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

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Abstract. In this paper, we explore the next generation of analog game (i.e., board and card games) experiences by combining a traditional analog game with mixed reality technology. First, we transfer an existing analog game into a virtual reality (VR) environment that enhanced the gameplay with an animated model, visual effects, and sound effects. Second, we implement a multi-player interaction to allow collaborative play in virtual environments even when players are isolated from each other physically. Third, we conduct an experiment to compare the VR environment with the original analog game. Finally, we showcase *cARd*, the resulting collaborative mixed reality version of the game that combines the strength of the traditional analog game with VR by using both VR and augmented reality (AR) technology. This mixed reality approach aims to enhance the player experience while keeping the benefits of the traditional analog game, in particular manipulating tangible objects.

Keywords: Mixed reality · Analog games · Virtual reality · Augmented reality · Extended reality

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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 [9]. 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 [8,10,15].

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

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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 [9]. 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 users 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 [3], 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 [7]. 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 VR environment.

Here, we introduce a mixed reality game called *cARd* that integrates the VR environment with a traditional analog game. It allow players to play a 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 [6,15]. 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 [11] and minimize the impact of motion sickness. For developing *cARd*, we first translated an existing analog game to a VR environment and made multi-player interaction possible. Then we conducted a usability experiment 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. Based on all of this, we developed and present *cARd* and discuss the insights gained from our work.

2 Background

This section will give an overview of current virtual reality (VR) headsets, the use of tangible objects in analog, and the idea of 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 [12]. 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. 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 [5]. 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 have 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 [11]. 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, specifically in the context of an analog game called Warhammer 40,000! [2]. Based on that, bringing those real game pieces into VR could potentially improve the general game experience. We conjecture that 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 [9]. Some researchers also explored how social interaction in games influenced the experience of hybrid games [10,16]. Others focused on considering the influence of tangible pieces in hybrid games [13]. However, most previous work is limited by combining a 2D display with a traditional analog game. In recent years, there are studies trying to create some hybrid game format by using augmented reality and virtual reality headsets [1,7]. 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. For our work, we chose the memory game called *Concentration*. This analog game starts with a set of unrevealed (i.e., face-down) cards. Each player can flip two cards at their turn and players will play in turn in the same physical space. If the front pattern of the two flipped cards matches, the player who flips them will win the pair and take the cards off the table, and if not, players need to flip the cards back. The game ends when all cards are gone. The winner is the player with the most pairs.

The Gameplay. To better investigate the impact of tangible interaction, we first refined the original analog game by adding some real game pieces to represent the cards players win. There are in total four types of cards in the game and we represented them by four different types of game pieces. To make the game more intuitive, those pieces are divided into three different levels: when players successfully flip the same kind of card multiple times, they can replace their low-level pieces with high-level pieces. Thus, our analog game version of *Concentration* has both cards and game 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. The playground only serves as a VR environment, to enhance the analog game experience instead of recreating a completely new game, because we do not want players to lose the sense of real-world in the VR environment. Players should feel that they are still in the real world even as the surroundings altered. Thus in the virtual environment, we put a stone table in the middle as an anchor and the players should gather around the table.

To secure a smooth transition, the launch 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 button, a digital beep sound plays and digital matrix particle effects appear to imply the transition from real-world to the virtual environment. In the game scene, players flip two cards in turn with their controller. If they flip the same cards, the player will get points on their scoreboard and the corresponding digital model will spawn or evolve beside the player. When they make multiple double flips of a Digimon (see below), that Digimon levels up and the player gets more points.

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 online free assets) and made idle animation for each of them in Unity. The models are from a popular anime called Digimon. These models match the theme since the story of Digimon 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 different types of cards. Eight additional models represent the second level and third level Digimons. Beside the animated models, we added multiple visual effects to make the game look better and more vivid. For example, Fig. 1 shows the effect when a game starts, which depicts the transition from the real world to the virtual environment. Figure 2 shows that when players got their Digimon leveled up, a magic circle and particle effects appear, symbolizing the mythical power that drives the evolution of the evolving Digimon.

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 click connection, the server will search to join a game room, or create a game room if no game room is online. When the player joins a room, they will see their nickname displayed behind them and the game will start when two players are

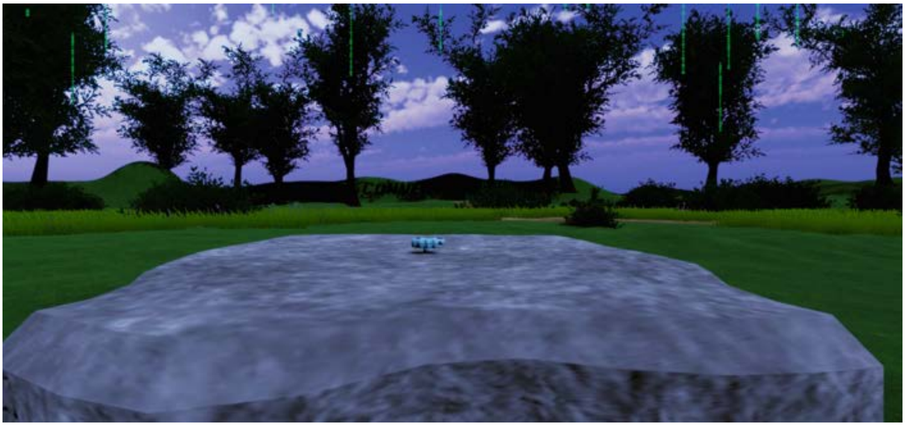

Fig. 1. Transition effect from the real to digital world

Fig. 2. The visual effects of when a Digimon levels up

in a room. In the game scene, all the actions, particle effects, and animation should be synchronized to both players. To achieve this, all the game objects in the scene are registered to a script called Photon View. The script assigns each game object a unique ID. The objects' positions, rotations, scales, and animations will synchronize between both players' game sessions if they share 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

To test differences in player experience and what we can learn from this in order to develop our mixed reality approach, we set up a usability experiment where all participants are required to play two versions: the revised analog game version and the VR version. Two participants first play the analog game in the traditional manner, followed by playing it in the 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 play with the VR headsets and controllers. The rules and the game itself are identical in both environments. Also, in both environments, the participants play in the same room so they can talk to each other during the game. In total 6 players participated. All the participants are graduate students at Northeastern University who have previous VR experience. All results are collected anonymously.

3.3 Survey

After the two game sessions (i.e., playing the traditional and VR version), we requested all participants to fill out a survey that measures their game experience. The survey is divided into three parts. The first two parts are questions about the game experience in the VR version of the game (first part) and the traditional version of the game (second part). Each part is divided into 4 sections. The detail of each section is listed as follows: (1) the general player experience, (2) the level of social engagement, (3) tangible interaction, and (4) open questions for pros-and-cons about this game (2 for VR version and 3 for traditional version). The last part is the demographics information.

In the first section (general player experience), we used Vanden Abeele et al.'s [14] 7-point Likert scale questionnaire to measure the general player experience. The original questionnaire has thirty questions divided into 10 different themes. We used one question from each theme, such as meaning, immersion, mastery, and challenge (10 Likert scale questions in the VR version and 10 Likert scale questions in the traditional version). In the second section (social engagement), we used in total ten 7-point Likert scale questions to ask about the interaction and social persistence during the game session (5 Likert scale questions in the VR version and 5 Likert scale questions in the traditional version). This section was taken from the social engagement section from Down's video game experience survey [4]. Originally there are 7 questions in the section but we removed two questions about teamwork, which are not applicable in this game. In the third section (tangible interaction), we developed three 7-point Likert scale questions about whether players like the tangible interaction (3 Likert scale questions in the traditional version) and whether they miss the tangible interaction (3 Likert scale questions in the VR version). The last section (open questions) contains five open questions about the pros-and-cons of the traditional version (two questions) versus the VR version (two questions) and one extra question asking what they miss in the VR version compared to the traditional one.

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, social engagement, and tangible interaction 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 five 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 generally have a better experience in a VR environment. The general play experience received a mean score of 5.10 ($SD = 1.95$) while the traditional analog game environment received a mean score of 4.37 ($SD = 1.81$). In terms of social engagement, the traditional analog game environment clearly beats the VR environment with a mean score of 5.00 ($SD = 1.5$) while in VR the mean is 3.50 ($SD = 1.5$). This indicates that although the players play in the same room in both versions, the traditional face-to-face analog game leads to more social interaction between players. The result of tangible interaction is unexpected; most players hold a neutral attitude towards the tangible interaction in the traditional analog game set up. It might because that for this specific game, the tangible interaction is not interesting enough and the game pieces we used did not match the players' expectations. The mean score of whether they enjoyed tangible interaction is only 4.10 ($SD = 1.88$), which indicates that players were neutral that tangible interaction influenced their general experience. For the questions about whether the player misses the feeling of tangible interaction during the time they play the VR game, the mean score slightly increased to 4.20 ($SD = 2.43$).

For the open questions, the positive attitudes towards the traditional manner are mainly about its capability of face-to-face interaction and straightforwardness; the VR environment, on the other hand, impressed players with the animated model and the vivid sound/visual effects. However, the visual and audio enhancements in the virtual environment also caused confusion. It takes time for players to figure out how the models spawn and they expressed that the visual and sound effects distracted them from the game-play. Some participants also reported that the lack of tangible interactions and social communication as the reason why they do not like the VR version.

Quantitative Analysis. Figure 3 shows the mean of the ten questions 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 clearer feedback and generally enjoyed the VR version more than the traditional version. However, the VR environment also increases

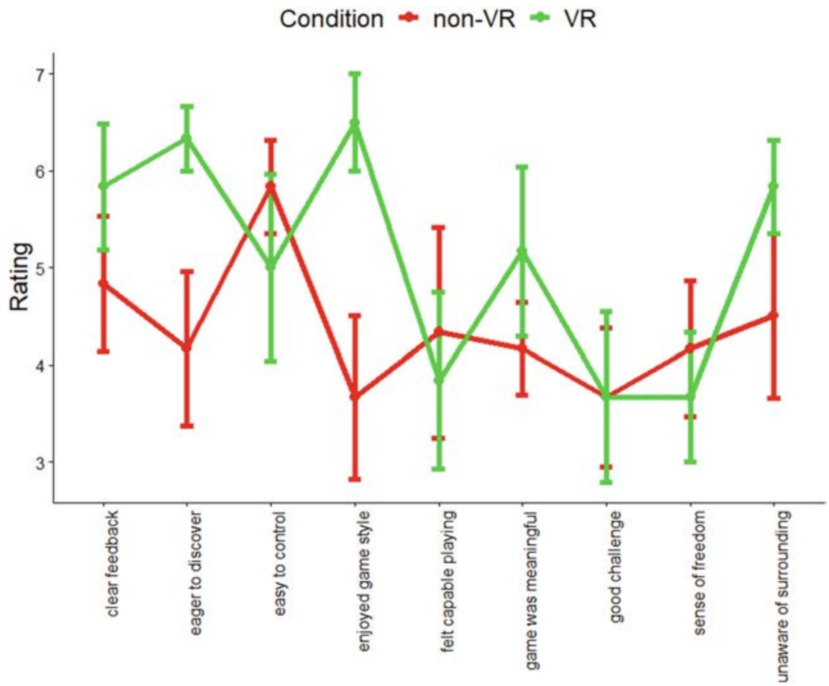

Fig. 3. The analysis of general game experience questions. The questions include: Playing this game was meaningful to me, I felt capable while playing this game, I was no longer aware of my surrounding while I was playing this game, I felt a sense of freedom about how I wanted to play this game, I felt 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. There are significant difference between responses in VR and non-VR conditions (ANOVA, $F(1{,}5) = 0.0422$). Posthoc comparison (TukeyHSD) indicate significant difference in VR vs non-VR in the following questions: "Eager to discover" ($p < 0.025$), "Enjoyed game style" ($p < 0.007$).

the difficulty of the game and limited how players can play this game due to technological constraints.

In terms of questions about social engagement, we found that the traditional set up outperformed the VR environment. Although with both setups players can talk to each other, players still feel less connected with the VR version. From Fig. 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 connection with the other player in the traditional manner.

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

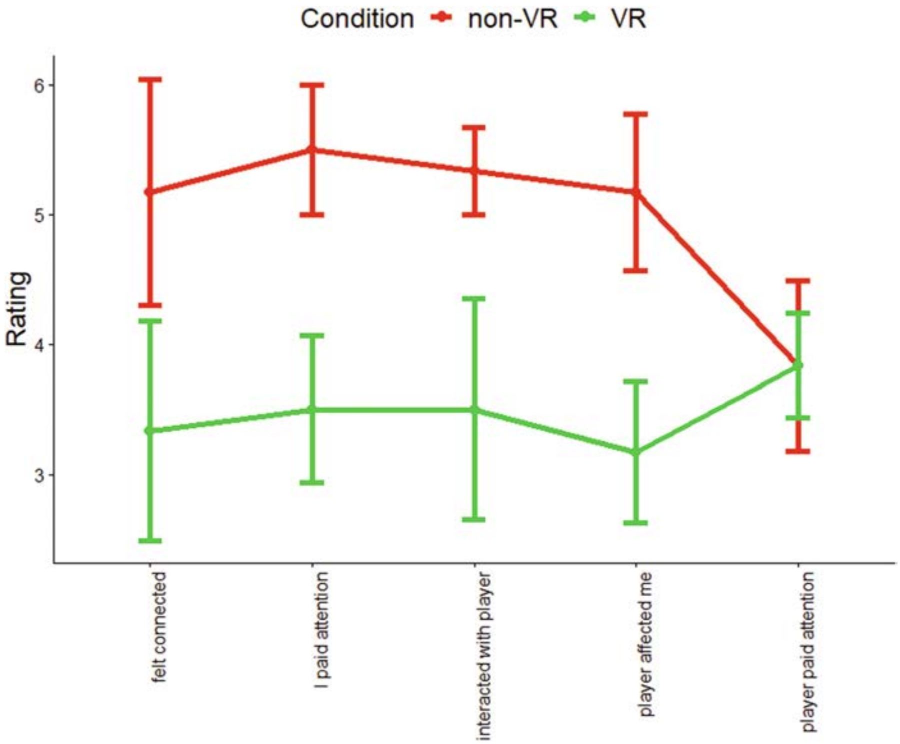

Fig. 4. The analysis of social engagement questions. The questions include: The player paid close attention to me during the game, I felt like I interacted with the player in the game, I paid close attention to the player during the game, I felt connected to the player during the game, What the player did/said affected me during the game. Significant difference between responses in VR and non-VR conditions (ANOVA, $F(1{,}5) = 0.00042$). Posthoc comparison (TukeyHSD) indicate significant difference in VR vs non-VR in the following questions: "Felt connected" ($p < 0.015$), "I paid attention" ($p < 0.01$), "Interacted with player" ($p < 0.015$), "Player affected me" ($p < 0.01$)

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.

Qualitative Analysis. The answers to the open questions were analyzed with the open coding method. All answers to the five questions are categorized into four main themes. As shown in Table 1, the player interaction seems to be the most essential part in the traditional manner. Players enjoy the rich, face-to-face interactions with others while playing board games. They all gave feedback about player interactions for either version of the game. This shows why players

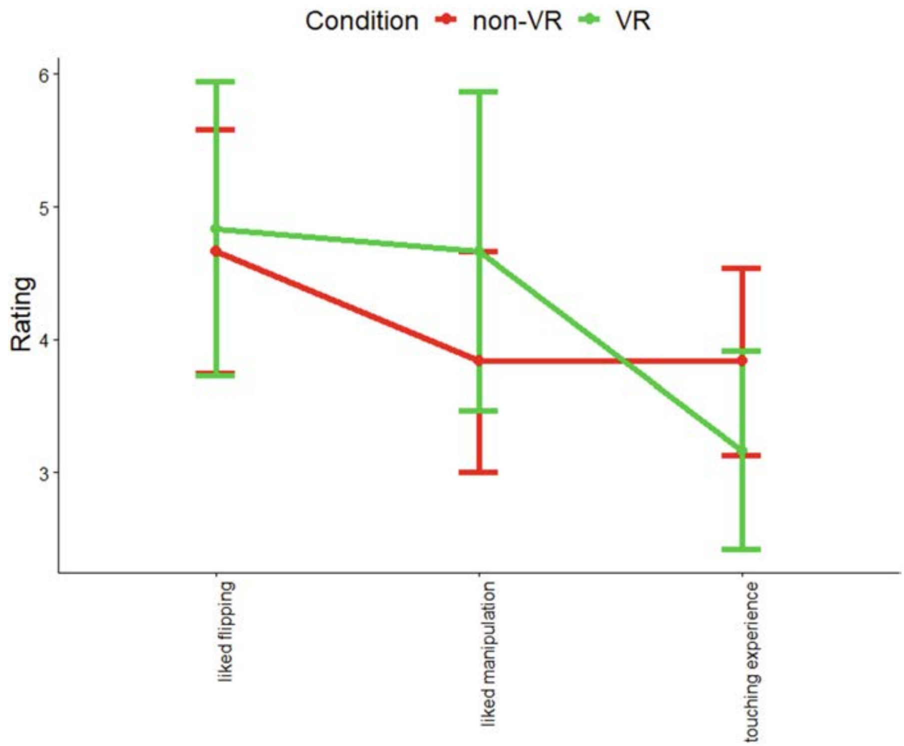

Fig. 5. The analysis of tangible interaction questions. The questions for the non-VR include: I like the feeling of flipping cards with my hand, I like to manipulate the tangible game pieces, Touching the cards and tangible game pieces increases my general game experience. For the VR: I miss the feeling 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. There were no significant differences between VR and non-VR conditions for any of the three questions.

like the traditional version of the game. Although the game-play does not require any communication between the two players, 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 visual effects (VFX) is the most popular answer among all the participants (P1, P2, P4, P5, P6). Another finding is that some players mentioned they find the game more complex, and that the visual and sound effects sometimes distract them from the gameplay. In terms of tangible interaction, only a few participants reported they want to flip with the real cards in the VR environment (P1, P2) while others didn't mention, and P6 even hated to flip the card manually because sometimes it could be annoying.

Table 1. The open coding result

Player interaction	Tangible interaction	Visual and sound feedback	Game complexity
I can communicate with another player in the non vr Game	Cannot flip cards with my friends	Evolution was cool	I am too noob to play this game. I got 1:23. Sad
Interactions with people is fun	Needs to flip back card manually	"Real" scaling digimons and SFX	Chess pieces are nice, cards are easy to remember
Can't see another player I can't see my opponent		The cool model of digimon and feedback the cool model	I can remember better what each card is I have to remember my level in Non VR card game
I can take advantage of opponent's miss		The 3d models are awesome	Pure luck-based game
I made my opponent nervous Love the interaction with people			The non VR version is too simple

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 a VR environment.

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 in 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 Fig. 6 and Fig. 7 show, when the camera recognizes the image on the card back, the system will generate a virtual card back at the relative location in the VR world. If it recognizes a card front, the system will generate the 3D model on top. Figure 7 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 Fig. 8 shows. This combination makes the system possible to both track cards and hands.

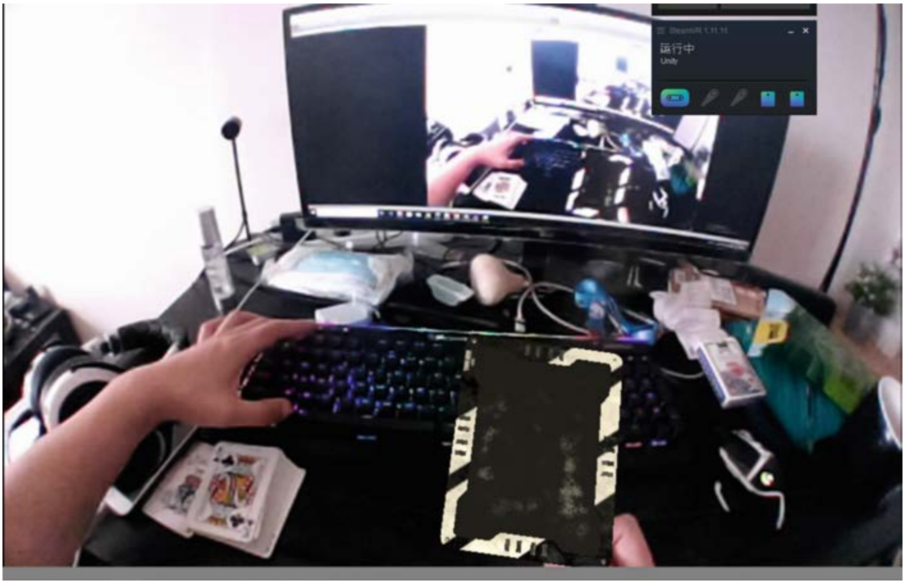

Fig. 6. The view in VR Headset with real world view on

Fig. 7. The view in VR Headset with real world view off

Fig. 8. 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 the 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 [9]. Based on the experiment results, the current VR game still needs some extra work to achieve that.

Although players are located in the same room while they are immersed in the 3D virtual environment and can thus communicate with each other, the social engaging scores are still less for the VR version 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 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 that those tangible interactions are beneficial towards their general experience. The can saw their avatar in virtual environment might also decreased the experience of tangible interaction.

6.2 VR vs.(plus) AR

In general, we can see a lot of potential for integrating mixed reality with the traditional analog game. We can do that with either augmented reality (AR) or virtual reality (VR). The VR headset provides us the opportunity to present digital 3D content in a totally immersive 3D environment. AR, 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 VR headset is blocking the user's original view and replaces it with a 3D screen display and using a tracking system to dynamically change the content in the scene. The benefit of current VR 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.

AR, 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 AR is that 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, it 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 functions 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 the 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 COVID-19. From this implementation, we encountered several problems such as that it is hard to recognize the image target with the current camera, and that the position of AR generated virtual objects sometimes have a slight deviation in the virtual environment. In the future, we can easily solve these issues by using a higher resolution camera and integrating 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 a larger-scale 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 deserve investigation.

7 Conclusion

We have shown that enhancement of an analog game experience with a VR headset can be beneficial. It allows players to enjoy a traditional face-to-face analog game remotely. Although compared 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 suggest that it is worthwhile to explore tangible interactions in virtual environments.

The current approach to implementing mixed reality systems for analog games is proved to be durable despite the image recognition not being as accurate as expected. What matters is that compared to other approaches like AR glasses and tactile sensing, the technology required by *cARd* approach is accessible enough. The limitation of the current approach is that it only works with markers like cards or QR code. We need to explore strategies for 3D objects as markers. Nevertheless, *cARd* demonstrates a possible mixed reality future for the next generation of analog games.

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