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| City, University of London MSc in Games Technology | |
| Project Report | |
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| Year | 2022 |
| Project Title | CardsAR, a social card game set in shared virtual world using multi-modal smartphone based augmented reality |
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## Abstract

This report outlines the ”design and build” process for a an augmented reality (AR) iOS multiplayer card game called CardsAR. The game has been designed in the Unity game engine using third party AR and networking tools. Players in the game are placed in a 3D virtual room around a circular table. 3D avatars of each player are used to show where each device is orientated in the game space. Placed in the centre of the table is a deck of cards that can be used to play card games while players. An audio call is also started for all players so they can communicate while playing any card game they wish.

## Keywords

Augmented Reality, Unity, Game Design, Card Game, Multiplayer

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# Chapter 1 – Introduction and Objectives

## 1.1 Introduction

This report covers the design and build of an augmented reality (AR) social game in order to fulfil the Individual Project of the MSc in Computer Games Technology at City University, London. The project was undertaken over six months from late June to early December 2022. The outcome of the project was an iOS game that could run on iPad and iPhone devices running iOS/iPadOS 15 or above. The resulting game was called CardsAR

The two primary design goals of CardsAR were to create an AR based card game using the Unity game engine and to also provide a social space more engaging than a standard video call.

The game has been designed to be played remotely. Each player logs into the game and is placed in a virtual room that, using AR technology, is anchored to their local environment. In this virtual world they can look around and interact with virtual avatars of other players and interact with the deck of cards placed on a table in the centre of the room.

CardsAR has been designed to eschews the common tropes of AR gaming, which raised significant challenges during development. During the development of the game, compromises had to be made as a result of the limitations of the third-party tools that were used. It is possible that the original design of CardsAR could be achieved but it would have required the writing multiple libraries which would have extended development time beyond the scope of this project.

## 1.2 Motivation

The coronavirus pandemic and its related lockdowns in 2020 and 2021, saw a large increase in online gaming the predominant form of socialising [CITATION]. Over this time, social video calling was also heavily relied upon [CITATION]. The design of CardsAR has been motivated by the lack of games that used video calling as an integrated part of their gameplay. [CITATION]

Playing cards in their current form have been in use for centuries [CITATION]. Their ubiquity in society makes them an ideal foundation to base this AR game around. If the appropriate set of card interactions are correctly modelled, it allows for players to decide their own games and rules. Players can also drop in and out without breaking any code-defined gameplay rules.

After the first waves of the pandemic, businesses like Meta started to invest heavily in virtual reality devices as a way for users to socialise remotely [CITATION]. During a company rebranding video Mark Zuckerberg explained that he saw smartphones are a part of the old internet and virtual reality headsets as the new primary internet device of the future [CITATION]. VR headsets have a high cost of entry, both socially and financially. By comparison, far more people have smartphones that are capable of augmented reality [CITATION]. This project is therefore an examination of smartphone technology and its ability to provide immersive virtual reality experiences without a headset.

## 1.3 Research Questions

The design of CardsAR aims to answer the following research question.

1. Is it possible to build a tabletop card game using smartphone AR tools.
2. What are the limitations of user interface design when creating an AR virtual world game.

3. To what extent can smartphones AR technology be used to allow player to socially interact in a virtual world.
4. Is this method of socialising online enjoyable to casual game player?

## 1.4 Work Plan

To achieve these research questions, the build section of CardsAR will split up into three builds.

Build 1 is a research build, where third party tools will be investigated, and proof of concept tests will be made. The code written in build 1 will not be used in the subsequent builds 2 and 3.

Build 2 is focussed on designing the core playing card gameplay and player networking.

Build 3 is reserved for refining the look and feel of the game and integrating a video call component to the game.

The detailed list of work plan is listed below.

1. Build 1 (June 15th – July 30th):
    1.1. Basic unity setup and device setups for testing.
        1.1.1. iPhone 12 Mini Testing
        1.1.2. iPad Mini Testing
    1.2. Basic multiplayer session setup using Lightship ARDK
    1.3. Single hand tracking using Manomotion
        1.3.1. Skeleton Detection
        1.3.2. Gesture recognition
        1.3.3. Fine skills test
    1.4. Device pointing as interaction technique test
    1.5. Face tracking test
        1.5.1. Facial Expression Detection
        1.5.2. Face position
    1.6. Streaming video call test
2. Build 2 (August 1st – Sept 30th):
    2.1. Creation of game space, and player placement.
    2.2. Card mechanics
        2.2.1. Placement of cards on table
        2.2.2. Pick up / Drop Mechanics
        2.2.3. Add and remove cards from the players “card hand”
        2.2.4. Show single cards to individual players.
    2.3. Card Deck mechanics
        2.3.1. Shuffle and Deal
        2.3.2. Pick up multiple cards
    2.4. Player audio.
    2.5. Multiplayer session management
3. Build 3 (October 1st – October 31st):
    3.1. Android Testing
    3.2. Player presence through animated avatars or floating video call screens.
    3.3. Refinement of interaction techniques based on user testing

3.4. Improved graphical treatment using shaders lighting and models taken from the Unity store.
3.5. Camera parallax through face tracking.
3.6. Player hand modelling.
3.7. Refactoring of game code.

## 1.6 Beneficiaries

There are multiple beneficiaries for the CardsAR project. Primarily, this experience in multiple technologies will not only broaden the authors skillset, but will also be an important step in one's career development. Further experience with Unity and augmented reality plugins and packages will allow for the author to specialise in augmented reality development post-graduation.

The author is also being partially financed through this part time masters course by their employer, Territory Studio. Territory is a multidisciplinary design studio whose work ranges from creative advertising to motion graphics to post production visual effects for film and television. The studio also has a growing immersive department which has focussed on interactive exhibitions using Unreal engine thus far. In financing the author's study, Territory is investing in the studio's technical skillset around mobile based AR and Unity based projects.

The planned development of CardsAR incorporates 3rd party tools that are active in promoting successful use of their tools. Hand tracking toolset Manomotion promoted community projects on the YouTube channel (Manomotion, 2021). Niantic's AR development toolset: Lightship ARDK, was released at the end of 2021. The company promotes their toolset through their website, social media channels, community game jams and yearly awards (Niantic, 2022). If this project is successful, it could be added to each company's community showcase.

Finally, as the project aims to experiment with new methods of game interaction modelling, the user experience (UX) and user interface (UI) research community will benefit from the final results.

## 1.7 Outcomes

The outcome of this project will be a build of CardsAR that can be distributed to volunteer testers via Apples Test Flight service. Test flight allows for builds to be shared through the App store without requiring the normal authentication and evaluation checks that a complete Apple App Store submission requires.

Players will also submit their CardsAR feedback through a Google forms questionnaire. The feedback will collected and anonymised before inclusion into the evaluation section of this report.

## 1.9 Significant Work Plan Changes

Midway through build 2, two significant issues were encountered that changed the plans for build 3. Originally Lightship ARDK was intended to be used for the multiplayer netcode, but the multiplayer sessions in ARDK are limited to players in the same physical space. CardsAR is designed to be played remotely so an alternative design was used for multiplayer netcode. This is

detailed in section X.X.
During build 2 it was also discovered that video calling disabled the AR camera. Therefore, the video call feature had to be reduced to an audio only call.

# Chapter 2 – Context

## 2.1 Multiplayer Social Games

In March 2020 the UK government, announced its first full lockdown to help prevent the spread of Covid 19 [CITATION] Millions of people had to work from home and the only way they could spent time with friends and family was online. This created a boom in social video calling as applications like Zoom became replacements for in-person social gathering [CITATION]. At the same time video game companies saw record breaking increases in demand for video game consoles as people looked for new ways to spend their free time [CITATION]. The increase in gaming was not limited to dedicated consoles, smart phone and web browser games rose in popularity at the same time. Covid 19 increased the national consumption of video games, but it also created a new type of video game player that didn't exist before. People who don't normally play multiplayer games but were in a situation where video games were one of the only forms of group social activity.

This change in the marketplace can be observed in the rise in popularity of Among Us [CITATION]. Among Us is an online multiplayer social deduction game [CITATION] inspired by the horror movie The Thing [CITATION]. In Among US players control a 2D character that has to undertake tasks along with their crewmates while trying to avoid being killed by the secret imposter crewmate who is trying to sabotage the team. Released in 2018 Among Us saw little mainstream popular attention and maintained a small audience for the next 18 months. In mid 2020 the games popularly skyrocketed and in the years since has become a multimillion dollar franchise. The games creators have attributed the games popularity to its low barrier, simple design and broad availability on multiple devices.

As well as playing online video games, it was common for people to try and translate in person games to remote friendly format. This could be using websites to play digital versions of board games, or using video calls to organise quizzes. In many of these situations, the video calls may be continued through a rotation of digital board games [CITATION].

Another company that took advantage of the change in the market was Houseparty. This social network application was available on PC, Mac, Android and iOS and let users play built in games like Heads Up, Trivia and Uno while on a video call. When playing games, the video call feeds from other players would be resized on screen to make space for a gameplay window. It was started in 2016 but saw a large increase in attention during the pandemic. Houseparty was however discontinued by its parent company Epic Games in 2021 due to low player numbers [CITATION].

## 2.2 Card Playing Games

Playing Cards have been represented in video game since the earliest graphical user interfaces were available. In 1990 with the release of Windows 3.0, Microsoft included Windows Solitaire as a free pre-installed game [CITATION]. It was designed partially as way to "to soothe people intimidated by the operating system,". The game has remained a part of the Windows since its initial release over 30 years ago and in 2019 The Strong National Museum of Play inducted Microsoft Solitaire to its World Video Game Hall of Fame [CITATION].

The increase of home internet usage in the 90s and early 00s also saw in increase in online poker playing, growing to a $2.4 billion industry in 2005. Online gambling also saw an increase in users during the Covid19 pandemic. Online poker interfaces are often web browser based and are designed around flat 2D representations of cards and poker chips.

A significant influence for the design of CardsAR is Tabletop Simulator. This is a PC and Mac game that allows players to play and create tabletop games in a multiplayer physics sandbox. The game is designed to allow any tabletop game to be played from within it. When installed it comes with royalty free games like chess, blackjack and mah-jong, but it has an open design that allows for players to easily develop their own games with imported 3d models and custom scripting. Table Top simulator also comes with a standard interface for playing cards. Compared to browser based online poker, Tabletop simulator has a high barrier to entry. At the time of writing it costs £14.99 at full price. In order to handle the physics simulations necessary for gameplay features like realistic dice rolls the game also has non-trivial hardware requirements.

During development a new game called All On Board was successfully crowdfunded on Kickstarter [CITATION]. All On Board is a VR game similar to Table Top simulator, that designed to be platform for users to create their own board games in virtual world [CITATION].

The market for playing cards games skews either to simple web browser interfaces or high end realistically simulated tabletop games. There is currently no successful 3D environment for playing cards that can be played on smartphones.

## 2.3 Augmented Reality

Augmented reality can be defined as an interactive experience that incorporates real word and digital content. Since the term was coined in 1990 [CITATION] companies have experimented with different use cases with different hardware input devices. In 2000 the Wearable Computer Lab at the University of South Australia created AR Quake. The game used a custom build backpack and headset to allow players to play a version of popular first-person shooter Quake projected into the real world through a head mounted display [CITATION].

It wasn't until the release of the first iPhone 2007 that the public would have access to an internet enabled device with a camera that could be used in AR tools and games. For the first few years, AR was used in novelty applications that weren't integrated into the daily lives of users [CITATION]. That changes with the release of Pokémon GO in 2016, the most popular and profitable augmented reality app of all time. Pokémon GO's core gameplay loop consists of players travelling to real world locations to then use their catch virtual pocket monsters that appear in the real world as seen through the phone camera.

### AR Survey

When researching the viability of CardsAR, a survey was taken of every popular augmented reality app on iPhone and Android. Apps were identified by searching both the google play and apple app store. Articles were also collected from the past 5 years that showcase AR apps.

The methods used to collect AR apps in the survey have limitations. Only apps that were currently available to download on either the Play store or App store were considered. This means that any app released in the last decade that has been discontinued were not reviewed. Reviewing the features of a discontinued app would be too unreliable to include in the survey. This leaves the possibility that an app with similar functionality to CardsAR may have already existed but has been removed from sale. Also, by limiting the survey to published apps, research projects and unreleased prototypes from environments like game jams, have not been covered.

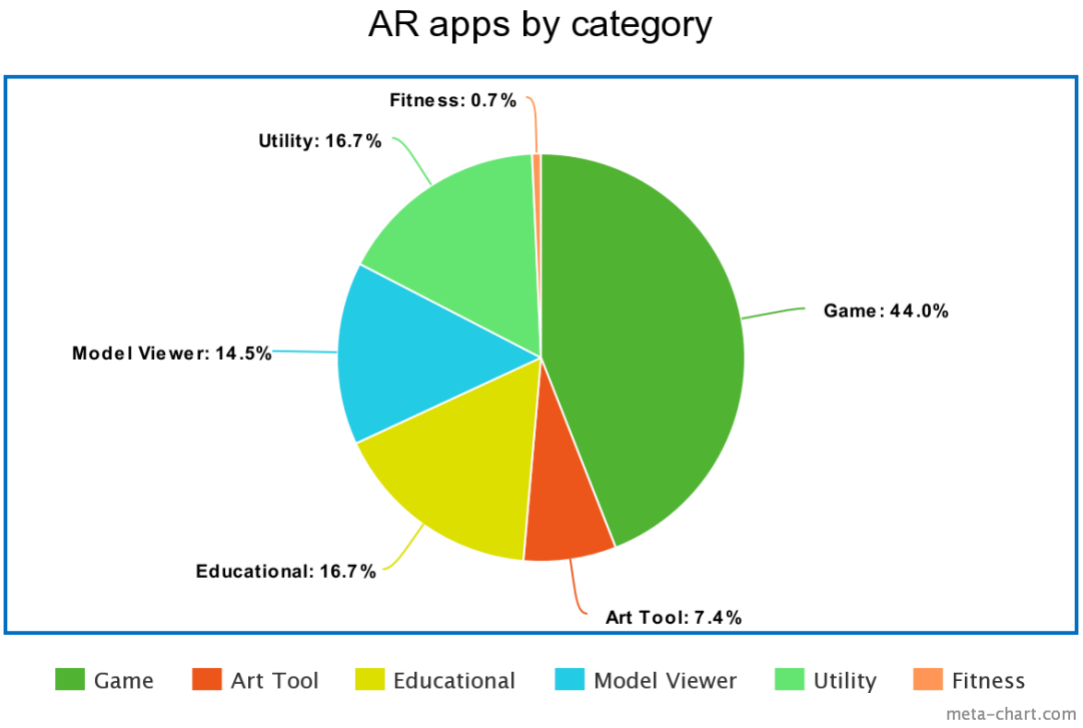
In total 149 smartphone AR apps were collected in the survey. Each app was grouped by app category and movement style.

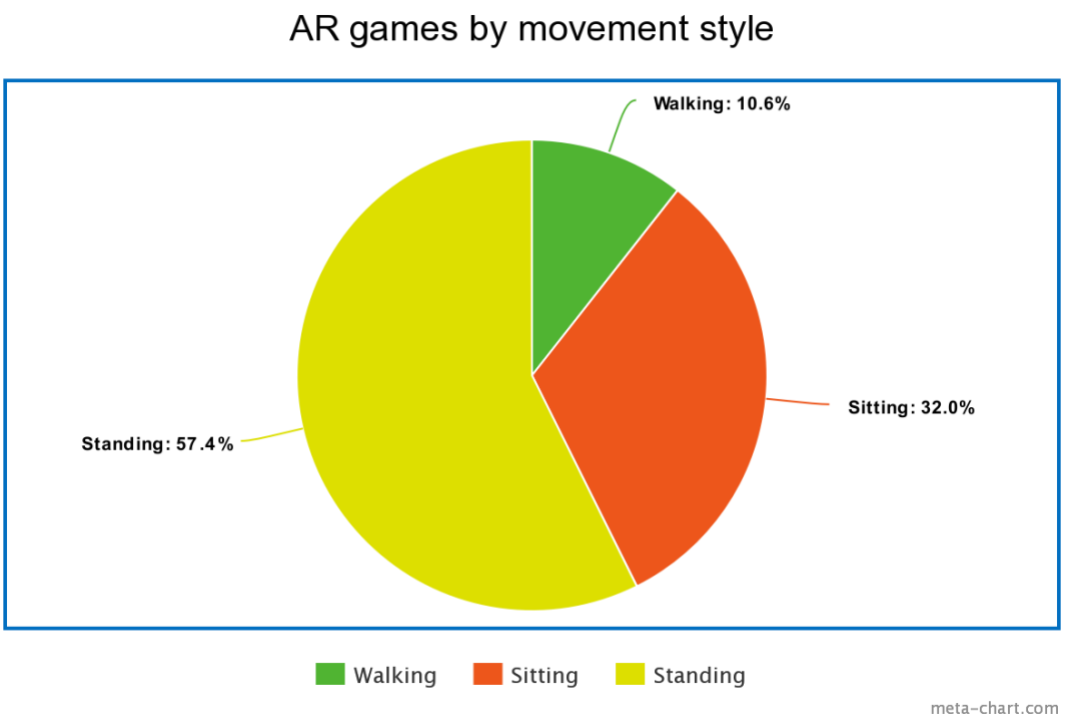
The AR app categories created for this survey are Game, Art-Tool, Educational, Model Viewer, Utility and Fitness. These size categories were based on the results of the survey and were a way to meaningfully differentiate the results.

| Category | Description |
|---|---|
| Game | Designed primarily as a game |
| Art-Tool | Designed to be a self-expression tool. Examples include drawing apps and face filter apps. |
| Educational | These apps are designed to tell a story or convey information through 3D models. |
| Model-Viewer | These apps let users place 3D models in their environment. This can be with a list of predefined novelty models like dinosaurs or vintage cars. Or it can be a community app that lets you look at models other users have created. |
| Utility | These apps achieve a task that AR is uniquely suited to. For example taking the measurements of a room. |
| Fitness | Fitness apps are primary for the tracking or fitness activities or for guidance on how to perform certain exercises. |

Each game was also groups by another criteria, movement style. The categories are seated, standing, and walking. Seated apps can be used while seated and do not require the user to stand or move significantly while using. Standing apps require or at least encourage players to move around a space to either look at multiple focal points on the space or look at a focal point from different perspective. Finally walking apps require that the user move from location to location. Walking apps normally incorporate GPS into their systems.

## AR Survey Results




From these results it can be seen that "standing" is the most common movement style for AR games. Standing games try to take advantage of the 3d space that a person is currently placed. A typical example of such a game is Euclidean Lands or ARise, both are puzzle games that have

the player walk around a 3D model that they project into the middle of a space. To solve puzzles players must look at the model from the different positions and angles to enable gameplay features.

CardsAR can be considered a sitting game. A common gameplay feature of sitting games is the projection of a 3D game board onto a flat surface in front of the player. Similarly to CardsAR games like Jenga AR and Lego Hidden Side attempt to create a digital simulation of a real like tabletop game. Many of the planned features for CardsAR were not identified in the survey. No game used playing cards as its focus, and none of the games focussed on socialising as a primary feature. Every game also displayed the 3D models overlaid onto the real world, none of the games took place in a virtual world like the one planned for CardsAR.

## 2.4 Hand Tracking

Hand tracking from the world facing camera has been considered as an interaction method. Some models of smartphone contain LIDAR scanners which could be used to accurately tracks hands and fingers. This feature is only available on new high-end iPhones Pro and iPad Pro models, which would negatively impact the availability of users to test this feature. Moreover, as CardsAR has been designed as a low-cost more broadly available alternative to high end VR devices, it should be designed with features available to the most number of devices.

Third party tools do exist for hand tracking from a single source RGB image. Manomotion was selected as the platform to build this feature upon. This choice was made as the company has a unity toolset for hand skeleton from the front facing camera.

## 2.5 Face Tracking

Face tracking is the most common AR use for front facing camera of a smartphone. Across the AR survey, this was the only use for the front facing camera. Glasses retailer Warby Parker has an app that lets users try on glassed in real time with a projected 3d model. Social media apps Snapchat, Instagram and TikTok all allow users to take pictures and record videos of themselves with 3d models and effects projects onto their tracked faces.

# Chapter 3 – Methods

## 3.1 Development Environment

### 3.1.1 Unity

Unity has been chosen as the game engine to develop CardsAR within. This was selected for its extensive support for smartphone-based AR development. Unity has multiple options for AR plugins as well as an active community and marketplace for models and plugins. This choice aligns with choices made by game development studios, both the Niantic and Rovio Entertainment develop their AR games in Unity.

### 3.1.2 AR Toolset

Multiple software development kits (SDK) are available in Unity for AR. Unity has support for both iOS's ARKit and Android's AR core. CardsAR will developed primarily on an iPhone, but it be tested on Android during Build 3. Therefore a cross-platform AR SDK solution is required. AR Foundation meets the requirements, it allows for AR apps for Android and iOS to be built from the same code. This SDK however doesn't have the breadth of features that Lightship ARDK has.

Lightship ARDK from Pokémon Go creators Niantic is a cross platform AR toolkit for unity that, in adds to the feature sets found in ARKit, AR Core, and AR Foundation. In addition to 3D plane detection, Lightship provides built in multiplayer netcode and session management. The toolkit also provides an in-editor world simulator for Unity. This allows for AR features to be tested without needing to build to an external device. Both these features allow for more time to be spent on feature development and less time on multiplayer testing.

### 3.1.3 Video and Audio

For the video call component for CardsAR, Agora was chosen. The Agora Video and Voice SDKs are both available as plugins in the Unity Asset store for free. This is the only video call plugin in the Unity store that has been marked as a "Verified Solution" by Unity. Verified Solutions are Unity packages that have been are compatible with the latest versions of Unity, and have been recognised as having long term dependability.

### 3.1.4 Hand Recognition

For hand gesture recognition the ManoMotion hand tracking SDK was used. This was selected as it was free to use in a university project, and it provided enough demo projects that the feasibility of hand gesture based control could be tested without significant work.

## 3.2 Software Development Practices

Throughout development a Git repo will be maintained on GitHub.com. Build 1 is focussed on research and third-party plugin experimentation which will be tracked in the CardsAR repository as no code from the tests will be carried through to Builds 2 and 3. Work on Cards AR will start being tracked with the feature development in Build 2 and 3. At the end of every day a commit

will be made to the main repository and uploaded to Github.com

All builds have been planned with the software project management tool Jira. The three builds and their associated features have been entered into the Jira database. Two views were set up for managing the development of CardsAR, a kanban board and a roadmap. Kanban is a framework for managing agile software development projects within a team. Tasks are displayed on a board with columns for their status (“to do”, “in progress”, “done”), and as the project progresses tasks and moved between columns.

[Example kanban]

The roadmap view allows for planning of the project timeline. Each feature has an allotted time, and each week the allocated times are adjusted depending on the work achieved that week.

[Roadmap screenshot]

## 3.2 Design

### 3.3.1 Scope

CardsAR is intended to be as close an analogue to real world card playing as possible. The game will contain a single deck of cards. As no predefined game rules will be designed into CardsAR the interaction model will attempt to cover all actions a player may need. Taking inspiration from video call social gaming, CardsAR will also be designed to be easy to drop in and out of. Players should be able to join and leave a game without breaking the current ongoing game. To keep development time down, there will be no multiplayer session interface, the final build will auto-join players into the gameplay session with hardcoded authentication credentials.

There will be no 3D physics model. Cards will either be held by a player, or be placed on the table. A dedicated physics model is unnecessary for the cards AR feature set. Also cards will not animate between positions, they will either be statically placed or dragged by players across the table.

### 3.3.2 Card Gameplay Model

The card gameplay model has the following features.

- Cards can be stacked on top of each other or individually laid out.
- Stacks of cards can be fanned across the table to allow users to see each card’s suit and number.
- Cards can be flipped individually or a whole stack can be flipped.
- Cards can be visible to all players or just a single player.
- Cards and stacks card can be highlighted by players
- When one player highlights a card/stack, no other player can highlight it.

- When a card/stack is highlighted one or more cards can be picked up and held by the player.
- A held card/stack can be placed onto the table again or added to an existing stack.
- Stacks of cards can be sorted and shuffled.

This feature set allows for cards to be arranged and placed in any order on the table. Card visibility allows users to have a card "hand", a set of cards only visible to themselves. A dedicated deal card function will not be added but card dealing can be achieved through picking up a stack of cards from a larger stack.

### 3.3.3 Environment

When players start CardsAR they will be set up their AR environment. As is common in most AR games, the virtual world needs to be aligned with the real world. Most AR games start with the user looking around their environment to allow the AR system to detect surfaces. The player is then asked to player a virtual marker on a detected surface. This marker will be used to orientate the virtual objects or gameplay area.

Cards AR will start off with a virtual marker placement. This marker will be used to orientate the virtual table on which the cards are placed.

[Diagram of table orientation]

The real world camera feed will be used by the AR tools to place the table. Contrary to most AR applications, the camera feed will not be shown during gameplay after the marker has been placed. The entire game will take place in a virtual room that players join. Setting the game in a purely virtual allows for other players to be represented in the game without needing to consider each others physical spaces. If the camera feed was used as the gameplay backdrop, moving player avatars would break the AR illusion as their movements wouldn't be restricted by each other's physical space.

### 3.3.4 Interaction Models

Built into the development process of CardsAR is an investigation into different interaction techniques. The first investigation will be into hand recognition and whether players can hold their phone with one hand and interact with cards using pinch/grab gestures with their free hand. If this is not feasible, the primary interaction technique will be a combination of on-screen buttons and using the phone are a pointing device for selecting cards.

[diagram of interactions]

# Chapter 4 – Results

## 4.1 Development

### 4.1.1 Build 1

#### *4.1.1.1 Augmented Reality*

#### *4.1.1.2 Gesture Recognition*

#### *4.1.1.3 Netcode Test*

### 4.1.2 Build 2

#### *4.1.2.1 Environment Setup*

#### *4.1.2.2 UI Design*

#### *4.1.2.3 Card Interaction Design*

### 4.1.3 Build 3

#### *4.1.3.1 Avatar Design*

#### *4.1.3.2 Netcode Redesign*

#### *4.1.3.3 Video Call*

#### *4.1.3.4 Audio Call*

## 4.2 Finished Game

### 4.2.1 In Game Screenshots

### 4.2.2 In Game Video

### 4.2.3 Photos of the game being played

## 4.3 Testing

### 4.3.1 Testing during development

### 4.3.2 Informal Testing

### 4.3.3 Formal Testing

#### *4.3.3.1 Distribution*

#### *4.3.3.2 Testing Sessions*

#### *4.3.3.2 Testing Feedback Form*

#### *4.3.3.3 Testing Feedback Results*

# Chapter 5 – Discussion

## 5.1 Project Management

## 5.2 Development Goals

## 5.4 Feedback

# Chapter 6 – Evaluation Reflections and Conclusions

## 6.1 Project Scope

## 6.2 Game Design

## 6.3 Mobile Phone Augmented Reality

## 6.4 Future Development

# Glossary

# References

# Appendices

## Appendice A: Project Proposal

## Appendice B: Figures

## Appendice B: CardsAR Code