Application of Arduino perceptron in virtual reality sport

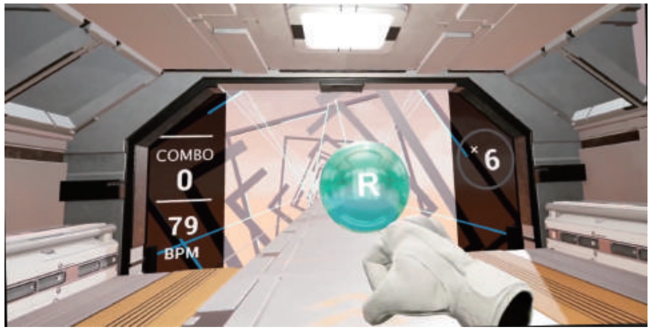
Hanlin Zhang
University of the Arts London
h.zhang0320211@arts.ac.uk

Youtube
https://youtu.be/nJqiUz-IT5w

ABSTRACT

This study illustrates the use of boxing games in virtual reality (VR) as the core, improving VR ()handle interaction while increasing VR's perception of human biological information for effective movement. The core concept stems from observations of user experience. It aims to improve VR games' adaptation to individual physical abilities, adjusting personalised difficulty settings. The article summarises the findings and makes suggestions for its future development.

KEYWORDS
VR, Arduino, Heart rate, Virtual-real interaction, Aerobic exercise



[A] **Figure 1.** The Screenshots of VR boxing game

I. INTRODUCTION

Through practical exploration, this article describes the iterative design process. In response to the phenomenon of difficulty-user mismatch in sports games, this virtual reality boxing game [A] is combined with a sensor that senses heart rate so that the handles can sense people's biological information in addition to the function of interface manipulation. As vibratory interaction is directly related to the user's immersive experience, it is important to provide appropriate vibrational feedback to the user as they play the game. This study aims to design more personalised and user-specific adaptations to help different target groups better utilise VR for practical fat loss exercises. At the same time, this article shows how different vibration feedback can provide immersion and a better experience for the user.

II. BACKGROUND

2.1 VR Virtual

Virtual reality (VR) technology has been widely used in various fields, including education, sports, and entertainment.[1] Early VR systems described a computer technology that enabled a user to look through a special display called an HMD- and instead of seeing the normal world, they saw a computer-generated world. One of this approach's perceived advantages was how it integrated the user with the virtual images. To begin with, the user's head movements are monitored electronically and fed back to the computer creating the images. As the user moves their head, objects in the scene remain stationary just as they do in real life. Most HMDs prevent the wearer from seeing the real world, which, together with a stereoscopic view, quickly immerses them in the substitute world.[2]

2.2 Fat-burning heart rate

Exercises exemplified by moderate-intensity exercises such as brisk walking and jogging and high-intensity activities such as weighted hiking and aerobic dancing can all burn fat.

When it comes to exercise, especially aerobic exercise, different heart rate zones correspond to different intensity levels. These levels are based on the MHR and determine the body's energy system during exercise, which directly affects the calories people burn. [3]

One of the main things scientists have found is that fat-burning zones occur at 55%-75% of the maximum heart rate during exercise. [4]Scientists have found that the fat-burning zone occurs at 55%-75% of the maximum heart rate[B].

Table: Target, maximum, and fat-burning heart rate by age (American Heart Association)

Age (years)	Target heart rate zone, 50%-85%	Average maximum heart rate, 100%	Fat-burning heart rate, 70%-80%
20	100 to 170 bpm	200 bpm	140 to 160 bpm
30	95 to 162 bpm	190 bpm	133 to 152 bpm
35	93 to 157 bpm	185 bpm	130 to 148 bpm
40	90 to 153 bpm	180 bpm	126 to 144 bpm
45	88 to 149 bpm	175 bpm	123 to 140 bpm
50	85 to 145 bpm	170 bpm	119 to 136 bpm
55	83 to 140 bpm	165 bpm	116 to 132 bpm
60	80 to 136 bpm	160 bpm	112 to 128 bpm
65	78 to 132 bpm	155 bpm	109 to 124 bpm
70	75 to 128 bpm	150 bpm	105 to 120 bpm

[B] **Table 1.** Target, maximum, and fat-burning heart rate by age(American Heart Association)

Aim for moderate to higher-intensity workouts and control calorie consumption to achieve maximum fat loss.

A fat-burning heart rate can be achieved by working out at 70%-80% of the maximum heart rate with moderate to high-intensity exercises.

2.3 User experience

This study aims to improve VR grip interaction while increasing the body's somatic sensation of VR in order to achieve the goal of adequate exercise.
Based on that, the following research questions are addressed.

1. What motion games best represent the advantages of VR hand controllers, and can users achieve the appropriate goals during movement?
2. What kind of vibration is most user-friendly and could provide users with a more intuitive and immersive experience?
3. which part of the hand has the most stable and easily perceived bio-information data?

III. RELATED RESEARCH WORK

3.1 Gamification of fat loss training

Gamification is a mode of prioritising human motivation in a cycle. [5] In essence, it is a human-centred design. People are driven by goals or rewards and are motivated to complete tasks. In addition, the environment is one factor that attracts users to continue playing or staying in the game. [6]

In Nurshamine Nazira Nor's article, he analyses the frequency of features of gamified VR in sports. He concludes that challenge is essential to the experience and that the user's goal is the boring practice and the game's challenge. Such challenges can provide greater motivation to complete tasks. Especially in games such as fat loss training, which require endurance and persistence, the importance of motivating behavioural design is highlighted.

With this in mind, the game should include a realistic simulation of real-world scenarios, combined with scoring, to increase the interest and challenge of the player to create a more enjoyable gaming experience.

3.2 Advantages of using VR in fat loss training

Trainers and athletes everywhere use VR to create realistic practice environments in any location. Football, basketball, and baseball VR training are becoming commonplace because of the technology's apparent benefits.[7]

There are several advantages to using VR in sports training: usability, cost reduction, convenience, safety, and realism. Of these, boxing games are particularly advantageous. Not only do boxing games avoid the real-life possibility of actual injuries to both players, but they can also be played at home and in a limited space.

Therefore, after a side-by-side comparison of different sports games, the final decision is to use boxing games as a form of fat-loss training.

3.3 Problems and solutions in the use of VR technology in boxing games

The possibility of cheating in training

By experiencing four VR games and one rhythm game, it was demonstrated that if the input device is based on the sensing of an external manipulator, it is difficult to avoid the tendency to cheat or cheat the machine. In STEAM Just Dance, for example, it is not necessary to dance all over the body, but to swing and hold the game controller to score the appropriate points; or in FitXR, for example.

The game is set up to expect the player to do a squat exercise. However, the player can bend over instead of squatting as they should due to limited external grip judgement conditions. This inaccuracy can lead to players deliberately breaking or ignoring the rules.

These are the main ideas of doing this game: enhancing supervision through biological information for a truly effective workout.

IV. PROCESS AND METHODOLOGY

4.1 Arduino

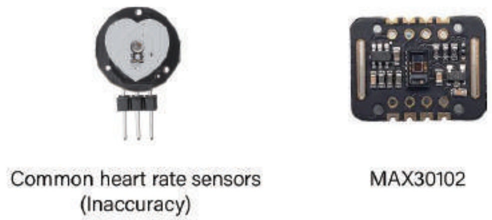
[C] **Figure 2.** Arduino Design mind map

Design ideas

In the original Arduino design idea, the heart rate sensor reads the user's heart rate every second. It transmits the data to the PC while also receiving the string "0" from the computer to start the vibration for 0.5 seconds [C]. The Arduino device can then be made into a wearable sensor. During the design process, the following questions arose.

1. Which heart rate sensor to choose?
2. What part of the body should the heart rate sensor be placed on that is most stable?
3. What type of vibration module could be used? How many of them?

Based on the above questions, the initial design ideas were gradually changed. The details will be mentioned in a later article.



[D] **Figure 3.** Comparison of two heart rate sensors

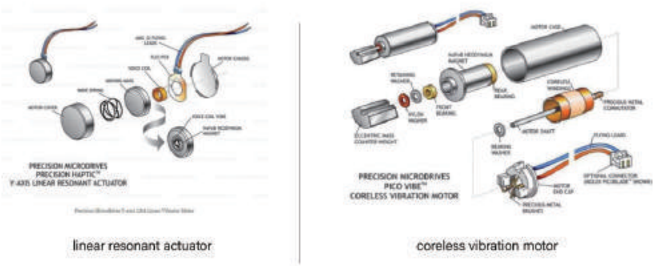
[E] **Figure 4.** Heart rate numerical stability test

Heart Rate Sensor

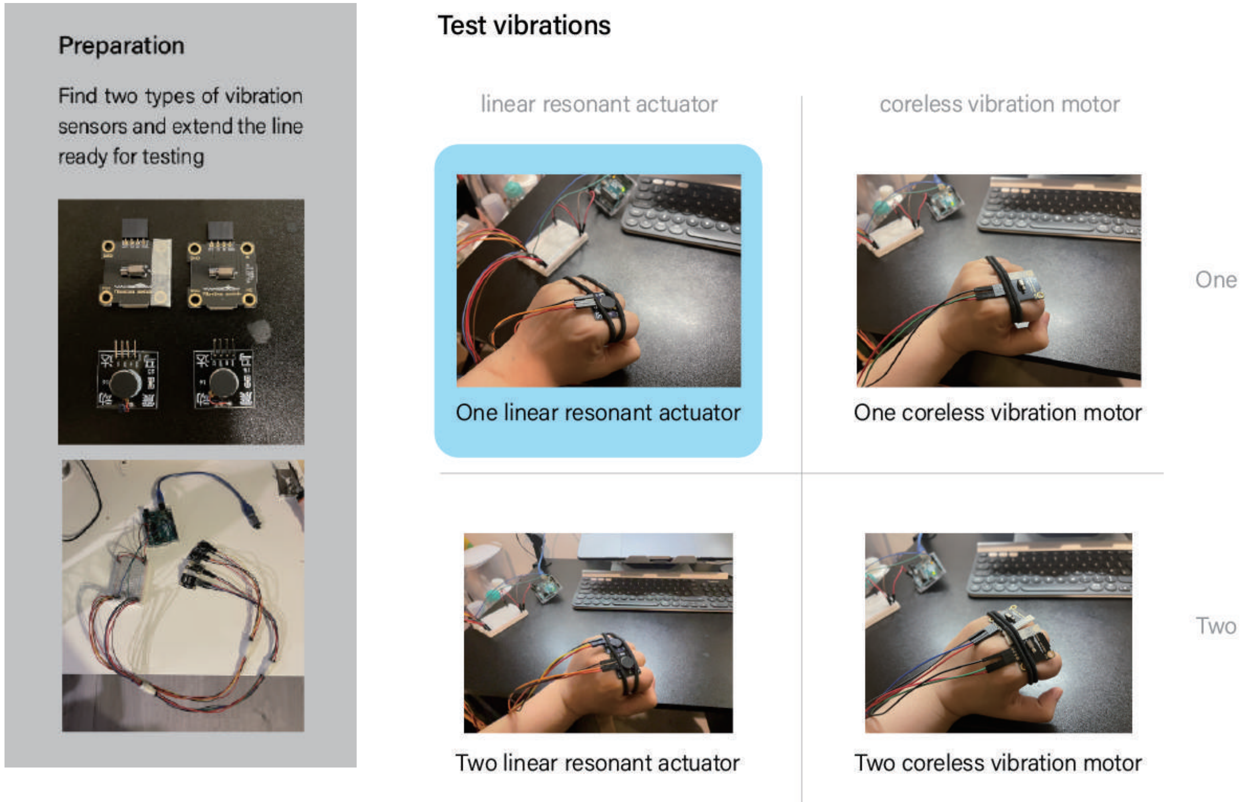
In the beginning, a standard heart rate sensor was chosen for testing, but after testing, it was found to be not very accurate. The MAX30102 model was then chosen among the available high-accuracy heart rate sensors[D]. The data test results were highly stable and less costly. After testing the front of the wrist, the back of the wrist and the fingertips, it was concluded that the fingertip data was the most stable[E].

Vibration module

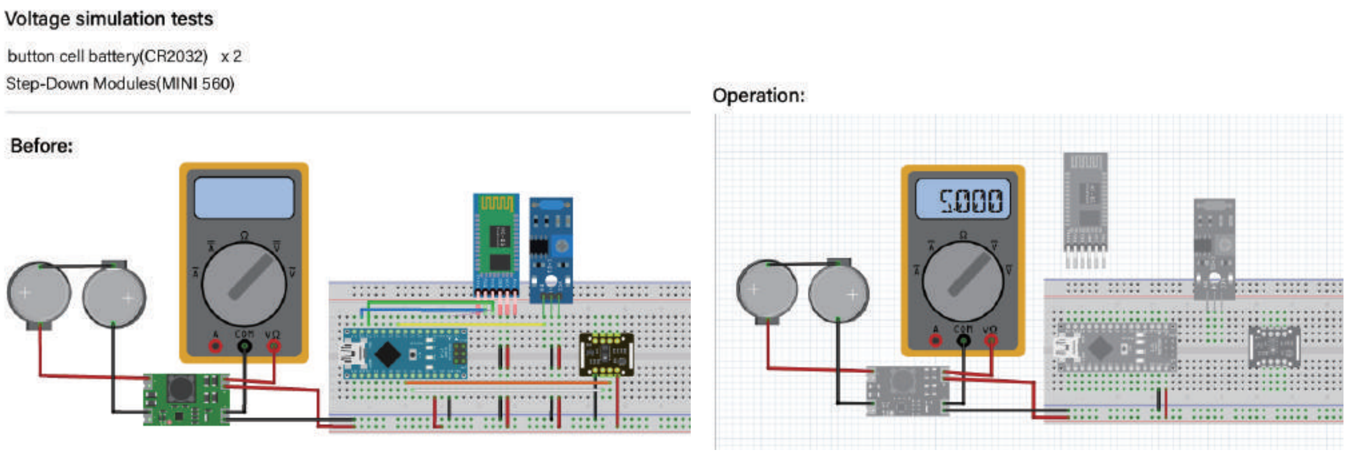
In the test, the Arduino's vibration motor vibrated when Arduino sent the character "1". So people can feel the difference between the different types of sensors and degrees of vibrations. Also, two types of vibration sensors are prepared. Testers are invited to test them together after the sensors are strapped to the back of their fingers. The final result was that one linear resonant actuator worked best. At the same time, two sensors caused the vibration to be too pronounced. According to the testers, the coreless vibration motor was more intense than the former. It did not feel like hitting a ball, and it was uncomfortable.



[F] **Figure 5.** Linear resonant actuator and coreless vibration motor



[G] **Figure 6.** Compare the sensation of different types and numbers of vibration sensors



[H] **Figure 7.** Voltage simulation tests

power supply. The options are 4 AA power supplies, 2 AAA power supplies, and 2 CR2032 coin cell batteries.

Although the three batteries have different voltages, they can be boosted or bucked to reach 5V power. So the priority consideration is given to the size of the batteries. 2 CR2032 coin cell batteries, with the addition of a mini560 buck module, can bring the voltage down from 9v to 5v [H], which can meet the voltage requirements of the Arduino. Furthermore, in terms of size, the CR2032 coin cell with the buck module is still smaller than 2 AAA power supplies.

Problems

In testing the link between Arduino and Unreal Engine, it was found that the existing Unreal Engine plug-in for linking to Arduino (SerialCOM) did not support Bluetooth links. Instead, only the data serial links to Arduino, so the design method of the game is changed.

4.2 VR Game

VR Game Survey

Most of the VR games currently on the market for sports are mainly boxing, rowing, cycling, golf, basketball and table tennis. However, after examining a certain amount of VR games, the reasons I did not consider the following game types were: golf was low in consumption; basketball required a lot of space; table tennis required pairing with other players; and rowing and cycling, two sports that tend to cause vertigo for users in VR.

Ultimately, the boxing game is chosen for the following three reasons. Firstly, players do not need to move their bodies much, and the area of space used is small. Secondly, boxing can be aerobic (as it is inconvenient to do anaerobic exercises while wearing the Oculus, and it tends to sweat and affect vision). Thirdly, because it does not require frequent position changes, players are also less likely to cause 3D vertigo.

Survey of VR boxing games

I examined four commercially available VR boxing games: Les Mills Bodycombat, REAKT Performance Trainer, Liteboxer and FitXR, and summarised each of them with the following conclusions. The common advantages of these games are the low learning difficulty, the ability to quantify the amount of exercise involved in boxing, and the conversion into game points to stimulate users to exercise. The disadvantages are that they have a poor percussive feel, and the user does not get the thrill of the blows. Secondly, the difficulty varies. Some games are too tricky, while others are too easy. It would be better if the difficulty of the games could be adjusted. To this end, this will be the focus of the later discussion to solve, i.e. using the Arduino to sense the player's biological information to make the game automatically adjust its difficulty.

Game Framework

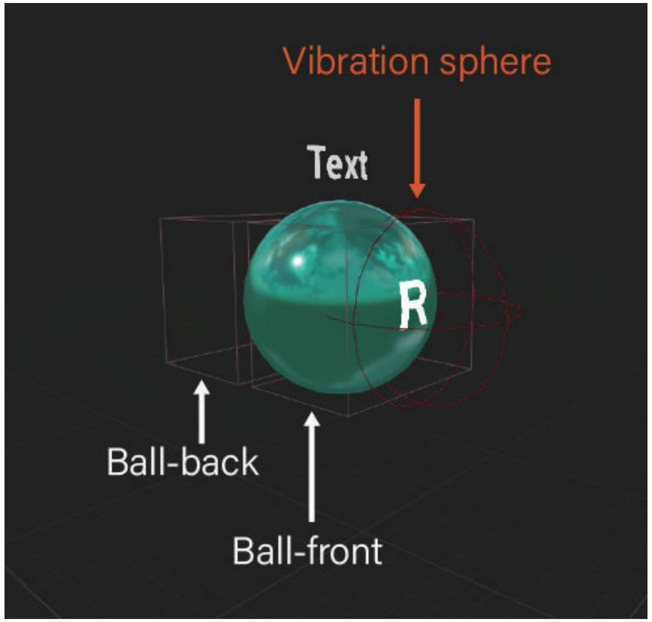
In order to design a VR boxing game based on the pre-Arduino setup. It will be necessary to set up several basic game frameworks:

1. Turning the ordinary control handle into a hand model.
2. Making the striking ball, including making the ball material and making the striking effect.
3. 3D modelling the broken ball, including making the blueprint logic of the broken ball and making the breaking sound.
4. Making the bomb and wall.
5. Making the ball launcher (blueprints control ball out speed)
6. Scoring system.
7. Game end judgment system.
8. Scene making.
9. Arduino and Unreal connection, including the vibration design of the handle, heart rate affects the speed of the ball launcher blueprint and vibration blueprint.

Hitting the ball

Firstly, two spheres are made: an entire sphere (object) and a broken sphere (animation). When the VR Hand overlaps the colliding body of the intact sphere, the entire sphere disappears. The material choice of the ball is a clear glass texture. The shattering of the glass enhances the overall visual effect and adds interest.

When the player hits the ball, the animation of the broken sphere will play, which to the player appears to be the glass ball being shattered.



[I] **Figure 8.** Ball 3 Trigger Description

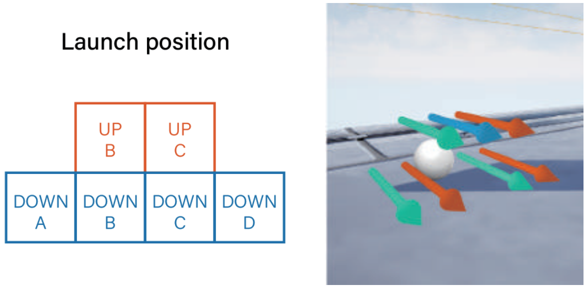
When making the sphere, I designed three collision bodies for the sphere [I], namely the front box (the sphere will trigger an explosion animation when the hand overlaps with this part), the back box (the box will not disappear when the hand overlaps with this part) and the vibration sphere (the collision zone that transmits the vibration signal to the Arduino).

The Emitter

In the Unreal Engine, six launch points are set [J]. From the six launch points, there would be spheres, bombs and glass walls launching[K].

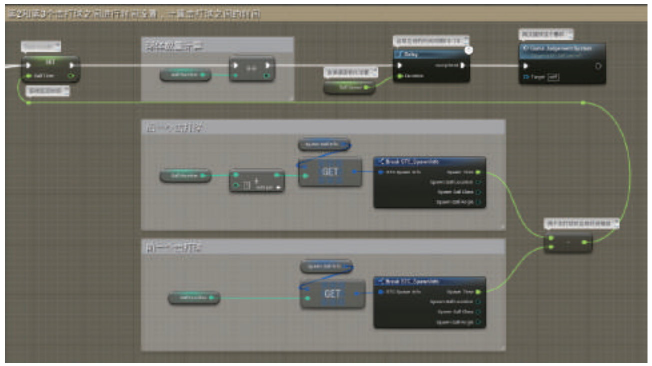
The traditional approach is to reference the spheres in the blueprint of the emitters and set the values one by one. However, given the large number of spheres emitted in this game, an enumeration-type approach is introduced. The enumeration type helps associate the objects, the spots, and the order to the same panel, an external settings window. Obviously, it is easier to set them all together.

In addition, a blueprint is built to set the time spacing between the two upcoming balls[L]. The time spacing between the upcoming balls is set, and this is closely linked to the speed of the balls and the user's heart rate; the faster the heart rate, the slower the upcoming balls.
`



[J] **Figure 9.** Emitter launch position

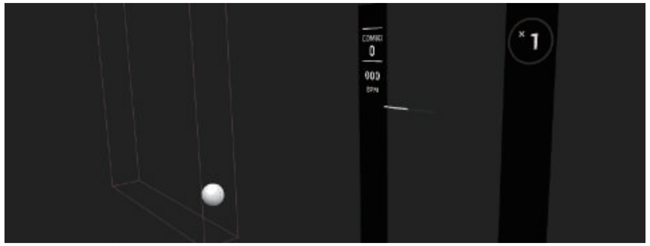
[K] **Figure 10.** Launched object



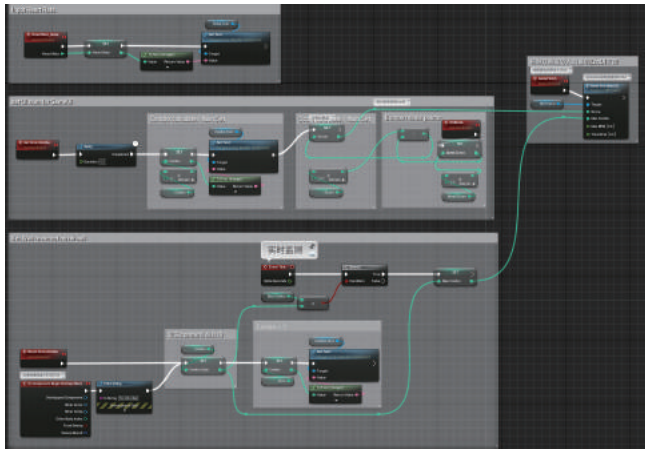
[L] **Figure 11.** Blueprint of the time interval between two launch objects

Scoring system

First of all, a transparent wall inside the game is set [M]. When the player misses a ball or touches a bomb, the ball will definitely touch the transparent wall, and the scoring system [N] will record the number of missed balls to the blueprint behind the screen and deduct the corresponding score. Similarly, the number of successful hits will also be recorded when the VR hand touches the ball.



[M] **Figure 12.** The invisible wall inside the game (Purple frame)



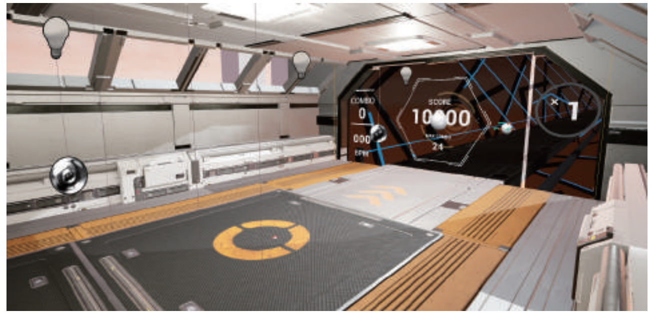
[N] **Figure 13.** The blueprint of the scoring system

When a hand is overlapped with a bomb, the blueprint of the hand detects that the overlapping object is labelled as a bomb. At this point, this data is sent to the scoring system, and 5 points are deducted within the scoring system. At the same time, the bomb explodes and is destroyed.

Scenery and sound

The scenery is an essential part of the game's design. Extraordinary scenery makes a lasting impression on the player, which is one of the reasons why the space boxing room is chosen[O]. Moreover, the sound in a game is equally important. In life, people's emotions can be influenced by various sound elements around them. Just like when players are playing a game, different situations require various sound elements to create a soundscape that fits the game's plot. "Sound effects" can bring a feast to the gamers' ears and immerse them in the game's world. [8] For the background sound, a dynamic style song is a good choice because it fits the fast rhythm of the sports game and can effectively stimulate players to be active. Besides, when the player hits the sphere, the sound of breaking glass will appear, which is a sound that makes the player feel excited and can effectively increase the player's enthusiasm

[O] **Figure 14.** Screenshot of the begin level



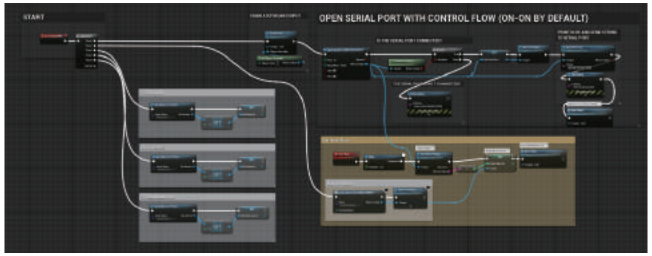
[P] **Figure 15.** Screenshot of the boxing game level (front)

[Q] **Figure 16.** Screenshot of the boxing game level (Back)

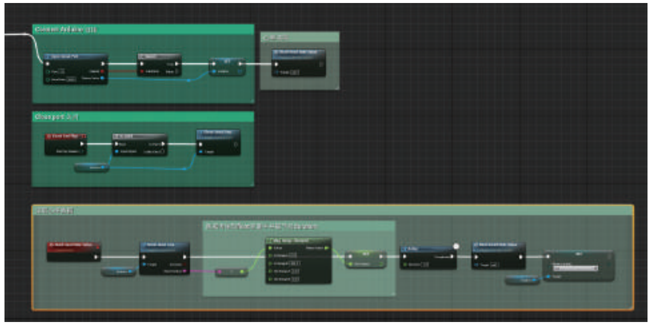
4.3 Connectivity

The Arduino senses the player's heart rate value, and this value is transmitted back to the Unreal Engine via the SerialCOM plug-in that receives the heart rate [R]. And eventually, the Unreal Engine uses a blueprint node to render the value on the UI Text. The user can then see their real-time heart rate directly within the game. At the same time, the launcher can also reference this value and use it to influence the time interval between the two balls being launched [S].

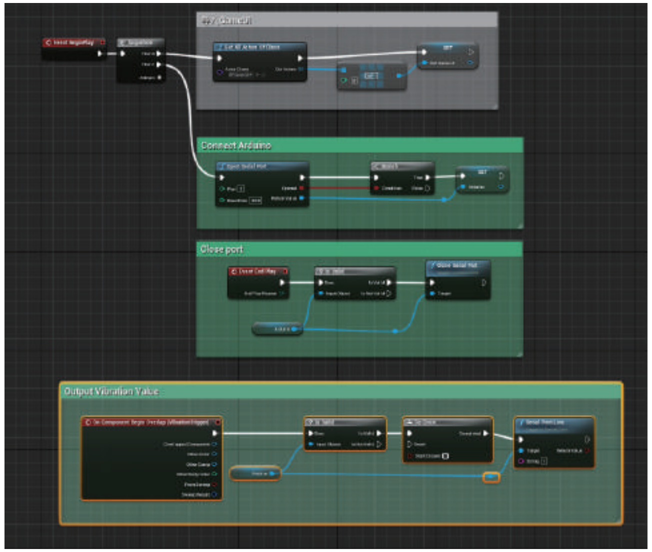
In addition, the front of the ball is fitted with a Vibration Trigger, which emits a value of "0" back to the Arduino when the Trigger touches the VR Hand [T], and the Arduino vibrates for 0.5s upon receiving this value.



[R] **Figure 17.** Blueprint for the import of arduino data into the UE



[S] **Figure 18.** Blueprint for setting ball speed based on heart rate values



[T] **Figure 19.** UE blueprint for transferring vibration data to Arduino

V. TESTING AND RESULTS

Ten testers were randomly arranged to wear heart rate sensors and vibration sensors. The participants entered the VR world and gave qualitative feedback through a 20-minute workout. Participants are asked to assess whether the difficulty was appropriate for them so that improvements could be followed up with.

For the most part, participants responded positively to the game but also provided some valuable feedback that will inform subsequent iterations of the game.

All participants reported that the scenarios were engaging and innovative and that they felt the difficulty met their needs. Most participants found the pace of movement and the feel of the strokes to be comfortable. However, one participant found the stroke-only interaction to be "boring". Moreover, if it were just about ball speed, it would only work on reflexes and not be effective for aerobic exercise. One participant said that before the game, he would not have noticed if his workout had reached the stage where he started to burn fat. Suggestions were also made to add different hitting directions and different angles to the ball, to display the calorie count for this exercise on the checkout screen, and to recognise that adding a human voice to remind the player to simulate the urging of the trainer would be more conducive to perseverance.

VI. EVALUATION

In this article, there is a development of The Boxing Room. This game uses an Arduino sensor to measure the player's heart rate and change the difficulty of the game based on the response. By measuring the user's heart rate in real-time and comparing it to a standard heart rate measurement, the speed of the ball will change during the game.

As a result, by trying out this game, it is practical to give people a more realistic and effective workout than in previous games. In previous games, we focused on gameplay and the feel of the trial. However, in this work, we focused on physiological information, and we were able to effectively supervise the player's workout by monitoring heart rate in real time.

At the same time, there were a number of issues worth being taken into consideration. For example, could the difficulty of the game be varied rather than being reflected in a single-stroke speed? In addition, the game is designed for general users, but the possibility of including disabled people, older people and children in the game to create a more diverse user profile should be considered in future work.

Secondly, there is no personalised evaluation for measuring heart rate, for example, in terms of what affects it, including weather, mood, weight, medication, caffeine and nicotine. It would be more beneficial for players to personalise their state before playing the game to achieve fat loss effectively.

Thirdly, could the sensors and grips be more simplified? For example, it is an excellent option to use the bare-hand controller to replace the actual hand controller, which could make it easier for the player to exercise. However, there is no denying that the proposed concept of incorporating heart rate monitoring (or sensing systems) into games could materially improve certain player experiences and would be used in a broader range of scenarios. For example, Hayato Araki proposed the development of a horror game that uses the player's pulse to determine a branching route [9]. Selecting a route that gives the player an emotion of fear based on pulse rate effectively gives fear to players who do not have a sense of fear.

VII. DISCUSSION AND FUTURE WORK

This review discussed the research and exploration of virtual reality. With the goal of effective fat loss and a sensor that senses heart rate, experimented with and implemented under a human-centred philosophy.

Through its use the VR game was used to achieve increased fat loss. In this research, we investigated the simultaneous inclusion of sensors in an immersive VR environment to aid physical exercise. Through the results of the user experience, it can be demonstrated that the improvement can ensure that the heart rate values are monitored at all times and encourage better rule enforcement by the athlete or user while retaining the user experience. In addition, four boxing games in VR are discussed, listing their advantages and limitations. However, the findings require a more diverse population, for example, athletes, children and the elderly. Also, depending on the factors affecting heart rate, whether or not alcohol or medication is consumed prior to exercise can be a factor in the accuracy of the monitoring. Based on this, more detailed settings, such as setting up questions in advance for the user's height and weight, medication intake, and whether or not they have consumed alcohol, to get a more personalised difficulty setting and objective results after heart rate monitoring.

VIII. CONCLUSION

In this paper, we developed a boxing game that measures the player's heart rate by incorporating a sensor that senses heart rate in combination with a VR hand-worn joystick as physiological information, and the system automatically adjusts the game difficulty according to the heart rate. Furthermore, by measuring the user's heart rate in real-time and comparing it to the value obtained by inputting a standard heart rate algorithm, the speed of the ball in the game is automatically adjusted accordingly.

As a result, by trying out this game, we were able to pay closer attention to individual variability and provide real-time feedback than in previous games. In previous work, we focused on the player experience and fun. However, in this work, we focused on physiological information that we could use in time to exercise more effectively through heart rate detection.

In the future, we will follow the results of this experiment and make even better-personalised settings.

REFERENCES

[1] "Get Ready to Hear a Lot More About 'XR'". *Wired*. 1 May 2019. ISSN 1059-1028. Retrieved 29 August 2020.

[2] Vince, J. (2004) Introduction to virtual reality. London: Springer.

[3] Paige Waehner, C.P.T. (2022) *Fat-burning heart rate: What it is and how to Target it*, *Verywell Fit*. Verywell Fit. Available at: https://www.verywellfit.com/the-truth-about-the-fat-burning-zone-1231545 (Accessed: November 21, 2022).

[4] Divya Jacob, P.D. (2021) *What is a fat-burning heart rate? chart*, *MedicineNet*. MedicineNet. Available at: https://www.medicinenet.com/what_is_a_fat-burning_heart_rate/article.htm (Accessed: November 21, 2022).

[5] Y .-K. Chou, “Actionable gamification: Beyond points, badges, and leaderboards,” *Octalysis Media*, pp. 1-151, 2016.

[6] F. Rebelo, P. Noriega, E. Duarte, and M. Soares, “Using virtual reality to assess user experience,” *Hum. Factors*, vol. 54, no. 6, pp. 964-982, 2012.

[7] Zakzuk, A. (2022) *Pros and cons of VR in sports training: Soluntech*, *Custom Software Services for Forward-Thinking Organizations*. Custom Software Services for Forward-Thinking Organizations. Available at: https://www.soluntech.com/blog/pros-and-cons-of-vr-in-sports-training (Accessed: November 28, 2022).

[8] Meigs, T. (1970) *Ultimate Game Design: Building game worlds: Semantic scholar*, *undefined*. Available at: https://www.semanticscholar.org/paper/Ultimate-Game-Design%3A-Building-Game-Worlds-Meigs/8695c7dd11f24a3d38db96f814cb0e39fcd2f9a0 (Accessed: November 28, 2022).

[9] Araki, H. et al. (2018) “Development of a horror game that route branches by the player's Pulse Rate,” Proceedings of the 23rd International Conference on Intelligent User Interfaces Companion [Preprint]. Available at: https://doi.org/10.1145/3180308.3180322.