Using an Augmented Reality Exercise Game to Improve Exercise Experiences

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Despite the well documented health benefits of regular physical activity, people struggle to incorporate exercise into daily life. Past work in Human-Computer Interaction (HCI) has shown that video games can be used to promote exercise and help people convert sedentary screen time into physical activity. In addition, augmented reality (AR) systems can increase task engagement and regular use of AR physical therapy systems can have significant health benefits. We conducted a within-participants experiment (n=10) to investigate how to combine video games and AR systems to improve exercise experiences and promote an active lifestyle. Participants performed squats exercises using our prototype AR game, and we measured effects of the system on engagement, enjoyment, and performance. While participants' interview responses showed a preference for the AR system, we found no statistically significant effect of the game on participant evaluations. Thus, we see that AR video games show promise for promoting exercise, but more work is needed to conclude how AR games can influence exercise experiences.

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1 INTRODUCTION

It is important for people to maintain a healthy and active lifestyle. Many experts in the area of healthcare agree that regular exercise has positive health benefits [2, 12, 13, 18, 19]. For example, regular physical activity can improve cardiovascular fitness [2] and build muscle [19]. Exercise also has positive effects on mental health [12, 13, 18]. Regular exercise has been shown to reduce anxiety levels and can be used to treat symptoms of mild depression [12, 18]. Thus, the health benefits of regular exercise are clear.

Despite the well documented health benefits of exercise, it can be difficult for people to find motivation to exercise regularly [1]. One obstacle to the development of healthy exercise habits is that people who do exercise regularly may choose to quit if the benefits of exercise are not seen immediately [1]. In addition, people may create personal goals that are difficult to achieve in a short time frame, which can negatively impact satisfaction with the exercises [1]. Some research has investigated the use of extrinsic motivations= to promote regular exercise. For example, providing financial incentives to exercise regularly can help people develop exercise habits that continue even after the payments stop [7]. These results suggest that providing people with extrinsic motivation to exercise can help them overcome obstacles and live a more active life.

There is evidence that video games can provide the extrinsic motivation needed to build and maintain healthy exercise habits [6, 9, 16]. In a past HCI study, participants found exercise games developed for the Microsoft Kinect fun to play and easy to learn [9]. Researchers have also found that engaging in supervised exercise video games can lead to greater uptake and maintenance of physical activity compared to standard exercise such as treadmills and stationary bicycles [6]. Active video games such as Wii Sports can be used in a person's daily life to convert sedentary screen time into exercise sessions, and can induce energy expenditure consistent with moderate

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Fig. 1. Snapshot of a user exercising with our AR game.

physical activity when played as intended [16]. These findings highlight how video games can be used to improve exercise experiences and promote a healthy lifestyle.

There is also a small body of work showing that augmented reality (AR) systems can increase task engagement [15] and AR software can be used to implement effective physical therapy programs [10, 22]. Recent work in HCI showed that gamified AR systems can boost performance and increase engagement in users training for an industrial task [15]. In addition, regular use of the exercise game Otago was shown to increase balance, gait, and falls efficacy in elderly women [22]. Similarly, elderly women who used the AR exercise system UINCARE-HEALTH were able to significantly increase their performance across a variety of measures, including the Senior Fitness Test [10]. Thus, we find evidence to suggest that combining video games and AR technologies could be an effective technique for motivating people to engage in more physical activity in their daily lives.

In our work, we investigate how an AR video game can improve exercise experiences and consequently encourage people to exercise more often. We followed guidelines from the games literature to implement a prototype AR exercise game, and we designed and conducted a within-participants study (n=10) to evaluate participants' experiences exercising with and without our prototype game. Our initial findings contribute to an understanding of how to design effective AR exercise games.

2 RELATED WORK

There is a large body of work on exercise video games and the various techniques that can be employed to motivate people to exercise. Smeddinck *et al.* [17] found that exercise games that link in-game rewards to real-world exercise can increase exercise performance. For example, a sedentary game that uses data from a player's smartwatch (such as step count or acceleration) to boost the capabilities of the player's in-game avatar. Relatedly, Niforatos *et al.* [4] developed the mobile exercise game Goalkeeper, in which groups of peers set up exercise challenges and deposit fixed amounts of money into a collective pool. If a player fails to complete the challenge, Goalkeeper redistributes their deposit to the players who did complete the challenge. This strategy of linking exercise to real-world financial risk was shown to induce a loss-aversion bias and increase exercise motivation. In addition, Yansun *et al.* [20] created CoXercise, a social role-playing exercise game in which movement of the players in the real world is reflected in the game world. Participants reported increased enjoyment with the multi-player game, compared to an equivalent single-player game. These past works highlight the broadness and diversity of exercise games research and the ways in which future games like ours can motivate people to exercise.

Other work in the games literature has aimed to review and organize the findings on exercise video games. Yim and Graham [21] evaluated the properties of exercise games that help motivate people to start and maintain physical activity in daily routines, with the goal of deriving a set of requirements for exercise video games. Based on an extensive literature review, the researchers identified six requirements: integrate music, provide guidance for novice players, provide achievable goals, hide players' fitness levels, avoid restrictive mechanics that limit who social interactions amongst players, and assist players in forming social groups. More recently, Mouatt *et al.* [14] conducted a literature review on the use of virtual reality (VR) to improve exercise experiences. Two prominent VR strategies emerged: the use of immersion and the use of virtual avatars and trainers. In general, highly immersive VR has more beneficial effects than low-immersion or non-VR games. Further, there is a connection between specific game techniques (for example, the level of immersion or the use of a virtual avatar) and measurable outcomes such as enjoyment and engagement. These past literature reviews can help guide the design of our own AR exercise game.

There is a growing body of work investigating the use of AR to aid in exercise-like activities such as physical therapy. Regular use of the AR exercise systems Otago [22] and UINCARE-HEALTH [10] were both shown to have significant health benefits for older women. These results show that AR exercise systems can be used to guide people through movement routines, with the potential to supplement or replace in-person exercise programs. In addition, Anderson *et al.* [3] designed and implemented YouMove, an interactive AR mirror that allows users to record and learn movement sequences. Compared to learning movements from videos, participants who trained with YouMove showed improved learning and higher retention in tests. These findings hint at the potential for an AR system to engage users in exercise scenarios. There is also evidence that an AR system can increase exercise effort compared to controller-based games. Controller-free systems such as the XBox Kinect or an AR interface can induce higher physical activity because experienced players may learn to cheat the controller and play controller-based games without performing any physical activity [16]. Thus, we see that the potential usefulness of an AR exercise game to promote physical activity is clear.

In summary, the related work suggests that exploring how to combine video games and AR systems could yield valuable insights into how to motivate people to exercise. We designed and implemented a prototype AR exercise game for the Microsoft Holo Lens 2 based on the related work. To our knowledge, no other published work has directly investigated how to design an AR exercise game for the Holo Lens 2. We add to the existing literature on exercise video games and AR exercise games by conducting a within-participants experiment to investigate how our AR exercise game can improve exercise experiences and consequently encourage more physical activity in a person's daily life.

3 HYPOTHESES

In this preliminary work, we aim to investigate the research question of how an AR video game can be used to improve exercise experiences. Given the past work on using games to motivate people to exercise, we evaluate the AR system on specific and measurable criteria using the following hypotheses:

- **H1:** Using the AR exercise game will increase participants' reported engagement.
- **H2:** Using the AR exercise game will increase participants' reported enjoyment.
- **H3:** Using the AR exercise game will increase participants' performance.

4 SYSTEM DESIGN

Fig. 2. UI design of our system, as seen from the user's perspective.

We designed and implemented an exercise video game for the Microsoft Holo Lens 2 platform. To render and position the interface, users scanned a QR code that was printed onto a sheet of paper. The score counter was controlled using the Wizard-of-Oz technique, in which the experimenter used a wireless keyboard to increment the in-game score each time the participant completed a proper squat.

4.1 User Interface and Game Mechanics

We considered features that would make users more engaged and perform better. Figure 2 shows the user interface (UI) from a users' point-of-view. We added the Reps Counter feature to display the number of exercise repetitions the user has completed in the current set. In addition, we added the Star Rating feature to introduce smaller achievable milestones into the exercise routine, as recommended by Yim and Graham [21]. Users must perform a predetermined number of repetitions (roughly calibrated based on the number of squats the researchers were able achieve in one minute) to gather stars. For example, users collect the first star for completing 5 total repetitions, the second star for completing 15 total repetitions, and so on. In addition, because the number of repetitions required to collect each star is not always equal (it becomes increasingly difficult to perform more repetitions as the exercise set progresses), we saw that users may be confused about when they would reach the next star milestone. To solve this problem, we added the circular Progress Indicator feature. With each repetition the user performs, a percentage of the green Progress Indicator fills up to signal progress toward the next milestone. Finally, we added a Motivational Text feature to display encouraging messages throughout the exercise. As the user completes squats, the Motivational Text at the top of the UI changes to give a sense of support. The messages were coded so that users always saw the same text in the same order. This feature is in line with the work of Asimakopoulos *et al.* [5] which highlights the importance of providing users with motivational feedback based on findings from a four-week diary study.

4.2 Limitations of the Prototype System

Due to limited time and resources, we were not able to implement an autonomous system as envisioned. While our prototype implementation uses the Wizard-of-Oz technique to increment the Reps Counter, we conceived of a system that tracks a user's posture to measure the number of repetitions they perform and evaluate their overall form. The imagined system would achieve this by using the Holo Lens camera and a standard full-length mirror. From the reflected image of the user, the Holo Lens could use pose estimation to capture and evaluate the user's movements. This system would be powered by a machine learning model that capable of determining the user has completed a repetition of their chosen exercise. The system could use this data to increment the Reps Counter and display appropriate feedback to the user. Thus, we chose to use a full-length mirror in our experiment with the prototype exercise game to reflect the experience of using the AR system as envisioned.

5 METHOD

We designed and conducted a within-participants experiment to investigate if an AR video game can increase engagement with an exercise task. We chose a within-participants design to increase exposure to the AR game.

5.1 Experimental Design

We conducted a within-participants experiment in which participants were asked to perform squats in front of a mirror. Participants were told to stand with feet about shoulder-width apart, and to bend the knees to a 90-degree angle while keeping the feet firmly on the ground and the shoulders back. We chose the squats exercise because they are easy to count and require no specialized equipment. Throughout the study, participants performed four one-minute exercise sets in which they were instructed to perform as many proper squats as possible. After each exercise set, participants took a one-minute break. The experiment had one independent variable, which was the use of the AR exercise game. Our two experimental conditions were *AR* and *No AR*. In the *AR* condition, participants performed the exercise task using the AR game. In the *No AR* condition, participants were told to perform as many squats as possible for one minute, and to replicate the experience of exercising individually, participants were not given additional information such as number of squats performed. Participants were not shown the amount of time remaining in the session in any condition to avoid confounding effects of showing the time visually in the in-game interface in the *AR* condition compared to verbally in the *No AR* condition. Between conditions, participants were asked to take a longer five-minute break to recover. To counterbalance ordering effects, participants were randomly divided into two groups: one group was exposed to the *AR* condition first, while the other was exposed to the *No AR* condition first. The experiment flow is shown in Figure 3.

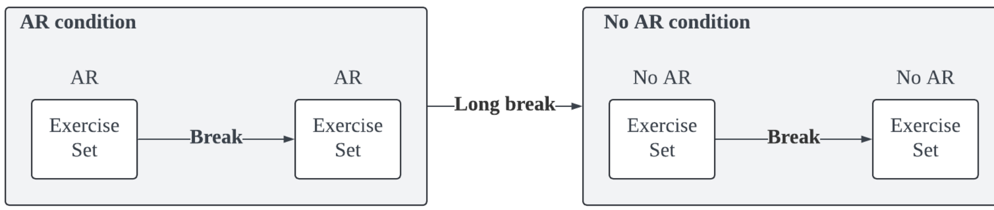


Fig. 3. Example flow of the experiment in which participants are exposed to the AR condition first. Exercise sets lasted one minute, breaks lasted one minute, and long breaks lasted five minutes.

5.2 Experimental Procedure

Participants were welcomed into a large room with the body-length mirror propped against a wall, and were asked review and fill out the consent form, along with a pre-experiment questionnaire to collect demographic data. Participants were told they would be comparing exercise with an AR game to exercising without the game. Participants were told the exercise would be squats and observed as the experimented explained and demonstrated the proper technique. Participants were then asked to perform a proper squat to verify their understanding of the task. Participants were told the flow of the experiment and the length of each exercise set and break. The experimenter then guided participants through the exercises. In the first condition, participants performed two one-minute exercise sets and took a one-minute break between the sets. Participants then took a longer five-minute break and filled out a post-condition questionnaire to evaluate their experience of the physical activity. In the second condition, participants again performed two one-minute exercise sets with a one-minute break in between. Participants were given another five-minute break and filled out the post-condition questionnaire a second time. After the exercise, the experimenter conducted a semi-structured interview to evaluate the participants' perceptions of their experience and how they found exercising with the AR game compared to exercising without.

5.3 Participants

We recruited 10 students from the University of Waterloo using convenience sampling. The average age of participants was 26.4 (SD = 4.38), with 5 male and 5 female participants. Participants varied in prior experience using AR or VR technologies (80% used an AR or VR headset at least once) and regularity of use in the past 12 months (10% more than once a week, 40% a few times, 50% no use at all). No participants reported having a preexisting health condition which would prevent them from completing the exercise sessions. Participation in the study was voluntary and participants did not receive remuneration.

5.4 Measurements

Pre-experiment, participants filled out a survey to record demographics such as age, gender, and prior experience using VR or AR systems. We also administered the 36-item Affective Exercise Experiences Questionnaire (AFFEXX) [8] to measure participants' preexisting attitudes towards exercise. During the one-minute exercise sets, we counted the number of complete squats (bending the knees to a 90-degree angle and returning to a standing position) participants performed. After each condition, we asked participants to rate their experience using the Physical Activity Enjoyment Scale (PACES) [11] in the post-condition questionnaire. Finally, we conducted a semi-structured interview to evaluate the participants' engagement and enjoyment during the sessions, and their perceptions of the AR game.

6 RESULTS

6.1 Quantitative Analysis

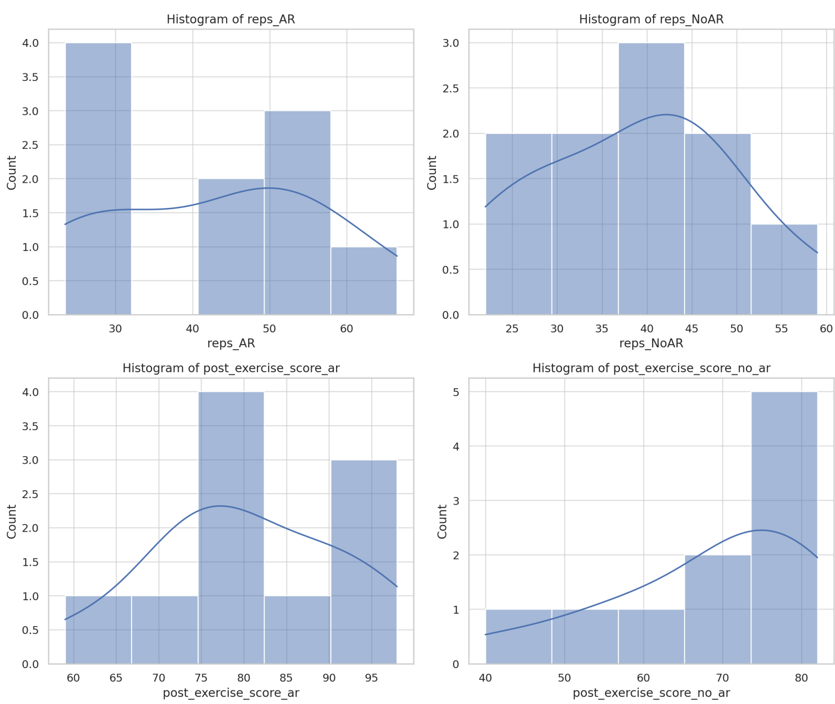


Fig. 4. Histogram showing data distribution overlaid with a kernel density estimator.

We performed repeated measures ANOVAs to investigate the effects of the use of the AR game on participants' performance, enjoyment, and engagement. We used the mean number of squats participants performed in each condition to evaluate performance, with a higher number of squats showing higher performance. To measure enjoyment and engagement, we used the participants' scores in the PACES questionnaire, with higher scores indicating higher levels of enjoyment and engagement. Thus, our analysis had one independent variable (the use of the AR game, with the two factors *AR* and *No AR)* and two dependent variables: the mean number of squats participants performed in each condition and the PACES scores.

6.1.1 Verifying Data Normality. To assess the normality of the data, we conducted a visual test by plotting the data points in the form of histograms with a kernel density estimate overlay to give a smoother estimate of the data distribution (see Figure 4). We additionally validated the normality of the data using the Shapiro-Wilk test. Our analysis shows a p-value greater than 0.05 for all quantitative measurements (see Table 1), confirming a normal distribution. Thus, we were able to safely assume a normal distribution of our data throughout the analysis.

	AR	*No AR*
Mean number of squats performed	p = 0.48	p = 0.78
PACES score	p = 0.80	p = 0.17

Table 1. Shapiro-Wilk test p-values confirm a normal distribution of our data.

6.1.2 Engagement, Enjoyment, and Performance. We used the SPSS Statistics software to perform repeated measures ANOVAs on the participants' PACES scores and the mean number of squats performed to examine the effects of the two conditions (*AR* and *No AR*) on participants' engagement, enjoyment, and performance. In addition, we considered four covariates from participants' responses to the AFFEXX questionnaire: Interest, Pleasure, Competence, and Energy. No significant effects of AFFEXX scores on the dependent variables were found (p >0.03 for all four covariates). Further, we found no significant difference between PACES scores (see Figure 5) for participants in the *AR* condition compared to the *No AR* condition (p = 0.054). Similarly, we found no significant difference in mean number of squats (see Figure 6) performed by participants in the *AR* condition compared to the *No AR* condition (p = 0.068).

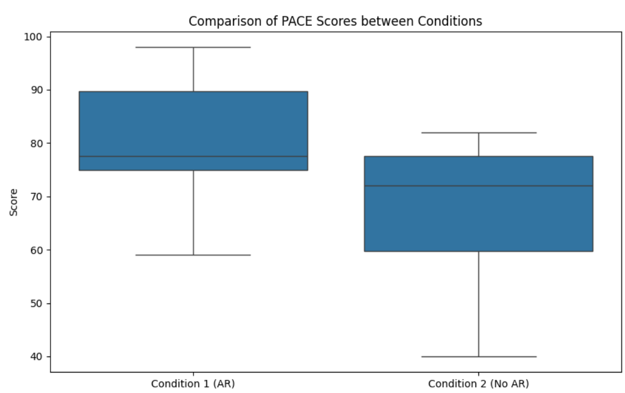
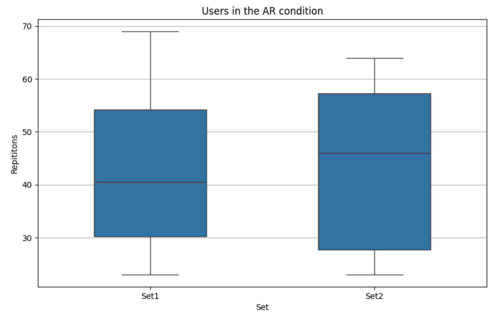


Fig. 5. There was no significant difference in the PACES scores of participants in the *AR* condition compared to the *No AR* condition.

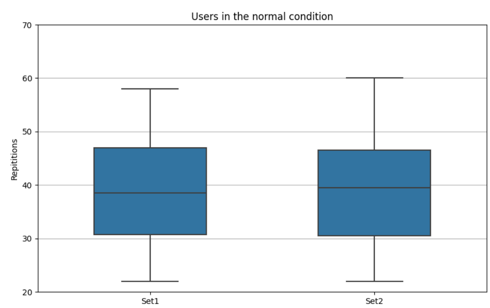
6.2 Qualitative Analysis

Participants' answers to the interview questions were analyzed using a thematic coding approach, and all the categories were developed inductively based on the transcript data collected. Participants' responses were then classified to fall into one or more of the following categories: Engaging Elements, Motivating Features, Pain Points, and Feature Suggestions.

6.2.1 Engaging Elements. In response to the interview question "Did you find exercising with the AR game more engaging than exercising without the game", 8/10 participants explicitly stated that they found the AR game more engaging. In general, the statement "I feel like it's a lot more fun to have something visual to look at" (P5) summarizes feelings about how the game can increase engagement. In addition, 10/10 participants stated that having a visual representation of their progress to watch kept them engaged with the activity, even if they did not find it more engaging than exercising without the AR game.



(a) Figure 1



(b) Figure 2

Fig. 6. There was no significant difference in the number of squats per set performed by participants in the *AR* condition (a) compared to the *No AR* condition (b).

6.2.2 *Motivating Features.* Participants reported the Star Rating feature strongly motivated them to work harder and perform better in the exercise tasks. In general, the statement "I was able to see my target in terms of reps counted and then the rating, so I have the motivation to do more, to beat my target" (P1) represented attitudes toward the motivational aspects of the game. 10/10 participants referred to the motivational capabilities of the main game mechanic which included the Star Rating, Progress Indicator, and Reps Counter features. 3/10 reported that seeing the Reps Counter inspired them to beat a target number of squats, while 7/10 participants reported the Star Rating and Progress Indicator pushed them to work harder, with one participant commenting "I wanted to see three stars to feel accomplishment at the end of each session" (P2). Compared to tracking number of squats mentally without the AR game, participants tended to find using the game more pleasant. Some participants found self-counting less desirable because it increased their cognitive workload (3/10 participants) or was perceived as less accurate than the AR game (2/10 participants). Surprisingly, 1/10 participants stated they would rather count the number of squats themselves.

6.2.3 *Pain Points.* In addition to the positive feedback on engagement and motivation, participants found numerous problems while using the AR game. Participants found the UI was positioned too high for them to comfortably see the entire screen in their field of vision, with 5/10 participants (4 women and 1 man) making comments similar to "The panel was up [very] high, so I could barely see the words" (P4). Relatedly, participants struggled to read or failed to notice the Motivational Text feature: 5/10 participants chose to ignore or could not clearly read the text, 2/10 participants explicitly stated they were not aware of the text at all, and 2/10 participants did not mention the Motivating Text at any point during the interview. This comment "I didn't even notice there was an encouraging message there. So I guess I ignored that feature" (P3) tends to summarize experiences with the Motivational Text. In contrast, only 1 participant (1 woman) found the text helpful and stated that "the sentences were pushing me through" (P9). Further, some participants found the Holo Lens cumbersome or otherwise uncomfortable to wear. 1/10 participants (1 man) reported the Holo Lens was heavy and uncomfortable, 1/10 participants (1 woman) stated the device restricted their movement, and 3/10 participants noted the Holo Lens was not comfortable to use with eyeglasses.

6.2.4 Feature Suggestions. Participants offered many ideas on how to improve the system. To help solve problems with the Motivational Text feature, 1/10 participants explicitly suggested we replace the text with audio. Relatedly, 1/10 participants suggested adding music, which is in line with Yim and Graham's stipulation that exercise games should use music [21]. Participants also noticed the simplistic design and mechanics of the system (3/10 participants wished to add more gamification and make the system more game-like) and suggested ways to increase the gamification and add game-like elements. Features to increase gamification could include virtual avatars or coaches (3/10 participants suggested this feature) which is a popular technique in VR exercise games [14]. Participants also suggested we display the time remaining in the exercise session (2/10).

7 DISCUSSION

We found qualitative evidence to support our hypotheses **H1** and **H2** which predicted that the use of an AR exercise game could increase engagement and enjoyment in an exercise scenario, respectively. Participants reported the visualization of their progress in the AR game was engaging, and 8/10 participants explicitly stated exercising with the AR game was more engaging than exercising without. Participants also tended to find the Star Rating and Reps Counter features highly motivating, and tended to agree it was more pleasant to exercise when the AR game tracked their progress for them. However, our quantitative findings did not support **H1**, **H2**, or **H3**. We found no significant effect of our conditions *AR* and *No AR* on the PACES scores or number of squats performed in each set. While these results do not support the hypotheses, analysis of the PACES scores found a p-value of 0.054, which is close to statistical significance. These findings hint at the existence of a significant effect of the conditions *AR* and *No AR* on PACES scores, which would support **H1** and **H2**.

In addition, participants identified many pain points in the experience of using the game and provided helpful ideas for new features. Both male and female participants of varying heights reported the UI was too high to view comfortably, demonstrating that participant height did not contribute to this problem. Relatedly, the majority of participants found the Motivational Text feature too difficult to read while exercising or did not even notice the feature because it was positioned outside their field of view. These findings suggest that AR games should place important elements within the comfortable field of view because elements falling outside this zone may not be noticed at all. Further, some participants found the Holo Lens burdensome or uncomfortable to wear while exercising. This feedback speaks to the limitations of the Holo Lens device, and shows a need for lightweight and comfortable AR wearables in order to create popular mainstream AR exercise systems.

8 FUTURE WORK

The interview evaluation revealed many pain points and potential improvements for our prototype AR game. More work is needed to analyze and implement these ideas. Given our initial findings, we recommend taking the following steps to improve the AR game before proceeding with further user studies: calibrate the position of the UI so that it is easily observable in the user's field of vision, add more gamification and game-like elements, and replace the Motivational Text feature with motivating audio bytes and music. Further, we recommend re-conducting the study with a revised AR system and a larger number of participants. Given how close our statistical analysis came to showing a significant effect of conditions *VR* and *No VR* on PACES scores ($p = 0.054$), it is likely that increasing the number of participants could reveal significant effects of the AR game on the dependent variables (engagement and enjoyment as measured by the PACES questionnaire, and potentially performance too), especially if the pain points discovered in this work are addressed beforehand.

9 CONCLUSION

We designed and implemented a prototype AR exercise game for the Microsoft Holo Lens 2 system. We used the prototype in a within-participants user study (n=10) to explore how an AR game could improve exercise experiences for participants. Participants evaluated the system by performing squats exercises with and without the AR game. During the experiment, we measured participant engagement, enjoyment, and performance. Our qualitative interview results show participants tended to find the AR game more engaging, motivating, and enjoyable compared to exercising without the game. However, these findings are not supported by our quantitative analysis which did not show a significant effect of experimental conditions *AR* and *No AR* on PACES scores or participant performance. Thus, our preliminary results provide guidelines for improving our prototype AR game and hint at the possibility that AR games can improve exercise experiences. Due to our overly simplistic prototype and low number of participants, more work is needed to provide conclusive evidence that AR games can or cannot be used to promote regular exercise and a healthy, active lifestyle.

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