cARd: a Mixed Reality Approach for Total Immersive Analog Game Experience

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Abstract. The rapid development of mixed reality technology has made an enhanced analog game environment that combines physical and digital realms possible. We explore the next generation of game (i.e., board and card games) experiences that improves player experience with the combination of a traditional analog game with mixed reality technology. First, an existing analog game is transferred into a virtual environment that enhanced the gameplay with an animated model, visual effects, and sound effects. Second, multi-player interaction is implemented to allow collaborative play in virtual environments even when players are isolated from each other physically. Third, an experiment is conducted to compare the VR environment with the original analog game and a survey is collected from users. The result shows that the immersive virtual reality environment can improve player experience compared to traditional analog games. *cARd* is the resulting collaborative mixed reality version of the game that combines the strength of traditional analog games with VR experiences. This mixed reality approach aims to provide an enhanced analog game experience while still keeping the benefits of the traditional analog game such as tangible objects and social interaction.

Keywords: mixed reality, analog games, connected VR, augmented reality, extended reality

Website: for videos and demos see the project website at https://exploratorydesign2020.wordpress.com/card/

1 Introduction

Traditional analog games contain rich face-to-face interaction between players and real game pieces that can be interacted with. However, digital games can present richer audio and visual support (Magerkurth, Memisoglu, Engelke, & Streitz, 2004). In the past decades, several studies have tried to combine the benefits of traditional analog games with digital games by making hybrid games, which combine the digital display experience with traditional analog games elements, such as social interaction and tangible game pieces. It has been shown that, generally, these kinds of hybrid games could provide a better game experience (Wallace et al., 2012; Mandryk & Maranan, 2002; Magerkurth, Cheok, Mandryk, & Nilsen, 2005).

Due to technology limitations, these previous studies used traditional screen displays to provide digital content. The problem of such a traditional screen display is that it often takes an additional set up to merge the tangible objects with the digital content. For instance, the STARS platform consists of a dedicated hardware setup of devices such as public vertical displays and personal digital assistants (PDAs) centered on a smart interactive table (Magerkurth et al., 2004). It makes these hybrid experiences harder to access by the public and the games provided are also limited by the devices.

Virtual Reality (VR) has been rapidly growing and has drawn worldwide attention in recent years. Compared to the flat-screen display, the benefit of the VR environment is that it creates a completely immersive 3D experience. However, current interaction with the VR headset still relies on voice commands, gaze, or a direct physical controller which might create an inconsistency between the digital content and the interactions user attempt in the virtual world. This inconsistency is often because of the difference between the actual and expected motion. For instance, current moving actions in common VR games often use the controller. It will bring inconsistency since the brain processes this action as moving because it recognizes the dynamic change of the position, but the players did not actually move their leg in the real world. This kind of inconsistency causes the problem of motion sickness (Chung et al., 2007), which symptoms include nausea, vomiting, and headache. As a result, using a consistent input system in a VR environment is essential to provide a better user experience.

A previous study has tried to combine the hand tracking technology with a VR headset in a puzzle game to solve the problem (Lee, Wang, Tung, Lin, & Valstar, 2015). This kind of interface allows players to actually move the virtual puzzle pieces with the hands rather than using a controller to select and place. But the problem is that the player will lose the sense of holding and moving the object. This project extended the hand tracking interaction by integrating an augmented reality (AR) camera with the current VR headset so that it allows tangible interaction in the virtual reality environment.

Here, we introduce a mixed reality game called *cARd* that integrates the virtual reality environment with a traditional analog game. It allow players to play traditional analog game remotely with an enhanced visual and audio experience without much additional set up. Previous studies have shown how digital content

improves the general experience in board games (Wallace et al., 2012; Huynh, Raveendran, Xu, Spreen, & MacIntyre, 2009). In this game, the digital content is enhanced with a VR display instead of a flat-screen display. We use real cards as input by adding an AR camera on the top of the current VR headset. The tangible interaction could potentially increase the game experience (Rogerson, Gibbs, & Smith, 2016) and minimize the impact of motion sickness. First, an experiment is used to validate what contributes to the player experience in traditional analog games on the one hand and VR games on the other. The experiment will specifically focus on general experience, social interaction, and tangible object interaction. Second, details on implementation of *cARd* in a connected mixed reality environment are given.

2 Background

This section will give an overview of current virtual reality (VR) headsets, tangible objects in analog, and hybrid games. The first part introduces the current problems in VR. The second part shows why tangible object interaction could be a potential solution. The last part discusses the benefits of hybrid games.

2.1 Virtual Reality

Virtual reality (VR) generally refers to a medium, including motion-sensing gloves, computers, and head-mounted display (Steuer, 1992). In recent years, it generally narrowed its definition to the total immersive head-mounted devices and its related input system rather than the traditional 2D screen display with keyboard and mouse input. VR technologies have seen major, rapid development in the recent ten years. Computer technology, especially small and powerful mobile technologies, have exploded while prices are constantly driven down. The rise of smartphones with high-density displays and 3D graphics capabilities has enabled a generation of lightweight and practical VR devices. Besides, with the increase of computation power of graphic cards and CPU, the head-mounted headset has also been able to meet the requirement of rendering high-quality 3D environment in real-time.

Nevertheless, the input system of the current VR headset is still not unified. Depth sensing cameras, sensor suites, motion controllers all have been tried as the input resources. All these attempts are to provide the user with a consistent immersive experience. The video games industry, as one of the main use cases of this technology, has always sought an affordable simplified solution to this problem. Previous research has explored how physically touching virtual objects enhances people's general experience in VR worlds (Hoffman, 1998). A recently released VR headset has already integrated the camera on the headset which can capture human body movement. So making use of those cameras to capture objects' movements, and creating a corresponding interactive virtual environment might be a potential solution to this problem.

2.2 Tangible Objects in Analog Games

Analog games have been around for thousands of years. From the ancient GO game to modern thousands of different analog games, tangible game pieces haven always been an essential part of analog games. Those specially made game pieces are often representing real-world objects. Such representation gives these small pieces value that contributes significantly to the game experience (Rogerson et al., 2016). In addition, a previous study has addressed the material practices associated with analog games, highlighting the important role that the material plays in those games, in the context of an analog game called Warhammer 40,000! (Carter, Harrop, & Gibbs, 2014). Based on that, bringing those real game pieces into VR could potentially improve the general game experience. In addition, using tangible objects as the input of the VR system will provide the user with a more realistic experience since what they see matches what they feel.

2.3 Hybrid Games

Modern analog games often contain face-to-face interaction and physical pieces while digital games provide more possibilities in in-game formats and content with a better visual and audio presentation. Previous studies have made multiple attempts to combine the benefits by creating hybrid games. For example, *The STARS Platform* introduced an augmented tabletop games platform that allows people to play tangible objects on a digital table (Magerkurth et al., 2004). Some researchers also explored how social interaction in games influenced the experience of hybrid games (Xu, Barba, Radu, Gandy, & MacIntyre, 2011; Mandryk & Maranan, 2002). Others focused on considering the influence of tangible pieces in hybrid games (Ulbricht & Schmalstieg, 2003). However, most previous works are limited by combining a 2D display with a traditional analog game. In recent years, there are studies trying to create some hybrid format game by using augmented reality and virtual reality headsets (Bedoya-Rodriguez, Gomez-Urbano, Uribe-Quevedoy, & Quintero, 2014; Lee et al., 2015). The benefits of integrating a mixed reality device into a hybrid game are that it is much easier to set up at home compared to previous hybrid systems because it only requires a mobile device or VR headset.

3 Methodology

This section discussed the process of exploring the tangible interaction in a mixed reality environment. It includes (1) the development and design of the game, (2) the experiment set up, and (3) the survey protocol and how the survey results were analyzed.

3.1 The Game

In this section, we illustrate (1) how the analog game works, and (2) the development process of the game. The memory game called *Concentration* starts

with a set of unrevealed cards. Each players can flip two cards at their turn and players will play in turn in the same physical space. If those two cards front pattern matches, the player who flips it will win the pair, and if not the players need to flip the cards back.

The Gameplay To better investigate the impact of tangible interaction, in the traditional analog game set up, we refined the game by adding some real game pieces to represent the cards player wins. There are in total four types of cards in the game and they are represented by four different types of game pieces. To make the game more intuitive, those pieces are divided into three different levels so when players successfully flipped the same kind of card multiple times, they can replace their low-level pieces with high-level pieces.

In the VR environment, the card front is replaced, and the game pieces in the real world set up are replaced with different animated 3D models. Visuals and sound effects are also applied to enhance the immersive experience. There are two scenes in this game. This first scene is for players to enter their nickname and launch the game, while the second scene is the playground. A virtual reality environment is used to enhance the analog game experience instead of recreating a completely new game, because we wanted players to still keep the sense of real-world in the virtual reality environment. In another word, players should feel that they are still in the real world even as the surrounding environment is morphed. Thus in the virtual environment, we put a stone table in the middle and the players will gather around the table.

To make sure the transition is smooth, the launching scene starts with the camera view of the real world, and players need to scan a QR code on the table to start the game. For demo purposes, the player can also start the game with the controller. After the player hits connect, there will a digital beep sound and digital matrix particle effects appear to indicate the transition from real-world to the virtual environment. In the game scene, the players can flip cards with the controller. If they successfully flipped the right cards, the player will get marks on their scoreboard and the relative monster model will spawn besides the player. One player takes turn after another in a digitally connected emobodied setup.

Development The VR implementation of the game has two essential parts. The first part is the visual effect, and the second part is the network connection. In the first part, we used available 3D models (Unity Asset Store) and made idle animation for each of them in Unity. The models I used are from a popular anime called Digimon; those models match the theme since the story of it is about the integration of the digital world and the real world. There are four types of cards in the game so we used four different first-level Digimon models to represent a different types of cards. 8 additional models represent the second level and third level Digimons. Besides those animated models, we added special visual effects with the particle system in Unity. Figure 1 shows the game start effect which indicates the transition from the real world to the virtual environment. Figure 2 is the particle effect when players got their Digimon leveled up.

Fig. 1. Transition Effect

Fig. 2. The Digimon Level Up VFX

The other essential part of this game is networking. The Photon Unity Networking (PUN) serves as the game server. The Photon Cloud provides the server service which allows players to create or join game rooms. When players clicked

connection, the server will search to join a game room or create a game room if there is no existing one online. When the player joins a room, they will see their nickname displayed behind them and the game will start when there are two players in a room. In the game scene, all the actions, particle effect, and animation should be synchronized to both players. To achieve this, all the game objects in the scene were assigned to a script called photon view. The script will give each object a unique id, the objects' position, rotation, scale, and animation will be synchronized if they have the same id. Thus multiple players can interact in the same digital space even when they are in different places in the world.

3.2 Experiment

In the experiment, all the participants are required to play two versions of this game. They need to choose another participant as their opponent first then they will play the analog game in both the traditional manner and VR environment. In the traditional manner, the participants play face-to-face with the real cards and game pieces while in the VR environment they played with the VR headset and controller. The rules and the game itself is completely the same in both environments. Also, in both environments, the participants are playing in the same room so they can talk to each other during the game. There are in total 6 participants who participated in this experiment. All results are collected anonymously.

3.3 Survey

After the game session, all the participants are asked to fill out a survey that is designed to measure their game experience. The survey is divided into three part. The first part ask questions about the traditional analog game while second part is similar questions about the VR version of the game, and the third part is demographics. The questions of the first two part include (1) the general player experience of traditional version (10 Likert scale questions) and the VR version (10 Likert scale questions), (2) the level of social engagement in traditional version (5 Likert scale questions) and VR version (5 Likert scale questions), (3) whether they like the tangible interaction in the traditional environment (3 Likert scale questions) and if they want to keep it in VR environment (3 Likert scale questions), and (4) open questions for pros and cons about this game (5 open questions).

We used the Vanden Abeele et al.'s (Vanden Abeele, Spiel, Nacke, Johnson, & Gerling, 2019) Likert scale questionnaire to measure player experience. The original questionnaire has thirty questions divided into 10 different themes. One question is used from each theme. All of them are 7-point Likert scale questions asking about aesthetics, immersion, controlling, and learning of the game. In the second part, in total five 7-point Likert scale questions are used to ask about the interaction and social persistence during the game session. This part was taken from the social engagement section from Down's video game experience survey (Downs, Vetere, Howard, & Loughnan, 2013). Originally there are in

total 7 questions in the section but two about teamwork which is not applicable in this game are removed. In the third part, we developed three 7-point Likert scale questions about whether players like the tangible interaction (traditional version) and whether they miss the tangible interaction (VR version). The last part contains 4 open questions asking about the pros and cons of traditional manner and VR version and one question asking what do they miss in VR game compared to the traditional game.

4 Results

In this section, we discuss the results of the survey, which has four different sections. The first three sections report the results from the 7-point Likert scale questionnaires about general player experiences, tangible interaction, and social engagement during the game. For all these items, participants can choose from 1 to 7 to indicate their attitude toward the question with 1 representing strongly disagree and 7 representing strongly agree. The last section discusses the two open questions that explore what players like and dislike about playing this game in the two different environments.

4.1 Summary Analysis

The overall result shows that the players have a better general experience in a VR environment. The general play experience got a median score of 5.10 (SD = 1.95) while the traditional analog game environment got 4.37 (SD = 1.81) for an average score. In terms of social engagement, the traditional analog game environment shows clearly surpasses the virtual reality environment with an average score of 5.00 (SD = 1.5) while in VR it is 3.50 (SD = 1.5). This data indicates that even when the players play in the same room, the traditional face-to-face analog game still leads players to have more social interaction. The result of tangible interaction is unexpected; most players hold a neutral attitude towards the tangible interaction in the traditional analog game set up. The reason behind that might be that for this specific game the tangible interaction is not interesting enough and the game pieces we used do not match the player's expectation. The average score of whether they enjoy tangible interaction is only reported to be 4.10 (SD = 1.88), which indicates that players are holding a neutral attitude that tangible interaction influenced their general experience. When it comes to the questions about whether the player misses the feeling of tangible interaction during the time they play the VR game, the average score is increased to 4.20(SD = 2.43).

For the open questions, the positive attitude towards the traditional manner are mainly about that it allows for face-to-face interaction and that the gameplay is more straightforward; the VR environment, on the other hand, impressed players with the animated model and the sound/visual effects. However, those added elements in the virtual environment also caused confusion. Players needed time to figure out how the model spawn and they expressed that the visual

and sound effects distracted them. The lack of tangible interaction and social communication also been reported by some of the participants as the reason why they do not like the VR version of this game.

Quantitative Analysis Figure 3 shows the mean of the ten questions asking about the general game experience. The results show that the VR version of this game provides a more immersive and engaging experience compared to the traditional version. Players could get more clear feedback and generally enjoy the VR version more. However, the VR environment also increases the difficulty and limited the freedom of how players play this game.

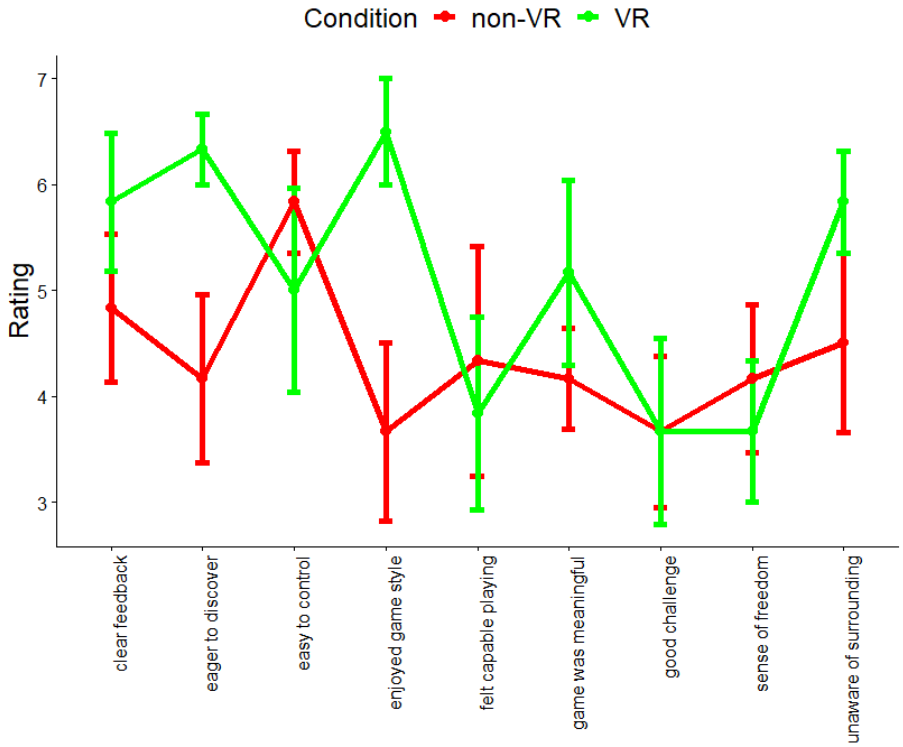

Fig. 3. The analysis of General Game Experience Questions, The questions includes: Playing this game was meaningful to me, I felt capable while playing this game, I was no longer aware of my surrounding while I was playing this game, I felt a sense of freedom about how I wanted to play this game, I felt eager to discover how the game continued, I thought the game was easy to control, The game was challenging but not too challenging, The game gave clear feedback on my progress towards the goals, I enjoyed the way the game was styled

In terms of questions about social engagement, we found that the traditional set up outperformed the VR environment. Although both with setups players can talk to each other, players still feel less connected with the VR version. From Figure 4 we can see that most players slightly disagree towards interacting with other players in the VR environment while strongly agreed that they have some sort of interaction and connect with the other player in the traditional manner.

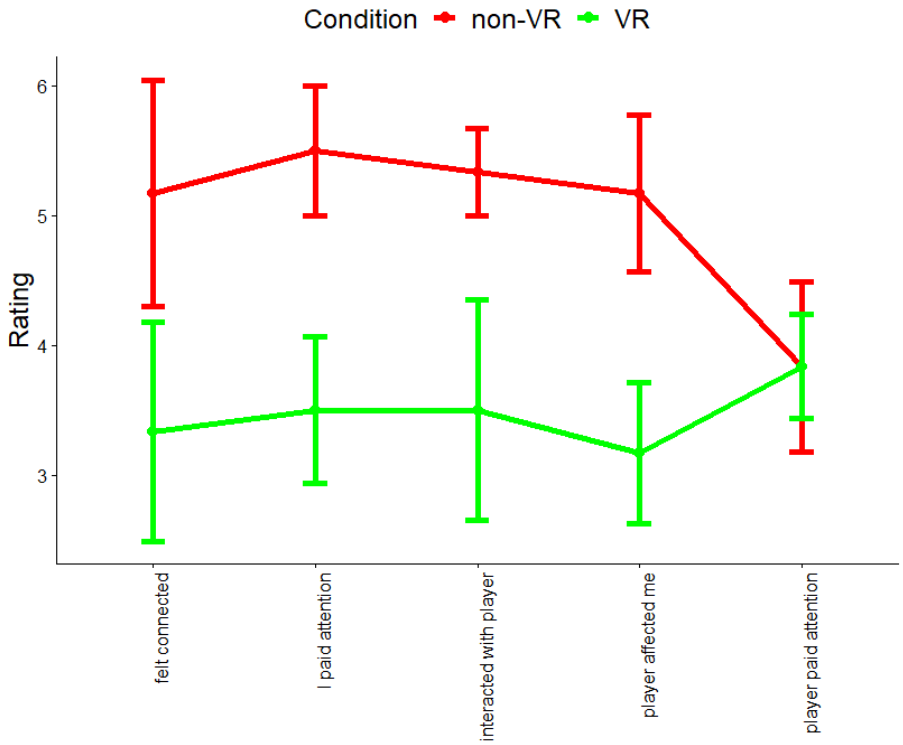

Fig. 4. The analysis of Social Engagement Questions, The questions includes: The player paid close attention to me during the game, I felt like I interacted with the player in the game, I paid close attention to the player during the game, I felt connected to the player during the game, What the player did/said affected me during the game

Figure 5 shows that most players hold a neutral attitude towards the tangible interaction and the mean result even shows that sometimes they even disagree that tangible interaction would improve their player experience. But when they switched to the VR environment, most players started to miss the feeling of touching cards and those game pieces. This result shows that although the players do not think to add those tangible interactions will improve their general

experience, they still prefer the original cards and pieces compared to the controller.

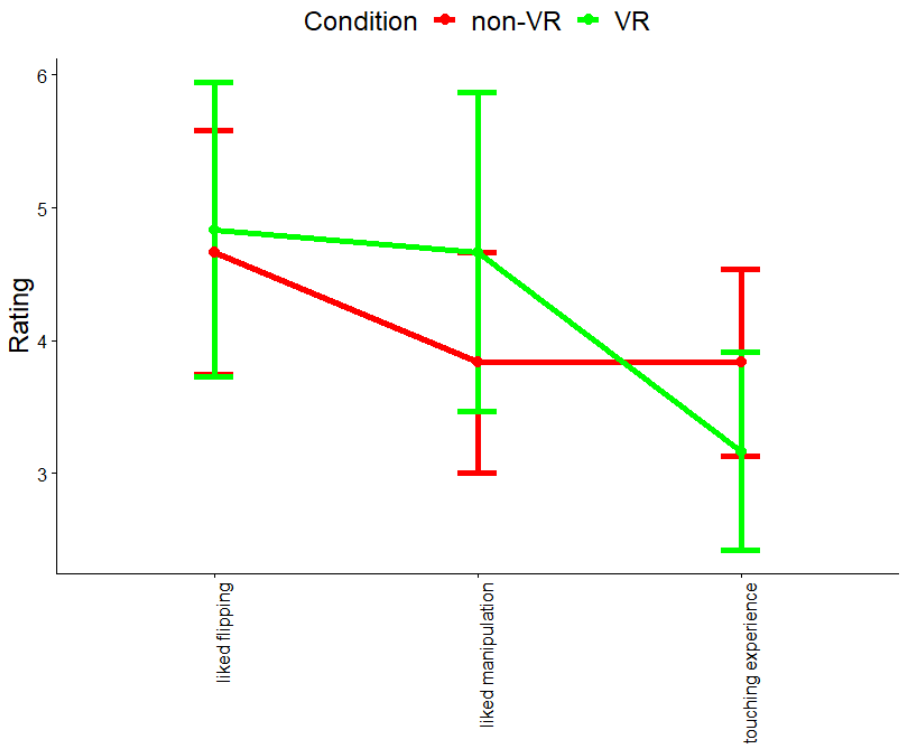

Fig. 5. The analysis of Tangible Interaction Questions, The questions includes: I like the feeling of flipping cards with my hand, I like to manipulate the tangible game pieces, Touching the cards and tangible game pieces increases my general game experience, I miss the feeling of flipping cards with my hand in the VR game, I miss manipulating the tangible pieces in the VR game, Not touching the cards and tangible game pieces decreases my general game experience

Qualitative Analysis The answers to the open questions were analyzed with the open coding method. All the answers to the five questions are categorized into four main themes. As shown in Figure 6, the player interaction seems to be the most essential part in the traditional manner.

"Shouting when flipping the card" – P1

This quote shows why players like the traditional version of the game. I noticed that although this game does not require any communication during the game-play, almost all of the participants talked to each other when they play this

game face to face, but only some of them are talking when they play with the VR headset. When it comes to why they like the VR version of the game. The 3D models and VFX are the most popular answer among all the participants (P1, P2, P4, P5, P6). The other interesting finding in the result is that players mention that the complexity of the game will increase in the VR environment because the visual and sound effects could become a distraction. In terms of tangible interaction, only a few mentioned they want to flip with the real cards in the VR environment(P1, P2), and P6 even wants to flip the card manually although sometime it could be annoying.

Player Interaction	Tangible Interaction	Visual and Sound Feedback	Game Complexity
Shouting when flipping the card	Real flipping	The animals are cute	Too many distractions
I can communicate with another player in the non vr Game		Evolution was cool	I am too noob to play this game. I got 1：23. Sad.
look at the face of my opponent	Cannot flip cards with my friends	"Real" scaling digimons and SFX	The digimon is not touchable, the game objects are too distractive
Interactions with people is fun	Needs to flip back card manually	The cool model of digimon and feedback	Chess pieces are nice, cards are easy to remember
Can't see another player		the cool model	I can remember better what each card is
I can't see my opponent		The 3d models are awesome	I have to remember my level in Non VR card game
I can take advantage of opponent's miss			Pure luck-based game
I made Boss Si nervous			The non VR version is too simple
Love the interaction with people			

Fig. 6. The Open Coding Result

5 Mixed Reality Implementation

Based on the VR card game and experiment, the idea of adding tangible interaction into a VR game shows potential. In this section, we present one approach to allow tangible interaction in an VR environment.

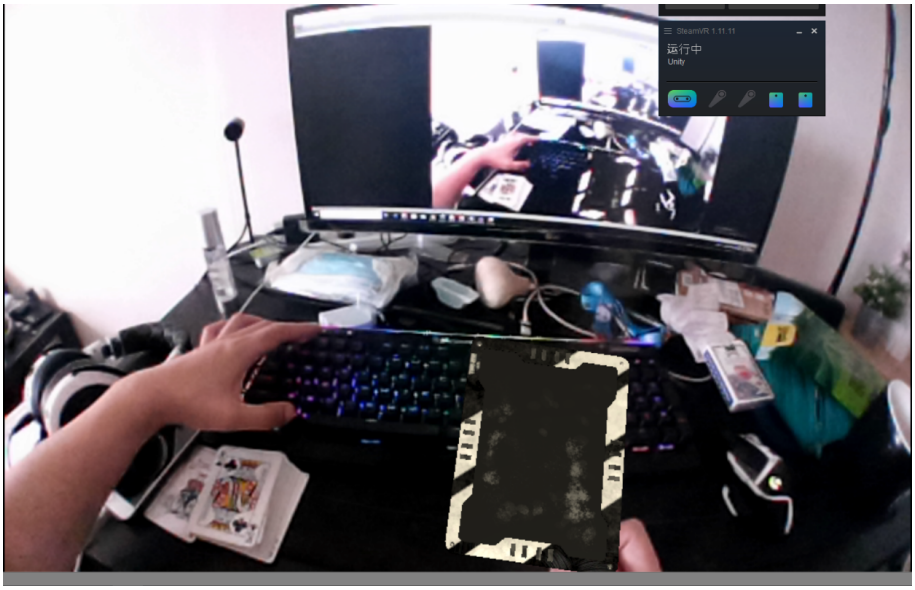

Fig. 7. The view in VR Headset with Real World View on

The basic idea to achieve this mixed reality approach is by combining Augmented Reality (AR) with a current VR headset. We used the *Vive Pro* headset because it has two front cameras integrated with the headset. We used the Vuforia package to access the camera data and do image tracking. We uploaded the image of a card front and card back to the AR database. As Figure **??** and Figure **??** show, when the camera recognized the image on the card back, it will generate a virtual card back on top of it, and if it was the card front, it will generate the 3D model on top of that. Figure 8 shows how it looks in the VR environment when the panel displaying the real-world environment is removed. However, we found that it can be difficult to grab the real card when disabling the real-world environment panel if players cannot see their hands. The front cameras cannot do hand tracking and AR image tracking at the same time so the solution of it is attaching an additional camera as Figure 9 shows.

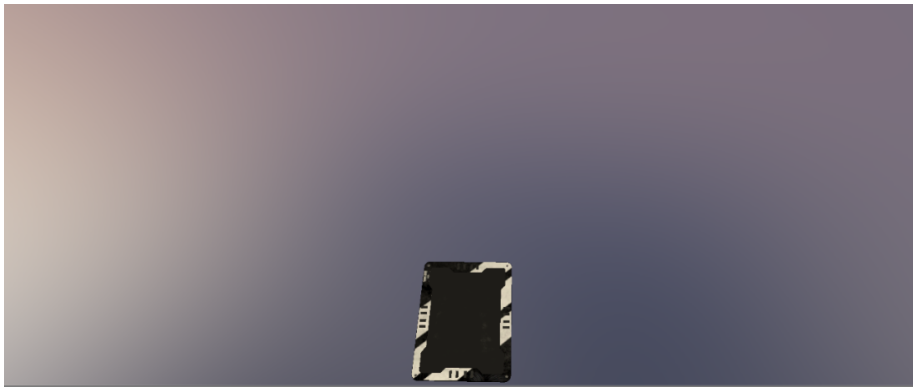

Fig. 8. The view in VR Headset with Real World View off

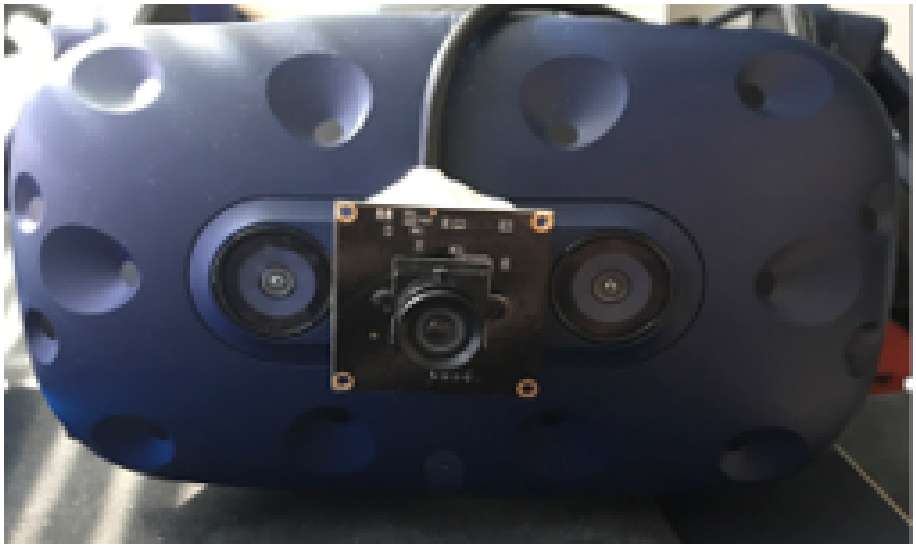

Fig. 9. The Mixed Reality Headset

6 Discussion

The results show that the VR environment can improve the traditional analog experience. However, the current VR environment still brought a lot of problems that did not exist in the traditional analog game like the lack of social engagement and increased level of complexity. This section discusses (1) insights from the experiment, (2) the comparison between the AR and VR approach to mixed

reality experience, (3) implementation of the mixed reality experience, and (4) the limitations and future work.

6.1 Insight from the Experiment

From the survey, almost all participants reported they had a better game experience in the VR environment. It indicated that the visual effects and immersive environment do help to make the game intuitive and interesting. However, to explore an enhanced analog game experience rather than recreating an analog game in a VR environment, the game should have digital content without losing the original elements of a traditional analog game. A previous study indicated that social engagement and tangible interaction served as the major reason for the popularity of the traditional analog games (Magerkurth et al., 2004). Based on the experiment results, the current VR game still needs some extra work to achieve that.

From the social engagement result, although players are playing in an immersive 3D environment, located in the same room and can communicate with each other, the social engaging scores are still way less compared to the traditional analog game. The reason for that could be the lack of social representation in the game. One of the participants mentioned that it would be good to have a virtual avatar represent himself in the game instead of just a player name, and it would be even better if the virtual avatar can mimic the action of players in real-time. This could be a possible solution to increase the social engagement level in VR environments.

In terms of tangible interaction, most participants think they miss tangible interaction in the VR environment, even if they reported to be neutral towards tangible interaction in the traditional manner. It shows that players might not be aware when they play in a traditional manner but those tangible interactions are beneficial towards the general experience. Besides, the other reason why the player holds a neutral attitude towards tangible interactions might also be because they cannot see themselves in the VR environment.

6.2 VR vs.(plus) AR

In general, we can see a lot of potential of integrating mixed reality with the traditional analog game. We can do that with either augmented reality or virtual reality. The virtual reality headset provides us the opportunity to present digital 3D content in a totally immersive 3D environment. Augmented reality, on the other hand, can bring the 3D digital content to the real world to enhance the user experience. Both of them are trying to enhance the user experience by mixing digital content with the real world. The idea of a virtual reality headset is blocking the user's original view and replace it with a 3D screen display and using a tracking system to dynamically change the content in the scene. The benefit of current virtual reality is that it creates a completely independent virtual environment for people to be playing in. Because it does not have to be related to the surrounding real-world environment, people have more freedom

in the content of the VR environment. Additionally, because the current VR headset uses a graphic card to render the scene, the models and scene's quality are better than current AR devices.

On the other hand, because the content in virtual reality is always isolated from the real world, it is difficult for the user's to explore the virtual environment with real actions and movement. For instance, when users pick up an item in the scene, they do not pick up the item; instead, they just pull the trigger on the controller. This inconsistency between the visual and tactile sense breaks the immersive experience and sometimes even causes motion sickness.

Augmented reality, in contrast, rarely has this problem because the content of it is often based on the real-world environment. The idea of augmented reality is adding digital objects in the real world to enhance the general user experience. The benefit of augmented reality is it is always based on the real-world environment so users feel more natural and comfortable. But most of the current AR devices such as smartphones and AR glasses are less powerful than VR devices. So the complexity of the scenery will be limited. Besides, because the AR technology is always related to the real-world environment, it is essential to have the ability to recognize the environment. For now, the reorganization is still limited to certain images and objects. So current AR devices cannot render a completely virtual environment based on the real-world objects.

The current VR and AR technology all have their pros and cons and a possible solution to solve these problems could be the integration of both technologies. If we can have a complete high-quality virtual scene with the function of real-time recognition of a surrounding object, the user may get the chance to enjoy the fantastic digital content with real motion without the controller. The current technology has already got the potential to achieve it. The latest VR headsets have already integrated some front cameras and they provide some function to recognize the surrounding environment. Also, with the combination of 5G and cloud computing services such as Google Stadia, AR glasses might be a better choice since it is more lightweight. The AR glasses collect the real-world environment data and send it to the cloud service, and the cloud services do the rendering and computing work and send them back to the glasses and display to the user. The only problem could be the lag, which can potentially be resolved by 5G technology.

6.3 The Pros and Cons of Current Mixed Reality Approach

The main benefit of this mixed reality implementation is that it does not require many additional devices and set up. Besides, this hybrid format games allows players to enjoy traditional face to face analog games with enriched game contents remotely. It could be meaningful especially considering the current situation of Coivd-19. From this implementation, there are still problems like it is hard to recognize the image target with current camera, and the position of virtual objects needs additional revise. There is still a lot of potential in this mixed reality game. But in the future development we can easily solve them by using a higher resolution camera and integrate the position calibration to the

AR camera. However, in that case the size and portability of the setup may be called into question.

6.4 Limitation and Future work

There are several limitations related to this project. First, the number of participants in the experiment does not fully substantiate our results, but rather hints at our intervention's effectiveness. While we believe that the presented and proposed mixed reality environment improves player experience based on our limited findings, we could not do full testing due to the COVID-19 pandemic's effect on in-person testing. Thus whether this mixed reality experience is better than the VR environment and traditional analog game environment remains a topic to be explored post-pandemic.

We have explored how tangible interaction, social engagement, and digital content influence the general game experience, but additional directions and optimizations could be explored in future work. We have shown how we can integrate tangible interaction in a VR environment, but based on the results, we see that bringing more social interaction in a VR environment is worth exploring as well. In terms of the mixed reality system, it would be more reliable if we use a high-resolution auto-focus camera and write the position calibration code on our own. There are also other ways to achieve mixed reality experiences like using the mobile device camera and cardboard VR, or AR glasses with cloud computing services that deserves investigation.

7 Conclusion

We have shown that enhancement of analog game experience with a VR headset can be beneficial. It allow players to enjoy traditional face to face analog game remotely. Although comparing to the traditional analog games the current VR environment lacks the content that encourages social communication, we can potentially improve this by using virtual avatars, motion synchronization, and facial expression synchronization in future development. For tangible interaction, this game is limited to interacting with cards so more study is required in other environments. The results presented here suggest it is worth while to explore tangible interactions in virtual environments.

The current approach to implementing mixed reality systems for analog games proved to be durable despite the computer vision recognition not being as accurate as possible. What matters is that compared to other approaches like AR glasses and tactile sensing, the technology required for this method is already here and does not need any other bulky devices. The limitation of the current approach is that it only works well with flat markers. We need to explore strategies for 3D objects as markers. Nevertheless, this work demonstrates a possible mixed reality future for the next generation of analog games.

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