

VRabl: Stimulating Physical Activities through a Multiplayer Augmented Reality Sports Game

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ABSTRACT

Video games have become increasingly popular, but only a few focus on physical activity. Superhuman sports build upon this trend and try to stimulate physical activity while relying on technology to enhance human abilities. *VRabl* is such a superhuman sport. Being a multiplayer augmented reality sports game, it stimulates players to be physically active using similar mechanics as video games. It is based on the well-known and popular game dodgeball, to reach out to a large player community and have simple rules. The major goal of *VRabl* is to make dodgeball more attractive and engaging for younger generations. The game relies on two Microsoft HoloLenses to enable a novel multiplayer augmented reality sports game. A first evaluation shows that *VRabl* is enjoyable for people of every age group and stimulates physical activity, while having fun at the same time.

CCS CONCEPTS

- **Human-centered computing** → **Mixed / augmented reality**;
- **Software and its engineering** → **Interactive games**;

KEYWORDS

Game Design, Augmented Reality, Physical Activity, Human Augmentation, Superhuman Sports

1 INTRODUCTION

Games are an integral part of everybody's life - some might even say essential. Over the past years, eSports has exponentially grown in popularity as alternative to other spectator sports, particularly among younger viewers [5] and video gaming has become a standard activity. Unfortunately, there are downsides to this trend; a

recent study showed that children who play moderate amounts of electronic games weigh more than their counterparts that play less [15]. This effect is due to reduced physical activity. The latter has a positive effect on cognitive functioning [12] and is a necessary part of everybody's development, especially for young children and teenagers. Physical activities not only benefit children, they also help elderly fighting depression [11]. In general, we can say that 'exergames', i.e. games involving physical exercise, have a healthy impact on our lives [14]. We address this issue with a game combining physical activity and the fun of gaming.

Dodgeball is a well-known and popular sports in high school, but quickly forgotten afterwards. We use dodgeball as starting point for *VRabl* to rely on a simple game concept that is known to a large player community. Our aim is to make dodgeball attractive for younger generations and motivate physical activity.

VRabl is a combination of the words "virtual", "rabbits" and "ball". In our game, two Microsoft HoloLenses enable players to compete with each other in augmented reality (AR). Using AR, the resulting multiplayer game seamlessly relies on physical activity of the players when interacting with the virtual content of the game. The following section discusses general aspects of challenging and engaging games. Section 3 elaborates on the *VRabl* game design and functionality. Section 4 describes on how *VRabl* fosters engagement and physical activity. Before concluding, the following sections describe the implementation of *VRabl* and first user experiences while playing *VRabl*.

2 BACKGROUND

When a person is fully engaged in a game, the physical movements become less mandatory and more natural. According to Thomas W. Malone, challenges in games engage a person's self-esteem, and thus make it more captivating [10]. Both, competition and challenges, motivate the players [9]. Offering challenges and the opportunity to learn something is sufficient to create a motivating game that is fun to play [4]. Learning to overcome these challenges is a truly fundamental motivation of playing games [3]. When the player develops more skills to overcome the current challenges, the difficulty should rise accordingly to keep the player motivated [13]. There are multiple aspects we need to consider to make a game

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challenging. The important aspects for challenging and engaging games are [10]:

- Simple and clear goal: The player directly understands the general gameplay. This offers the ability to reason about the rules as well.
- Multiple difficulties: Games are enjoyable when they are neither too hard nor too easy. Every player should have the right amount of challenge.
- Useful goals: The goals must feel rewarding. Performing a job using a particular skill, without any specific goal, tends to get boring.
- Multiple goals: When trying to accomplish a bigger goal, succeeding in smaller sub-goals will keep the player motivated.
- Hidden information: When the optimal strategy of a game is not obvious, it will leave room for fantasy, which renders a game more engaging.
- Randomness: Making the game unpredictable prevents it from becoming boring. Dynamic strategies and good anticipation will also be rewarded.

3 GAME CONCEPT

VRabl relies on AR to seamlessly combine physical interaction with virtual content (see Figure 1). Up to now, the most popular examples for AR games are Pokémon GO and Ingress. Both games contain some physical activity and are motivating people to walk to certain places [8]. Both games were a success considering the popularity it gained in a short amount of time and the impact it had on its player's health [2]. Those games show that attractive augmented reality games are able to motivate people to be more physically active.

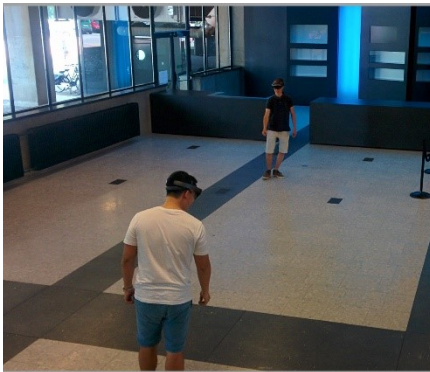


Figure 1: Two players wearing the Microsoft HoloLens preparing for the game to start.

VRabl is a competitive augmented reality sports game, where players compete against one another. A green virtual playing field is placed into the real world. The game can be played at any location as long as there is a flat and open area available.

The goal of the game is to hit the opponent's targets by throwing balls (see Figure 2). The targets are 3D-models of rabbits, as can be seen in Figure 3. We got these models from the Unity Asset Store. We decided to use these rabbits, since they have good animation

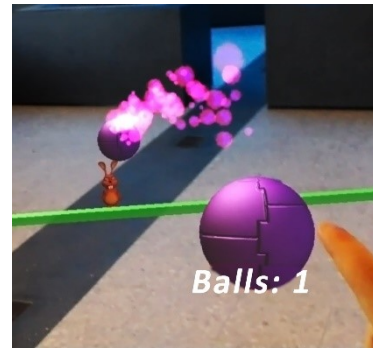


Figure 2: An in-game real world screenshot. You can see the combination of the physical world combined with augmented objects. The current player just shot a ball in the direction of a target (rabbit).

capabilities and they are universal characters that are attractive to a wide audience. Both players can defend their targets. A player can block a shot of the opponent by catching the ball before it hits a target. The balls bounce on real world objects allowing players to make use of the physical environment when aiming at the targets. This further means that a player cannot throw a ball through the ground or through other objects placed in the room. The amount of balls is limited. Therefore, it is important for players to keep track of the amount of balls they have left. Every thrown ball has four possible outcomes:

- (1) The opponent catches the ball and gets an extra ball.
- (2) A target is hit and the ball disappears.
- (3) The ball remains somewhere on the ground and disappears after a defined time limit.
- (4) The ball remains on the floor, but is picked up later by one of the players.

Eventually most balls will slowly disappear from the game. Depending on the amount of balls left, new balls are spawned in the field. The field is divided into two halves and both players have their own half. When a player leaves this half, all augmented skills are disabled until the player returns to the correct half. Those augmented skills include picking up and throwing balls and picking up power-ups.

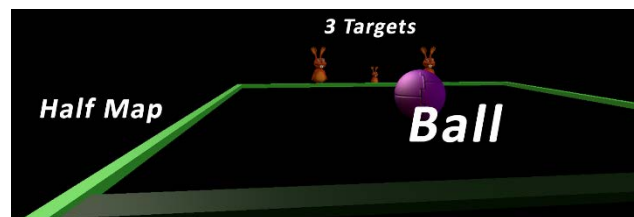


Figure 3: Screenshot of the game without a real world environment. The screenshot shows a player's perspective while standing on his/her side of the field and looking in the direction of the opponent's targets.

A game has multiple rounds. A round ends when a defined time or score limit is reached. Targets give different amounts of points. A small rabbit is worth more points than the bigger ones.

During the game, carrot power-ups will be randomly spawned on the field, as can be seen in Figure 4. A player can pick these up, depending on which half of the field the carrot appears in. The power-up can be activated by a voice command. When activated, a carrot will spawn at the opponent's half. One of the opponent's rabbits will walk towards this carrot and try to pick it up. At this moment, the rabbit is much more vulnerable, because it is much closer to the other half. It is also possible to defend the rabbit by picking up the carrot. The rabbit will directly turn and walk back in that case. The defending player then owns the carrot and can use it on the opponent in the same way.

VRabl allows for different playing strategies. In general, a player can play offensively or defensively. Standing close to the border which separates both halves reduces the distances to the targets. Less distance means more accuracy and less travel time for the ball. Standing in the back is a good defensive strategy. This makes the travel distance and time of the fired balls longer. Extra time to anticipate the opponent's moves will contribute to a greater chance of catching balls. After a while, the defensive player will have more balls.

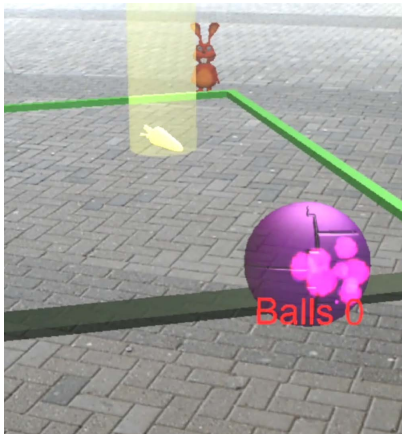


Figure 4: A carrot power-up just spawned on the orange player's half. The light beam makes the power-up more notable.

4 ENGAGEMENT AND PHYSICAL ACTIVITY

The most important goal of *VRabl* is to immerse players to such an extent that they are not aware of the physical activities anymore. Keeping a good flow while integrating physical activity is important to make the game more enjoyable [1]. *VRabl* enforces physical activity by implementing multiple aspects to the game. During one round, balls and power-ups are spawned at random places within the playing field. In order to obtain the items, a player needs to stand on top of these. This enforces players to move around the field in order to stay competitive. Additionally, players can 'catch' balls of the opponent by facing the ball, while it is approaching them. This gives the player an extra ball and the option to defend

his/her rabbits. Moving around while throwing balls increases the chance of hitting the opponent's targets. This makes it harder for the opponent to block thrown balls. All these aspects stimulate players to be physically active, without interrupting the game or without demanding full focus on the physical task. It also ensures a continuous flow and thus is crucial for motivating users to engage in physical activity [1]. It is clear that the extra physical movements give players a small advantage. This advantage is not big enough to win the game. Strategy and skill also play an important role. In addition, *VRabl* contains random components. These components stimulate players to be as physically active as their playing style allows them to be. This way the game automatically matches the intensity of the game to the fitness level of the player [13].

Apart from the physical activities, *VRabl* aims at continuously engaging players and ensuring that players have fun playing the game. Following the discussed design recommendations for challenging and engaging games as discussed in Section 2, *VRabl* has clearly defined goals: to hit the rabbits of the opponent in order to gain a higher score. This goal can be subdivided into smaller sub-goals that help toward achieving the main goal. Those sub-goals include retrieving extra balls, picking up power-ups and making sure that the opponent runs out of balls. It can be made as difficult and as challenging as needed by playing against skilled opponents. Multiple sound and visual effects are added in order to make scoring and shooting more rewarding. The game does not have one optimal strategy. There are many different strategy styles that can be used to win. This encourages players to use their creativity and fantasy to create their own strategies [3]. They can then proceed to test different strategies against different opponents. The random game elements, like the spawning of items, make the game unpredictable, which helps the game from becoming boring [10]. Last but not least, the game rules are simple and easy to learn. However, there is a clear learning progression, while playing the game. In the beginning, most players find it difficult to accurately throw balls or find a good strategy, but after a few rounds of playing players become much more skilled in the game. This allows players to make their own progress. When players master throwing balls accurately, they can focus on other components of the game. For example, collecting more items. An even more skilled player can focus more on strategy, because they do the easy tasks more easily. When your own skill level rises, the game offers more options and becomes automatically more challenging [13]. This way the difficulty of the game is not only depending on the skill of the opponent.

5 IMPLEMENTATION

VRabl was built using the Unity game engine and the C# programming language. The HoloToolkit was used in combination with two Microsoft HoloLenses. This toolkit consists of multiple (Unity) scripts and components intended to accelerate the development of augmented reality applications. Figure 5 provides a general overview of the system architecture underlying *VRabl*. Two different networking servers are used to enable communication between the 2 HoloLenses worn by the players. The first server is the Microsoft Sharing Service, which is part of the Sharing library within the HoloToolkit. This server is used to share game objects, or so

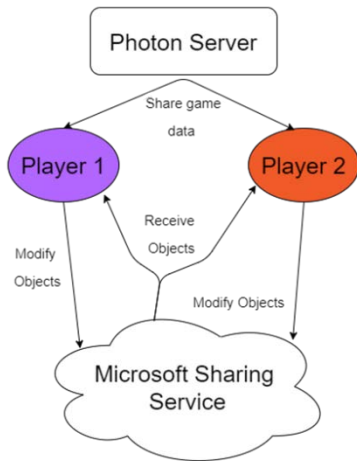


Figure 5: An illustration of how the HoloLenses communicate with each other.

called holograms, between the users. The second server is the Photon Unity Networking framework. This is a cloud server that let users join specific sessions and send messages to each other. The Photon server is used to share game data, as this server has better support for real-time communication in a physical multiplayer game.

6 USER EXPERIENCE

We conducted two evaluation rounds in which different people tested *VRabl* and provided feedback: (1) a game demo during a research exhibition and (2) a formal user study on game experience. During the research exhibition, roughly 35 people of different age were interested in our game. All had positive first impressions. They were interested in the AR aspect and engaged with lots of enthusiasm in the game. A group of 20 high school students reported they liked the novel concept and technology. They especially liked the virtual rabbits and other game objects.

Compared to the students, some older adults played the game. An elderly man who was interested in *VRabl* reported to be positively surprised. In summary, no matter what age, everybody got immersed into the game and enjoyed it.

We also conducted a formal user study with fifteen students. All of them participated voluntarily, played the game for at least two rounds. The participants got a short explanation of *VRabl* before they started playing. After playing, participants completed the core module and post-game module of the Game Experience Questionnaire (GEQ) [6]. The focus of the GEQ is on characterization of game experience. With a large range of measurements, this questionnaire can reduce uncertainty associated with measuring a single modality. This results in increased validity, robustness and wider applicability of the total set of measures [7]. The main goal was to measure to what extent people were immersed into the game. Another sub goal was to find out how much physical activity the game enforces. In order to evaluate the GEQ, a standard ratings scale of 0-4 was used, denoting: 0-Not at all, 1-Slightly, 2-Moderately, 3-fairly, 4-extremely.

Table 1 and 2 show the resulting average scores of the GEQ modules. The tables reveal that the “Competence” is not high. This is justifiable by the fact that some components of the game are not easy to learn, e.g., the tap gesture of the HoloLens appeared to be difficult for the participants. The second problem is the limited field of view that the HoloLens provides. This makes it hard to keep a good overview of everything that happens in the game. The third problem is the delay in communication between the lenses. Sometimes the opponent’s ball is only visible after a delay of roughly one second. This makes it hard to follow the game and defend your targets properly.

Table 1: Average scores of the core module and its components.

Core Module	Score	Variance
Competence	2.08	0.65
Sensory and Imaginative Immersion	1.90	0.64
Flow	2.44	0.85
Tension/Annoyance	0.89	0.85
Challenge	1.73	0.79
Negative affect	0.88	0.48
Positive affect	3.13	0.68

Table 2: Average scores of the post-game module and its components.

Post-game Module	Score	Variance
Positive Experience	1.86	0.93
Negative Experience	0.52	0.61
Tiredness	0.93	1.13
Returning to Reality	0.93	0.82

The average score for tiredness is 0.93 showing that our game requires physical activity. Further, players only played for two rounds. Often the first round did not cost much energy, because it was more of a try-out. Tiredness also has a high variance, which means that people experience the amount of tiredness differently. This is likely due to the fact that people have different stamina levels.

When watching the players, we observed that almost every player moved a lot from the moment that they understood the game. Afterwards a part of the players even reported being exhausted because they played competitively. Multiple rounds will increase this fatigue.

Players reported feeling immersed during the game session. All users enjoyed playing *VRabl*. This can be seen from the positive affect score of 3.13 in Table 1. Overall the user study provided us with helpful input on how to improve the game experience.

7 CONCLUSION AND FUTURE WORK

Within this project, we designed and implemented *VRabl*, a multiplayer augmented reality sports game for the Microsoft HoloLens.

Starting from dodgeball, we added virtual targets and new rules to make the game more fun and attractive for younger generations. Specific game aspects like competition, achievements, strategy and social aspects motivate people to do their best. The ultimate reward is winning the game and in order to increase the chance to do so you need to put more physical effort in the game than your opponent does. Our game demonstrates that using new technologies, innovative physically stimulating video games can be created. VRabl is not ready for an official release. Even when building upon the most recent augmented-reality technology, there are still improvements necessary in terms of comfort, precision, and responsiveness. The technology allows for more supernatural enhancements, e.g. instantly building and destroying virtual walls. Such future improvements could make VRabl more attractive. Still, this game clearly illustrates the potential benefits of a Superhuman Sport; stimulating people to be more physically active, while having fun at the same time. This result is also supported by our user study. Based on the user feedback, when technology matures, games like VRabl will have an important impact on the gaming industry.

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