A BEFITTING SINGLE-PLAYER SQUASH PROGRAM TO EDUCATE AND ASSIST DISABLED/AUTISTIC PEOPLE USING POSE ESTIMATION AND UNITY

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ABSTRACT

The COVID pandemic has had a notable impact on sports education and exercise over the past few years [7]. Many students have lost access to physical education classes due to school closures or virtual instruction. This paper develops an application using pose estimation that allows users to experience a digital squash game that involves body movements on their phones or computers. Using post estimation, this application can track and identify player movements that let players control game avatars with their movements [8]. A crucial factor that deserves consideration is the degree of difficulty a game offers. The game has a bot as an opponent that can score points precisely. The game may make it easier for the player to move in the direction of the squash ball in order to lessen the challenge that the bot presents. In the experiment, the efficacy of post estimation was tested. In twenty-five swings, all swings were successfully accomplished. With the pandemic restricting access to public sports facilities and other fitness facilities, the application provides a convenient way to exercise from home and the opportunity to learn more about squash.

KEYWORDS

Pose Estimation, Unity, Single-player, Squash

1. INTRODUCTION

The COVID-19 pandemic has had a notable influence on the domains of sports education and physical activity. Due to the closure or transition to virtual instruction in educational institutions, a considerable number of students have been deprived of the opportunity to participate in conventional physical education courses. The curtailment of sports facilities, parks, and community centers has constricted avenues for physical activity beyond the educational institution. The findings of research conducted on 455,404 distinct smartphone users hailing from 187 nations indicate a swift reduction in the global daily step count following the World Health Organization's announcement of COVID-19 as a pandemic. Following the declaration of the pandemic, there was a notable reduction in the mean number of steps taken by individuals. Specifically, within a span of 10 days, there was a 5.5% decrease in mean steps, equivalent to 287 steps. Furthermore, within a period of 30 days, the mean number of steps taken decreased by 27.3%, which translates to a reduction of 1,432 steps [1]. Furthermore, social distancing measures have made it difficult for group sports and activities to take place, and many sports

David C. Wyld et al. (Eds): ICDIPV, CBIoT, ICAIT, WIMO, NC, CRYPIS, ITCSE, NLCA, CAIML -2023
pp. 67-77, 2023. CS & IT - CSCP 2023 DOI: 10.5121/csit.2023.131306

leagues and events have been canceled or postponed [2]. The aforementioned disturbances may result in enduring impacts on the physical activity levels of individuals, which could potentially culminate in adverse health consequences in the future. Consequently, this had a notable effect on social welfare over an extended period of time, resulting in decreased social engagement and a heightened risk of isolation. The outbreak of the pandemic has caused a disturbance in conventional sports education and physical activity opportunities, resulting in a decrease in the chances for individuals to participate in physical activity, socialize with others, and establish social connections. Initially, it should be noted that physical activity and sports education hold significant importance for both physical and mental well-being. Consistent exercise has been associated with a multitude of advantages, such as enhanced cardiovascular health, improved mental health, and a decreased prevalence of chronic ailments [3]. However, following the declaration of COVID-19 as a public health emergency, a significant proportion of the younger population in China, approximately 40%, reported experiencing psychological distress, including but not limited to post-traumatic stress disorder (14%), negative coping, and stress [4].

The Chinese researchers provided students with field and real-world experience by using game-based learning since resource and geographical restrictions hindered their expertise in tourist planning [9]. The research solely examines the game's efficacy in terms of knowledge-attitude-usability and its long-term effects on ecotourism behavior and attitudes are unknown. The squash game's bot can simulate several scenarios. It does this by adapting to different environments and following regulations. In the second scholarly source, three Italian researchers implemented a game-based curriculum to improve students' knowledge and confidence in water conservation and sustainable water usage. Nevertheless, the solution was tested on a small group of grade 4-6 pupils in a rural South African community; hence, the sample size was tiny. The game-based curriculum may not work in other environments or with different age groups. However, the squash project included a large sample of people of all ages. In the last scholarly source, the researchers created a watch-summarize-question online game-based learning strategy to improve knowledge retention and engagement during the COVID-19 pandemic. Nonetheless, the study was limited to nursing students and may not be applicable to other demographics or educational settings. Due to pandemic limits, the squash game was developed for distance learning.

Mental and physical health can be enhanced by proposing an application that will allow users to experience a digital squash game on their phones or computers. The application employs pose estimation to monitor and identify the motions executed by the players. Pose estimation is capable of delivering instantaneous feedback on the players' form and execution of exercises or sports skills by monitoring their body movements during gameplay. Moreover, the utilization of pose estimation technology can enhance the level of immersion and interactivity in the game by enabling players to manipulate game avatars through their physical gestures. Upon swinging their arm, the game avatar will execute a corresponding arm movement to strike the ball in the course of gameplay. This is an effective solution to the reduction in sports education and physical activity during the COVID-19 pandemic because it provides a safe and accessible way for individuals to engage in physical activity and sports education from their homes. With the closure of public sports facilities and restrictions on group sports and activities, people have had limited options for engaging in physical activity. The application is designed to encourage individuals to exercise more regularly and educate people about squash. Moreover, this application has the potential to acquaint individuals who have not yet had the opportunity to engage with it with the sport of squash. This can be especially captivating for younger individuals who are habituated to engaging in video games. In light of the pandemic, engaging in pose estimation games at home is a novel and pragmatic approach to sustaining and enhancing both physical and mental wellness.
The experiments targeted blind spots regarding the efficacy of pose estimation and the functionality of the game. The solution to evaluating the efficacy of pose estimation is to assess the number of swings that can be completed in five trials. The experiment was done in a separate

scene in Unity. Since it separates and defines the components that impact pose estimation, it can better assess its performance. The result of this experiment is five successful swings on average. Since post estimation is straightforward to use, attaining all successful swings is reasonable. Through Google Forms, the second experiment surveyed COVID pandemic survivors. The game is considered challenging since the first question has the lowest average. The other three questions have a median of five on a scale of one to five. This data was expected because the bot is exact, making the game challenging. Moreover, the game follows squash regulations, which lends credibility.

2. CHALLENGES

In order to build the project, a few challenges have been identified as follows.

2.1. The Selection of an Appropriate Sport

The selection of an appropriate sport is crucial for the solution; however, there are various factors that need to be considered. Regarding the sport, it must have widespread popularity and global participation while also being an individual sport [10]. With that being stated, it presents a challenge to determine the most appropriate individual sport. One potential resolution to this issue would involve selecting the option that offers the greatest advantages, as this approach has the potential to produce favorable results for physical and mental health, ultimately promoting a gradual and sustained enjoyment of the exercise in question. Alternatively, suppose the objective is to enhance one's mental or physical well-being. In this case, it may be prudent to conduct a more thorough analysis of each sporting pursuit to determine which offers greater intensity and advantages.

2.2. Pose Estimation

Given the crucial role that pose estimation plays in the game, it must operate at optimal levels. Occasionally, there may be delays in the pose estimation process, resulting in a potential delay in accurately tracking a player's bodily movements and positioning. Consequently, it is possible that the representation of the player's actions or movements within the game may not be entirely precise. Frequent occurrences may result in a feeling of motion sickness or other forms of discomfort for the player, thereby potentially impeding their overall gaming experience. Hence, it is imperative to select a proficient pose estimation technique for the game that can furnish players with a smooth and gratifying experience.

2.3. The Game's Level of Difficulty

The game's level of difficulty must not hinder its playability. The difficulty of a game is an important factor because it could have a significant impact on the player's overall experience. If a game lacks sufficient challenge, it could quickly become boring. On the other hand, if it is too challenging, it could create frustration for the player and make them feel discouraged. Thus, the game must be balanced and provide some satisfying challenges. Consequently, the game could incorporate a bot as an opponent for the player, which would consistently exhibit excellent precision in achieving points. Instead, the game will autonomously monitor the path of the ball and move the player toward it. This can potentially enhance the players' experience as it eliminates the need for them to be concerned about the ball's location, allowing them to focus solely on identifying the optimal angle for striking the ball.

3. SOLUTION

The primary framework of the game is straightforward. The main menu comprises a straightforward interface that affords users the options of initiating gameplay, accessing the settings, or exiting the game. The gameplay itself consists of many components as it tries to replicate the rules and real-life situations of the sport. There are three major components of the program that make the gameplay possible. The game state is a crucial component of the program, as it governs distinct rules for various game states, such as the rally state, idle state, and serving state. Typically, when a program first launches, it starts in the serving state and then uses the Pose Estimate library as a crucial component to identify a swing through the use of the webcam. One of the program's intricate components is the scoring system, which involves assessing various conditions during gameplay to determine the player who qualifies for a point and/or triggers a turn switch. In summary, the game starts with a serve from our player, and the pose estimate is utilized to verify a genuine right-hand swing, which activates a swing animation for the player, initiating gameplay until a final score of 11 or a leading score is achieved. Subsequently, a series of criteria are assessed to determine if the ball has crossed the serving line subsequent to the server's hit or if it has rebounded on the ground more than twice, which would result in the awarding of a point.

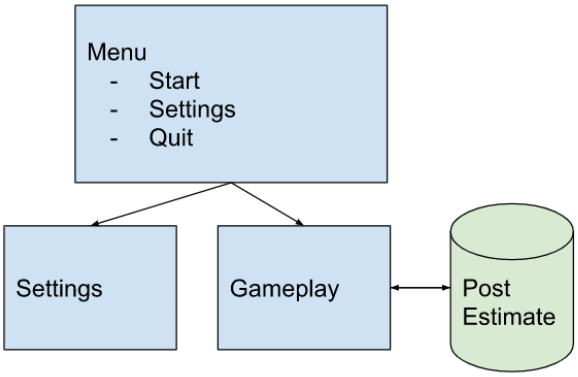

Figure 1. Overview of the solution

One of the main components is the game state. The game state determines the current stage of gameplay. The game can be divided into three distinct states: the serving state, the rally state, and the idle or no state. The game states are instrumental in determining the movement patterns of both the player and the opponent. They are also utilized to evaluate various game conditions, such as the appropriateness of enabling the opponent's AI to pursue the ball [14].

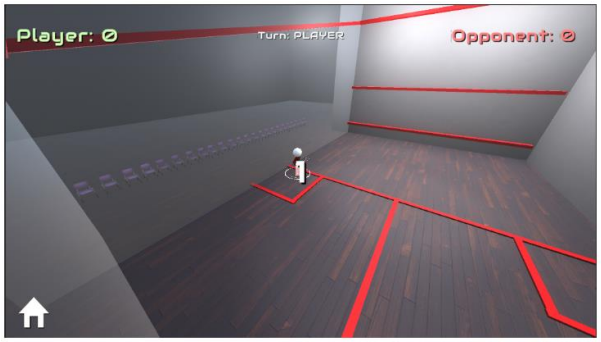

Figure 2. Screenshot of the game 1

```
if(gameState == GameState.SERVING)
{
    if(!serving)
    {
        serving = true;

        SoundManager.Instance.PlayCheer();
        countdownStart = startingCountdown;
        currentlyHitting = lastServedTurn;
        BallHit.Instance.canHit = false;
        ball.GetComponent<Rigidbody>().isKinematic = true;

        GotoServiceArea();
    }
}
else if(gameState == GameState.RALLY)
{
    //AllowPlayerMovement(true);
    opponent.GetComponent<Opponent>().allowMove = true;
    serving = false;
} else if(gameState == GameState.IDLE)
{
    AllowPlayerMovement(false);
    opponent.GetComponent<Opponent>().allowMove = false;
    serving = false;
} else
{
    AllowPlayerMovement(false);
    opponent.GetComponent<Opponent>().allowMove = false;
    countdownText.text = "";
    serving = false;
}
```

Figure 3. Screenshot of code 1

Now the game state code exists throughout the game, changing interchangeably for different conditions and being used to check current game states. In the code sample, we can see the check for different game states. The initial step involves verifying whether the system is currently in the "serving state." During this state, various variables are initialized or reset, such as the activation of a cheering sound, the resetting of the server countdown, and the invocation of the “GotoServiceArea” function, which facilitates the teleportation of both the player and opponent to their respective serving areas. These events occur consistently whenever the game state transitions to the serving state. In contrast to the idle state, which restricts the movement of the opponent AI, other states, such as the rally state, facilitate the movement of the opponent AI. The aforementioned mechanics are of a general nature and pertain to the occurrence of game state transitions. However, conditional checks determine the game state, and other mechanics are contingent on the current game state.

One of the other main components of the project is the pose estimate library, or more specifically, the use of it. The pose estimate library basically instantiates these points and line renderers at the start of the game that correspond to the real-life location of body features using your camera and activates and deactivates them whether they are seen in the webcam or not. These point and line renderers live in a 2D plane and do not have depth [15].

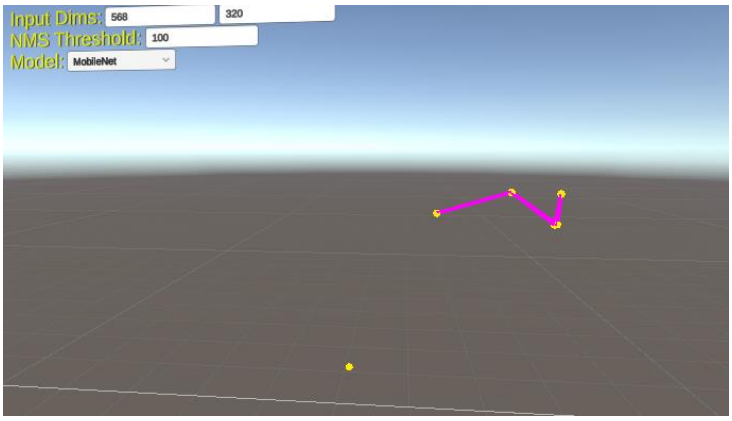

Figure 4. Screenshot of game 2

```
if(rightShoulder == null && !Gameplay.Instance.mouseMode && PoseEstimator.Instance.ready)
{
    if(GameObject.Find("rightShoulder"))
        rightShoulder = GameObject.Find("rightShoulder").transform;
}
if(rightWrist == null && !Gameplay.Instance.mouseMode && PoseEstimator.Instance.ready)
{
    if(GameObject.Find("rightWrist"))
        rightWrist = GameObject.Find("rightWrist").transform;
}

if(rightShoulder != null && rightWrist != null && PoseEstimator.Instance.ready)
{
    if(!Gameplay.Instance.mouseMode && rightShoulder.position.x > rightWrist.position.x)
    {
        print("Swing");
        animator.SetTrigger("Swing");
    }
}
```

Figure 5. Screenshot of code 2

As mentioned earlier, the pose estimation spawns points and line renderers that follow body features such as the nose or wrist. This project focused on accurately detecting a real-life swing through the observation of the right shoulder and right wrist. Checking whether the right wrist passes through the right shoulder enables identification of the swing. The code above is responsible for the identification of the instantiated points and line renderers generated by the Pose Estimate library, in order to establish a point of reference. Then, after checking if they exist or not, it checks for a swing by checking if the right shoulder's x position is greater than the right wrist's x position, and then it plays a swing animation. If the right shoulder's x position is greater than the right wrist, then that means the right shoulder is to the right of the wrist in the x-coordinate, implying the wrist is now past the right shoulder going towards the chest, which resembles the motion of a swing in real life.

The last of the main components of the project is the scoring. There are a lot of rules and conditions for scoring in this sport. The conditions can be whether the ball has bounced twice on the floor and who let it happen, or whether the ball hit the front wall before hitting the ground after one of the players hit it. A large number of condition checks are implemented to determine the identity of the player who made the most recent move or whether the current stroke was the initial stroke after the serve.

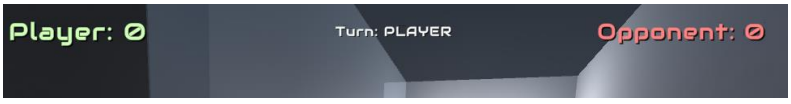

Figure 6. Screenshot of game 3

```
Unity Message
void Update()
{
    if (groundHitCount >= 2 && Gameplay.Instance.gameState != Gameplay.GameState.SERVING)
    {
        if (Gameplay.Instance.currentlyHitting == Gameplay.Turns.OPPONENT)
        {
            Gameplay.Instance.playerScore++;
            groundHitCount = 0;
            Gameplay.Instance.gameState = Gameplay.GameState.SERVING;
            Gameplay.Instance.hasServedFirstTime = false;
            return;
        }
        else
        {
            Gameplay.Instance.oppScore++;
            groundHitCount = 0;
            Gameplay.Instance.gameState = Gameplay.GameState.SERVING;
            Gameplay.Instance.hasServedFirstTime = false;
            return;
        }

    }
}
```

Figure 7. Screenshot of code 3

Since the scoring of the sport can be complex, we can explore one of the ways either the player or the opponent scores. One condition check we can make for scoring is if the ball has touched the ground two or more times. In this code, we have a groundHitCount variable that keeps track of how many times a ball has bounced off the ground. We only make this check if we're not in the serving state, so this check is likely to be made during the rally game state (the ball is hidden and not bouncing in the idle game state). After we determine if the ball has touched the ground more than once, we check whose turn it is. If the current hitting player is the opponent (referenced through the currentlyHitting variable), then the player gets a score and we immediately switch to the serving game state, and likewise, if it's us who is currently hitting, then the opponent gets the point.

4. EXPERIMENT

4.1. Experiment 1

Pose estimation is an essential element of the game because it enables accurate tracking of the player's arm movements within the game. The camera that records users' arm posture and movement keeps track of their arm movements. After that, the captured data is used to animate a visual representation in the game.

The experiment involves the creation of a new scene using pose estimation within the Unity platform. This particular scene is distinct from the game and solely encompasses the aspect of pose estimation. Hence, it can be used to evaluate the efficacy of pose estimation more effectively as it isolates and identifies the specific factors that affect the outcome of pose estimation. The solution to this blind spot is therefore to test the number of swings that can be successfully executed in five attempts out of five trials. A swing is considered successful when the right wrist surpasses the right shoulder or the left wrist surpasses the left shoulder and the pose estimation icon is triggered, indicating a shift in the index.

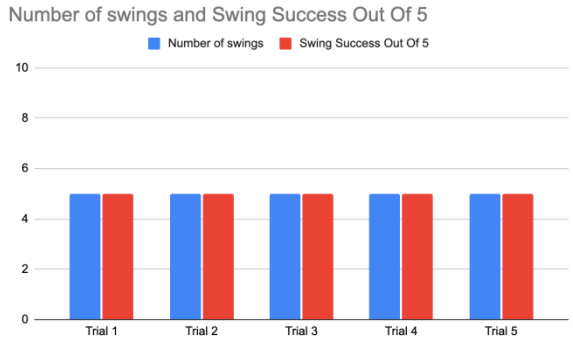

Figure 8. Figure of experiment 1

The graph above is a graphical visualization of the number of successfully executed swings versus the number of attempts. The blue columns represent the number of attempted swings, whereas the red columns represent the number of successful swings. The average number of successful swings is five, which is also the highest possible number that can be attained. This is not surprising because the pose estimation aspect is not designed to be difficult to use, which means getting all successful swings is very reasonable. Prior to the experiment, it is predetermined that the outcome will be highly favorable, given that extraneous variables exert minimal impact on the pose estimation. There are no negative results in this experiment; however, results may vary from person to person because players may not execute a swing with their left or right wrist that exceeds their left or right shoulder.

4.2. Experiment 2

Other than the efficacy of pose estimation, the functionality of the game is an important aspect in determining the physical interaction and its entertainment. The second experiment addresses this concern by surveying different individuals to see their opinions and comments on the game.

This experiment is different from the previous experiment, which involved surveying people who had experienced the COVID pandemic. It is because surveys can be designed to collect specific types of data or information that it is possible to tailor the questions to research interests and objectives. Twenty people were asked four questions: "How easy was it to play or score a point?" and “Imagine you are in quarantine. How effectively do you think this game will help you exercise?” and “Imagine if you had never played squash. How effective would this game be in enhancing your knowledge of the sport?” and “How effective does playing this game put you into a good mood?” on a linear scale of 1 to 5, with one being the least functional and five being the most functional.

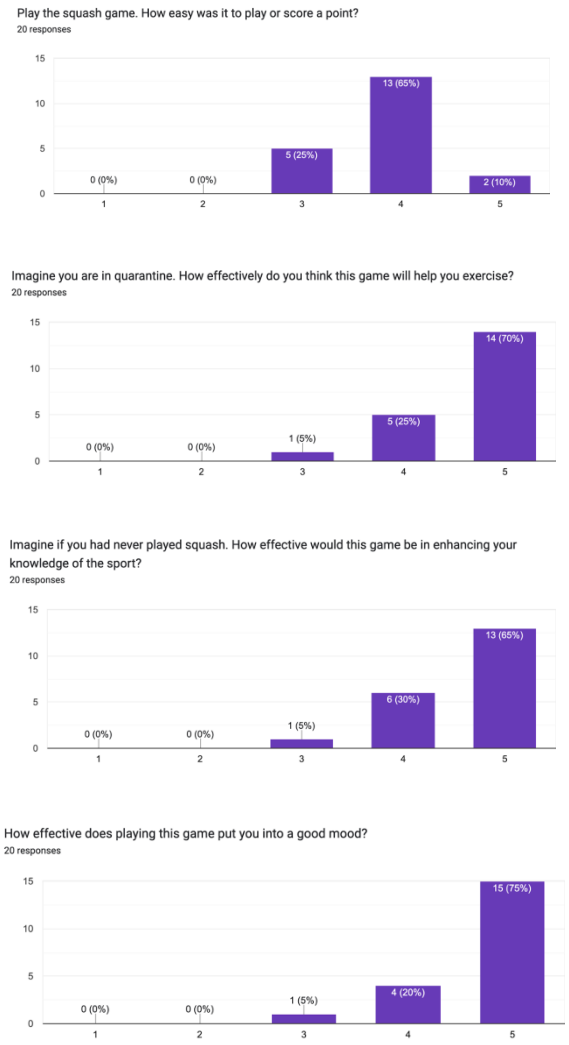

Figure 9. Figure of experiment 2

The graphs above are visualizations of the data collected through the survey. The numerical value displayed in the column shaded in purple denotes the count of responses, while the percentage value corresponds to the proportion of the count out of a total of 20. The first question has the lowest average, thereby signifying a considerable level of difficulty in the game. The median of the remaining three questions is 5, and they have a percentage greater than 50. This data was expected because the bot is designed to be highly precise, which increases the level of difficulty in the game. Moreover, the rules of squash are intact and implemented in the game, which makes the game more credible and legitimate. The respondent's age, the game's functionality, and the game's attractiveness would all have an impact on the outcomes. In addition, the wording of the survey questions may have influenced the way respondents interpret and answer them, leading to potential biases and inaccuracies in the results.

5. RELATED WORK

A Chinese researcher from the Chinese University of Hong Kong, Chan Chung-Shing, collaborated with his colleagues to design an online ecotourism scenario game that provides

students with field and real-world experience in the classroom [5]. They faced resource and geographical constraints that impeded an important aspect of knowledge about tourism planning; they therefore decided to apply game-based learning. The efficacy of the solution lies in its ability to generate diverse tourism development scenarios and forms, thereby facilitating classroom instruction to a significant extent. This is particularly beneficial given the geographical, temporal, and resource limitations that often impede field visits. However, the study evaluates the effectiveness of the game based only on the knowledge-attitude-usability dimensions. It is unclear whether the game has a long-term impact on learners' behavior and attitudes towards ecotourism. In contrast, the squash game that has been developed incorporates a bot that is capable of simulating a wide range of scenarios. This is achieved through its ability to adapt to various situations and respond in accordance with predefined rules.

Three Italian researchers, Ennio Bilancini, Leonardo Boncinelli, and Roberto Di Paolo, designed a curriculum to teach students about water conservation and sustainable water use through an interactive, game-based learning approach [6]. Students who took part in the game-based curriculum improved their comprehension of water conservation and sustainable water use practices, as well as their confidence in their capacity to follow these practices in their everyday lives. As a result, the method given in the article is helpful in encouraging young students to adopt sustainable water consumption. The answer, however, has a tiny sample size because the study was done on a small group of grade 4-6 pupils in a rural South African community. This restricts the findings' generalizability, and it's unclear if the game-based curriculum would work in other contexts or with various age groups. Furthermore, there was no long-term follow-up to see if the students recalled the knowledge and abilities they gained from the game-based curriculum. It is uncertain if the short-term improvements in sustainable water usage practices will result in long-term behavior change. The experiments with the squash game involved people from different age groups, which had a relatively large sample size.

Three Chinese researchers, Ching-Yi Chang, Min-Huey Chung, and Jie Chi Yang, designed an online game-based learning approach using the watch-summarize-question framework [11]. Based on the results of the quasi-experimental study outlined in the article, it appears that students who were taught using the game-based watch-summarize-question approach showed better knowledge retention and higher levels of engagement than those in the traditional course during the COVID-19 pandemic. Therefore, it can be inferred that the solution presented in the article is effective in helping nursing students develop skills and knowledge in a remote learning environment. However, the study involved a specific group of nursing students, and the results may not be generalizable to other populations or educational contexts. The squash game is also designed to be used in a remote learning environment because of the restrictions during the pandemic.

6. CONCLUSIONS

There are a few limitations to this application. Personalization is lacking in this application because it is primarily focused on squash [12]. It is not suited to a single individual's fitness objectives or needs. This implies that the game could not provide the amount of challenge or intensity that some individuals need to reach their fitness objectives. Furthermore, it may not be in line with an individual's interests or ambitions. A person who wishes to focus on strength training, for example, may not be able to locate a sports game that has the exercises or equipment they want. Because it does not have the same support as in-person fitness courses or events, the application also lacks a sense of social connection. The application can be improved by adding more sports games, which can improve customization and personalization. Regardless, the application can be made customizable. Players may specify their favorite routines depending on their fitness level, objectives, and preferences, which helps to customize the game. Options for

adjusting the intensity, length, or exercises in games might be included. Furthermore, social elements like leaderboards, challenges, or online communities can make the game more social and engaging [13].

The development of this project requires the consideration of numerous factors. However, given the limited time available, certain factors were overlooked in order to produce the most optimal content in the given time frame. Although this application may not be specifically advantageous for individuals seeking to engage in physical activity during the pandemic, it serves as an excellent means of promoting the sport of squash and facilitating consistent physical fitness.

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