VRocky: A Virtual Reality Boxing Simulator for Skill Development in Amateur and Disabled Youth

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Abstract. VRocky is an immersive virtual reality (VR) boxing simulator designed to make boxing training more accessible, engaging, and safeparticularly for amateurs and young individuals with disabilities. Developed in Unity, the system recreates an interactive boxing gym where users can explore fundamental techniques through structured lessons and gamified mini-games. By adopting a learn-by-doing methodology, VRocky promotes the development of motor coordination, cognitive functions, and physical fitness in an entertaining environment.

A distinctive feature of VRocky is its focus on inclusive sport participation. The system supports personalized training intensities and learning paces, making it suitable for users with motor or cognitive impairments. This adaptability aligns with current evidence demonstrating the efficacy of VR-assisted boxing training in improving upper limb function, balance, and cognitive ability in rehabilitation contexts.

The simulator was evaluated by a group of students with disabilities (aged 18-24) from the ASPOC association.

Their feedback confirmed the application's high usability, engagement, and accessibility, underscoring its potential as a digital tool for adaptive physical education.

By removing the risk of injury inherent in traditional boxing, VRocky broadens participation in the sport empowering users across different abilities, ages, and backgrounds to engage in a safe, motivating, and inclusive training experience.

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Boxing is a worldwide phenomenon entertaining thousands of fans. Besides the critics that can be moved to the violence involved in this sport, is undeniable and demonstrated ([3], [4], [7]) that boxing training has countless benefits, both from the physical and mental point of view.

In this article, we exploit the possibility to apply the VR [11, 14] technology to this sport, in order to involve amateurs and children in such healthy activity without the inconvenience of being hurt: in this way more and more people could get closer to this beautiful sport and train themselves while having fun. To accomplish this task, an interactive boxing-related VR video-game has been created using the *Unity* software: the game consists in a stimulating and interactive environment where the user is enticed to explore a virtual gym where he can follow short lessons about the correct boxing's techniques and then apply what learned in four different mini-games. Since the basic idea behind the architecture of the VR application is the possibility of exploring in freedom the environment, users are free to find out and try new things about boxing, but especially to learn more because driven by their curiosity (this approach of learning is more active than classical frontal lessons, and further explanations are presented in Chapter 2). Moreover, the learning is reinforced by the so called "learn-by-doing" mechanism proposed by the mini-games; this represent also a good way to make physical activity in a fun and entertaining way.

1 STATE OF THE ART

Unfortunately boxing is not as popular as other sports, probably due to its apparent 'violent' nature. Nevertheless some articles ([3], [4], [7]) manage to explain the benefits of a boxing training, even at amateur level. In addition, other studies demonstrate the positive aspects of rehabilitation procedures which use VR applications where this sport is involved, [2]. In particular, in [4] is shown the therapeutic power of a boxing training simulated through VR technology for patients hit by stroke: *'The study showed that virtual and real boxing training methods (...) improve upper extremity, balance, and cognitive functions in patients with hemiparetic stroke'*. Not only physical abilities can be trained, but also cognitive abilities seem to improve after session of trainings that mix virtual reality and boxing ([7, 9, 6]). Besides VR applications, articles highlight that also a simple boxing training is a good way to improve motor skills both for impaired patients or for users with partial disabilities ([4, 1]), and also for healthy subjects that want to stay in shape ([10]). Considering what present in literature, therefore it seems a good idea to develop an interactive boxing video-game that would require the user to develop both his cognitive and his physical skills.[13, 8] In this context, it has been developed a VR application where a boxing environment is recreated and that is explicitly meant for amateurs (thus for people who know few about boxing) and even for children. Thanks to this application they could empower their cognitive skills by memorizing moves and their combinations in an interactive environment, which requires to focus on lessons chosen directly from the user while background music plays. In addition, the players could also practice the learned movements and could stay active by playing with all the mini-games and the challenges present in the application, which would stimulate and entertain the player while using the application. Finally, besides all the positive and healthy benefits of this type of training, another goal of this virtual environment is to bring people closer to such a beautiful sport as boxing, which is often victim of prejudice and unfairly labeled as 'violent'. Getting people in touch with boxing as a game can be a 'win-win' situation both for the users and for this sport: in fact, the user could improve its cognitive and physical skills, while boxing could grow as a healthy, inclusive and entertaining movement. [5], [12]

2 DEVELOPMENT OF THE VR APP

2.1 Navigation and Architecture of the Game

The VR application starts with the player inside a boxe gym, which is purposely created to replicate as realistically as possible a real boxing training environment. As in all the virtual reality environments, the player can move freely in all the virtual ambient: thus, he could go up and down the ring, or he could look around and choose to listen a specific movement's lesson, or also to play at one of the four mini-games (and much more besides).

In particular, one fundamental feature present in the application, is a "Canvas Menu", which is equipped with three buttons: "Play", "Quit" and "Option". The "Play" button allows to start the interactive virtual reality experience going on with the exploration of the overall game: in fact, if pressed (thanks to the ray interaction from XR controllers) it shows four "Activation-Cubes" all around the whole gym environment, those permit to start the four games associated to each of them (the cube-game relationship and the activation of the games will be explained later). The "Quit" button is the one that simply closes the game, so it ends the whole VR application. Instead, the third button (at top-right on the "Canvas Menu") is an additional optional feature that, if pressed (by clicking the controller's frontal button when its ray hits the button "Option", as done for the previous two buttons), it opens a second menu-layer in the "Canvas Menu", where the player can choose between three different levels of difficulty for all the "mini-games" present into VR application, and then go back to the precedent menu-layer. Hence, supposing that the player wants to play a certain and a specific mini-game, on the first screen of the "Canvas Menu" he has to set the right and wanted level and to press the button "Play", after which the "Canvas" disappears and four "Activation-Cubes" appear around the gym.

After having defined the initial "Canvas Menu" of the game, a deeper focus on the architecture and on the navigation of the game is necessary. In fact, after having done what described before, the player could move around in the gym and approach to an "Activation-Cube" to start a specific game. Indeed, he has to simply touch, with the right hand, the bright sphere placed over "Activation-Cube" of the chosen game. As soon the contact between the player "hand" - so the XR controller - and the sphere is detected, he will be transported in another scene. In the new scene, the selected game immediately starts, allowing the player entertainment since the initial time-instant. This "immediate start" is not a problem because each of the games effectively requires an active player's interaction only some seconds after its activation. Obviously, with the change of the scene also the information about the selected level is "transported" into the new game's scene: this allows to modify some of the games' features and parameters, in order to adapt the difficulty to the selected one. The end of each game is defined in different ways: some of them have a timer that after a defined interval shows the final score to the player and closes the scene bringing him back to the gym scene. Instead, for one, that recreate a boxing sparring, the end is determined by the lost of the "Total Life" score of the Enemy or of the player. In Table 1 are presented the associations of each "Activation-Cube" with each of the implemented mini-games.

Game for each cube

Cube	Games
1	Test Your Reflexes
2	Combo Caos
3	Combo Caos PRO
4	Virtual Sparring

Table 1: Games/Activation-Cubes relationships

After having described the general architecture of the VR application and the navigation through the different difficulty-levels and the mini-games, another main feature of the VR application should be described. In fact, on the furthest wall of the gym w.r.t. the initial position of the player (so the one where the "Canvas Menu" appears and requires an interaction) are placed the so called "Lessons". These features are short tutorials that the user can attend to learn (singularly) the basic movements of boxe. Indeed, each tutorial permits to learn one single "fundamental" of boxing thanks to the combination of a visual demonstration (that consists of an animation of the correct movement performed by the built-in avatar provided by *Captury Live* software) and of a vocal explanation of the movement. The player could simply listen and watch the visual demonstration, or he could also replicate the movement of the avatar. The final goal of the lessons is to both increase the knowledge of the player about the fundamentals of boxing, and also to increase the user's skills before playing the mini-games (which could be used both as an additional training and as a test of the learned abilities).

2.2 Implementation of the VR Environment

Creating a realistic and engaging environment for the user is been considered a critical development-step for the video-game fabrication. With this perspective, a realistic boxing gym has been created from scratches in order to better model every single feature and object present in a real gym. The gym contains a ring that has been 3D modeled through the use of the software *Autocad Inventor* and imported as an FBX file (generated thanks to *Autodesk 3ds Max* software) in the *Unity* project. This ring is the fundamental feature of the environment because it is the place on which all the mini-games take place (when activated according to the mechanism described in the previous chapters). Also the four mini-games have been created from scratches in different *Unity* projects (in which a simpler implementation and test could be performed) and then imported in the different game's scenes as "Prefabs" (a more detailed description of the games and of their development will be provided in the next chapters). Most of the features and of the *Unity GameObjects* present in each game have been created as 3D models by using, again, the software *Autodesk Inventor*: real boxing pads and toolkit have been taken as references in order to be as realistic as possible in their modeling. Moreover, stick-like obstacles and boxing gloves have been appositely designed in order to implement some objects that have to be dodged during the games, making them more engaging. The walls and the columns present in the main scene of the game have been customized through the use of realistic 3D textures, which were downloaded from the *Unity Asset Store*. Background music have been added too: a code randomizes the choice of a song between a pool of ten predefined tracks. Music playback is endowed with spatiality so that the users would hear it differently if it moves around the gym. This is a necessary game's feature because while near to the Lessons' area it should be fundamental to hear the vocal explanation over the background music. Once again, the choice of adding background music aimed to improve the experience of the user. A general view of the aesthetic of the gym can be seen from Figure 1 presented below.

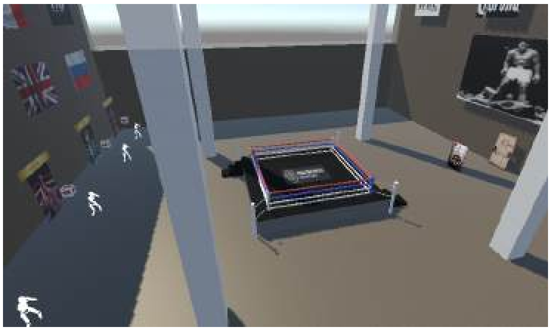

Figure 1: General view of the gym

2.3 Boxing Lessons

As anticipated in the introduction, the Lessons' aim is the one of excite curiosity in the user rather than imposing him mandatory tutorials about each single correct boxing techniques. To accomplish this task, the five basic movements of boxing (Guard, Jab, Cross, Hook, Uppercut) have been registered by using the apposite cameras connected to the *Captury Live* software (Figure 2). Each movement has been repeated twice by an expert for each recording: the first trial has been performed slowly (in order to show all the little characteristics of each movement), and then the second trial has been realized at normal speed (to show also the correct velocity at which the task should be performed).

Figure 2: Frame of the Recording Procedure

Once the Lessons' FBX files has been generated by *Captury Live* software and imported in the main scene of the VR application, the animations that drove them have been put "in-loop": in this way the user can carefully look at them for all the time needed and up to when he feels confident about the learned movement. In addition, as mentioned in the previous paragraphs, a short vocal explanation of each movement has been registered and loaded as a *Unity Asset* to the *Unity* project. Behind each animated *Captury Live*'s built-in avatar, a cube customized with the *Unity Particle System* and a picture have been placed. The idea is that the player can constantly look at the movement (which is reproducing "in-loop"), and that when he touches the cube he can hear to the vocal explanation, so the effective "lesson".

Finally, for aesthetic purposes and to increase the immersive power of the VR application, pictures of professional and legendary boxers are placed behind each cube and Lesson's area, together with golden banners containing the name of each cube's relative movement. In Figure 3 is presented a general view of the implemented Lessons' area.

Figure 3: General view of the Lessons' area

2.4 Canvas Menu

A fundamental feature of the VR application is the "Canvas Menu". This *Unity GameObject* is created with the main goal of providing to the player a tool to start the mini-games and to set and define the appropriate and wanted "difficulty-levels". The "Canvas Menu" is composed of two different *Unity Canvas GameObjects*

(respectively named "Main" and "Option"), which are implemented as children of the parent "Canvas Menu" *Unity Empty GameObject*. In addition, it is equipped with a *Unity Panel Component*, to define its graphics layout.
The "Main" Canvas layer is implemented with three *TextmeshButtons* that permit to realize the components with which the user will interact. Each button is equipped with the built-in function *'OnClick()'* (of the homonym *Unity Component*) that allows to set up and define the actions or the "recalls" to specific functions present in other *C#* scripts active in the scene (also if they are assigned to different *GameObjects* w.r.t. the Canvas one). The recall of the target script is possible by simply dragging and dropping the *GameObject* equipped with this target script in the appropriate field in the *'OnClick()' Unity Component* of the correct considered button. With this implementation, by pressing a single button, it is possible to make different and multiple actions depending on all the target *GameObjects* with which we have "filled" the above presented *Component*'s fields.
Hence, thanks to this specific function, it is possible to activate and/or deactivate the different layers of the overall "Canvas Menu". In particular, this implemented functionality is fundamental to activate the cubes that permits to start the mini-games (as presented in the previous chapters) or also to quit from the VR application.

Once the "difficulty-level" is chosen by the user, one main and necessary step is to pass this information to the different scenes where the mini-games are implemented and active. To accomplish this task, an "indestructible" *Empty GameObject* is implemented, equipped with a script that stores the "number" of selected level. Hence, when the VR application switches from the main scene to one of the mini-game scenes, each mini-game manages to extract the selected information from this "indestructible" *GameObject* and to correctly change the difficulty's parameters.
In Figure 4 is presented a view of the implemented "Menu Canvas" *Unity GameObject*.

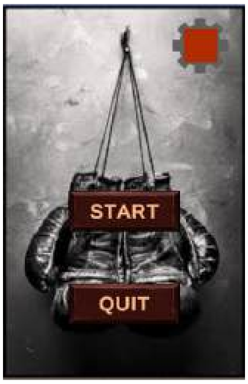

Figure 4: View of "Main" layer of Menu Canvas

2.5 Activation-Cubes

Before presenting the games' implementation, a short explanation of the *Unity GameObjects* that allow to switch from one scene to the other is necessary. The "Activation-Cubes" are appositely implemented prefabs created by us, composed by different *Unity GameObjects*, which are positioned in some specific places of the gym environment and thanks to which the user chooses one of the available mini-games. Each "Cube" is composed of a *Unity Cube GameObject* (equipped with a *TextMesh Unity Component* where the name of the associated game is reported) and of a simple *Unity Sphere GameObject*, positioned directly above the Cube and defined as its child. Furthermore, an additional Canvas is positioned above each Activation-Cube:

on it the name of the prefab's associated mini-game is reported. All the *GameObjects* (that compose the investigated Cube prefab) are equipped with an image that permits to give to each of them a specific color. In addition, on their *Sphere GameObjects* are implemented also some additional components like a light source and a sound-reproducer to make the experience more immersive. The *Sphere GameObject* has a specific *Unity C# Script Component* that allows to deactivate all the other - so the non-touched - Activation-Cubes and to switch to the scene of the mini-game associated with the specific Cube prefab activated. Summing up, the *Sphere GameObject* works as a sort of 3D Button that thanks to an "on-trigger" mechanism permits to move to the other scenes. This mechanism is possible thanks to the *'OnTriggerEnter()'* function present in the previously presented script: by simply detecting the "collision" between the player's glove and the *Collider Unity Component* present on the *Sphere*, the action presented before will correctly occur.
In Figure 5 is reported a view of the developed Activation-Cube prefab *GameObject*.

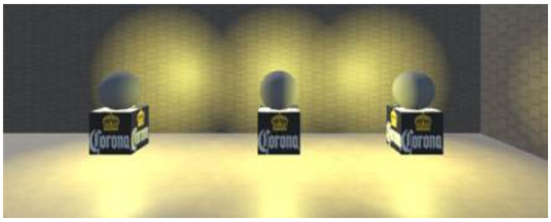

Figure 5: View of the Activation-Cube

2.6 Mini-Games implementation

The main objectives of the created VR experience are both the entertainment of the user and his actual training. As a consequence, the virtual reality application contains four different games: each of them has a different target ability. The first two games aim to train the fundamental gestures of boxe (explained in the demonstration lessons present in the gym) and the footwork. The third has the reactivity and the training of the reflexes as target. Finally, the fourth game intends to recreate real fight conditions, where all the previous presented abilities are involved.

2.6.1 Combo Caos and Combo Caos PRO

The first two games are discussed together because, even if they have two different target abilities, they have similar structures. The main difference between the two is that *Combo Caos PRO* is thought and implemented to train also the footwork and the control of the posture, which are basic fundamentals of the considered discipline. The main component of both the VR games is obviously the 'XR Oculus player', around whom all the application architecture is constructed. The XR controllers are associated with appositely created boxing gloves' 3D models, in order to let the player to have the effective equipment of the discipline and a more interactive reality. In addition, the other fundamental *GameObject* present in the games is a *Respawner*, which is appositely created to fulfill the function of generating one within a group of four different 'enemy' prefabs, in a random way and with a predetermined re-spawning frequency (associated to the 'difficulty-Level' chosen in the main scene of the VR application) - thanks to the *'Instantiate()'* function.

Starting from the simple 'Paddle' prefab, since after its re spawning it moves towards the player at an height similar to the user's shoulder one, it is thought to be hit with a punch: once a collision with one of the player's gloves occurs, it destroys and the score increases. Obviously, the player is invited to use one of the four basic fundamental movements of boxe to hit the 'enemy', which are the ones previously explained in the gym environment. While considering the 'Body Paddle' prefab, since its motion is toward the player but at an height similar to the human's hip one, the interaction required to the player is different. In fact, this 'enemy' *GameObject* is meant to allow the training of delivering few punches in a little time period and in the same restricted area. Thus, the 'Body Paddle' stops once it reaches a certain distance from the player and permits to be hit by several punches (three punches for the implemented game), after which its destroys and the score increases. If its movement toward the player is implemented with the same combination of the above presented lines of code, this prefab's additional behaviors are obtained thanks to the creation of a *Unity Capsule Collider* around the player and thanks to the combination of *'OnTriggerEnter()' Unity Class* and *'FindGameObjectWithTag()'* function: once the presented collider senses a collision, the before reported *Unity Class* allows to detect it and the last presented function allows to address properly to the only "Body Paddle" prefabs and to nullify their speed (stopping them).

In order to increase the player's entertainment and to give a direct feedback of the well or bad performing, both sounds and special light effects are implemented in the game. In fact, the sound effects permit to identify when a punch reaches its target or when an obstacle is correctly dodged. Instead, while entering in the game all the ambient's lights are turned off excepts for an appositely created (and positioned) *Unity Spot Light*: the implemented light will considerably increase the "immersion" of the player in the VR experience and will increase the concentration of the user. Furthermore, equipping the game with a soundtrack allows to increase the playful part of the application. In addition, a vibration is sent to the subject as a haptic feedback every time he correctly hits one of the game's prefabs: this is possible through the controlled vibration of the correct XR controller.

The difference between the *Combo Caos* and the *Combo Caos PRO* needs to be presented. If *Combo Caos* is implemented with a logic for which the re-spawning of the 'enemy' prefabs occurs always in the same position in the 'game-space', in particular exactly in front to the player, instead *Combo Caos PRO* is thought to re-spawn these 3D models in a wide region in front to the user. This is done in order to trigger the same actions from the player, but with the additional requirements of training the footwork and the control of the posture: this is possible by orienting the body following the random directions from which the same 'enemy' prefabs are arriving from. In Figure 6 is reported a frame of the developed *Combo Caos PRO* mini-game.

Figure 6: Frame of *Combo Caos PRO*

2.6.2 Testing Your Reflexes

As said before, the third game has the objective of training the reactivity and the reflexes of the player. Even if these abilities are intrinsically trained also in the first two games (especially when the re-spawn frequency increases with the selection of higher difficulty-levels), an apposite VR mini-application is realized. To implement the game, the inspiration is taken from the reality and from real-life devices: indeed, on the market there are some products that permit to train reflexes and reactivity through boxing and in an entertaining way (thus with music and different visual expedients).

Also for this game, the main component of the game is the 'XR Oculus player', which is still equipped with a pair of appositely created boxing gloves 3D models. The other fundamental *GameObject* present in the VR application is a 2D 'Quad' element, which is placed directly in front of the player and that has *(1m x 1m)* as dimensions. The 2D *GameObject* is placed at a distance from the player that allows the interaction between the two. On the 'Quad' element six equal dimensions (*0.2m x 0.2m*) quadrilateral 'Buttons' are symmetrically displaced in order to form a 'simil-circular' pattern. To conclude the description of the architecture of the game, the score is placed directly at the center of the 'Quad' element, in order to be continuously visible to the player.

In order to increase the player entertainment and to give a direct feedback of the well or bad performing, both sounds and lights effects are implemented in the game. In fact, as done for the previously presented games, the sound effects permit to identify when a punch reaches its target. In addition, also in this game all the ambient's lights are turned off excepts for an appositely created (and positioned) *Unity Spot Light*: this is done to increase the "immersion" of the player in the VR experience and to trigger his concentration. Furthermore, equipping the game with a soundtrack allows to increase the playful part of the application. In addition, a vibration is sent to the subject as an haptic feedback every time he correctly hits one of the game's prefabs: this is possible through the vibration of the correct XR controller.

The main objectives of the application are correctly and constantly (or better "continuously") triggered and trained. In addition, also a cognitive training is performed thanks to this VR game: the continuous focus on the "Quad" required to the player, combined with the triggering of the reactivity, permits to train also the coordination and the cognitive abilities of the user.

2.6.3 Virtual Sparring

Finally, the fourth game is both a sort of a summary of the presented, explained and trained abilities, and also a full entertaining VR application. In fact, the idea behind this last virtual reality game is to permit to the user to assess the acquired and trained abilities by actively applying them in a 'real' boxing fight. The inspiration of this last application is taken from many of the already implemented games present on *Oculus Quest 3*, but its implementation is performed with the aim of increasing the realism sensation. In fact, most of the games available for free on the device present a lack of realism: the enemy is repetitively playing the same action, without caring about the possible actions of the user.

In the realized VR game the main components are the 'XR Oculus player' and an 'Enemy' avatar. As for the previously presented games, the player is equipped with a pair of appositely modeled boxing gloves, but in this last application, also the avatar has a pair of gloves. The 'Enemy' avatar is implemented in order to be the actual enemy to be defeated in the fight. Thus, some real motions are assigned to it: this is the reason why the movements recorded with the *Captury Live* system become of fundamental importance. In fact, from the recorded actions, both the actual 'Mesh Node' (that is representing the actual avatar) and both the 'Animations' (with which the 'Enemy' is equipped with) are extracted and properly used. The 'Enemy' *GameObject* is realized as an avatar with an *Animator Unity Component*. Thanks to this component, it is possible to control the movements and the 'Animations' of the 'Enemy', in order to recreate an "as realistic as possible" game.

In order to increase the player entertainment and to give a direct feedback of the well or bad performing, both sound and visual effects are implemented in the game. In fact, as done for the previously presented games, the sound effects permit to identify when a punch (both from the player or from the 'Enemy') reaches its target. On the other hand, the visual representations of both fighters' lives and of their decrease (when someone gets hit) or increase (when someone manages to block an enemy's punch with the gloves - over which some colliders are placed too) is implemented. In addition, also in this game the only present light is a *Unity Spot Light* that lights up the only ring: this is done to increase the 'immersion' of the player by recreating real fight conditions, and also to trigger subject's concentration. Furthermore, equipping the game with a soundtrack allows to increase the playful part of the application. In addition, a vibration is sent to the subject as an haptic feedback every time he correctly hits one of the game's prefabs: this is possible through the vibration of the correct XR controller.

This final game succeeds in training the player in an interactive and entertaining way. In fact, both reflexes, reactivity and fundamental movements are "triggered", but their training is performed with an entertaining game that consists in a effective boxing sparring. In Figure 7 is reported a frame of the developed *Virtual Sparring* mini-game.

Figure 7: Frame of *Virtual Sparring*

2.6.4 Considerations about mini-games endings

All the Mini-Games except the *Virtual Sparring* one are built with a predefined "playing-time". In fact, once the player is "transported" to the single game scene, he will immediately start playing and he will do this until a limit "playing-time" of 70 seconds has passed. The limit "playing-time" can be eventually changed in some specific *Unity C# Script Components* in each mini-games' scene (before re-loading the entire VR application on the *Oculus Quest 3* device), but considering the simplicity and the high repetitiveness of each game is set by default equal to 70 seconds.

What has been described above is the general implementation of the mechanism to end the active phase of a game and to return back to the main scene. However, not all the developed mini-games have the exact full implementation of the above presented architecture: indeed, in *Test Your Reflexes* (above presented) an appositely created *Unity Canvas GameObject* is not displayed since the *GameObjects* present in the game provides yet a clear score reportage when the active phase ends. Finally, the *Virtual Sparring* mini-game is implemented with a slightly different architecture: indeed, it has not a limit "playing-time", but the game will end when one between the enemy and the player reaches the "zero-life" condition. It will end with the displacement of a *Unity Canvas GameObject* with the outcome of the fight and with the return to the main scene after a predefined time-period (considered from the end of the active phase).

3 TESTING AND SYSTEM USABILITY

To evaluate the usability of the VRocky application, a System Usability Scale (SUS) questionnaire was administered to a group of volunteers who had already tested the VR experience. The SUS is a standardized and widely adopted tool for assessing user perceptions of a system's ease of use and overall satisfaction.

The results, updated as of January 15, 2025, yielded a SUS score of (87.75 ± 13.44), indicating a high level of usability and user engagement, as can be seen from Figure 8. Most participants found the game entertaining, intuitive, and easy to navigate. The lessons were particularly appreciated for their educational value, although several users suggested translating the content into English to make the application accessible to a broader audience.

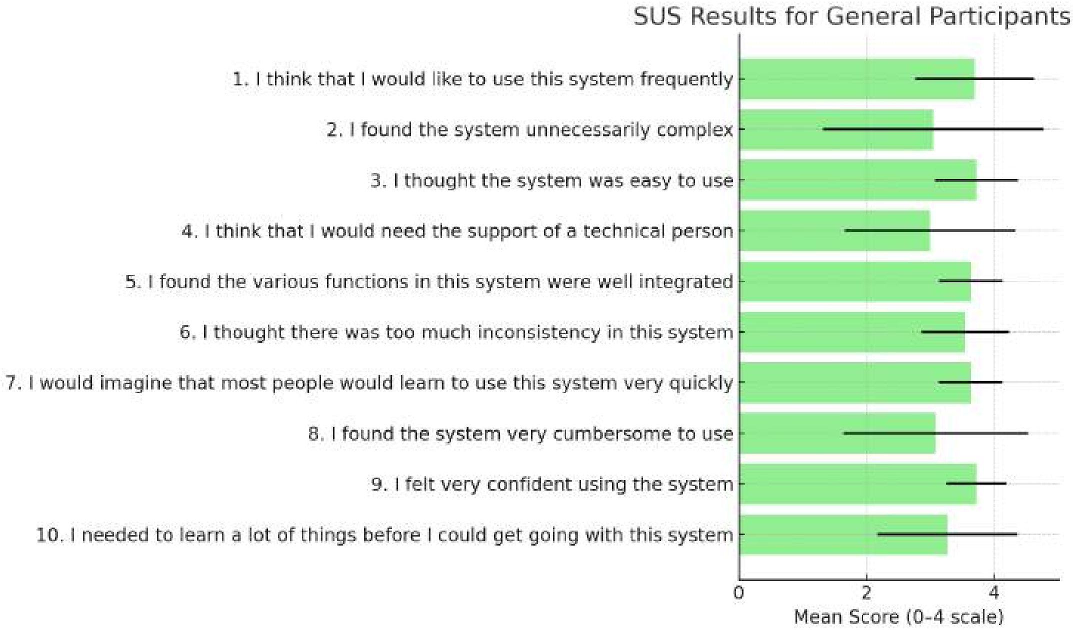

Figure 8: System Usability Scale (SUS) results for general participants. The chart illustrates the mean score and standard deviation for each of the ten SUS questions on a normalized 0–4 scale.

Despite these positive outcomes, some limitations were identified. Notably, all tests were conducted in the presence of a developer who provided basic guidance, such as how to start specific features or use the controllers. Without this assistance, the experience may have been less intuitive. To address this, future iterations of the application could incorporate an automated vocal tutorial or contextual audio prompts that guide the user through the environment.

Feedback on the interface also pointed to potential improvements. Specifically, users recommended adding textual annotations above the difficulty-setting button in the main canvas menu to make the functionality more visible. Additional enhancements could include on-screen labels, visual banners for navigation, and smoother transitions between scenes to improve the flow of the experience.

Finally, the audio lessons, currently recorded in Italian and voiced by non-professional actors, were highlighted as an area for improvement. Re-recording these lessons in English with professional boxing coaches and voice talent would enhance both the educational and immersive quality of the application.

In summary, the SUS evaluation strongly supports the effectiveness of the VRocky application in terms of usability and engagement. Constructive user feedback has also provided a clear roadmap for refining the system to achieve a more autonomous and accessible experience.ely tailored on the desired target patients.

Figure 9 illustrates the average severity of cybersickness symptoms reported by 14 students from the ASPOC association following their interaction with the VRocky boxing simulation. The symptoms were rated on a scale from 0 (none) to 3 (severe). The most commonly reported symptoms included fatigue (mean = 0.9), eye strain (0.8), and headache (0.7), indicating mild to moderate discomfort during or after the VR experience. Nausea, dizziness, and disorientation were also present but at slightly lower levels, all averaging below 0.7. Vertigo and sweating were the least reported symptoms, with mean values of 0.3 and 0.4 respectively. Standard deviations ranged from 0.2 to 0.6, suggesting a moderate variability in individual responses. Overall, the results indicate that while some symptoms of cybersickness were experienced, their intensity remained within mild levels for most users, suggesting that the VR system is generally well-tolerated among students with disabilities.

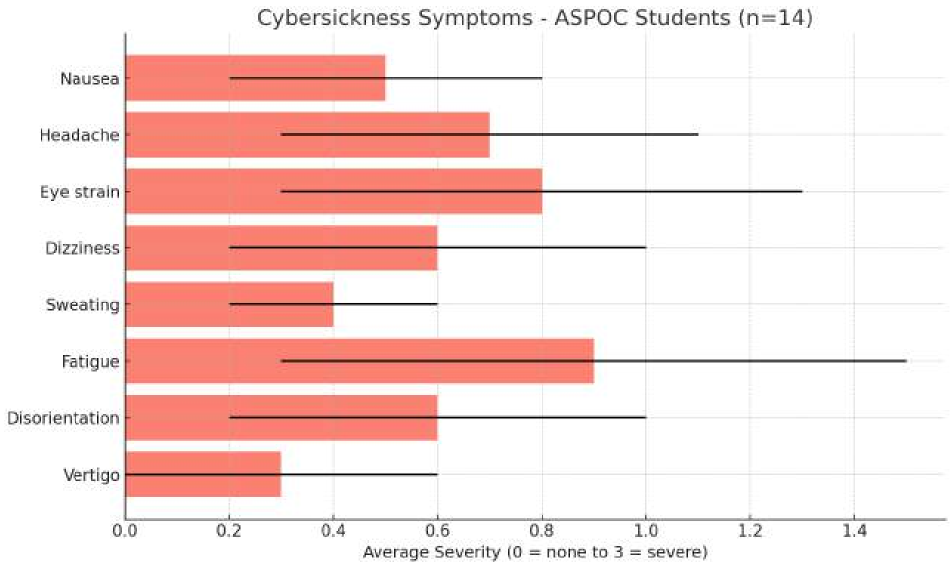

Figure 9: Average severity of cybersickness symptoms experienced by ASPOC students (n=14) after using the VRocky boxing simulator. Symptoms were rated on a scale from 0 (none) to 3 (severe).

Figure 10 presents the System Usability Scale (SUS) results gathered from 14 students with disabilities from the ASPOC association after using the VRocky application. The responses, normalized on a 0 to 4 scale, show consistently high usability scores across most statements. In particular, participants reported strong agreement with the system being easy to use (mean = 3.29), well-integrated (3.27), and something they would like to use frequently (3.20). Confidence while using the system was also relatively high (2.92). On the other hand, slightly lower scores were observed on statements related to the need for technical support (1.73) and initial learning requirements (2.79), indicating that some guidance was beneficial during onboarding. Overall, the total SUS score of 77 indicates a good level of usability, suggesting that the VR experience was accessible and engaging for students with cognitive or physical impairments.

It is important to acknowledge the limitations of the study, particularly the relatively small sample size, which may affect the generalizability of the results. Future evaluations involving a broader user based including trained archers could offer valuable additional perspectives. As noted earlier in the report, one intended use of the application is to support athletes who require continued training during periods of physical limitation or rehabilitation. Whether the current simulation complexity is sufficient to meet the training needs of more advanced users remains an open question for future research.

The feedback from the pilot study indicated a high level of interest and engagement among students. Many were excited about the possibility of seeing and interacting with virtual entities, an activity not commonly encountered in their usual learning environment. The data analysis revealed significant differences in usability among the three configurations tested.

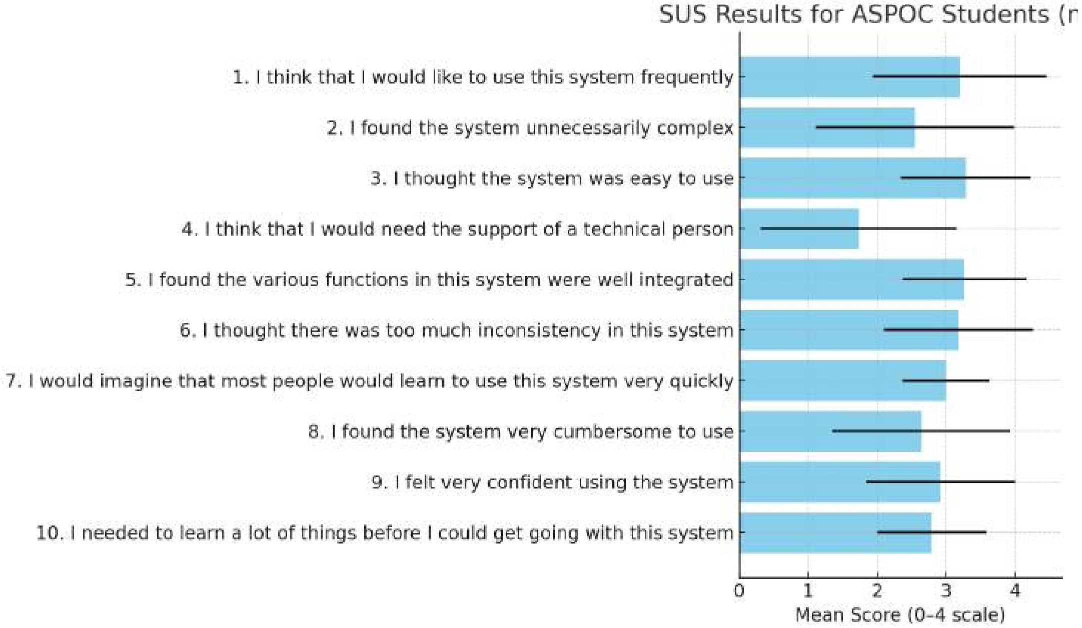

Figure 10: System Usability Scale (SUS) results for ASPOC students. The chart shows the mean score and standard deviation for each of the ten standard SUS questions, based on the normalized 0–4 scale.

4 CONCLUSIONS

VRocky represents a significant step forward in the integration of immersive technologies for inclusive sports training and rehabilitation. By combining realistic boxing mechanics with user-centered design, the application successfully lowers barriers to participation for individuals with diverse physical and cognitive abilities. Its engaging virtual environment, adaptive gameplay, and positive user feedback especially from students with disabilities highlight its effectiveness as both a training and educational tool. As the platform continues to evolve, future developments such as AI driven performance analysis, multiplayer functionality, and enhanced motion tracking could further expand its applicability in personalized rehabilitation and sport-for-inclusion initiatives. Ultimately, VRocky exemplifies how VR can reshape the way we approach physical activity, learning, and accessibility in sports. The ultimate goal of this VR application is to give everyone the opportunity to play a sport that is not very widespread and known. Furthermore, the secondary objective is to bring people to love this sport, which is often viewed and thought a violent sport while, instead, it is a bearer of healthy and positive values.

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