Immersive Goalkeeper Training in Virtual Reality for Amateurs and Students with Disabilities

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Abstract. This paper presents the design, development, and evaluation of a Virtual Reality (VR) goalkeeper simulator aimed at promoting inclusive sports training for both amateur players and students with disabilities. The simulator creates an immersive training environment that replicates key aspects of goalkeeping in soccer, integrating realistic stadium settings, motion-captured animations, and adaptive gameplay mechanics. A central feature of the system is its customizable difficulty, which allows users to modify parameters such as ball speed, trajectory, and shot force to match individual skill levels and cognitive or motor capabilities. Importantly, the simulator is fully operable while seated, enabling accessibility for individuals with limited mobility, including wheelchair users. The system was tested with 15 young participants from the ASPOC association, demonstrating its usability and potential to foster inclusive participation in sports. User feedback, collected via the System Usability Scale (SUS), indicated a high level of engagement and ease of use, particularly among individuals with no prior experience in virtual environments. The results support the effectiveness of VR as a tool for adaptive training and rehabilitation, highlighting its value in expanding access to physical activity, skill acquisition, and social inclusion through technology-driven sports simulation.

Keywords: Virtual Reality, Goalkeeper simulator, virtual coach, Sport Inclusion
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1 INTRODUCTION

The Goal Keeper simulator game is, as the name suggests, a Virtual Reality game focused on mimicking the action of a goalkeeper. An incentive for the creation of this game is the desire to recreate the training environment of a football goalkeeper in virtual reality. This would allow for a new training regiment to be created allowing for training in the off-season of the sport. In order to have a meaningful impact, the training must accurately mimic the motions and habits that the real sport requires. Furthermore, the possibility to calibrate the difficulties according to the level of the player by modifying some parameters such as the speed of the ball, the force of the shot and, in a minor part, also the trajectory of the ball, allows to target it towards the specific tasks that need to be trained. To better emulate real conditions, the game is set in a "real" soccer stadium, also background noises are added to better recreate the environment. Another application of this game is for rehabilitation of patients with disabilities. Indeed, the game can be played entirely while sitting down and only requires the movement of the hands. This would allow wheelchair-bound patients to experience playing sports.

2 STATE OF THE ART

The idea of virtual reality is by no means a new concept, during the 1950's the first virtual reality machine hit the market. The Sensorama was one of the earliest attempts at creating a multi-sensory immersive experience. It combined visual, auditory, tactile, and even olfactory stimuli, allowing users to feel as if they were part of scenarios like a motorcycle ride or a busy city street. Although this early system was primitive and limited by the technology of its time, the Sensorama contained all the elements that are associated with VR today. Over the decades, advancements in computing power, graphics, and motion tracking transformed VR from experimental prototypes into mainstream tools for gaming, athlete training, physical rehabilitation and education.

Nowadays, due to the development of this field, three classes are needed to accurately classify the level of immersion that the user experiences:

- Virtual Reality (VR): it creates an entirely immersive digital environment, isolating users from the real world. Users experience VR through headsets that fully replace their surroundings with a simulated 3D space, making it a fully immersive environment;
- Augmented Reality (AR): it overlays digital content onto the physical world, enhancing reality rather than replacing it, it can display virtual objects in the real world.
- Mixed Reality (MR): it sits between VR and AR, and integrates virtual objects into the real world while allowing users to interact with them seamlessly, and with an higher level of interaction, making it ideal for collaborative design, training, and other immersive applications that require real-time integration.

Examples of the different applications are given in Figure 1.

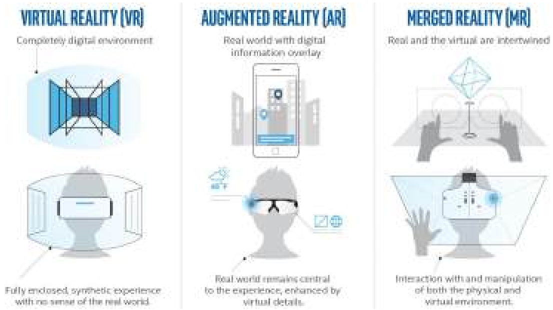

Figure 1: Difference between Virtual Reality, Augmented Reality, and Mixed Reality.

A further distinction between VR platforms must be made based on the level of immersion that the user experiences:

- non-immersive systems provide limited engagement with virtual content with information displayed on standard screens and users interact using keyboards or game controllers;
- semi-immersive systems offer a more engaging experience by incorporating larger screens that wrap beyond the field of vision of the user, these systems may also include dynamic servo platforms to provide motion to the player;
- fully immersive systems represent the pinnacle of immersion employing technologies like VR headsets, motion controllers, haptic feedback, and 360-degree tracking to envelop users completely in a digital environment. These systems eliminate almost all sensory connections to the real world, offering unparalleled realism and interaction. The applications of these totally immersive systems span from gaming, rehabilitation, to athlete training.

For the purposes of this simulation, a fully immersive Virtual Reality was chosen, this allows to have the player in a "real" environment wherever he decides to train, furthermore the no controllers option was chosen to better recreate the real conditions of a goalkeeper. Using the controllers would have indeed limited the possibilities of recreating real-life conditions.

Between the many VR headsets available on the market; the Meta Quest VR, shown in Figure 2 was selected for this project; this is designed to deliver an immersive, wireless VR experience. It offers a standalone system that doesn't require a PC or console, allowing users to explore virtual worlds without the burden of cumbersome cables. To perform the hand tracking that, as will be explained Paragraph 3.2, is fundamental for the purposes of this game, the Quest is equipped with outward facing cameras that can scan the environment, and user's hands in real time. These cameras capture the position, shape, and motion of the hands from various angles. From this information, the system can recreate a 3D virtual model of the hands based on the key detected points. This model updates dynamically as the hands move, enabling precise representation in the virtual environment. The last leap necessary to fully replace a traditional controller is gesture recognition, indeed the software is able recognize pinching, pointing, or grabbing, to trigger actions within VR applications.

Even if with VR it is possible to interact with all five senses, the current game is only able to stimulate vision and hearing. Both inputs come from the Meta Quest Headset; eyesight is the core of VR; it is enabled by high-resolution displays and 3D graphics in the headset that create a lifelike visual representation of the digital world. VR headsets cover the entire field of vision and block out all unwanted inputs making this sensory input very realistic. Hearing is equally crucial, with spatial audio systems delivering directional sound that aligns with the virtual environment, allowing users to perceive sounds as if they originate from specific locations.

One recent addition to the consumer market that has taken VR to the next level is haptic gloves. Haptic gloves are equipped with sensors that track the position, orientation, and movement of the hands and fingers. This data can then be fed into the VR software increasing the immersion level and realism. The force feedback mechanics of the gloves can resist finger movements. This creates the sensation of gripping an object or interacting with solid surfaces. Despite their potential, haptic gloves face challenges such as cost, bulkiness, and the need for precise integration with VR systems. Their development is poised to revolutionize interaction with virtual environments, bridging the gap between physical and digital worlds. This new product can be integrated in future developments of the game, to give also a tactile sensation to the user and to better recreate real life conditions.

Figure 2: Meta Quest VR, headset system used for the project.

2.1 Bibliographic Review

Kulpa et al. [7] demonstrated how, in soccer training, the VR methodologies can revolutionize goalkeeper training by simulating dynamic scenarios, such as varying wall configurations during free kicks [11, 1, 4]. By tracking real time movements and providing immersive visuals, VR enhances the player's ability to respond to realistic game situations in a controlled environment. This has practical implications for improving decision-making, reaction time, and spatial awareness, making VR a valuable tool for refining skills and preparing athletes for competitive performance. Further studies from Shimi et al. [8, 9] and from Vignais et al. [10] examined the critical role of cognitive abilities in soccer goalkeeping, focusing on attentional networks alerting, orienting, and executive control using immersive virtual reality (VR). Participants performed a goalkeeping task in VR and completed tests measuring attentional and inhibitory control, including the Attention Network Test and Whack-a-Mole task. The findings revealed that all three attention networks significantly contributed to performance, with inhibitory control also strongly correlated to success. These results emphasize the importance of cognitive skills in soccer-specific tasks and highlight the potential of VR training to enhance attentional abilities and decision making for improved real-world goalkeeping performance. [5], [2]

To create a realistic virtual training environment for athletes a variety of hurdles must be overcome. An athlete's response to an opponent's action is largely based on the moments leading up to the action rather than solely the action itself. During a football penalty kick, the goalkeeper is carefully studying the kickers run into the moment of the impact with the ball. Based on the information they receive, it allows a split second more time to make a decision and corresponding action. To unlock the full potential of VR training it is essential to create an accurate animation model for the players to ensure the correct goalkeeper response to these actions. Bideau et al. [3], [6] used a motion capture system to create a realistic animation, data from 12 professional handball athletes during a standardized throw were recorded. The skeletal models that were created were then simplified and averaged to create a master model. The model was then tested with professional handball goalkeeper; by modifying the trajectory of the skeletal model, the goal keeper's response was highly influenced. When the skeletal model was unmodified the keeper performed very well. By adjusting the trunk rotation angle, or wrist position during the release the goal keeper's accuracy was greatly reduced. This study showed the importance of creating an atomically accurate model so that the training matches the real play condition.

3 DEVELOPMENT OF THE VR APP

When starting the game, the main page is a menu that allows to access all the other levels. Each level, from first to fourth, is developed with an increasing difficulty, further descriptions will be given in the following paragraphs. Each level is designed to have three initial lives that are reduced by one every time a goal is scored, while a point is given for every saved goal; once all the three lives are spent due to mistakes of the player, the game automatically returns to the main page to start a new level. The other two buttons in the main menu are the Academy one, which allows to try each level, and the Penalty one. The Academy option allows, starting from the first level, to try all the levels in order of increasing difficulty. Each time 5 points are reached, the game automatically switches to the next level. Three new lives are given at the beginning of every new level. The Penalty button instead simulates penalty kicks.

3.1 Scripts and Game Logic

In the following paragraphs the scripts that were used to develop the game will be described.

3.1.1 Main Menu

The main menu, shown in Figure 3, is controlled by the script `UIMainMenu`. It contains all the buttons present in the Main Menu (Level 1, Level 2, Level 3, Level 4, Academy, and Penalty). Each button, when clicked, recalls a `SceneManager` public class that is what actually allows to change the scene and so the different levels. The scene is automatically reloaded every time all lives are lost in order for the player to start a new game.

Figure 3: Main Menu and use of hands to interact with it.

3.1.2 Level 1

When clicking on the Level 1 button the first level loads. This is the easiest level of all, no special features were added and it was left on purpose as easy as possible just to allow the user to understand how the game, and the virtual reality works. It is the level suggested for people approaching the game, or virtual reality, for the first time. An example of the graphic interface is shown in Figure 4.

The level starts with a ball being spawned at a slightly variable distance and location from the goal. The first spawn of the object is controlled by a function that initiates the level and has no other purposes. After the first spawn of the ball, the game is completely controlled by the script linked to the ball. After the first ball is spawned it is shot towards the goal with the function `AddForce`. The vector that controls the `AddForce` function has a range of values that is randomly chosen from a set of values that was carefully calibrated for the ball to aim at the goal. Some shots were intentionally calibrated to let some balls go outside the goal itself to make the game more realistic and to better emulate real life conditions. Indeed, in a real life environment, it is important to evaluate the trajectory of the ball and to assess whether or not the ball aims at the goal.

The most interesting part of this script is the big if condition at the end; this is what allows to understand what happens to the ball after being shot. This if cycle is what distinguishes what the ball collides with and, according to that, what happens to the game:

- if the ball collides with the player's hands the `GameManager` public class is recalled and the score is updated adding one point to the total score that is displayed on the screen for the player to see it. Two additional actions are performed in this case: the disappearing of the ball, with a delay of a couple of seconds, and the spawning of a new ball to make the game restart. The delay in the disappearing action was added to make the game as realistic as possible and to give the player the visual input of the save, indeed, the ball is able to bounce on the hands of the player and to change the direction before disappearing;
- if the ball collides with the out zone (planes that surround the goal and the goal structure itself), the ball is simply instructed to disappear and a new one is respawned. Also in this case a little delay is applied to the disappear function to give a more realistic aspect to the game. No points are given to the player in this case;
- if the ball collides with the goal, a life is subtracted from the total and the ball disappears, then the remaining amount of lives is checked. If the total reaches 0, it means that all the initial lives have already been used, the game goes back to the Main Menu so that the user can choose another level. If instead the remaining lives are more than zero, the life counter is updated, still using the `GameManager` public class, and a new ball is respawned to make the game go on.

Figure 4: Example of basic level of the game, the virtual hands are shown to help the user in the save.

One additional variable, really useful for the purpose of the game, is the Boolean `_col` variable, this is used to avoid that multiple collisions are detected between the first collision and the moment the ball disappears, which happens with a delay of a few seconds.

3.1.3 Level 2

The second level, like all the following ones, is for the most part similar to the previous one. Still, as the player enters the game a ball appears; in this case the force seems to be given by the animation of a soccer player kicking the ball, a frame of the animation is displayed in Figure 5. This animation was acquired with the Captury system, but further descriptions will be given in Paragraph 3.3. What actually happens in the game is thanks to a synchronization between the animation and the application of the force, furthermore, in this case a randomized spin effect was given to the ball. Thanks to the spin effect of the ball, and to the use of the MagnusEffect the ball is able to describe a curved trajectory in the air to emulate some peculiar shots that can be performed during a game. This function uses the spin and the force applied to the ball to compute the proper trajectory so that the physics of the launch reflects the real ones. This was made to try and emulate the most real conditions possible. One problem that can arise while using such animation is that the ball does not reflect what can be deduced from the position and from the actions of the soccer player since the animation used is always the same. This can be a problem for high level goalkeepers that use the movement of the opponent to try to predict the final position of the ball. For this reason, multiple acquisitions of the action should be recorded and implemented in the game according to the force given to the ball.

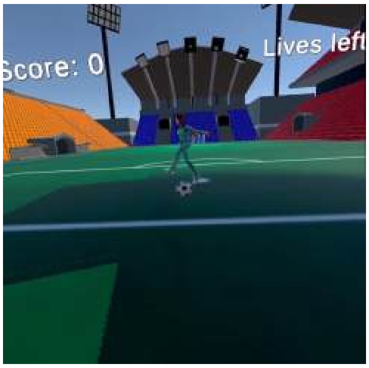

Figure 5: Example of the animation added for Level 2.

3.1.4 Level 3

The third level is for the most part the same as the previous ones, the only difference is that the animation regards not only the kick from the soccer player, but also the wall that appears between the soccer player and the goalkeeper. This level was thought to emulate a real-life situation where the goalkeeper has to operate in a field with distraction elements, here given by other football players located between the player and the ball. This level also contains a special feature added for the holidays.

A new kicker and wall are spawned together with the ball and with a properly set offset from it to recreate a condition as close as possible to the real one. These elements have been programmed to disappear after the ball has received the force and has passed the wall (their life is set to be 3 seconds long, after this time they automatically disappear). The wall was intentionally left without a collider so that the ball can pass through it, this was allowed from two main reasons: first of all, also in real life situations, if not done properly, the ball can pass through the wall; the second reason is to avoid slowing the game down. In case of a collision between the ball and the wall, the ball would disappear and respawn after a while taking time from the game, considering that the ball would interact with the wall the majority of the times, it would result in a slow and not interactive game. Without allowing the collision, instead, every shot reaches the player so that there is no empty time, and the game is overall more fun and enjoyable.

3.1.5 Level 4

The fourth level is the one that is further from the reality of a goalkeeper activity but is more focused on training the attention and recognition skills of the athlete. It is structured as Level 1, with no animations used to kick the ball nor to simulate the wall, but it uses the MagnusEffect to recreate real-life trajectory of the balls. The only difference is that three different colors balls are used with different purposes: green balls are the ones that follow the same logic as the balls used for the other levels (one point if saved, one life subtracted if the goal is hit), blue and red balls are used as distracting elements: if they enter the goal, no lives are taken from the player and no points are added, but if the player saves them, distracting him from the green target ball, then they take one life from the total. Due to this additional element of distracting-colored balls, this level is set to have five initial lives. To manage this level, some changes in the scripts were made: the green ball is managed by a new version of the same script used before, the first ball is spawned using the external script as explained for Level 1, the following green balls respawn after the collision is detected. The difference is that the life count is directly managed by the `GameManager` since both the green and the distractions balls need to interact with this variable; this script is in charge of both the life count and the display of this variable on the score board visible by the user. The blue and red balls are managed by the same external script that makes the first green ball appear; in this case, a red/blue ball is spawned every three seconds by recalling the spawn function from the external function. The color of the ball, that from the point of view of the game makes no difference, is decided by the generation of a random number that is then used to enter an if condition that spawns a blue or a red ball. The time interval between the different balls is set according to the time needed by the ball to travel from the spawn location to the goal. The collision of these elements has a slightly different effect on the game: if the ball collides with the player the `GameManager` is recalled to subtract a life, while if the ball collides with the goal, or with the outside region, the ball simply disappears. In this case, is not the collision that allows for a new ball to be re spawned, but the external function previously described.

3.1.6 Academy

As briefly explained in previous section the Academy option allows to test all the levels, starting from the first one and moving on towards the fourth, for a limited amounts of points (5) after moving on with the following level. To obtain this a boolean variable (`_acc`) is set to `true` when the Academy button is selected in the Main Menu. The first level is then loaded, the ball is spawned and the game starts. The scripts used for each level are the same that have been described above, what has been omitted in the descriptions given so far is the presence of an if condition in each of the scripts that checks the score value; if the score reaches 5 the next level is loaded, while if the life count reaches 0 the user is redirected to the Main Menu as for all the other levels. The life count is restored to 3, or 5 in the case of Level 4, each time a new level is restarted; this was specifically done to allow the user to have more chances in actually reaching the end of this training. When the last level is completed, the game goes back to the Main Menu, and any other level can be selected. What has been fundamental in the coding of this level, is to set the (`_acc`) variable back to `false` when the Academy experience ends, this is to avoid that the variable remains set to `true` repeating the experience every time any level is selected.

3.1.7 Penalty

One last option that is presented in the Main Menu is the Penalty simulation; as the name suggests, this option allows to recreate the Penalty kick of soccer matches. The script of this level is the exact same as Level 2, with the exception that the ball, and the related soccer player are always spawned in the same location that is indeed the penalty spot of the field. To make the game more enjoyable for the user proper speed of the ball and force were selected, using the same as Level 2, in which the ball is further from the player, would result in an impossible shot to be saved by the user.

3.2 Interaction

To provide the user with a fully immersive virtual soccer reality experience and to make the goalkeeping experience realistic, XR hand tracking controls were implemented in Unity. This eliminates the need for controllers and facilitates save movements. To achieve this, the necessary packages were installed in the project: XR Plugin Management and OpenXR Plugin, which are essential for managing XR in Unity. Once installed, it was possible to add the XR Hands Interaction Setup for hand tracking to the game scene and to apply to the hands the correct materials to ensure proper visualization without overlaps.

After achieving the correct visualization, colliders were added to the hands, specifically capsule colliders for each hand part, carefully resized so that the entire hand was consistently covered. This setup ensures highly accurate ball detection every time the ball comes into contact with the hands.

3.3 Animation and Acquisition

Figure 6: Example of the recording of the animation in a proper lab setup.

As discussed previously, some levels contain animations that recreate some typical soccer movements, such as player kicks and wall jumps. These movements were recorded in a lab using a Captury system as shown in Figure 6. This has been done to make the game as close as possible to real conditions. Indeed, people with some soccer experiences participated in the process. Multiple acquisitions were made, and the best ones were then used in the final game version. Level 3 involves two different animations (player kick and wall jump). The two movements were recorded in the same acquisition to recreate the reaction of people in the wall to the incoming ball. In fact, the system used allowed recording different subjects at the same time. This choice showed some advantages during the coding procedure because it allowed skipping the synchronization step.

Once the animations were recorded, they were imported to Unity by flagging the humanoid option. Then, the size of the players recorded was adjusted according to the surrounding. The player kick animation was placed in the correct position by using the script linked to the ball. This script was used to control both the position of the animation and of the ball, to let the player hit the ball in the right spot. Moreover, the animation was synchronized with the appearance of the ball. In this way, the ball starts its trajectory only when the player hits it. Moreover, in Level 3, where also the wall is present, the distance between the animation of the kick and the ones of the jumps were carefully selected to let the goalkeeper see the ball in a similar condition with respect to a real soccer match. Eventually, some prefabs were added to the animation to make the game more engaging.

4 TESTING

The testing phase involved two primary groups: students from the Politecnico di Milano and athletes from the Vittoria Junior Soccer Team, a female soccer team based in Milan. These groups provided valuable feedback on the usability and realism of the VR goalkeeper simulation. Also, 15 students from the ASPOC association successfully tried the application, demonstrating its accessibility and effectiveness in promoting sports inclusion. The participants were introduced to the hand-tracking system and the game mechanics before engaging in various levels of difficulty. Their feedback, gathered through a System Usability Scale (SUS) survey, indicated a generally positive response, with particular appreciation for the immersive experience and the intuitive interaction with the virtual environment.

Figure 7: Example of a testing session, one of the developer is explaining the user how to interact with the game, explaining also the proper hand gesture necessary.

The subjects were asked to try the game according to their desire, they were briefly instructed on how to interact with Virtual Reality without the use of controllers of any kind. Once they were confident, they were asked to select any level they wanted and to play the game for some time. The suggestion was to start with Level 1 to build confidence with the game; after that, they were left free to explore the game as they liked. The main difficulties in this part were found in understanding how to interact with the Main Menu. In fact, this operation was found to be the most difficult part of the game by many users. After they were satisfied with the trial, they were asked to fill in the System Usability Scale (SUS) protocol on a Google Form, answering both the standard questions and two additional ones concerning their previous soccer experience: subjects were asked if they had ever played soccer and if they played in the role of a goalkeeper. The results are displayed in Figure 8 and Figure 9.

Based on the feedback of the survey participants, shown in Figure 9, the majority of users found the game software easy to navigate. These results indicate that the game is well laid out for the user and is easy to navigate through the levels. One possible addition that may improve the user experience would be a set of instructions to educate the player about the necessary hand gestures to control the Oculus. This would eliminate some of the learning curve that the user experiences.

The results of the survey show that the software is user-friendly and can be navigated easily by new users. This is highlighted also considering the answers to the question "I would imagine that most people would learn to use this app very quickly". In fact, most of the users agree strongly with this sentence. So, even if some troubles may be present at first (especially considering the previously mentioned problem of the selection of the game level), they can be rapidly solved simply by playing to get more used to the VR's logic. Good feedback was also given considering the integration of the various functions of the app, its consistency and

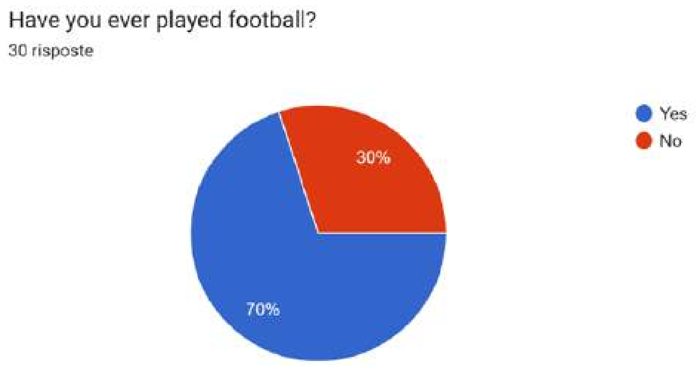

Figure 8: Results of the SUS Survey. Of the people who played soccer, 26 percent also played as a goalkeeper.

the assistance needed to make the all game user-friendly.

The System Usability Scale (SUS) protocol was administered to a cohort of 15 students with disabilities from the ASPOC association to assess the accessibility and inclusiveness of the VR Goalkeeper application. These participants, who presented diverse cognitive and physical profiles as well as varying levels of familiarity with virtual reality technologies, followed the same structured usability testing procedure as the initial evaluation group. Their feedback offered critical insights into the application's effectiveness in accommodating users with specific challenges. Overall, the responses reflected a positive reception, with many participants praising the clarity of the instructions and the soothing qualities of the virtual environment. However, some users identified areas for improvement, particularly in terms of onboarding guidance and the need for more customizable control options. These considerations will inform future development efforts aimed at enhancing user accessibility and engagement.

Complementary findings from the initial pilot study revealed strong user engagement and interest. Participants expressed enthusiasm about interacting with virtual elements, an opportunity not commonly available in their traditional learning environments. Quantitative analysis of the usability data highlighted significant differences across the three tested configurations, emphasizing the importance of adaptive design in addressing diverse user needs.

User testing, conducted with 15 students from the ASPOC association, confirmed the simulator's accessibility and ease of use. Feedback gathered via the System Usability Scale (SUS) indicated a high level of user satisfaction, especially in terms of engagement, intuitiveness, and immersive experience. While some participants initially encountered challenges with hand-tracking controls, these were generally overcome quickly, demonstrating the system's learnability.

Beyond the technical and usability outcomes, this project underscores the broader societal value of VR in promoting inclusive participation in sports. By removing physical barriers and supporting seated gameplay, the simulator offers a unique opportunity for individuals with limited mobility or other disabilities to engage in athletic training and recreation experiences that are often inaccessible in traditional settings. The simulator's capacity to adapt to a wide range of physical and cognitive abilities makes it a promising tool not only for skill development and rehabilitation but also for enhancing social inclusion through technology enabled sports experiences.

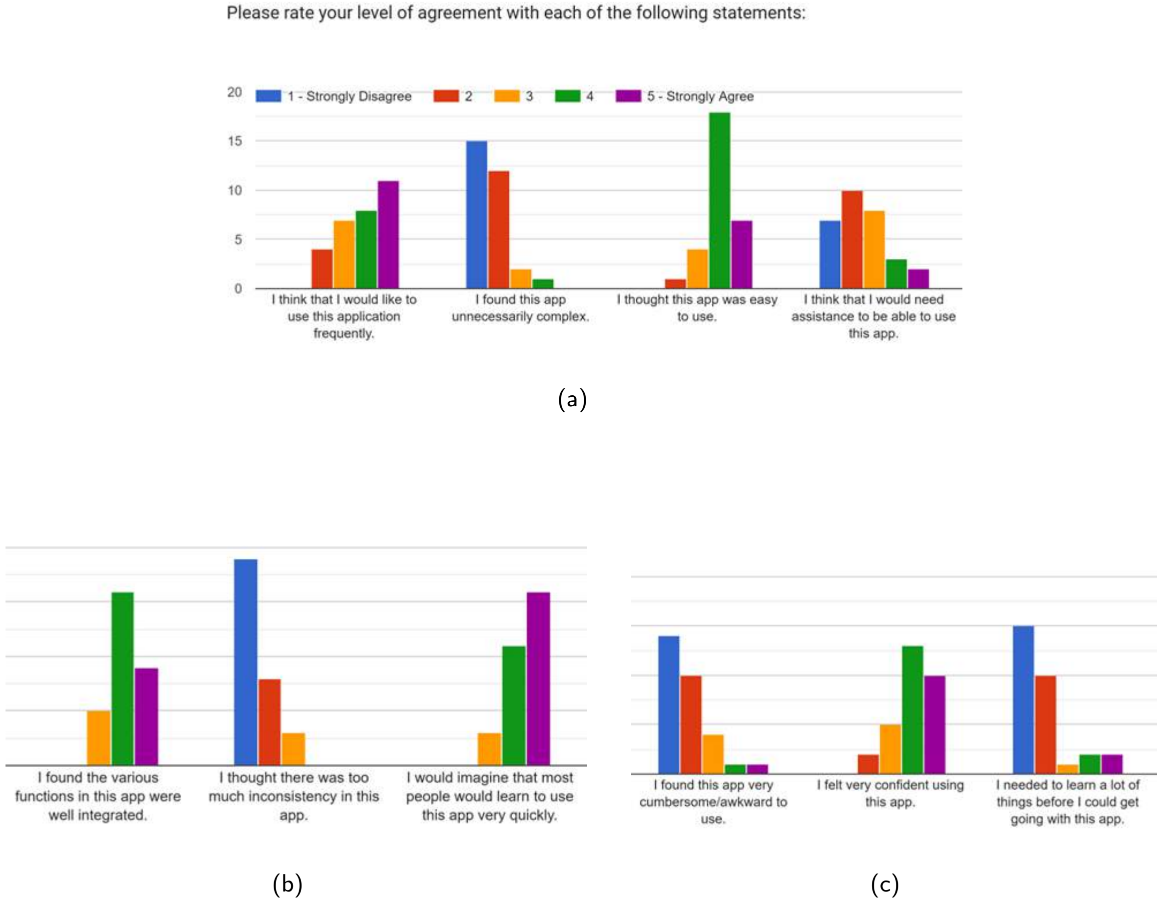

Figure 9: Results of the SUS Survey. Students from the Politecnico di Milano and athletes from the Vittoria Junior Soccer Team, a female soccer team based in Milan.

5 FUTURE WORKS

One of the most logical next steps would be the addition of more levels to the game. These could be tailored to suit an individual's need or skill level. A level with tunable parameters, such as ball speed, ball spin, and trajectory, that can be easily selected by the user itself would allow a goalkeeper to fine tune the game to their specific skill level. To further increase the difficulty of the game some visual restrictions can be introduced, such as blurring the ball or reducing the visual field. In this way the game could be made more challenging. Another option for a new level would be a more chaotic setting that simulates a corner kick scenario. This would require the addition of numerous players that could interact with the ball and would greatly complicate the coding of the game.

The addition of haptic gloves would allow for a further level of immersion to be created in this game. The gloves could be used to give a tactile feel to catching the football. The heating and cooling function of the glove could help simulate play under different pitch conditions such as rain or extreme heat. A further feature that would increase the realism of this game would be the addition of more kick animations. Expanding the animations to include right and left footed kicks, and different styles of kick to better mimic real match play.

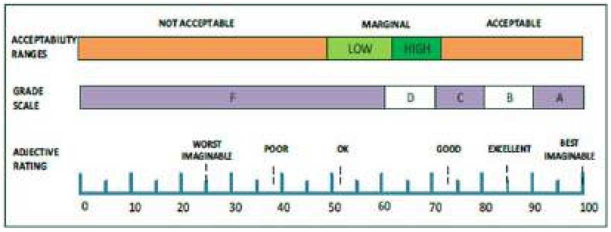

Figure 10: SUS *score scale evaluation.*

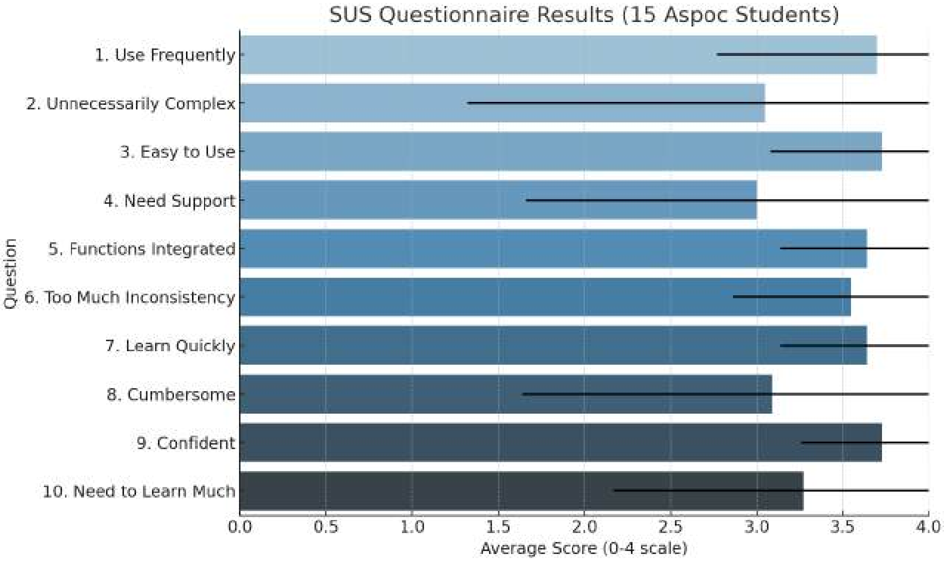

Figure 11: SUS Questionnaire Results for 15 ASPOC Students. The chart shows the mean score for each SUS statement on a 0–4 scale with corresponding standard deviations.

This addition would require a lot of motion capture performed at the lab but it is will within an expansion version.

6 CONCLUSIONS

This study presented the development and evaluation of a Virtual Reality archery training application aimed at teaching fundamental techniques in an immersive, accessible, and structured environment. Unlike existing VR archery games that focus primarily on entertainment, this system was designed with a pedagogical approach, offering users a three-phase experience comprising a guided tutorial, targeted training exercises, and a semi-realistic simulation.

Usability testing conducted with 18 novice users yielded an average SUS score of 87, demonstrating strong usability and validating the effectiveness of the design in promoting ease of use and engagement. Furthermore, an additional evaluation involving 15 students with disabilities from the ASPOC association confirmed the application's potential for inclusive training, highlighting its accessibility and overall positive user experience. These findings support the use of VR as a promising alternative for skill acquisition, particularly in contexts where physical limitations, space constraints, or motivational challenges might prevent traditional practice.

While the results are encouraging, the study also identified areas for future improvement, including enhancing on boarding support, refining control intuitiveness, and increasing user customization. The next stages of development will focus on integrating adaptive difficulty settings, improving haptic feedback, and exploring applications for more advanced archers or athletes undergoing rehabilitation.

Ultimately, this project underscores the valuable role of VR in democratizing access to sport training and offers a foundation for future research into its broader applications in physical education, therapy, and inclusive recreation.

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