April 2019

Reality Wizards- An AR Card Game

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Reality Wizards

A spell crafting AR card game

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Abstract

Reality Wizards is an augmented reality card game for mobile phones designed for two to four players, in which players defeat monsters by creating spells through the combination of four different elements. By using Google's ARCore software for Android, we created a new experience that blends traditional card games with digital technologies.

Acknowledgments

Our Wonderful advisors Joshua Rosenstock, Farley Chery, and Charlie Roberts.

Special thanks to Johnnie and Dolores Jackson for the artwork they contributed.

All the playtesters that helped to polish our game.

A very special thanks to Dean O'Donnell without whom this game would not exist.

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1. Introduction

Reality Wizards is a multiplayer augmented reality card game which allows players to discover and craft spells as they play. In the game, players take turns combining element cards (fire, water, air, and earth) to make spells. These spells are then used to fight against Angra Mainyu and his minions.

An important aspect of our game was the inclusion of cultures and mythologies that have generally been overlooked in gaming. To keep true to these cultures and mythologies our team did extensive research to assure we were portraying them accurately.

We saw in our research that many AR games don't make full use of the capabilities of AR. For example, many games that include AR allow players to turn it off entirely. We wanted to make an experience that could only be had with AR. So our game seeks to show that AR isn't just for looks or novelty and can be used as a key mechanic in games.

The main problems our team faced were internal difficulties with communication and planning. Our game went through large changes toward the end of its development cycle to rescope and reshape so that it would be content complete by the deadline. We learned the importance of proper planning and research when working with new technology and unfamiliar software that has unknown capabilities and limitations.

2. Background Research

We investigated five key subjects that would help to inform our design goals. We looked at cultures and mythologies that are underused in games, traditional board game mechanics, AR types, AR supported mediums and AR software.

2.1 Cultural and Mythological background

In the following section, we discuss our research into cultures that feature myths with magic as an integral component. Later, as discussed in section 3.5 this research was used to design enemies and player characters.

In Zoroastrianism, water and fire are key parts of purification rituals. In Zoroastrian cosmogony, water and fire are the second and last primordial elements respectively, to have been created. The creator of the universe and sole God of Zoroastrianism is named Ahura Mazda. Ahura Mazda is both good and wise. Both water and fire are considered necessary to sustaining life. Both water and fire are represented within the precinct of a fire temple. Zoroastrians typically pray in the presence of fire in one form or another. (35)

It can be inferred from Bedouin poetry that the gods, even Allah, were less important to the Bedouins than Fate. (34) The Bedouins regarded some trees, caves, and stones as sacred objects. Numerous mentions of jinn in the Quran and testimony from pre-Islamic as well as Islamic literature indicate that the belief in spirits was

common in pre-Islamic Bedouin religion. Some observations hold that such spirits were thought to inhabit lonely dark places and that they were feared and had to be protected against rather than worshipped. The Bedouin religion also included a cult of ancestors. Rather than considering the dead powerful beings capable of manipulating the world, they were seen as lacking protecting and in need of charity from the living. Additionally, this charity was seen as a continuation of social obligations. Only certain, famous individuals, from whom the tribes got their names, were objects of actual worship. (27)

Shintoism is the indigenous religious beliefs and practices of Japan. The world Shinto literally means “the way of kami”. Kami are generally considered to be divine power, specifically named gods or minor deities. In the 7th century, the rise of Confucianism and Daoism stimulated the development of Shinto ethical teachings. As power steadily centralized, Shinto began to develop nationally. Myths of various clans were combined and re-organized into cross-Japanese mythology with the Imperial House at the center. According to Shintoism, in the beginning, a certain number of kami emerged and a pair of kami, Izanagi and Izanami, birthed the Japanese islands as well as the kami who became the ancestors of the various clans. At the core of Shintoism are the beliefs in the mysterious power of the kami as well as the will of the kami. Kami cannot be fully explained as they transcend the cognitive understanding that a human mind is capable of. However, devoted followers are able to understand kami through faith. Shinto ethics emphasize the importance of seeking a dynamic life-attitude that brings forth virtues of loyalty, filial piety, love, and faithfulness. (33)

Polynesian beliefs emphasized animism, a perspective that holds that all things, living and inanimate, are believed to be endowed to some degree with sacred supernatural power. That power is known as mana and could be nullified by human actions. There were many restrictions in place with the intent of preventing the loss of mana. These restrictions were known as tapu. Polynesian leaders had great mana, so great that in certain areas if a commoner touched the chief's shadow they could be put to death for damaging the leader's mana. Even today there are many actions, such as stepping over another's leg, that are seen as poor taste as they sap another's mana. Women were known to have great mana, with the evidence being that only they were able to birth new life. Men, having less mana, had to protect it carefully through purification rituals and syllable specific songs. Magic was common in Polynesian societies; with everyone engaging in actions to ensure success in love, war, or more mundane activities. Magical specialists could be consulted in more serious moments when an ordinary individual's magic was not enough for the problem at hand. (24)(25)(26)

2.2 - Game Research

2.2.1 Game Mechanic Research

Tabletop role-playing games have many mechanics, even in the case of simplified systems such as Apocalypse World. From asking fellow students, we learned that many consider the action of sitting around a table together to be a big part of what

made tabletop role-playing games so much fun. Two popular tabletop role-playing games that inspired us were Pathfinder and Dungeons and Dragons. In Pathfinder and Dungeons and Dragons, player characters are based around 6 key stats. In Pathfinder, there are additional statistics about skills for various actions. In both Pathfinder and Dungeons and Dragons, there are many species (incorrectly referred to as races) to choose from. Put simply, the two systems were too complicated for a small team to implement properly in a year. Apocalypse World is different in that it focuses on fewer player stats. The problem is that Apocalypse World is intended to focus on the narrative aspect of TRPG's rather than the mechanical side of things. The result is a system where DM's have much more options at their hand for influencing various aspects of the game, but there wouldn't be a place for AR mechanics.

An early goal was to encourage replayability by having the game space be randomly generated. In pursuit of this, we looked into games that featured random layouts. The most promising of which, due to the team's familiarity with it, and due to the sheer number of results it creates, was Betrayal at the House on the Hill. Betrayal at the House on the Hill is a very fun board game, however, in our research we did not focus on the gameplay, but on the map itself. In Betrayal at the House on the Hill, the board starts with three entrance rooms, each on a different 'floor'. Each entrance point has several empty 'doorways' branching off of it. On a player's turn, they draw from the dungeon tile deck and place the card on the indicated floor, wherever an open doorway is. As the game progresses, the map is built outwards as more rooms are placed. Some rooms contain malevolent effects, other items that provide aid. Still, other room types

transport the player around the game board. It is a simple system that provides a great amount of variety in play.

Once we decided not to modify a TRPG, we switched strategies and decided to focus on magic. The game Magicka was investigated for its unique combat system. Unlike other games with spellcasting, Magicka features no mana bar, or any feature to limit spells, Magicka also has very few items that buff the character. All of the player's strength is from their spellcasting ability. In *Magicka*, there are eight base elements. These can be mixed to create a variety of different spells. Magicka also features two additional elements that can be created from mixing two base elements there are powerful attacks called magicks that the players can find. These spells require specific combinations but produce unique effects.

2.2.2 AR Game Research

We did research on other AR applications and games and to how they made use of AR. We looked at Pokémon GO(17), AR DnD Kickstarter Reality and Dragons(6), among others (8). From our research on these game, we started to get a sense of the different types of AR most commonly used for games and the role AR generally plays. From this research, we found that the most common type of AR in gaming is recognition based AR with even some board games like Chronicles of Crime using it (31). But often times we saw that games use AR for artistic effect without mechanical importance. An example of this is in Pokémon GO where the player can simply turn off the AR when

catching Pokémon. Seeing that AR is often used for novelty we were inspired to try and make AR a more important part of our game than others.

2.3 Types of AR

Augmented Reality (AR) is “an enhanced version of reality where live direct or indirect views of physical real-world environments are augmented with superimposed computer-generated images over a user’s view of the real-world, thus enhancing one’s current perception of reality” (4). With the broad definition of AR, it was important to understand the different types of AR and their use. We found AR is categorized into 5 types: Projection, Recognition, Location, Outlining, and Superimposition (1)(4).

Projection-based AR is the projection of digital images onto a physical object. This type of AR can be seen in projected keyboards. These keyboard project an image onto a flat surface and detect finger movement using infrared sensors to type. Another example we looked at was the augmented reality sandbox. This AR table uses sensors to project topology on based on the sand and is later talked about in section 2.4.

Figure 1: Projected keyboard reference image (19)

Recognition AR is the most well-known type of AR and is often associated with Quick Response (QR) codes. Recognition uses a camera and visual markers to produce some action when detected. While this type of AR was popularized by QR codes it can work with any image given it has enough detail.

Figure 2: QR code to Wikipedia's page for QR codes (20)

Location-based AR uses GPS, digital compass, and the accelerometer to determine user location. This allows the device to take actions based on location. This is used in the popular game Pokémon GO that will track player position globally. Not all location-based AR need to be global though as it can be used for relative or local positioning.

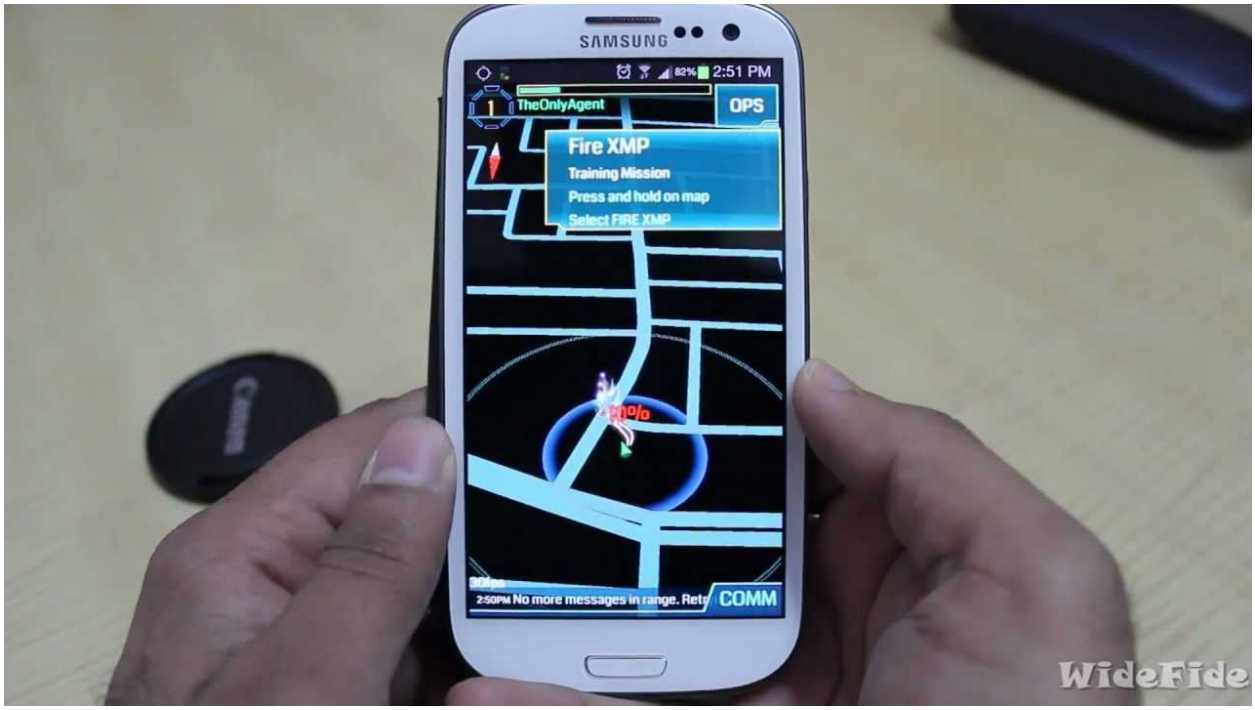


Figure 3: Example of location-based AR for Niantic's first game Ingress (21)

Outlining AR is a combination of two previous types mentioned. Borrowing from both recognition and projection. Outlining recognizes boundaries and edges and then uses projection to highlight or outline them. An example of this is that some modern cars will recognize and outline the boundaries of the road with light when it gets dark.

Superimposition AR is where a digital object is used to mask or replace an object or part of the augmented view. An example of this can be seen in the use of night vision and infrared view used by the military (1).

Figure 4: Example of Superimposition AR using an iPad and model building (22)

2.4 AR mediums

AR is predicated on the idea of digital devices sensing and responding to the physical world. So another set of research we did was on types of devices used for AR and how they interacted with the physical world.

During project presentations, one example of AR shown was the AR sandbox. "The augmented reality (AR) sandbox allows users to create topography models by shaping real sand, which is then augmented in real time by an elevation color map, topographic contour lines, and simulated water. The system teaches geographic, geologic, and hydrologic concepts such as how to read a topography map, the meaning of contour lines, watersheds, catchment areas, levees, etc" (2). The AR sandbox fits

under a broader category of AR devices called AR tables. AR tables are table display that often uses a top-down camera and projector combination that focuses on Projection AR and in some cases also makes use of image recognition. Another example of an AR table is Artificial Nature, a project by Haru Ji and Graham Wakefield. Their project uses sand and sculptures with motion sensors to create an interactive art exhibit for visitors (15).

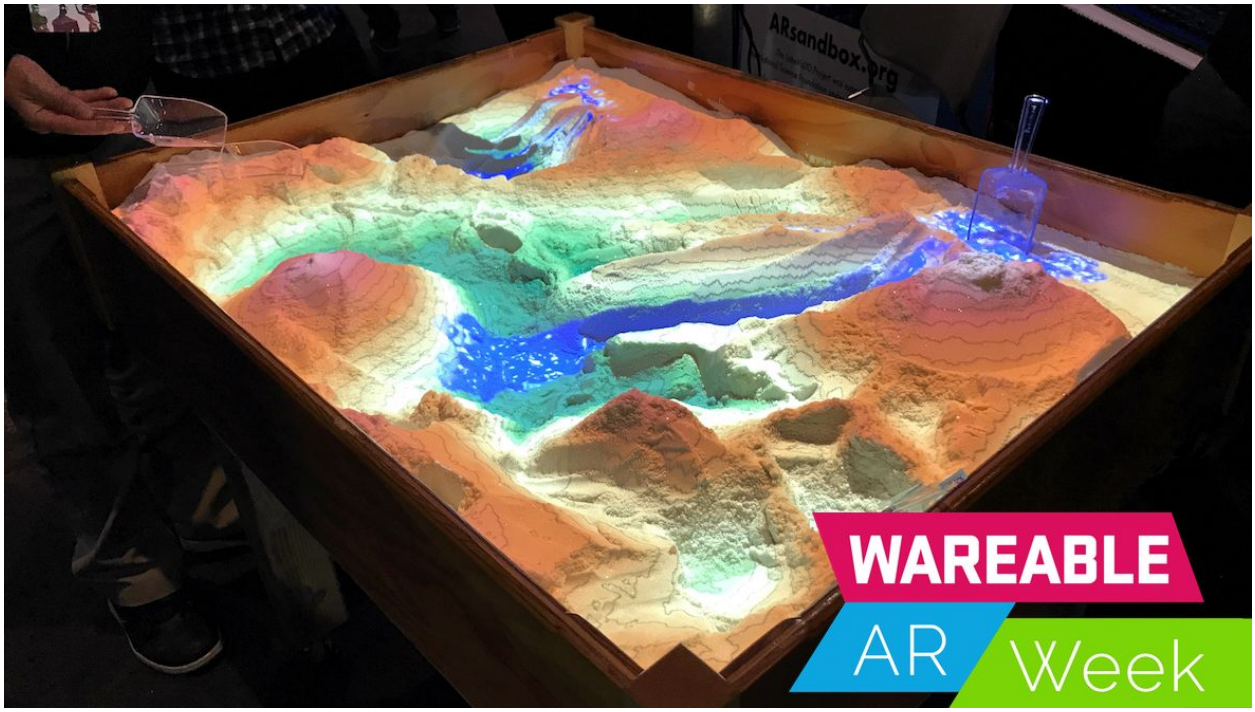


Figure 5: AR sandbox (23)

While researching AR table we saw that many of them used either blocks or sand to help make projection more three dimensional. We ended up looking into a few different ways to create holograms (7). The one that ended standing out the most used an optical illusion to create holograms. Pepper's ghost illusion is "using a transparent pane to reflect an object positioned behind an observer in such a way that it appears to

be in front of the viewer" (16). Pepper’s ghost was discovered by John Pepper and Henry Dricks in the 1820s when it was found that the illusion could be manually re-created for the theater (3). While the illusion has found many forms from theater to Disneyland its most recent form inspired us to research it. By cutting a translucent material such as the plastic used in cd case covers and constructing an upside-down open-topped pyramid you can capture a 3D hologram inside using a projection from your mobile device.

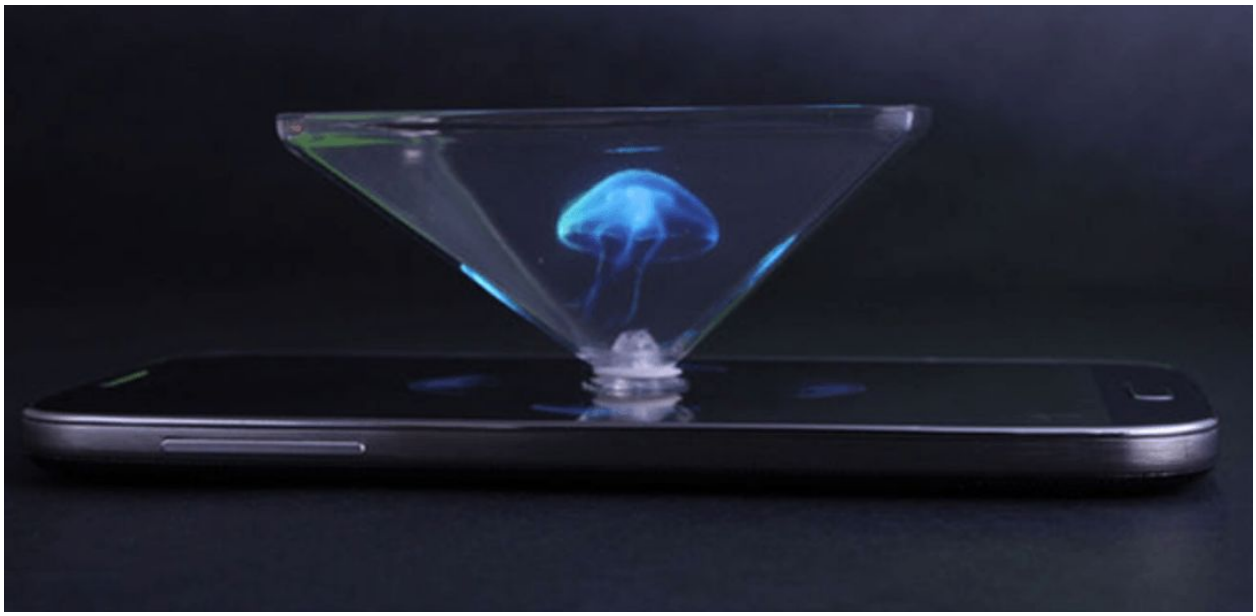


Figure 6: Example of Pepper’s ghost as described (18)

The idea we came up with was a combination of the Pepper's ghost illusion and an AR tables. Using the projection with this illusion would allow us to create a grid-based table that would be able to project select images to each grid square based on the location of the game pieces. This would allow for the creation of many games seen in sci-fi like holochess seen in Star Wars.

We also researched other devices where AR is commonly used. An obvious choice to research was mobile phones wherein 2016 AR's biggest splash was made by the mobile game Pokémon GO (17). We researched the affordances and limitations that come with using a mobile device for AR. One of the main affordances that the mobile device provided our game was a free roaming camera unlike the fixed camera of the AR table. This means our game could be played in any location or potentially on the go should we so desire. It also enabled the use of location-based AR and other sensors such as the accelerometer that come with most modern mobile devices. Additionally, from a business perspective, the game would be much more accessible as most people own mobile devices meaning they would only need to get the app and physical game pieces. Making a mobile game enabled us to use specific AR software (as discussed in section 2.3). As for limitations, there was one that stood out most during our initial research and that was the small screen size of a mobile phone that we discuss in section 5.2.2.

2.5 AR Software

For our project, we did research into two leading AR software development kits, ARCore and Vuforia. These development kits enable a few different types of AR but we were specifically interested in their image recognition ability. These software kits work by integrating into a game engine and providing an "AR camera". This camera will detect, recognize and track images from an image target databases that store the images to be recognized when scanned. Once the camera tracks an image they can

then work to find their location in 3D space based on the position of the camera in relation to the image. We discuss more our tests and findings for the software in section 5.2.3.

3. Design and Gameplay

3.1 Intended Gameplay

The gameplay goal was to create an experience where players felt as though they were powerful wizards, capable of manipulating the elements with a mere thought. In most games, being a wizard means nothing more than having weapons that shoot fire or electricity. Often wizards are given arbitrary limitations to prevent them from using magic all of the time. Warriors are never given limitations on how much they can swing their sword, and archers can shoot as long as they have arrows, so why should wizards have to stop casting magic? We wanted then, a system where, if the player has the means, then they can cast whatever spell they want.

3.2 Core Design Goal

Our core design goal was to create a game where AR elements and physical tabletop game mechanics have equal importance. For the first term of the year, our efforts and through them our game were unfocused. We had a hard time agreeing on any major mechanic. This changed when our programmer showed us the chemistry

video mentioned in 4.2. Upon seeing this we knew we had found our core AR mechanic. The idea of putting two image targets next to one another to create a third, fully digital object, was enticing. The video demonstrates the principles with elements from the periodic table. We knew we wanted to create a game based in a fantasy setting, but seeing that video set us on the right path. The video showed what could be done with elements, so we had the notion to use the principle with magic. One of us recalled a game known as *Magika*, further explained in section 2.2.1. *Magika* focused on casting spells using eight base elements. Given that AR excelled with visualizing digital objects in the real world, we agreed that a spellcasting system, with physical card elements but digital representations of attacks was the perfect core mechanic.

Figure 7: gameplay of spells being placed before combining

3.3 Spell Casting System

Our spellcasting system is based on *Magicka's* combat system. To simplify matters, we based our system not around eight elements, but around five. These were: water, earth, fire, air, and holy. Also like *Magicka,* we created four combination elements: steam, lightning, magma, and ice. To add depth to the system, we elected

combination elements to apply status effects. Spells can be cast for as cheaply as two cards: either two of the same, or two to make up a combination element. For basic elemental attacks, each additional card adds to the damage of the attack. For combination element attacks, an additional pair of elements are needed to increase the strength of the attack.

Element	Effect	Element 1	Element 2
Lightning	Deals additional damage	Earth	Air
Magma	Halves next enemy attack	Earth	Fire
Steam	Deals same damage next turn	Water	Fire
Ice	Prevents next action, deals no damage	Water	Air

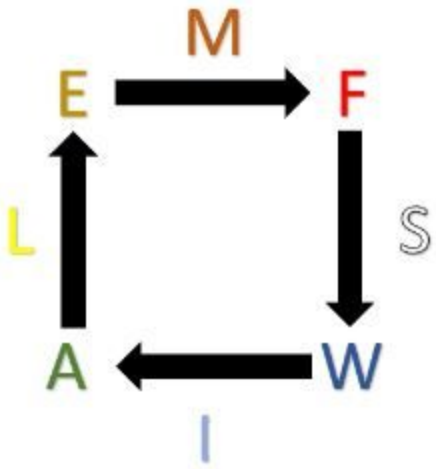
Figure 8 (Combination Element Descriptions)

Holy was our fifth element, each character was to refer to holy as something different. It was supposed to be pure magic, with each character naming it according to their background. Holy served two purposes. First, players could use the holy element to regain health at a one to one ratio. The other purpose holy served was to modify spells so that they could target specific foes. We originally intended for certain enemies to be immune to damage except through spells modified by the holy element, however, several times during testing it was noted that holy did not add depth to combat. When

these thoughts were expressed by playtesters during Alphafest, we chose to remove the holy element.

In our original concept, each monster indicated which element it was effective against, and which it was weak too. This was a cumbersome system that made combat sometimes a guessing game however, it added a further level of choice to player's actions. To remedy the situation, we developed the elements to have a rock-paper-scissors type of interaction with each other. Each basic element is strong against another element, weak to another, and neutral to a third.

Initial	Element
E	Earth
M	Magma
F	Fire
S	Steam
W	Water
I	Ice



A	Air
L	Lightning

Figure 9 (Element Wheel and List)

We spent several weeks debating whether the combination elements were also a part of the rock-paper-scissors equation. Ultimately, both for simplicity's sake and to give basic elements more purpose, we decided against having the combination elements be a part of the equation.

We faced two issues for much of the game's development. The first was that there was not much depth to the combat system. A player's best option was always to use as many cards as possible to make an attack. The other issue we repeatedly ran into was that our wizards always felt either too flimsy or too strong in the face of combat. We did not want players to fear their character being hit from the start of the game, but we also did not want these wizards to be able to tank attack after attack. After trying to work out a balance between monster damage and wizard health we had a eureka moment. From a board game mechanic perspective, this is a hand-management game and there was no real hand management to speak of. *We needed players to think about what cards they used*.

In many of their depictions, wizards do not stand still and face attacks; they almost always have some form of barrier to protect them. We divided combat into two phases: one for staging an attack, and one for preparing a defense. First, players would lay out the cards that would make up their attack. Then players would use their

remaining cards to power their character's barrier. After testing several ways of reducing damage through barriers, we settled on a fairly simple system. Each element put into the barrier decreased the damage the wizard would take from their opponent's attack by one. Adding elements the wizard has an affinity with would count as double. This change did necessitate increasing the number of cards in a hand. Before the player's hand size was four and that was determined by players to feel very underwhelming. Bumping the hand size up to seven completely nixed those comments.

3.4 Dungeon Design

Our original plan was to use a system similar to *Betrayal at the House on the Hill* to create a random generation system that could create hundreds of different dungeon layouts. Because of Vuforia, we changed to a static dungeon. This is further explained in section 4.2, but to summarize Vuforia has an image target limit of 5. For reference, our random dungeon was made up of at least 25 segments. We also previously had every fight be completely random, with no rhyme or reason as to who was fought. Feedback told us that this just was not fun, it was far too easy to face a difficult enemy early on, and lose almost before the game started. Our solution was to separate our monsters into three different difficulties. These difficulties would be indicated by the color of the back of the monster card, and the color of the room. There are three difficulties: green is the easiest, yellow enemies are intermediate, and orange enemies are the hardest. Our dungeon is made up of seventeen rooms. Eight of these were green, six were yellow, and three were orange.

Visually, our dungeon was intended to look like an ancient Persian Empire trading post, before our artists left the team. Given that where the dungeon was to be located, our monsters were picked from the area. Our goal was to create a system where more dungeons and foes could be added in expansion packs. The idea was that each expansion pack could contain a new dungeon and new monsters.

3.5 Cultural Integration/Representation

One of our goals was to accurately represent less known cultures and mythologies. We did not want our representations to be thought of as tokenism. That would defeat the purpose. Given a world full of myths to choose from, we had to narrow our choices. We wanted to highlight non-European myths and Egyptian myths. Both of us were very familiar with Egyptian myths thanks to its prevalence in modern media. and we wanted to explore others. One of us had been playing the game *Okami* during the early stages of the project. Because of this we immediately chose the Shinto religion and myths from Japan as our first featured group.

The other one of us had recently seen *Moana*, and given that neither of us was familiar with Polynesian religions nor mythologies, we decided that they would make very interesting subjects. We investigated Native American myths, as well as Central and Southern American myths but only found sources that we did not have complete faith in the legitimacy of. We did, however, find that there is a large amount of information on Persian myths. Most of these myths are based on Zoroastrian teachings and stories. Finally, one of us remembered a story they heard in a history class, that

before the prophet Muhammad's time, Arabia was full of polytheistic religions. The rise of Islam saw many of these lost to time, but in trying to identify some of them, we ended up learning about the Bedouin nomads.

3.5.1 Monsters

From the beginning, we knew we wanted our enemies to be based on mythological creatures. We wanted it to be that if a player knew the myths of the enemy they faced, that player would not question our decisions as designers.
We did not want players to face enemies from

To avoid treating each of these religions and mythologies as a coat of paint, we first decided that this game would be set in a dungeon influenced by a single myth. Given the large amount of information, we elected to make it a Persian-themed dungeon.

We wanted to avoid a *Final Fantasy* style of representing myths where each figure becomes another monster to fight. We spent time finding both antagonistic figures in Zoroastrianism as well as bestial mythological creatures. These creatures came not just from Iranian myths, but also Turkish myths. The area, referred to as “the Persian Empire”, has changed hands numerous times over the course of history. We thought this would be a reasonable reason to feature such a variety of mythological creatures.

When we divided our dungeon into three tiers of difficulty, we did the same to the monsters. Out of a total of 25 monsters, 12 were of the easy difficulty, 8 were of the intermediate difficulty, and 4 were hard. Our last monster is the boss. The boss or big

bad of this dungeon is the primary antagonist in the Zoroastrian religion, a being known as Angra Mainyu. We chose him as our final boss because we could not find any depictions of him, and we thought it would be very interesting visualize an amorphous being of pure evil.

3.5.2 Characters

For the longest time, our player characters were generic wizards, differentiated solely by which element they had an affinity with. To add novelty to the game, we elected to make each character a member of one of the groups we researched. We wanted each character to feel like a unique representation of their background.

Our first character was the Trickster, hailing from Polynesia. Named after the folk hero Māui, a famous trickster figure. The special ability of the Trickster is that they possess mana. Mechanically, mana is treated as untyped energy that can be used any place an element card would be otherwise. The Trickster's affinity is water.

Next, we have The Shinto Priest, hailing from Japan. The Shinto Priest's special ability is to summon the 'Divine Wind'. Mechanically this is treated as swapping one's opponent for a different opponent of the same difficulty. Even though this ability is based on the story of the kamikaze, unfortunately, today the term 'kamikaze' is more often used to refer to the suicide attacks Japanese fighter planes attempted against the US Fleet during the latter years of World War 2. Because of this, we refer to the special ability as Divine Wind. Given this wind's importance, we felt confident making air the affinity of the Shinto Priest.

Our next character is the Magi, a follower of Zoroastrianism. (should already be stated that Magi are teachers). In various myths, when a horrible creature was causing havoc, it often fell to the magi to solve the issue. The ability of the Magi thus is named the Magi's Training. Using the Magi's Training gives the Magi the ability to power up a spell with +2 damage. In Zoroastrianism, fire is seen as a purifying light, and a symbol of the Ahura Mazda, the god of Zoroastrianism. It is because of this we made the Magi's affinity fire.

Our final character is the Nomad, a Bedouin nomad. While Bedouins adopted some of the ritualistic practices of the areas they traveled, nothing held greater importance than Fate. So, we made the Nomad's ability Fate. By spending a fate point, the Nomad forces its opponent to re-roll its last action. As the Bedouin are nomads, we felt justified in making earth the Nomad's affinity.

4. AR and Gameplay implementation

4.1 Picking AR type, medium, and software

The first technical decision our team had to make after our initial research period was what type of AR we wanted to use. We had started to brainstorm some basic ideas for games and potential AR types that would be appropriate. After some debate, we decided that the best type of AR for a board game would be recognition-based AR. We came to this conclusion based on our findings in section 5.2.1 that recognition-based AR is the most developed, and most compatible with board games. We felt that

reliability and compatibility were the most important for our game because these would help AR to play a bigger role in our game. If AR was found to be unstable or gimmicky most players would be put off of the game as a whole. So making sure that AR could both work reliably and fit seamlessly into board game mechanics was of utmost importance.

After picking an AR type that we wanted to work with we spent time researching AR tables and mobile phones, as we thought that these two devices would work with an AR board game. While both devices had high compatibility for both recognition AR and board games, in the end, we went with a mobile game for a few key reasons. The mobile device allowed for less setup time, and more freedom of movement while falling short of the AR table in terms of player view as discussed in section 5.2.2. Additionally, we had already spent a non-insignificant amount of time doing research and designing and we needed to move onto prototyping and testing. Going with an AR table would have required more research into how to build one and building it would have eaten into both funds and time. The mobile device also provides players more freedom of movement in the 3D environment. The idea of a free-roaming camera that players controlled meant that it would allow for more exploration of the planned virtual environment than the static camera and projector setup we saw with most AR tables. One foreseeable problem with mobile phones would be the limited view given from the small screen of mobile phones this would limit the user's ability to be immersed in the AR and amount of objects viewable at once. In the end, we felt that the drawback of

working with the AR table was too harsh and that mobile phones allowed for a more creative exploration of AR.

After selecting both an AR type and device for our game we then had to choose the right AR developer kit. We looked at two main game engines that had the ability to incorporate 3rd party AR development kits: Unity and the Unreal Engine. We talked with fellow student Mikel Matticoli who had prior experience working in AR. His information combined with the research we did showed that Unity had better integration of AR and could utilize two different development kits. This made Unity the clear choice to work in. After this decision, we researched and tested with both development kits: Vuforia and ARCore. Our findings can be found in section 5.2.3 and they led us to use ARCore. We initially started working in Vuforia as we found it easier to work in with a much heavier “drag and drop” design over ARCore. This made Vuforia easier to experiment and test with compared to ARCore and allowed us to quickly gain insights into what limitations AR would impose on the design of our game. After looking through the capabilities of each of the different software and how they tracked images we decided to transition from Vuforia to ARCore. We made this change as the limitations that Vuforia had on art and design were too constraining. The limited ability to work with smooth or organic designs made our initial prototype art very blocky and rough which was an art design we felt didn’t fit well with our game. The number of maximum trackable targets also became a point of concern as Vuforia’s capacity of five limited the use of our game’s core mechanic of combining elements, which required the tracking of multiple targets at the same time (11). Lastly, We found the most convincing reason to switch to ARCore be

how the frameworks handle image tracking and persistence. Vuforia would require a large amount of backend to keep track of the state of all objects when they left the view. This lack of persistence would also cause problems when trying to fit multiple elements and monster in the frame just to cast a spell. We found ARCore to be much less computationally heavy in the way it handles tracking by favoring a moving virtual camera that mimics the physical camera movements and anchoring objects in virtual space (14). This let players focus on scanning single cards at a time and not worry about framing the scene close together. It also allowed for a much larger image target capacity of 20 (32). These factors allowed for our design to be less constrained and were the leading causes of our switch to ARCore.

4.2 Designing with AR

One of our earliest design principles was that AR and physical elements of the game should play equal importance. We felt we needed this design principle established early on because we saw a pattern in a lot of different AR games where AR was often given a secondary role where players either could ignore AR elements or simply turn them off if need be. We felt that it was a disservice to the capabilities of AR to limit it to a secondary game mechanic, or a paint job on a game that could otherwise be played without it. It was from this standpoint that we decided our main mechanic would rely heavily on AR thus providing a wholly unique experience that could not be had without AR. This lead to the creation of our game mechanic of combining game objects in virtual space a feat undoable by conventional tabletop means.

The first major design choice that we made early on was to our main AR mechanic combining elements. We were initially inspired by the chemistry video reference (30), that shows the combination of different periodic table elements to form more complex molecules. This inspired us to try a take on this mechanic with magically combining elements to forge spells. While we initially tested with a proximity-based combination system like was seen in the video we found that this came with some problems. While testing we found those spell elements would often merge on accident if they were not given enough space. Due to these accidents and in order to lower the amount of space each card need we decided to switch to a different method of combination. This new method combined all elements that were active in the scene when the user scans a card. This meant that not only would players no longer be accidentally combining cards it also allowed for less space to be taken up by each card.

The next major design we made around AR had to do with sequencing and turn structure. In all online tabletop games whenever a player wishes to switch phases or end their turn they normally have to give some explicit input to the game to do so. This problem occurs in almost all digital version of tabletop games but is often accompanied by the game passing through phases for the player when they lack any action to take. In the case of AR since the board game takes place in both digital and physical space, the game is unable to determine what actions the player can and cannot take. This means all transitions and actions in the game need to be explicitly given to the game by the player. This informed our design that players should not be spending too much time telling the game what they were doing as opposed to just doing it. This lead to the turn

structure we see in our final game where turns are comprised of a single attack phase. Players then identify the end of their turn using the cast spell card. Once the spell fuses and hits the enemy the monster takes an automated action on the player that hit it and play passes to the next player.

Another major design choice we made due to discoveries in AR was the use of a game board. We had initially planned and prototyped a game board for our game that players would traverse and encounter monsters within. Unfortunately, when testing the idea of a 3D dungeon we came across the problem of player's views being blocked. At table height, we found that the dungeon walls would often block the side view to all objects within it. This became a problem as people often adopted a top-down view to play the game so that all objects would be visible. This type of play style was not conducive to the type of experience we wanted for players as it limited 3D environmental exploration. Due to this fact, we decided to go with an open game space with no boundaries. With these players would be free to use the open space as they see fit and would allow for the uninhibited use of the free-roaming camera of the mobile phone.

4.3 Programming

We initially used Vuforia to practice and understand core AR concepts and while this was helpful to start designing with AR we stated in section 4.1 we switched to using ARCore. This switch didn't come without its own set of difficulties mostly that the two pieces of software handle tracking and persistence so differently than most of the code

could not be brought over. Instead, the code had to be recreated in ARCore to get back up to where it was in Vuforia. This action was very important as ARCore allowed for much more interaction with low-level features of the software such as image tagging.

Our game is predicated on the ARcore software development kit and as such all of our code is an interaction with their underlying image detection system. The way we find image targets is using an image target database that store and grades all the images we use. It then takes a snapshot of the camera's current view and attempts to locate any and all images from that database that appear. After detecting an image it places an anchor point in 3D virtual space based on the current virtual camera position. Then our program uses the anchor points that are paired with these images to instantiate objects that correlate to each image. Unfortunately some lower level features we could not edit. One such feature was the tagging of certain images as being tracked or untracked. We were unable to affect either the tagging process or the list that stored what images were tagged with. So, in the end, we had to implement a higher level solution of making our own copy of the list of tracked images using the specification we needed. We did this because we needed certain images to always instantiate new objects whether they were previously tracked or not and others to only instantiate once and then move if they were tagged as already being tracked.

5. Testing and findings

5.1 Design Testing

In our testing, we primarily were focused on making certain that our gameplay mechanics paired themselves to the affordances granted by AR. The first victim of this testing was our AR board. Originally we had conceived a 3D dungeon centered on the game table. During testing, we discovered that this caused the game board to be all but unviewable from any angle except for top-down. Our only conceivable solution to this problem was to flatten the board but doing this would effectively eliminate the reasons for having a board depicted in AR. Other playtesting proved that our core mechanic was actually fun. While unfortunately data to support this has been lost to computer gremlins, our early playtesters all agreed that the combination mechanic was fun. This early feedback gave us confidence in the mechanic to push forward with the design. Feedback from Alphafest told us that players were uninterested in fighting one another, preferring to work together to defeat enemies. This brought us an agreement that the best experience was to create a player versus environment type game.

5.2 AR Findings

5.2.1 AR types findings

In our research of AR, we found that most of the types either didn't fit well with our core design principles or were not compatible with board game mechanics. Location-based AR is too large scale and didn't work well with the idea of a board game. Because of these two reasons, location-based AR was the first option we decided against pursuing. As for outlining AR, we found from our research that it had mostly practical uses in engineering and was hard to interact with causing us to come up short on designing possible mechanics around it. Superimposition-based AR was very exciting and was one of the types that showed the most potential for creating immersion. Unfortunately, superimposition went against our core design principle as superimposition acts to mask or overwrite physical elements rather than work alongside them. This left us with two types that we had come up with some ideas for recognition and projection. The main reasons we went with recognition over projection was that we found more examples and documentation for games that used recognition. Additionally, out of examples, projection alone didn't provide a lot of interaction and was often used alongside a sensor or with recognition-AR. We also wanted our game to be able to explore a 3D board space which projection could not accomplish alone which is what lead to our research into the Pepper's ghost illusion. In the end, we concluded that recognition AR was best suited to the needs of an AR board game.

5.2.2 AR Mediums findings

For our research into AR mediums, we looked at two main devices, AR tables, and mobile phones. We decided to pursue research into these two in particular as they both were able to make full use of recognition-based AR and could adapt well to being used for a board game.

One main difference between these two mediums was freedom vs constraint with the camera. The free roaming camera fo the phone allows players to fully make use of the 3D environment that can be provided with AR. However, a fixed camera has more reliability and can even do specific actions based on relative position or rotation to the fixed camera. This could not be accomplished if the camera could have any position or rotation, such as is the case with the mobile phone's free-roaming camera. In the end, we decided that maintaining the freedom to explore the 3D environment was too important. This was an aspect we felt was very unique to AR and without it, our game would be less of a unique experience.

Unfortunately, with mobile phones, we did feel that the smaller screen would make for a lower level of immersion in the effects of AR. Holding a phone up to your face is not immersive and can get in the way of gameplay. We considered the potential ramifications that this drawback would have on our game and concluded that there were ways to plan or design around this pitfall. One was that you would only need to be holding the phone when one was using the AR so when a player is planning their turn and setting up they would not need the use of their phone. Additionally, we concluded

that the use of tablets with their larger screens and kickstands would help to remedy this problem.

Finally, the largest positive of going with mobile phones was due to the amount of set up that would be needed for an AR table. Our team was excited and eager to try our hands at making and programming an AR table. Although as we conducted more research and learned from those who had made their own AR tables, we found that making the table itself was an endeavor. After taking into careful consideration the scope and scale we wanted this game to be we decided that our team lacked the technical expertise to pursue any project with significant hardware requirements.

5.2.3 AR Software Findings

Software:	vuforia™ (13)	ARCore (5)
Image requirements	• Rich in features • Good contrast • No repetitive patterns • Proper formatting	• Good Contrast • No repetitive patterns
Trackable image capacity	5	20

Persistence	In view only	Both in an out of view

Figure 10: Chart comparing Vuforia and ARCores main features

Through both research and testing, we started to better understand the limitations and capabilities of each of the AR development kits we worked with. We were able to comprise a list of major differences that informed our decision to switch from Vuforia to ARCore as is discussed in section 4.1 and shown in Figure 9.

Each AR development kit comes with their own grading rubric and requirements for acceptable images. Vuforia and ARCore share two key requirements for image detection, good contrast, and no repetitive patterns. Good contrast means that the images should have contrasting colors to help the software define notable shapes and colors that make up the image (10), while repetitive patterns make it harder for image detectors to recognize images. Vuforia also has two other requirements for images, they need to be rich in features and adhere to a specific format. "A feature is a sharp, spiked, chiseled detail in the image, such as the ones present in textured objects" (9). This means that Vuforia has trouble identifying organic and smooth objects such as circles. Vuforia images also "must be 8- or 24-bit PNG and JPG formats; less than 2 MB in size; JPGs must be RGB or greyscale (no CMYK)" (9). Both Vuforia and ARCore put hard caps on their maximum trackable targets. Both state that if they allowed users to go over these caps they would see a large drop in performance of the software. In our research, we found that Vuforia is only able to handle tracking up to 5 image targets while ARCore can track up to 20 (11)(12)(32). The reason why has to do with how each

program handles persistence and image detection. Vuforia works off a system of tracking camera position based on image location. This means that the Vuforia camera does not have a position while an image is not detected. This is because Vuforia only tracks images that are currently in the camera's view. Whenever an image goes off screen the object associated with it is destroyed as it is no longer in view. ARCore works using a system they call anchor points where when an image is scanned it will place an anchor point in 3D space where the image is. Using the sensors of the phone it can determine the movement of the camera allowing the virtual camera to move throughout the 3D digital space the same way the physical camera does. This allows for objects to remain active in the scene even when objects are not in view.

7. Conclusion and Post Mortem

7.1 What we did right

As our first attempt at both a mobile game and an AR game, we approached the process with optimistic nervousness. We were able to make a one-of-a-kind unique experience that could only be had with our take on mixing board games with AR. The amount of mechanical importance our game places on AR is greater than in other AR games of the same platform. This was especially an important goal for our team and the inclusion of AR heavy mechanics was not an easy achievement. While this integration came with its own set of complications its inclusion takes what would otherwise be a normal card game and turns it into a novel, futuristic experience. The inspirations and

unique origins that our game utilizes help our game stand out as something more than your average western wizard-based magic game and furthers the inclusion of often overlooked cultures in gaming. The element combination mechanic performed better than we had initially hoped considering the number of challenges we faced with its implementation in AR. However, as it started to come together toward the final iteration it clearly started to stand out as our game's strongest asset. Lastly, we are very happy with how the switch to ARCore affected our game. Our programmer was worried that switching core software halfway through the project would prove too challenging and would delay further work on game mechanics. This action was important as removing the limitation imposed by Vuforia was needed for our game mechanics to flourish.

7.2 What we did wrong

We started very ambitiously with our intent for AR and while we do not believe that we were wrong to do so, our shallow initial understanding of AR guided us to over scope our project. This later caused us to spend a non-insignificant amount of time rescoping and reshaping ideas after gaining a better understanding of AR's capabilities and limitations.

Our team suffered from communication and planning problems where we had no clear team leader. This caused our design and initial prototyping period to last much longer than we had hoped. This plus the harsh restrictions placed on art lead to the departure of our two artists at the end of C-term. The lack of proper communication of goals and expectations lead to an eroding of trust between project members. This lead

to an isolation of teams outside of the weekly meetings. This isolation, given how closely the technical and art sides needed to work together for AR, lead to problems down the line.

7.3 What we learned

This project was a very big learning experience for all involved. As our team's first attempt at both a mobile and AR game we didn't fully understand the limitations imposed on our project. We quickly found that these combined with the limitations inherent in digital tabletop games constrained us more than we had expected. Many ideas we explored had to be set aside as we conducted our research into what was and wasn't feasible given our team's capabilities. Working with shifting goals and limitations was stressful but learning to deal with such situations will surely prove invaluable for future projects. Our programmer learned a lot about working with unfamiliar software and programming for a mobile device and for AR. We learned a lot about the pitfalls that come with working on a team and despite our team's failures we always got ourselves back up and brushed off the dirt to take the next step in stride.

7.4 Conclusions on AR

We recommend that if you plan to make a game where AR is the key focus of your game you design entirely around it and make no expectation for other mechanics to work alongside it until you have tested and proven that they will. Currently, the main drawback of AR is that action in the physical world does not translate seamlessly to a

digital medium. Trying to have both a physical and digital space exist in your game and interact comes with a lot of clunky gameplay. As it stands we do not wish to discourage others from trying, but let this be a warning that any attempt made into the foray of AR should be done with prior understanding and research on the full capabilities and limitation of the type, medium, and software that your AR plans to utilize.

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9. Appendix

9.1 Game instructions

Game Instructions

1. All players start with a hand size of seven cards.
2. At the start of a player's turn, scan your player card. Next scan the enemy card.
3. To attack, lay out the cards that compose the attack

Attack Name	Cast
Basic	Minimum of 2 cards of the same type, each additional card adds more damage
Combo	Comes in four types, requires 2 elements: Lightning - Earth + Air Steam - Water + Fire Magma - Fire + Earth Ice - Water + Air

Spell	Requires possession of spell cards

*Note, spell cards are gained after defeating an enemy

4. Scan the cards and when ready, scan the “Cast” card. The attack will be applied to the last scanned enemy.
5. After the player makes their attack, the monster retaliates.
6. Turn order then passes clockwise.
7. When all players have defeated their foe, the boss is summoned.
8. Boss combat runs the same as regular combat, except all players face a single foe.

9.2 Github Repository

https://github.com/sdwinter0/RealityWizards