research encourage incorporating option generation, cognitive processing and decision making in training, as these abilities are found to be different between elite and amateur players [19]. Consequently, we wanted to design the games in a way where targets only appear to the players when they jump in order to train their in-air decision-making skills.

Increasing handball relevance: adding a sensor

The workshop also emphasized that additional sensors in the game space were required to enforce handball relevant movements. The demo games rarely required the players to move more than few meters, and that is in contrast to actual handball, where players are in constant motion, often jumping whilst shooting towards goal. In order to address this issue and enable the design of training games that encouraged handball relevant movements, we needed to change the game space. Consequently, we incorporated an additional sensor, a large touch plate (50x150cm), which was placed on the ground, 6 m from the M-station. The

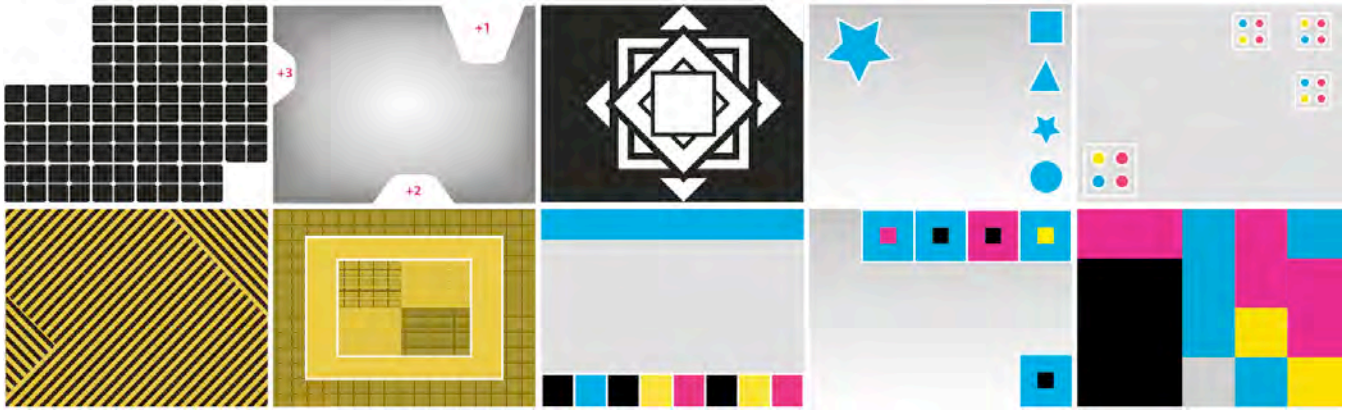

Figure 2. Examples of graphics used for the Wizard of Oz test

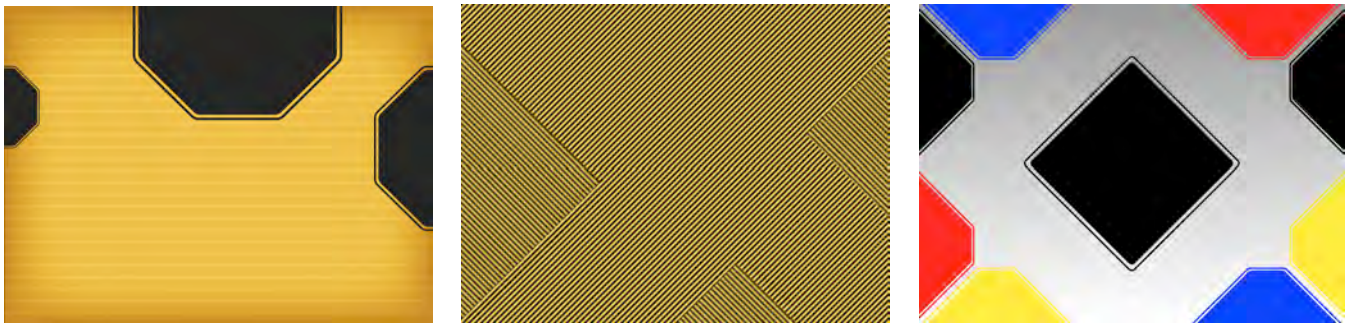

Figure 3. The three different graphic version, left: YellowBlack, middle: CounterStripes and right: ColorMatch

sensor was used to detect when a player jumps in order to change the graphics displayed and reveal the targets to hit. Moreover, in order to enforce handball-relevant movement patterns, we decided that training games should consist of multiple jumps and shots and have a high intensity.

Our final game concept

Bringing these elements together formed our game concept: A player starts 12 meter away from the screen with a ball. The game starts after a 5 seconds countdown, where the player then runs toward the screen and jumps off the touch plate. As the player's foot connects with the touch plate, the graphics on the screen changes, displaying different targets to hit. This forces the player to make decisions on where to hit, while being in the air. When the ball has been thrown, the player sprints back to the starting point, collects a new ball and runs towards the screen again. This continues for 40 seconds, and the aim of the game is for the player to get as many points as possible by hitting the appearing targets.

Relation to regular handball training

We are aware that jump shots and shot-time decision-making only represent a small part of handball, and training with The Bouncer should be considered as *part-progressive practice* [12]. Therefore, it should be part of a training session, where the elements trained are understood in relation to the sport as a whole. Training with The Bouncer is similar to traditional handball training, where in a typical shooting exercise, the players would run towards goal and shoot either to score on a goalkeeper or to hit cones or jersey placed in the goal as static targets. However, our game concept differ significantly, as 1) it allows for individual training with dynamic targets, and 2) forces players to make decisions in air based on their perception. Both are opportunities not present in traditional training. On the other hand The Bouncer has a limitation, as it does not cover the relationship between goalkeeper and shooter, who often anticipate and react to each other's movements. However, our intension has not been to cover all aspects, but instead to make the training independent of the opposing goalkeeper's skill level, and truly force the players to make their decisions in air.

Designing the training game graphics

Having settled on the basic game concept, we explored different graphic versions for the virtual targets (see Figure 2). The different graphics were tested using the Wizard of Oz method in order to ascertain their difficulty, handball relevance, and decision-making demands.

By experimenting with different graphics, we found that different graphical representations emphasized different aspects of the decision-making process. For example, we found that some level of cognitive load in the graphics made the game more engaging, however, overly complex graphics made the games too difficult, as players were unable to perceive the targets, make decisions and throw the ball, while being in the air. The use of abstract graphics also made it possible to create different sized targets, giving different scores, thus, introducing another game mechanic to the training game. This led us to design three different games based on the same game concept, in order to explore how they altered players' perception of the training games' handball relevance while considering engagement.

The three new training games (see Figure 3) were: 1) *YellowBlack*, which had three targets in three varying sizes, where the largest target had the lowest score, and the smallest the highest score, 2) *CounterStripes*, which also had three targets and the same scoring as YellowBlack, but displayed the targets more subdued, and 3) *ColorMatch*, which had 8 colored targets located around a center, with the point-giving targets determined by the color in the center. The three games were designed to highlight different aspects of the decision-making process, such as; choosing a target between different options (YellowBlack), shifting focus (ColorMatch), and pushing players' ability to locate targets (CounterStripes).

For each of the three games, we developed two different difficulty levels in order to see how players coped with an increased cognitive load. In YellowBlack and CounterStripes, the level was increased by removing the largest target within the first second after the targets appeared. The rationale was to simulate a goalkeeper luring the player to shoot at a certain location in order to anticipate and save the shot, as suggested by goalkeeper training manuals, e.g. [25]. By removing the largest target we forced players to rethink where they should hit, thus, increasing

the cognitive demand. In ColorMatch the difficulty was increased by having eight different colors, rather than four, giving the players only one target to locate and hit.

USER STUDY

We conducted a study of the three games in order to explore how proficient handball players experienced the different training games, as well as how the graphics affected the handball relevance.

Participants

For this study, we recruited 10 participants (8 male and 2 female) aged between 24 and 27, with an average age of 25 years. We recruited the participants by engaging with a local handball club as well as Aarhus University´s School of Sports Science's social forum. The participants had an average handball experience of 16 years, and they were active amateur players, who trained 2-4 times per week, except one, who only played occasionally after having played 4 times a week for 7 years. The combined participants covered all of the different positions in handball: Wing, backcourt, pivot and goalkeeper.

Procedure

After the participants had warmed up, they were introduced to the system and the structure of the study. The study consisted of playing each of the three games on the two levels of difficulty. Before each game the participants could choose whether they wished to see a live demonstration of the game or try it out in a slow pace. Each of the 6 games lasted for 40 seconds and was followed by a semi-structured interview. We restricted the study to 6 repetitions due to the high intensity of the training exercise. We mixed the order in which the participants played the training games by applying a Latin square to minimize the influence of fatigue, maturation of the participants and carry-over effects, giving each game equal terms of evaluation. Each study took between 60 and 90 minutes, and each participant received a $40 gift certificate for participating in the study.

Data Collection and Analysis

We used video recordings from three different angles in order to compare whether the movements of the participants altered when playing the games. The interviews were audio recorded and transcribed. We used a coding process to structure the transcriptions and identify key concepts in the data. These concepts were then placed in an affinity diagram and through an iterative sorting process we derived dominant themes from the study. These themes, which summarize and conclude the collected data, will be presented as findings in the following section.

EXPERIENCES WITH THE BOUNCER

All participants stated that they enjoyed training with The Bouncer. They had a high level of exertion throughout the games and were focused on their score and performance. Although, increasing the engagement and enjoyment of the training had been a focus in our design, the relevance of the handball training had higher priority as The Bouncer was created to be a handball-training tool. All participants stated that the training games had relevance for their handball training, supported by comments such as, *"It's a good mix between throwing and hitting targets, plus you have to force yourself to stay in the air"* (P1), and, *"it creates a coupling between reacting to something quickly, as you would have to with a goalkeeper, which makes it a great tool*" (P9).

The following sections present findings from the study categorized by the three dominant themes that emerged from the data: Movement patterns, perceptual reactions, and context characteristics

Movement patterns

Movement patterns relate to the way players move, and cover the execution of technique-related skills, e.g. throwing and jumping in handball.

Finding 1: Exploring different movement strategies

All of the players experimented with different ways of jumping in order to get more time in the air to survey the screen and locate the targets. 7 of the participants stated that they tried to jump higher, as the graphics got more complicated. One participant noted, *"I am focusing a lot more on getting to the plate and in the air now, instead of the speed"* (P9), as he went on to play ColorMatch. Another participant realized during a game that he had to jump higher to locate the targets: *"In the beginning I was just jumping and shooting […] but in the end I found that I had to stay in the air to locate the targets"* (P6). Figure 4 illustrates how one of the players altered the style of his

Figure 4. Example of altering the jump

jump, from a forward to a more upwards jump. In relation to handball, he answered, *"It is better to jump up than forward, but you should be able to do both, dependent on the situation"* (P4). Although both ways of jumping are useful in handball, jumping upward seems to improve players' ability to survey the screen. However, consulting the video showed no significant difference between the jump types in terms of time in the air.

Rather than focusing on jumping higher, 4 participants stated that they experimented with slowing down to get more precision, *"We were told to get as many points at possible, so I thought I would take fewer shots with higher precision. But if I had increased the intensity I might have gotten more points, so I will try that next"* (P3) and *"I slowed down a little so I had a more energy in the air to sort out where the colors were"* (P4). In general, the game forced the players to find a balance between intensity and precision, because as one participant noted, *"as soon as the intensity goes up, the technique goes down"* (P10).

Finding 2: Movement patterns are affected by fatigue

Fatigue and stress caused by the high tempo also impacted the players' jumping abilities, as one stated, *"I could feel the lactic acid here in the end. It gets harder to jump high enough in order to get time enough to think"* (P10). Others noted that fatigue impacted their shooting abilities, stating that they go to their habitual shot, if the were unable to locate the targets. This was emphasized as a positive element of the training game, e.g. by one players, who noted, *"There are many, who has habitual shots, so if you can remove that from a player, also when he is tired, I believe that would optimize his abilities as a player"* (P4). Thus, the high intensity of the game increased the training relevance, by creating a situation of fatigue, similar to the last period of handball matches, where players often tend to fall back to their habitual shot due to exhaustion. Training in this specific physical state might help the players to make better decisions in these situations.

Finding 3: Facilitating self insights of movement patterns

Playing the training games provided the participants with knowledge about themselves and their habits: 7 players commented on their shooting habits, e.g. "*I found that I start looking at the top and then at the bottom [of the screen], and that made me aware that I prefer to shoot up there"* (P8). One player noted that playing the game *"gives you a better overview, so you don't just do you habitual shot. And you do get pressured, maybe not physically in the air, but mentally"* (P6). In summary, because the games dictated where players could score, it provided them with insights on their habits, and helped raise reflection on areas where they could improve.

Finding 4: Altering relevant actions to improve score

All the players wanted to get high scores in the games, however, the strategies they employed to perform well were not always conforming to how they would act when playing handball. When asked what he did differently from the last game, one participant answered, "*I slowed down*" (P3). The interviewer questioned the proficiency in relation to handball to which he answered, "*in the last round, which was not so good, I did as I would do if I played handball, so now I chose a tactic, where I did not do as I would do when playing handball",* and elaborated, *"I did it because of this game. It is probably not a good idea in relation to handball"*. However, when asked how the game then succeeded as a training game, he answered, *"It might be that I would become a better handball player by doing it this way"*. Thus, it is not apparent if altering the way players normally move is positive or negative.

Perceptual reaction

Perceptual reaction refers to the way players are able to perceive a situation and react accordingly.

Finding 5: Perception of abstract representations impact the level of difficulty

The graphics of the games provided different levels of difficulty in terms of perceiving the targets. All participants regarded the complexity of YellowBlack as being easier than the other two. One player described the difference between CounterStripes and YellowBlack as, *"It was much easier to focus (in YellowBlack) than in the striped one. The stripes really confused me, because it was the same colors all the way round, but they were just divided. When I was shown the game, in the beginning I couldn't even see where the targets were, so it was difficult compared to this one, where the targets were clearly marked"* (P6). However, despite the unanimous agreement that YellowBlack was easier than CounterStripes, surveying the data from the games showed that the average hit percentage was higher in CounterStripes (93,3%) than YellowBlack (78,7%). The discrepancy might be caused by the larger target sizes in CounterStripes, or because players tended to shoot more after the big targets in CounterStripes. This was evident as the average hit score was lower in YellowBlack (119 points per shot) compared to CounterStripes (98 points per shot) despite the higher average hit rate.

The graphics of ColorMatch required the players to combine two tasks, namely to identify the color to hit and locate a corresponding target. While this might seem as an easy task when standing still, it showed to be a difficult task to perform in air, as one player noted, *"I was surprised that it was so difficult to locate the colors. When I was just observing the first few times, I thought it was easy to see where they were, but when you hang in the air, there is suddenly not that much time. It was more difficult than I thought"* (P4). Many players admitted to panic in the air, e.g. "*when there is a color you have to hit, and you can't find it, then I ended up shooting right in the center*" (P3) or *"I ended up shooting at the big one in the center. I certainly think I could learn something from this"* (P5).

Finding 6: Enforced decision making is engaging

In YellowBlack and CounterStripes the different sized targets allowed players to choose different strategies in order to score points. The choice of targets left the players in a dilemma, which was phrased by one player as, *"should I go for the easy solution and score, or should I choose the difficult one and maybe miss"* (P6). The players often altered their tactics along the way, aiming for smaller targets if they were unhappy with their score, or if they had gained confidence from a previous game, as one described as, *"the tactic was a bit different now, because I know that I haven't got time for that many rounds, and I know that I can hit the small one. I showed that when I got the 900 point"* (P7). Although most had the intention to hit the small targets, they did not always succeed, and when the large target disappeared in the second level of the games, the players had to reconsider their decisions, e.g. *"when there were three targets to hit, then you felt that the largest one was kind of a buffer, if you couldn't hit the other two, but here you quickly have to eliminate it, and see if you can hit the others"* (P4).

Finding 7: Coherence between the abstract graphical representations and handball training

The three games were perceived differently in regard to handball relevance. The graphics in CounterStripes was hardest for the players to relate to playing handball. One player stated, *"I don't see great transferability to playing handball. As I see it, the goal has a color and the goalkeeper typically has a different color"* (P9). Another pointed out that, "*it was a fun game and it trains you, […], but I just find it a bit difficult to relate it to handball […] it demand something else to be able to detect the patterns, whereas in handball, if there is a free space, you can always see it"* (P3), and others viewed the graphics as being a cognitive test, rather than related to handball. However, one player preferred CounterStripes, as *"the yellow and black were sometimes too easy to see, it was too clear, whereas this one (CounterStripes), you had to be more focused"* (P4). Thus, even though the graphics might be hard to relate directly to handball, they can still offer valuable training in terms of cognitive processing and perception.

Where the graphics of YellowBlack and CounterStripes might relate to identifying scoring opportunities in the goal, the graphics in ColorMatch present a less clear link to handball goalkeepers. However, many players related the way of surveying the goal to handball, noting that, *"it's like reacting to how a goalkeeper stands, you look for the free space. Here you look for a colour, so in that sense I think it's transferable"* (P5).

The notion of removing the targets in YellowBlack and CounterStripes was by some related to a goalkeeper luring the player to shoot in a specific place, which he then closed off, as one player noted, "*that an element disappears is a bit like if there is a goalkeeper that closes it off*" (P6). However, one found the situation less relatable, *"I don't know if it makes sense in relation to handball […] it's just because it's a different sensation, when you look at the goalkeeper, you don't know if she tries to lure you"* (P10).

Finding 8: Abstract representation allows for alternative target shooting training

2 players noted that the abstract representations provided players with an opportunity to train elements that might be difficult to train with a real goalkeeper: *"I can feel that I am being challenged on something you might not always think about, if you play against a goalkeeper, […] here you are forced to do what you really don't want to do, which may be more difficult against a goalkeeper"* (P5), and *"I definitely think that I could transfer it, the way of thinking, when you are in the air, the execution of your shot, everything, it might sometimes be a bit farfetched on a goalkeeper, […] here that just how it is"* (P6). The two quotes illustrate how the games trained desirable skills, which might be difficult to train on a handball field. The isolation of decision-making and shot execution enables the players to explicitly focus on developing these skills.

Context characteristics

Context characteristics refer to the context of a game, covering both the physical and the digital game space, and the environment that facilitates a game.

Finding 9: Changing the physical game space could increase relevance

All participants positively received the game space, and they found the distance between the touch plate and the rebounder appropriate for viewing and hitting the targets and ensuring a high tempo in the game. However, 4 participants also noted that in order to increase the handball relevance to their position (backcourt and wing), the distance had to be increased. Two participants also stated that it would improve the game to have a physical obstacle to jump over, *"so you jump upward and not forward"* (P8).

Finding 10: Sensors impact game difficulty and relevance

The participants applauded the touch plate sensor that required a jump in order to trigger the targets, stated as, *"So everything is fun! Also because there are different things to train, so it's not all about precision"* (P10), and, *"The relevance only increases the more handball elements you incorporate: How many can you hit, how hard you are shooting, and maybe how high and far you jump"* (P2). This last comment articulate an opinion that additional sensors would be interesting, supported by 3 other players stating that, *"if you can measure jumping height and shot strength you could evaluate other exercises. For example, if bench pressing makes you shoot harder"* (P9), and, *"it would be a good idea to incorporate shot strength because you tend to get careful and thinking just about hitting and not about shooting as a real handball shot"* (P8). When asked how to increase the difficulty of the games, one

participant suggested changing the floor sensor to detect touch off instead of foot contact in order to force players to jump higher.

CHALLENGES WHEN DESIGNING TRAINING GAMES

We now articulate a set of characteristic challenges that should be addressed when designing training games. The challenges are derived based on related work, our experiences with creating The Bouncer as well as insights gained from the study. We present each challenge followed by a strategy for addressing it. The challenges and strategies might be applicable to other areas where balancing engagement and purpose is needed, e.g. serious games.

Challenge 1: Maintaining relevance when translating physical elements into digital representations

Designing training games usually requires translating physical objects or opponents into a digital representation. For example, in The Bouncer a handball goalkeeper is transformed into abstract graphical targets. Another example is Football Lab [10], where co-players are replaced by light and sound signals. Designing these representations poses a challenge of extracting relevant elements from the sport and choosing an appropriate type of representation, without reducing the sport relevance.

A digital representation requires a translation from sport to game. This translation can be literal, such as a virtual goalkeeper simulation, or abstract, as in the games for The Bouncer. Choosing a literal translation poses a range of technical requirements in order to make players perceive it as a useful training tool, as players potentially hold the same expectations for the digital representation as they do for a real goalkeeper. Thus, in order to create a realistic training situation, a simulated goalkeeper would require complex and expensive sensing and interpretation of player movements in order to enable intelligent reactions to the player's actions.

Choosing an abstract representation provides designers with more freedom to utilize game mechanics and elements in their design. Abstract representations also require less extended sensing, as players do not have predetermined expectations. Furthermore, abstract representations enable designers to extract and highlight different elements of a skill, e.g. different aspects of decision-making, as illustrated by our three different games.

Utilize abstract representations and cognitive elements

The challenge of maintaining relevance in the digital representation is therefore not simply a matter of being able to replicate elements of the sports as realistically as possible, but instead a matter of extracting relevant aspects of the game and translate them in an appropriate manner. This relates to Campbell et al.'s [2] view on representation in fitness applications, stating that a good representation; is an abstraction without loss of meaning, is neither too complex nor too shallow, provides context for play and drives player interactions. Our study indicates that although the graphics looked nothing like a goalkeeper, the players found the games relevant to handball and commented that they might even train aspects that would be difficult to train on a handball court in front of a real goalkeeper (finding 8).

Despite the challenges of maintaining sport relevance and creating a recognizable situation to the players, utilizing abstract representations holds a great potential for training games. We believe that applying abstract representations offers an extra level to the training game as it allows for the game to incorporate cognition and decision-making. By using abstract representations with different cognitive or decision-making layers in our three games, players found that the games offered an extra dimension compared to regular target shooting training (finding 8), and that the games allowed them try different decision-making strategies (finding 6). However, some found it easier than others to relate the abstract graphics to playing handball (finding 7).

When choosing an abstract representation over a literal one, we believe it is increasingly important to involve domain experts in order to identify important aspects. We propose to involve sport experts; not only in workshops and tests, but also directly in the design process in order to qualify decisions and enable constant experimentation, iteration and reflection.

Challenge 2: Choosing an appropriate level of sensing as game input

Almost all training games require some level of sensing of the player, which facilitates the interaction between player and game. The challenge when designing training games is choosing the appropriate level of sensing as game input, while ensuring sport relevance and allowing for engaging interactions.

As illustrated by the demo games used at the initial workshop with The Bouncer, games can be built based on sensing a single aspect. In these games, only the ball's impact position was used to facilitate game interactions. However, only sensing one element did not enable the games to encourage handball-like movement patterns, despite being designed with handball in mind. Thus, sensing a single aspect might limit the possibilities of designing training games, where several actions should impact the outcome of a training exercise. Contrary, games can be based on sensing every movement of the player. However, based on our findings we believe that creating training games, where every movement is sensed and dictated by the system, will affect the players' engagement negatively, but perhaps more importantly curtail their opportunity to experiment with different strategies.

Allow for autonomy and physical additions

Technology makes it possible to sense almost every aspect of a player's actions, however, the challenge lies in

determining the appropriate level of sensing as game input. Choosing the level of sensing requires a careful balance between the flexibility available from using a few sensors and the possibility of movement guidance enabled by using several sensors. Using only a few sensors allows for embracing ambiguity [5] in the design and assigning more decisions to the player, but entail the risk of introducing inexpedient behavior, as undetected inexpedient behavior might result in a better score. Using multiple sensors could reduce this risk, but simultaneously create a more rigid game space, as it would impose a specific behavior on the players, rather than letting them explore different strategies (finding 1). This corresponds to Park et al.'s notion of selecting key primitives of a sport exercise to fit the purpose of an exertion game, and how these choices influence gameplay and player experiences [18]. For example, sensing shot-power in order to only award powerful shots could potentially increase the handball relevance of The Bouncer (finding 10), but it could simultaneously prevent players from choosing particular types of shots.

It is a delicate balance to determine the right level of sensing, and we suggest that designers should find a balance, which encourages sport-relevant behaviors without hindering the freedom to make choices and try different strategies. We believe that designing for autonomy in training games will increase the engagement of players, supported by game research [20], and therefore games should be designed to encourage optimal movements for the sport, and reward these with the highest score. Instead of increasing the level of sensing, an alternate approach is to make changes to the physical space in order to increase sport relevance. This approach was supported by our study, where players suggested introducing physical obstacles to overcome in the game, rather than adding more sensors (finding 9). However, additional sensors could be used for gathering information about players' performances in order to assist players in self-reflection about their tendencies and abilities (finding 3).

Challenge 3: Introducing points in training exercises without reducing sport relevance

While game elements hold great potential to motivate players to exert themselves in training sessions, it also raises the challenge of avoiding influencing the sport relevance in a negative way.

The game elements in The Bouncer illustrate how introducing competition can motivate players to push their performance. However, our study also highlights the challenge of including a competitive element. The desire to get higher scores caused at least two of the players to make choices, which deviated from their regular handball actions, potentially inducing inexpedient movements. However, omitting points from the game would have removed the motivational, competitive element, as well as left the players without a way to gauge their performance. During the fast paced games it was difficult for the players to evaluate their performances, as returning to collect the next ball had higher priority than evaluating their immediate accuracy. Furthermore, the difficult-dependent amounts of points in YellowBlack and CounterStripes, compelled the players to search and go for the smaller targets, thus pushing themselves harder in terms of precision. We believe that without the differentiating points, players would generally have chosen easier targets, rather than engaging in the decision-making challenge.

Frame the training game and reward optimal performances

Introducing game elements and competition in training exercises introduces a risk of shifting the focus away from the training, as players will focus on getting a high score instead of perfectly executing the exercise-targeted movements. Thus, we believe that when using competitive elements it is important to clearly frame the game as training. By doing this the players will stay in a training mindset, and we believe that is the reason that caused the two players, who did alter their movements, to actually reflect about it (finding 4). This correlates to Chen et al.'s work that shows that framing exertion games as training instead of games made participants increase the duration of use [3].

Rewarding points based on effort and performance enable players to evaluate their own proficiency and compare it to others (finding 10). This relates to Mueller et al.'s understanding of exertion and context, stating that it is important that the mapping of players' gaming skills corresponds to the real world, so they do not over- or under-estimate their physical abilities [16]. Thus, we believe that it is important for the point system to be transparent and award players for making an extra effort. As a result, we recommend designers to ensure that achieving high scores in the game is correlated with performing handball relevant actions, e.g. by rewarding extra points for the optimal execution. This idea addresses Jensen et al.'s design sensitivities for training games [10], suggesting to design games so game optimal movements are not inexpedient or prohibited in the targeted sport. This sensitivity can be approached if designers ensure that perfect movements are generously rewarded in the training game.

LIMITATIONS

Even though our work is based on a design process involving handball experts and our participants related it to their regular training, we cannot ensure that players' handball abilities will improve over time by using the game. We acknowledge that transferability is a challenge for designers of both digital [4,10] and analogue [12] training equipment and exercises, and this is no exception for The Bouncer.

CONCLUSION

In this paper, we presented The Bouncer and 3 handball-training games. We presented a study of the training games, showing that they were engaging to play as well as handball relevant. Based on the study and our design insights, we proposed three challenges that designers of interactive sports-training games will need to consider: 1) Maintaining relevance when translating physical elements into digital representations. 2) Choosing an appropriate level of sensing as game input. 3) Introducing points in training exercises without reducing sport relevance. For each of the three challenges, we proposed strategies to help designers of future training games. With the work presented in this paper, we hope to contribute to improve the quality and design of future training games that engage athletes in their training. Furthermore, we hope that other game designers, who are balancing engagement and purpose, can use our work to support their process.

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