

The background of the entire page is a fantastical scene. It features a stone archway supported by several columns. In the center of the archway, a glowing orb or fireball is suspended, casting a warm light. The sky above is a deep blue, filled with stars and a bright, ethereal light source. The overall atmosphere is magical and ancient.

# MAGIC

## The Spectating

IMPROVING MtG SPECTATOR EXPERIENCE  
THROUGH DIGITALIZING THE CARD GAME

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**Abstract:**

This project revolves around creating a better experience for the spectators in a competitive trading card game called Magic: the Gathering (MtG). The research investigates already existing spectating methods and how to improve them. Some of these spectating methods, which involve streaming a top down view of the game table, are mainly used for tournaments.

The survey conducted in the preliminary analysis had led to narrowing down the target group from highly experienced MtG players to beginners, who do not have much knowledge of the cards released however can play the game very well. With this information in mind, the research focused on creating a prototype that contains features to help beginners follow the game and keep them updated about basic information such as player life, dice rolls and keywords. The implementation phase required the usage of two computers connected to each other through networking, which exchanged data from a physical table of the players playing and a display showing the game to the spectators. The prototype was overall finished however; some features had not been implemented either due to financial reasons or time restraints.

With the consent of the Magic: the Gathering store Faraos Cigarer, the prototype was set up at that location and a test was conducted, which tests the difference in spectators experience between the experimental group, who use the prototype, and a control group who watch a top down stream of the game. The test concluded that there is an improvement in the spectators experience when watching a digitized version of a game of MtG.

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# Abbreviations

<b>SOTA</b>	<b>State Of The Art</b>
<b>FPS</b>	<b>Final Problem Statement</b>
<b>IPS</b>	<b>Initial Problem Statement</b>
<b>MtG</b>	<b>Magic: the Gathering</b>
<b>GPIO</b>	<b>General-Purpose Input / Output</b>
<b>DSLR</b>	<b>Digital single lens reflex</b>
<b>oF</b>	<b>openFrameworks</b>
<b>GUI</b>	<b>Graphical User Interface</b>
<b>HCI</b>	<b>Human-Computer Interaction</b>
<b>GSR</b>	<b>Galvanic Skin Response</b>
<b>PANAS</b>	<b>Positive Affects and Negative Affect Scales</b>
<b>PA</b>	<b>Positive Affect</b>
<b>NA</b>	<b>Negative Affect</b>
<b>OCR</b>	<b>Optical Character Recognition</b>
<b>TCP</b>	<b>Transmission Control Protocol</b>
<b>UDP</b>	<b>User Datagram Protocol</b>

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# Chapter 1

## Introduction

“Magic: the Gathering” (MtG) is a collective trading card game, with various rules and thousands of different cards, each with different features and keywords. The game is played by millions of people from all around the world, and each year there are million dollar prizes in various tournaments. Nevertheless, a problem usually occurs in the context of tournaments and similar gatherings where the focus of a large audience is on a single MtG game. Spectating usually occurs at tournaments or in games streamed online, however, it has been noticed that generally there is a lack of proper representation of live MtG games. In fact, so far, games are recorded and streamed from above the game table and that is how far the technology has reached in the context of spectating Magic: the Gathering.

This project focuses on spectating MtG games, while the motivation for this come personal experience at local gatherings. Gatherings involve a large amount of MtG players meeting up to play challenging games against each other. Sometimes, however, there is a large amount of the players that want to spectate the game in progress, either for entertainment purposes or for trying to learn new decks their opponents use. Since a game is usually held at a table with mainly two players, it becomes a major problem for a large amount of players, who want to spectate the specific game. It is difficult to gather around a table and keep up with the game, either because they cannot read the card the players had placed on the table or reach and grab it for a closer look, since that would interrupt the players. It is also not easy to see what cards the players are holding, and as a spectator, you are allowed to see this information, however, currently, it is badly represented both at tournaments or gatherings and therefore it will hinder the spectator from being able to read the majority of the cards. As stated above, Magic: the Gathering is a card game with thousands of cards, and not being able to read the cards in play, makes it hard to follow the game progress. On each card, specific features are written which determine how the card is played and how it interacts with other cards. This highly interferes with the spectator’s experience, and can completely diminish it. This is due to the fact that if one was to follow a game completely, they would have to remember all the cards by heart since no help is given in this matter during tournaments, gatherings or traditional ways of spectating the game.

As spectators and players of Magic: the Gathering, this project is motivated by this issue and aims to improve the experience of spectating a MtG game. The report will start solving the issue from the perspective of both beginner and professional MtG players and the information gathered will then lead to the creation of a prototype of the idea. Based on the group’s interest in Magic: the Gathering and experience with this problem, an initial problem statement has been created.

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## Chapter 2

# Initial Problem Statement

*How is it possible to create an interactive platform for helping Magic: the Gathering players and make it more interesting for their audience?*

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## Chapter 3

# Preliminary Analysis

This project aims to create an interactive platform for helping Magic: the Gathering players and enhance the spectator experience for the audience. In order to do so, the first step is to understand the game itself, Magic: the Gathering. Therefore, the first part of the preliminary analysis will go through the basics of the game, explaining the rules and general features.

Then it will look into what has already been implemented in the context of this matter. State of the Art section will look into existing applications digitalizing Magic: the Gathering, and it will examine other alternatives to online card game solutions.

The preliminary analysis will also look into another aspect of the issue which also has raised the motivation for the Initial Problem Statement. In terms of tournaments, the problem occurs due to the many different rules in Magic: the Gathering and how it can be hard to follow a specific game at tournaments. Therefore, it will be looked into how these tournaments are conducted and how or if one could possibly improve the spectator experience.

The digitalized versions of Magic: the Gathering raise the issue of interactive platforms and how one can develop and design an interactive platform for this specific matter. In that context the preliminary analysis will look into interaction design, this includes research in the user experience, engagement (and how to keep the user engaged) and levels of engagement. Lastly it will research guidelines for designing a good interaction.

To verify the Initial Problem Statement a survey will be conducted. This survey will furthermore examine the essence of this matter and how one might approach the problem.

### 3.1 Introduction to Magic: the Gathering

Magic: the Gathering is the most widely played trading card game with over 12 million players throughout the whole world. It was originally released by “Wizards of the Coast” in 1993 and contains over 10000 cards in the game with around 500 cards being released every year. Magic: the Gathering combines collectable cards with a strategy game, which allows you to buy a premade deck or customize your own decks. The trading begins with the purchase of Magic boosters, which are packages of 15 random cards, some of these cards you can trade out with cards that other people gotten from their own boosters.

The basic idea behind the game is to reduce the life of the opponent to 0 life points. The game can be played by two or more players, each having their own personalized deck and each deck can contain between 40 and 100 cards. The cards used in Magic: the Gathering include *creatures*, *instants*, *sorceries*, *lands*, *artifacts*, *enchantments* or *planeswalkers*. The *lands* are the basic cards which are used to cast all the other cards in the deck, for example in order to cast a *creature* with a cost of three *lands*, you must have put down three *lands* in three different turns. There are five types of basic *land* cards; white, green, blue, black and red and certain *creature* cards require certain type

of *land*. The game has a wide set of rules, each one of these rules can be applied to the majority of the type of cards. Overall, the game has six zones:

- the library, the deck containing all the cards to be drawn
- the hand, the player's cards (each player starts out with seven cards)
- the battlefield, where *creatures* and *lands* are placed
- graveyard, contains *creatures* or cards that were used or destroyed during the current game
- exile, some cards can exile others which will then stop players from recasting them
- the stack, it keeps the *instant spells* cast on certain *creatures* during the current turn

There are also certain phases each player must follow when their turn is up. Firstly, the player has a beginning phase, where they *untap*<sup>1</sup> the cards and draw a card, followed by main phase, where they can place cards on the battlefield or use spells, then a combat phase, where the player may attack. Once the combat phase is over, the player is allowed to enter the main phase again and cast spells, lastly an ending phase where the player can activate abilities<sup>2</sup>, then pass the turn.

[Wizards of the Coast, 2013] [Wizards of the Coast, 2009]

Now that the basic mechanism of the game has been introduced, the following sections will take a look at how this game is treated in digital spaces as well as real life tournaments.

## 3.2 State of the Art

State of the Art will examine how this issue has been approached earlier on. This includes existing implementations and which problems they encounter. It is relevant to look into the digitalized version of Magic: the Gathering made by the founder of Magic: the Gathering cards, Magic Online. There has also been an alternative digitalized version of Magic: the Gathering developed, Cockatrice, however this version is not associated with Wizards of the Coast (creator of Magic: the Gathering).

Besides the two obvious choices of digitalized versions of Magic: the Gathering, the State of the Art will also examine two card games that only exist online. These two are Duel of Champions and Hearthstone which are also collective trading card games. Lastly, the State of the Art will look into the app made for Magic: the Gathering, iMtG.

### 3.2.1 Magic Online

Magic Online is a digital version of the card game Magic: the Gathering. The game is made by Wizards of the Coast, which also created Magic: the Gathering [Wizards of the Coast]. The game is a collective trading card game, meaning that, even though it is a digital game, players still have to buy packs of random expecting to find the right card for building one's collection. The basic version of the game costs \$10 and players can then purchase more cards later. The game Magic Online is played just like a regular Magic: the Gathering game, each player's steps are hard-coded<sup>3</sup> and the players cannot skip turn or do something against the rules. Since the game is a collective card game similar to the paper version, players can also trade cards or sell them online, just as players can with regular paper cards. Figure 3.1 shows a screenshot of Magic Online.

<sup>1</sup>Whenever a card is used it has to be *tapped*, meaning it rotates 90°, when a player *untaps* a card, the card is rotated 90° back.

<sup>2</sup>Some cards have extra abilities that can be used without casting a new card.

<sup>3</sup>Hard-Coded: "*Fix (data or parameters) in a program in such a way that they cannot be altered without modifying the program*" [Oxford Dictionaries]





Figure 3.1: Screenshot from Magic Online. To the left there is player information and information about the selected card. In the middle there is the players cards and the battle area. To the right there is a chat box for the players to communicate.

### 3.2.2 Cockatrice

Cockatrice is, like Magic Online, a digital version of the card game Magic: the Gathering. But unlike Magic Online, it is not made by Wizards of the Coast but by an independent developer named Max-Wilhelm Bruker [Bruker, 2013]. The game is different from Magic Online because the player has all available cards from the beginning, so there is no collective aspect of the game. The game is also free and does not have a starting price or a price for new cards. However, Cockatrice does not have any hard-coded rules, which means players can cheat and do illegal moves without the program stopping them. Figure 3.2 is an example of Cockatrice and to the left in the image, information about hand-size, deck-size, life and player information can be seen. The middle blue area is the battle area where players can play cards. The middle green area is the player's hand and to the right at the top information about the selected card is shown. Also to the right, but in the middle, information about players and spectators currently in the game is shown, while at the bottom, a chat for players to communicate is placed.

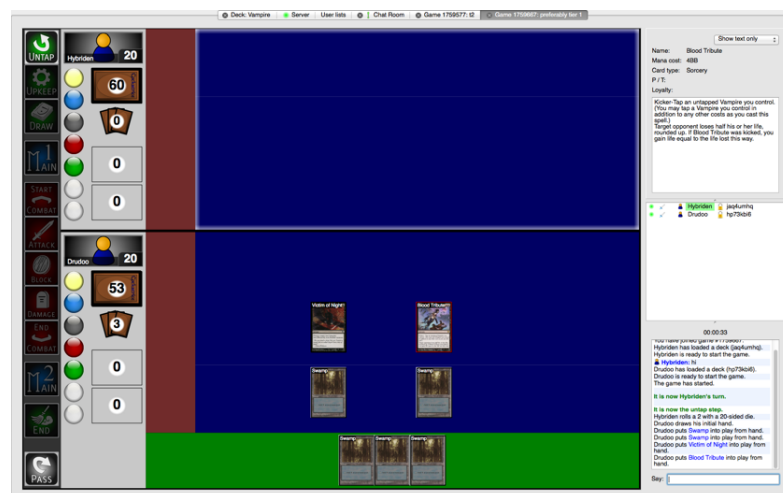


Figure 3.2: Screenshot from Cockatrice.

### 3.2.3 Duel of Champions

Duel of Champions is a collective trading card game based on Unisoft’s Might & Magic universe [Ubisoft]. The game is similar to Magic Online (see Section 3.2.1 Magic Online) because players also have to buy packs of random cards to build their collection and the player cannot cheat the same way they can in Cockatrice (see Section 3.2.2 Cockatrice). However, some rules are very different from Magic Online and therefore, a player that knows how to play Magic: the Gathering will have to learn how to play this new game. Figure 3.3 shows an example of a game of Duel of Champions, to the left the cards of the player can be seen while the battlefield is shown in the middle and above mana and similar points are added.



Figure 3.3: Screenshot from Duel of Champions

### 3.2.4 Hearthstone

Hearthstone is another digital-only collective trading card game. It is created by Blizzard Entertainment and based on the Warcraft Universe [Blizzard Entertainment]. As with Duel of Champions, players can buy digital cards to build their collection. One of the things that makes Hearthstone feel more like a physical game is their interface. The player’s collection of cards is a big binder where the player can turn pages to see their cards (see Figure 3.4).

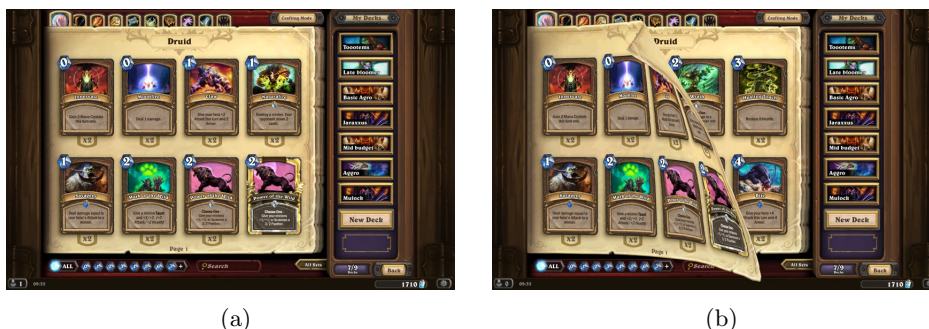


Figure 3.4: Screenshot from Hearthstone’s card collection. Figure 3.4a shows the binder of cards. Figure 3.4b shows how the turning of a page in the binder.

### 3.2.5 Collective Aspect of a Digital Game

Both Duel of Champions and Hearthstone try to keep some of the defining aspects of physical collective card game. In Magic: the Gathering each card has the artist’s name and a lot of cards

have flavor text. Flavor text is text that does not mean anything other than adding flavor or a little story to the card. Adam Lee from Magic’s creative team explains flavor text as; “[...] *the mortar that holds the story together. It’s in the cracks between the other storytelling venues that we have, and it fills in —bit by bit —story information and planar flavor that you can’t get anywhere else.*” [Lee, 2013]. In Hearthstone, Blizzard Entertainment has tried to add both artist names and flavor text to each card to make them feel more like real cards. An example can be seen in Figure 3.5.



Figure 3.5: Example of the card Cenarius with artist name (Alex Horley Orlandelli) and flavor text (“Yes, He’s a demigod. No, he doesn’t need to wear a shirt”).

In Magic: the Gathering there are a lot of different rules and keywords that players have to remember in order to play the game. However, not every card has a full description of the specific keywords, therefore this can be a problem for newer players that might not know all the rules. In both Duel of Champions and Hearthstone a player can select a card and there will be a description of the specific mechanism.

In Magic Online and Cockatrice this is not the case. Instead both of those games use digital versions of the real cards with the exact same text.

### 3.2.6 iMtG

During games, Magic: the Gathering players can use certain applications to count and remember their life. A popular application is iMtG, an app available for iOS which allows the user to set up the life of the players and it also allows them to connect two phones via Bluetooth or Game Center. This would then allow for the life to be changed on both phones at the same time. The life counter can be set as a portrait mode or landscape (see Figure 3.6).

Another feature accessible through this application is the scan option, which allows the user to scan a card. The application then searches through a database giving more information about the card. However, after several attempts, it was observed that the application rarely returns the right results from a scan, however cards can be searched through by typing the name as well. An important aspect of trading cards is to know the current value of a card, iMtG also includes the prices of each card with information taken from TCGplayer.com. Lastly, the application also allows players to log into the community forum and discuss ideas and tips for their decks or the current rules with each other. [Farbiszewski].

### 3.2.7 Sub-Conclusion

To sum up, iMtG is one way to make the games for players easier to follow, by gathering all the information, such as life and dice rolls in one place, where the players or spectators can see. There



Figure 3.6: Screenshots from iMtG

are also a lot of different rules and keywords that players have to remember in order to be able to play the game of Magic: the Gathering. Therefore it can be a problem for newer players that might not know all the rules. In both *Duel of Champions* and *Hearthstone*, a player can select a card and there will be a description of the specific mechanism. In *Magic Online* and *Cockatrice*, this is not the case, instead both of those games use a digital version of the real cards with the exact same text. Due to this reason, the project should not aim to make the game entirely digitalized, but rather preserve its uniqueness and focus on adding digitalized aspects only for improving the spectator's experience.

### 3.2.8 Tournaments

This section will take a look at the situation of spectating a game of Magic: the Gathering at two different tournaments, in order to see whether there is a need for improvement and what kind of improvement would most likely be required.

#### 3.2.8.1 Magic: the Gathering Pro Tour

A game of MtG at a tournament takes place in a sealed room, where only the players and participants to the Magic: the Gathering Pro Tour are allowed. Even though there are 1-6 tables in the room with different games going on, only one table is being focused on by being streamed and discussed by commentators.

The streaming starts out by having the two commentators discuss about the tournament in general and which deck they consider to be the most interesting and powerful, they also express their preferences in the decks that are being played at the moment. When moving the camera to the game table, the battlefield, each player's life and hands can be seen, Figure 3.7 shows how it is presented.

As it can be seen in Figure 3.7, it is not so easy to see what the battlefield contains, however it is possible to see how many cards are currently on the board and how many cards each player holds. The life is represented by the numbers (20) next to the player's name at the bottom of the figure and is an important aspect to the game, which determines who wins.

There are moments where they show the player's hands to the audience, however it is not so easy to see what they are holding and even if the names would be clear enough to read, a beginner to this game would have troubles knowing what each of them do. See Figure 3.8, for an example of how the player's cards are shown.



Figure 3.7: Screenshot from the stream of Pro Tour tournament [[magicprotour](#)]



Figure 3.8: Screenshot from the stream of Pro Tour tournament [[magicprotour](#)]

### 3.2.8.2 Grand Prix Prague

Grand Prix Prague semifinals are also presented using the same way the Pro Tour is and can be seen in Figure 3.9. The only difference is that they use headers to show the title of the match going on and the type of game they are playing (M14 draft). By knowing these things it would definitely make the spectating easier, hence the audience will know that all cards belong to the M14 edition.

Another interesting aspect to be considered is the way the battlefield and the “battle” going on is presented. Currently in Figure 3.10, four *creatures* are fighting and there are two *instants* or *enchantments* also used in this phase, however, as it can be seen, it is difficult to follow which *creatures* are fighting, how much life and power each have or what each other cards does to the battle’s outcome. By only having visuals it would be almost impossible to see what is happening, however as stated above, the commentators speak out the names of the cards used and the outcome of the battle, however they usually do not state the toughness/life of a *creature* that was used or what the *creature* does.

Overall, the streaming methods of Magic: The Gathering are the same, there are not many improvements added from one to another when it comes to showing a game in progress. It was noticed that the main focus is on having a top down view of the battlefield, however not showing individual cards when these are being used, this means by adding a small improvement in these type of streamings, spectators might learn and understand more from them.



Figure 3.9: Screenshot from the stream of Grand Prix tournament [Magic: the Gathering]

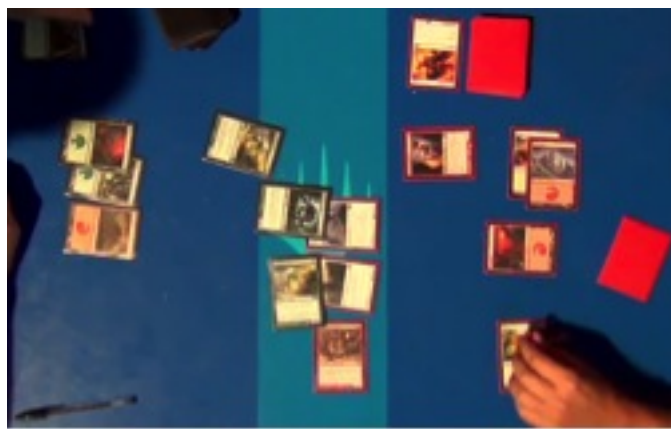


Figure 3.10: Screenshot from the stream of Grand Prix tournament [Magic: the Gathering]

### 3.3 Interactive Platforms

There is interaction all around us, we interact with objects, people and technical devices. The interaction goes both ways, —we talk and listen, we touch and feel, and we act and get feedback. In order to create an interactive platform it is important to understand how you can develop a good interaction design. This section aims to define what interaction design is and how to create a good interactive interface.

#### 3.3.1 What Is Interaction Design?

Interaction design is a broad term and has been defined in many different ways. This project uses the definition from Roger, Sharp, and Preece who define interaction design as follows:

*“[...] designing interactive products to support the way people communicate and interact in their everyday and working lives”* [Rogers et al., 2011, p. 9]

#### 3.3.2 The User Experience

The user experience is very central aspect when creating an interaction design. A part of the interaction, is the user’s experience with the product. Roger, Sharp, and Preece define the user experience as follows:

*“How people feel about a product and their pleasure and satisfaction when using it, looking at it, holding it, and opening or closing it”* [Rogers et al., 2011, p. 13]

### 3.3.2.1 Usability

In context of the user experience comes usability. It serves to improve the functionality, aesthetics, content, look, touch, sensual and emotional appeal [Rogers et al., 2011, p. 15]. In order to create an interaction design, usability goals have been developed:

- Effectiveness (effective to use)
- Efficiency (efficient to use)
- Safety (safe to use)
- Utility (having good utility)
- Learnability (easy to learn)
- Memorability (easy to remember how to use)

### 3.3.3 Interactive Media

This part describes interactive media in terms of basic interaction. It sums up the interactive part of the research done for the project according to the IPS.

An overall term for interactive interface types is navigation. The interface design serves to navigate the user around all features of the product. This concerns headings, categorization, menu design, and icon design. Each of them have different features and structures.

The combination of media and interactivity have proven to be highly effective for presenting information compared to ordinary medias like books, audio, or videos. This is very relevant in the context of the IPS. The differences between the interactive media and the ordinary media are:

- Easier learning
- Better understanding
- More engagement
- More pleasure

It is also possible to have multiple representations of information to the user. In fact, to such a degree that it instead can become a problem. If there are too many elements for the user to look at, some elements might be discarded subconsciously or consciously. This mean that some elements might never are looked at or used. This has led to the development of guidelines for interaction design creation [Rogers et al., 2011, p. 176]:

- Audio information - is used to stimulate the user’s imagination
- Movies - convey visual information
- Text - conveys details
- Diagrams - convey ideas

This section has defined interaction design as products people can use in different context. It revolves around the user experience, which is how the user perceives the interaction. In that context one uses usability which derives from the user experience and it describes the elements for making a good user experience; effectiveness, efficiency, safety, utility, learnability, and memorability.

Lastly, interactive media is a different platform where the user’s experience comes into play. The interactive medias are used to make learning easier, provide a better understanding, generate more engagement, and give more pleasure compared to using ordinary media e.g. books.

## 3.4 Engaging audience

The project's IPS aims to figure out if and how an interactive platform can maintain the interest of MtG spectators (see Section Section 2 Initial Problem Statement). Taking this into consideration, it is important to research what methods can be used in order to capture the audience's attention and keep them engaged.

In general, engagement is described as a broad and complex concept, dealing with attention, curiosity, intrinsic interest, motivation [Chapman, 1997], goals, mental models, motor skills [Said, 2004, p. 169-172] as well as user's activities and attitudes [Kappelman, 1995, p. 65-86]. However, in this particular situation, when engagement is not intended towards the primary users of the installation, but rather focuses on providing a better experience for the spectators, the concept of engagement can be simplified. Due to this reason out of the variety of engagement definitions, the one defined by Chapman, who simply states that *"something that engages us is something that draws us in, that attracts and holds our attention"* [Chapman, 1997], seems to be the most accurate in regards to this project. In addition to this, since the project focuses on a very specific group of people (see Section 5.1 Characterization of Target Group), who have a natural interest in the game, the relation between spectators and the interactive platform will be driven by intrinsic motivation. Intrinsic motivation refers to the motivation driven by an interest in the task itself, unlike extrinsic motivation, which is supported by the desire to obtain a reward, an outcome. [Ryan].

The following sections will present and explain a few theories concerning spectator engagement.

### 3.4.1 Levels of Spectator Engagement

Nowadays the role of a spectator might have different meanings in various situations. For instance, a spectator of an art installation in a public space can easily become its user<sup>4</sup>, or even viewers of a television show might have an interactive experience by voting and thus affecting the outcome of the show (common in TV reality shows). In other words, there are several different ways of spectator engagement, depending on how active the engagement is. To describe this, four classifications of spectator engagement ([Danieli et al., 2008, p. 13]) have been established:

1. Passive - there is no interactivity between the spectator and the experience, however, in his case visual aesthetics play a major role in keeping the spectator engaged (e.g. watching television).
2. Semi-passive - some interaction happens between the spectator and the experience, however it does not have an impact on the activity being followed (e.g. side betting in sport events).
3. Semi-active - there is minimal feedback from the spectator to the experience, however the spectator had very limited possibilities (e.g. voting off contestants of a talent show).
4. Active - the spectator is able to take part in the action, but without actually being a participant in an event (e.g. "ghosting" in real, augmented or virtual events).

In regards to this project, it seems appropriate to keep the spectators passive or semi-passive, because in this case the event is happening between the MtG players, and spectators should not be allowed to interfere with the gameplay. However, as previously mentioned, in such case the visual aesthetics should be well considered since it would be the main aspect capturing the audience's attention. On the other hand, they might be semi involved in the experience by, for instance, betting or ranking their favorite players, predicting how the game will end. This way the gameplay will not be affected, however, the spectators might get a more enjoyable experience.

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<sup>4</sup><http://youtu.be/DwahJKgWojU?t=1m15s> an example of spectators becoming users in a public space art installation.



### 3.4.2 Designing the Spectator Experience

Interaction is a two way process between humans and systems, and the interaction from the spectator approach and their input in regards to this project has been discussed above (see Section 3.3 Interactive Platforms). However, the other side of this process concerns designing the system in such way that will benefit to a positive experience. A group of researchers from The University of Nottingham have developed a design strategy oriented not towards the actual users, but rather the spectators of a public interactive system. [Reeves, Benford, and OMalley, 2005].

The strategy contains of four approaches that are defined by exposure of manipulations that the users perform with the system and the perceived effects as of these manipulations commonly in a form of graphical or audio feedback.

Figure 3.11 illustrates the concept of these design strategies, where the four different approaches are explained. Firstly, the magical approach, where manipulations are totally hidden, and the spectator is presented with impressive effects without comprehending what exactly caused them, thus making it appear mysterious. Another is the expressive approach, where both the effects and manipulations are not only revealed to the spectator, but even amplified. As the opposite of the expressive, the secretive approach does not reveal either the manipulations or the effects and may be used when the spectators are not supposed to understand the interaction by observing others, but rather try it themselves. Lastly, the suspenseful approach is similar to the secretive in a sense that the spectator does not get to experience the effects before trying to interact with the system [Reeves, Benford, and OMalley, 2005, p. 5]

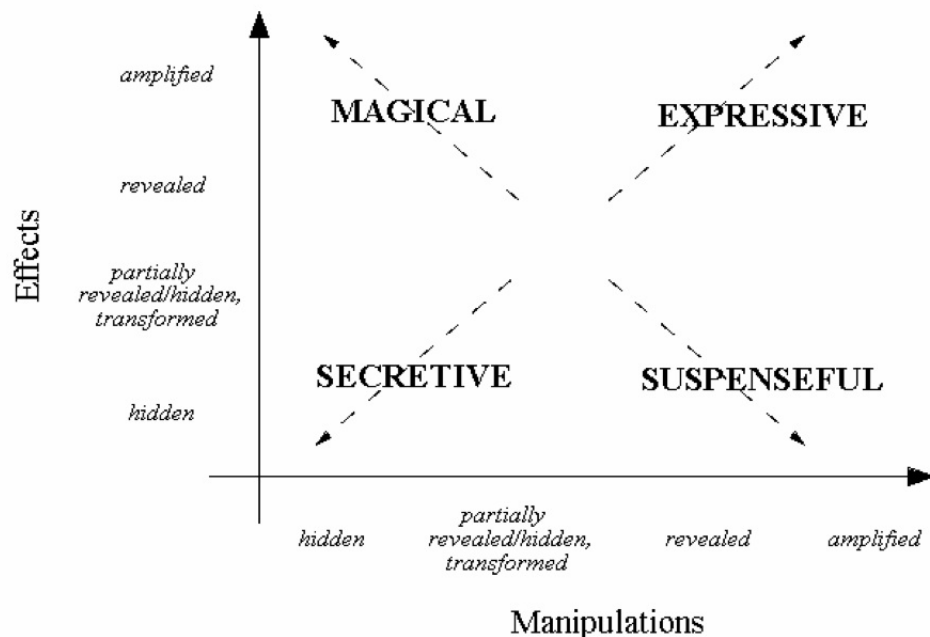


Figure 3.11: Spectator experience design model

If this design model was to be applied towards the spectators of this particular project, it appears that expressive is the approach that suits this project best. Mainly due to the reason that it is not intended to hide either the actions of the players or the effects that their manipulations might trigger in the system, since the effects are primarily aimed to help the spectators understand the game process easier and better.

## 3.5 Survey

The IPS (see Section 2 Initial Problem Statement) of this report refers to both helping the players and their audience. Before defining the Final Problem Statement, it was required to narrow down the topics that should be looked into, to see which direction the FPS would be best approached from. A survey was conducted, targeting only Magic: the Gathering players, as it was published online on a large Magic: the Gathering community on the website [reddit.com/r/magicTCG](https://www.reddit.com/r/magicTCG) [Reddit.com], being available to receiving answers between 19th and 21st of February 2014.

### 3.5.1 Questions

The survey contains 17 questions, but some questions are contingent, meaning the next questions are based on the response from the previous question [Lazer et al., 2010, p. 115]. It also consists of a mixture of closed-ended questions with unordered responses; multiple selection or single selection and open-ended questions [Lazer et al., 2010, p. 111-112]. The survey begins with a consent form where the participants were explained the purpose of the survey, who we are and also asked whether their results can be used for this project. Only the results from the participants that agreed to the consent form were used and since all participants agreed to the conditions, the majority of the results were viable for analysis. The first four questions helped narrow down the target group and show the demographic of the participants answering the survey. These questions collected information about:

- Age
- Country
- Sex
- Do you play Magic: the Gathering?

To get an idea of the participants' experience with gatherings, spectating games, and to figure out how their experience can be improved, seven questions were asked, concerning local Magic: the Gathering meet-ups. Based on participants' answers, some questions were not available to answering. After asking questions about the spectators' experience at local MtG gatherings, two questions were asked about improving the game for the player and two questions in the end about tournaments.

The final question was an open-ended question asking about general opinion on the questionnaire. A lot of people decided to use this opportunity to add additional comments and feedback.

### 3.5.2 Results

As mentioned in Section 3.5 Survey, this survey was published online on Reddit [Reddit.com], therefore there was no interaction between the researchers and the participants, which could lead to unviable or biased answers. While going through the responses two responses were removed because the answers were invalid since they were incomplete [Lazer et al., 2010, p. 120].

The survey was answered by a total of 605 people, where 603 responses were valid and used in the results representations and analysis.

#### 3.5.2.1 Demographic

The first questions contain data about the demographics and give an overview of the target group playing Magic: the Gathering. It seems that the majority of MtG players are males and that there is a small percentage (3%) of female players, however it can be due to the fact that the survey was published on [Reddit.com] which is assumed to have a higher percentage of male users than females.

Figure 3.12 shows a histogram of the participants' age and the data distribution. The majority of the participants are between 19 and 28 years old, however it is to be noticed that there are younger players of age 18 and under.

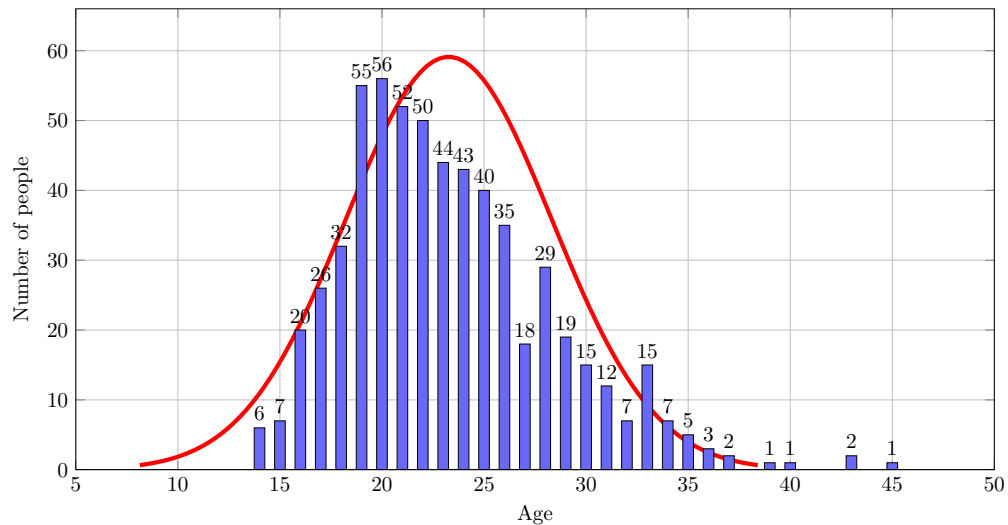


Figure 3.12: Normal Distribution fitted with histogram of participant's age ( $n = 603$ )

Before participants were asked about Magic: the Gathering, an optional question was added, which included information about which country the participants were from. Figure 3.13 shows a chart of the answers and it can be seen that the majority of the participants are from the United States of America and only seven participants were from Denmark.

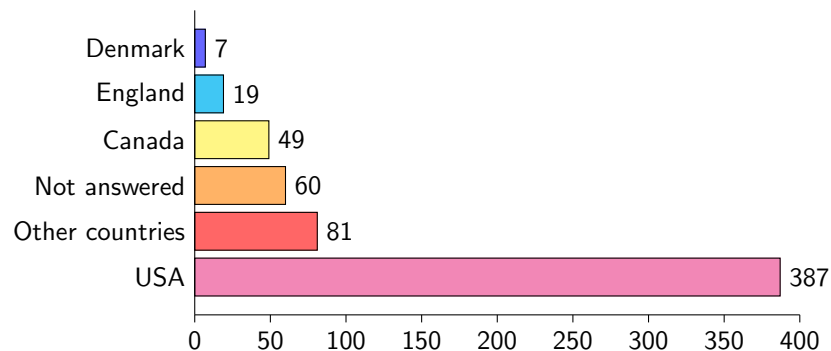


Figure 3.13: Country ( $n = 603$ )

Next, the question “Do you attend local Magic: the Gathering gatherings?” were asked. This question was asked because it was important to figure out how many of the participants actually attend to local gatherings or if participants just play at home with their friends.

From the results it was clear that the majority (82%) of respondents attended local gatherings, which would then prove the importance of such events. When the 18% of the respondents that do not attend gatherings were asked for a reason, most of them answered that they have a group of friends they played with instead, however there is also a large amount of participants 19% that do not have time to attend the gatherings when they are scheduled.

Participants that do attend MtG gatherings were also asked whether they believe it is easy to spectate a game of MtG at such events. This question was asked because it is important to see if there is a need for making it easier for the audience to spectate a local game. Most people (92%) believe they have no problem following a game of MtG at a local gathering. The rest that answered

“No” (8%) were asked why they think it was hard to follow the game and the majority thinks there is too little room around the table and that they do not know the cards well enough to follow along without reading the card.

However, participants also had the option to type in their reason for not being able to spectate properly and some of the reasons can be seen below. Examples of the answers are:

- *“It’s awkward to stand and watch a seated match”*
- *“Hard to observe game state (life totals, cards in grave yard, cards in both player’s hands, etc)”*
- *“People play very quickly sometimes and it is hard to keep up”*
- *“Observers can have a negative effect on the game, either because of talking too loudly amongst themselves, being able to see both hands, or causing psychological pressure on the players due to proximity and reaction to plays. Also, it is not possible for an observer to ask for clarification on a rule, play, or card wording.”*

Even though the majority of the participants think spectating a game is easy, there are players that have a hard time keeping up and the comments presented above show some of the reasons why they think it is hard to keep up during a game in progress. These answers can be used to improve the spectating experience for a certain type of players, which in this case are the 8% that believe spectating is difficult. The next question asked everyone who attended local gatherings, was whether they would like to see an improvement in spectating.

This was asked to see whether they would prefer an improvement even though they believe it is easy to spectate or difficult. Even though 92% said they did not have any problems following a local game, 66% said they would like to see an improvement when spectating the game. After asking the participants if they wanted to see an improvement in spectating a local game, a multiple choice question was asked: *“What kind of improvement would you prefer?”*. This question offered several improvements and the participants could choose as many answers as they wanted. The possible answers were:

1. A screen showing the battlefield from above (261 participants)
2. Information about creatures on the battlefield (185)
3. Explanations of cards used and their abilities (175)
4. Show player life (291)
5. Creature life and damage taken this turn (95)
6. Show possibility of drawing a land card from player’s remaining library (86)
7. Showing coin flip / dice rolls (85)
8. Other (56)

The following two questions in this survey are targeted at the players of the game and asks them whether they would use an application during the game. The result can be seen in Figure 3.14.

Participants were then asked what kind of help they would like in an application, and the majority wanted to have the life, dice rolls, coin flips and explanation of keywords shown.

The last two questions contained information about MtG tournaments and the participants were asked whether they watched tournaments and if they think it was easy to spectate. There is a 79% of the participants that watch tournaments online and 75% also think that they were easy to follow. The full set of answers can be seen on the CD.

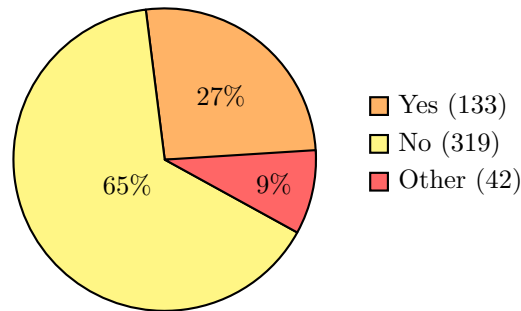


Figure 3.14: Would you use an application which helps you as a player? (n=494)

## 3.6 Conclusion

Both digital games (Hearthstone and Duel of Champions) correct some of the problems that arise with a physical card game like Magic: the Gathering. On a physical card there is a limited space for text, therefore often the complete rules cannot be explained and players need to look up rules or ask a judge, if available. The digital versions of Magic: the Gathering such as Cockatrice and Magic Online do not correct these problems and the players still need an extensive knowledge of the game. Looking back at the IPS (see Section 2 Initial Problem Statement), this project aims to try and give the players and audiences a better access to card rules and keywords. At tournaments, such as Pro Tour and Grand Prix, spectators are presented with an overview of the game and together with commentators the organizers try to present the game as well as possible through visual and audio feedback. In order to create good interaction in an application, it is important to follow the guidelines presented in Section 3.3.2.1 Usability in context of the user experience. This is due to the fact that this project aims to make the Magic: the Gathering more interesting. Good interaction design can ensure aspects such as easier learning, better understanding, more engagement, and more pleasure. In regards to engaging the audience, it has been decided to treat the spectators as passive or semi-passive, meaning that they would not have any impact on the game process. In addition to this, based on the spectator experience design model, the system should be designed in an expressive way by making both the manipulations and effects apparent to the audience.

### 3.6.1 Survey Conclusion

Even though 92% of the participants said they had no problem following a local game, 66% would still like to see an improvement in spectating a local game. This means that there seems to be a valid reason for continuing the project in the direction of figuring out how it is possible to improve spectating experience in a local MtG game. 65% said they would not like to use an application that helps the player, and 9% said “Other” which, based on their comment, can be added to the 65% that said “No”. This means there were 74% respondents that would not want to use an application that helps the player. Therefore this data strongly suggests that there is no reason to maintain the focus on both helping spectators and players, but rather only focus on improving the spectator’s experience. By looking at some of the comments, it was noticed that a high number of participants suggested they would like improvements in spectating a game if they are new to it and have little experience with it, however due to the fact that they are quite experienced in the game, they can easily keep up. Therefore, if any improvements to spectating would be added it should be aimed at Magic: the Gathering beginners. Based on the two questions regarding what kind of improvements participants would like, it is possible to see which type of help or improvements that the participants want and these are some of the things, which should be taken into consideration later on, when working on the final design. The feedback from this survey lays the foundation for the Final Problem Statement and which way the project should develop further.

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## Chapter 4

# Final Problem Statement

*To what degree can a beginner spectator's experience improve while following a game of Magic: the Gathering, if they are presented with visual representations that keep them updated about the game process, in comparison to the existing methods of spectating?*

### 4.1 Defining the Final Problem Statement

This section will explain the thoughts behind the Final Problem Statement. It will explain the terms and what was meant by them.

#### **To what degree?**

The reason we have chosen to ask “*to what degree*” is to test whether there is an improvement in adding an additional system when spectating the game. The audience might prefer all the information given, therefore a certain degree of improvement of the experience can be agreed upon.

#### **Magic: the Gathering beginner**

When it is stated that the project will be aimed at beginners, it is referred to the fact that the audience, on which the prototype is tested on, will also consist of MtG players, however these players have less than a year of experience of playing MtG and do not have much knowledge on the numerous cards released for MtG.

#### **Spectators**

As stated above, the spectators are constituted of MtG players, however in this case the players are only taking up the role of a spectator, which would exclude their direct interaction with the players and the game they are spectating.

#### **Visual representations**

By visual representations it is referred to technological means used to display information such as screens, tablets and projectors, which in this case can take the role of being the primary type of feedback when presenting an MtG game in progress and display it to an audience.

#### **Existing methods**

As mentioned in the State of the Art (see Section 3.2 State of the Art), there are certain ways to present data to MtG players during tournaments, where they use a screen and a commentator to read up information that is not so clear on the screen. This is one of the existing methods, however another existing method, which is also mentioned in the survey taken by the majority of the participants is the traditional way of following a game, which requires being around the table of the players whose game is in progress.

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# Chapter 5

## Analysis

The analysis will look further into relevant research according to the Final Problem Statement. Firstly, it will characterize the target group and determine who they are. Then it will go more in depth with the rules and features of Magic: the Gathering the game. This includes phases, cards and game features.

The analysis will research into how to go from a board game to a digitalized game version, and how to build an effective and efficient Graphical User Interface (GUI) using established interaction methods.

The analysis also considers methodologies in terms of testing the product. This includes definition of what exactly should be tested and how to test it. It concerns questionnaires, observations, focus groups, audio measurements, physiological reactivity such as heart rate, blood pressure, skin conductance and skin temperature etc. The analysis will come around Positive and Negative Affect Scales (PANAS) and Self-Assessment Manikin (SAM), which are two different methods for testing measuring emotional response.

Lastly, the research from the analysis will be used to set up requirements for development of a product, which will be designed in the next chapter. These requirements concern functions, features, and design of the prototype.

### 5.1 Characterization of Target Group

The initial online survey (see Section 3.5 Survey) has helped define the frames of the target group that this project applies to. The basic demographic characterization based on the survey results shows that players of MtG, who attend and spectate games at local gatherings or tournaments are mostly males between 18 and 27 years of old. However, taking into consideration that this project aims to improve the experience of being a spectator in a game of Magic: the Gathering through a visual display, the beginner players are in focus. In addition to this, the target group is considered to have an intrinsic motivation towards spectating the game and having a natural interest in it, while the system created during this project will only aim to improve their experience and knowledge of the game.

### 5.2 Magic: the Gathering

This section will mainly contain an in depth explanation of how the game works, which are the important keywords that will be implemented in this project. This section is aimed at providing enough knowledge of the game to understand the reason for specific design choices.

As mentioned in the preliminary analysis (see Section 3 Preliminary Analysis), MtG has a wide collective of players and is a card trading game. The game functions by creating decks of 40, 60 or 100 cards.

In order to play the game, it is usually required to have at least two decks each made of at least 40 cards. Each deck normally contains at least 17 *lands*, and the rest are *creatures*, *sorceries*, *instants* and *enchantments*. There are five different *mana types*, also known as *land cards*, which are required and used for certain cards to be placed on the battlefield or trigger their abilities. The different *mana types* are white / Plains, blue / Islands, black / Swamps, red / Mountains, green / Forests, which can be seen in Figure 5.1. Whenever a *land* is used for *mana* to cast cards, that card is *tapped* and cannot be *untapped* and used again until next turn. The same happens when a *creature* attacks, unless it has *vigilance*, this will be explained further on.



Figure 5.1: 5 diferent Mana/Land colors

All these cards will be used in the different phases that the game implies. As mentioned previously (see Section 3.1 Introduction to Magic: the Gathering), Magic: the Gathering has different cards and different phases. According to each phase, certain rules are set, which are important to keep in mind when creating a project that focuses on this game. It has five phases and each phase has certain rules which keep the game flow:

1. Beginning phase

- *Untapping* all cards that were *tapped* in the turn before
- Player draws a card

2. First main phase

- Player can place one *land* per turn
- Player may cast *creatures*, *sorceries*, *instants*
- Opponent can also activate abilities and play instants

3. Combat phase

- Both players can activate creature abilities
- The player whose turn it is will declare which of his/her *creatures* will be attacking (*creatures* that were placed during that turn have *summoning sickness* and cannot attack)
- Opponent will declare which *creature* he/she will be blocking and which damage he/she will take instead

4. Second main phase

- Players can once again cast cards and play a *land* only if they did not play one in the first main phase

5. Ending phase

- Includes the abilities that trigger at the end of the player's step



Figure 5.2: Explanation of a Magic: the Gathering card [Forsythe, 2006].

Each card in a deck has specific keywords, abilities and types that need to be taken in consideration when creating a deck. These types can determine the strength of the deck created and the certain abilities that can be taken in consideration in regards to the other cards. For example, by looking at Figure 5.2, in the text box of the card, it can be seen that the card triggers abilities on *creatures* that have *shadow*. *Shadow* is a specific keyword ability that allows *creatures* with *shadow* to attack only other *creatures* with *shadow* and blocking works the same way [MTG Salvation, a].

Another important keyword that can be noticed on this card (see Figure 5.2) is *Flying*. Creatures that contain the keyword *flying* can only be blocked by creatures that also have *flying* or *reach*. In a game of MtG it can be imagined that there are two levels of creatures, the ones set on the ground, which are the non-flying creatures and the ones that are flying, which are hovering above the ground creatures. In a combat, flying creatures can descend down and block ground creatures, however, ground creatures cannot block the flying ones, unless they have the ability called *Reach*.

Overall, Magic: the Gathering has a wide range of keyword abilities as the ones explained in the section above, however in this section only important keywords will be quickly explained and mentioned. Popular keyword abilities are:

- *Trample* - During the combat phase attacking creatures that have trample, can deal damage to a player even if it was blocked by a creature.
- *Haste* - Creatures with haste can attack during the turn they entered the battlefield and do not have summoning sickness.

- *Vigilance* - Creatures with vigilance do not tap after they attack.
- *Deathtouch* - Creatures with deathtouch deal any amount of damage as lethal damage.

[[MTG Salvation](#), b]

During the combat phase, the power and toughness of the creatures play an important role. These two determine whether the player gets to keep their creatures on the battlefield or if they will be placed in the graveyard. In the combat phase, creatures can be boosted or decrease their toughness by using instants or abilities that can be seen on creatures on the battlefield.

The section has covered the basics of Magic: the Gathering, while it is not enough knowledge to be able to play the game fully, it should help the reader understand the basic mechanism of the game. A basic understanding of *lands (mana)*, combat phases and keywords should have been obtained by reading the section and the image of a Magic: the Gathering card (see [Figure 5.2](#)) should help the reader understand what information is later digitalized and used. Once it is known what a game of Magic: the Gathering consists of and how it usually is performed, it is possible to get an idea of what the project should focus on throughout the following sections.

## 5.3 Building a Graphical User Interface

A graphical user interface (GUI) can be built using several different techniques. The GUI can contain different windows [[Rogers et al., 2011](#), p. 161], menus [[Rogers et al., 2011](#), p. 165-167] and icons [[Rogers et al., 2011](#), p. 169] but all of these elements or building blocks need to be presented in a way that is easy for the user to understand. Two of these techniques, Mental Model and Grid System, will be presented in this section.

### 5.3.1 Mental Model

Apple's Human Interface Guidelines suggest that the developer creates a mental model of the tasks the application should perform [[Apple](#)]. This model contains four aspects that the developer needs to think about before creating the GUI, these aspects are:

- **Familiarity:** The interface should use familiar interface components, which the user is experienced with.
- **Simplicity:** The interface should focus on the fundamental components and the components should not compete for the user's attention.
- **Availability:** The interface should only contain the key components, to simplify the interface, and rarely used components should not be equally available as essential components.
- **Discoverability:** The interface should promote interactive components and if a component is clickable it should look that way and not be hidden.

The mental model provides some guidelines for the graphical interface and what it should contain, but it does not help the developer with how the interface should be placed [[Apple](#)].

### 5.3.2 Grid System

The grid is a way for the developer to place different components in a grid system and therefore create orderliness and clarity of the interface (see [Figure 5.3](#)) [[Mller-Brockmann, 2010](#), p. 13]. The grid system provides a clear view of the information presented and can be used in many different medias. Before starting development it is important to know the components of the interface and then for the designer to make small-scale sketches of the grid. The grid can have different columns and these columns can often be subdivided into more columns for increased freedom. The disadvantage of too many columns is that the graphics and text becomes too small for the user to see. This can be

countered by a larger typeface, but switching from line to line while reading can cause fatigue for the eyes [Miller-Brockmann, 2010, p. 57].

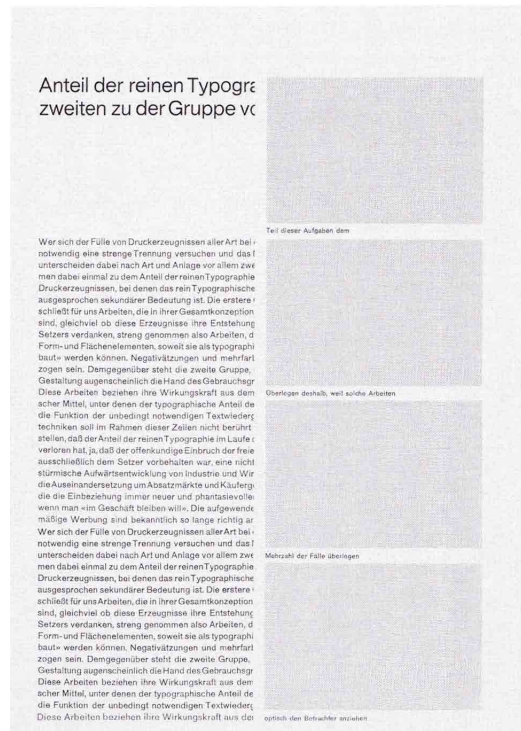


Figure 5.3: Example of an 8 field grid.

A grid system with 8 fields gives the designer a variety of ways to use two columns, when placing the grid vertically, or four columns, when placing the grid horizontally. Subsequently the grid can be divided into 16 fields instead to give more variety. A grid with 8 fields is often enough for print articles and it gives the designer a simple solution to setting up text and graphics [Miller-Brockmann, 2010, p. 72-75]. By dividing the grid into 20 fields, instead of 8, the designer is virtually unlimited in the ways of setting up graphics and text (see Figure 5.4). The grid should provide an easy way to guide the viewer's attention towards important information [Miller-Brockmann, 2010, p. 76], this could be combined with Simplicity and Availability from the Mental Model (see Section 5.3.1 Mental Model).

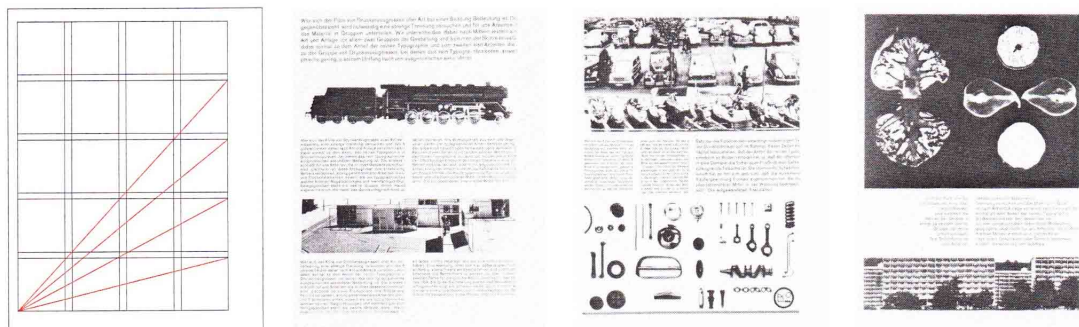


Figure 5.4: Example of an 20 field grid.

Even though a grid with 20 fields provides a variety of possibilities for setting up the interface components, a grid of 32 fields offers more possibilities and can be used in virtually every type of

work (see Figure 5.5). It is very important for the designer to maintain self-discipline and clarity when setting up an interface in a 32-field grid system. [Miller-Brockmann, 2010, p. 87].

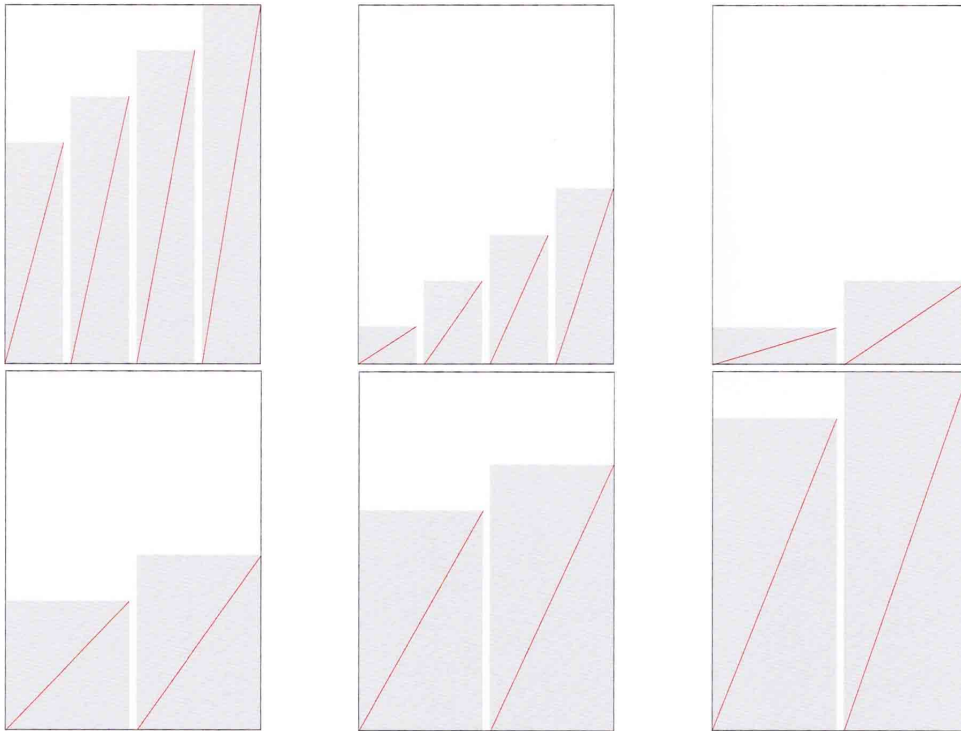


Figure 5.5: Example of six different ways of using a 32 field grid.

A combination of the theoretical Mental Model and the practical Grid System would provide an optimal way of creating a graphical user interface. This GUI would be able to display the important components to the audience and at the same time provide a clean and uncluttered way of displaying these components.

## 5.4 Methodologies

In order to determine what impact the interactive virtual representation would have on the audience's experience while observing a game of Magic: the Gathering, a way of measuring the experience had to be designed. Therefore, the following section will describe the possible methods of measuring experience as well as discuss which of them could be applied during the testing of the prototype.

Experience could be treated as an emotional response towards a certain stimuli, which can be measured in a form of, for instance, overt behavioral acts, affective reports and physiological reactivity [Lang, 1969].

### 5.4.1 Overt Behavioral Acts

One way of collecting information about how people react and what apparent emotions their body language seems to portray is through observations. In particular facial expressions are among the most universal forms of body language. However, it is still a rather subjective topic as only a few of the emotions, including happiness, sadness, anger, fear, disgust and surprise, have been proven to be universal throughout the world [Ekman and Friesen, 1971, p. 124-129]. As a matter of fact, several facial expression recognition software products<sup>1</sup> have already been created and proven

<sup>1</sup>Examples of facial expression recognition software: <http://www.emotient.com/products> and <http://www.noldus.com/human-behavior-research/products/facereader>

to work rather well in recognizing the previously mentioned emotions. On the other hand, such products as Emotient or Facereader can only analyze the emotions of a single person at the time in a well-lit environment. Therefore, taking this into consideration in regards to the project, it would be an inconvenient method for tracking multiple people in a poorly lit environment, which would then require a large and individual setups for each audience member.

Sounds are another quality of a human response, which can provide some useful information about their current state of emotion.

### 5.4.2 Audio Measurements

A way this relates to our project is due to the fact that what is wanted from this prototype is to be able to show a game to a larger audience without it being too difficult for them to see the game in progress. In order to test on a large crowd of people observing a game, audio measurements would be a good approach since it focuses on the noise/ chatter taking place in a room. The data gathered from the audio measurements can be then connected to the action happening on the display and, by comparing the differences or similarities in spikes of the two, assumptions regarding the spectator's experience can be made.

This section is based on a study called *A Survey of Affect Recognition Methods: Audio, Visuals, and Spontaneous Expressions* [Zeng et al., 2009] and it will mainly focus on the audio recognition method. It is relevant in the context of this project since it examines how to measure changes in users' affected behavior in Human-Computer-Interaction (HCI). The affected behavior means how the user is affected while interacting with a device. The study researches how to detect and measure these changes, the research for the automatic human affect analysis uses the following approaches:

- Displayed series of exaggerated affective expression
- Recognition of a small number of prototypical (basic) expressions of emotion (i.e. happiness, sadness, anger, fear, surprise, and disgust)
- Information processed by the computer system is limited to either face images or the speech signals

It is difficult to detect and measure any expressed emotion due to differences in visual appearance, audio profile, and timing from spontaneously occurring behavior. Due to said difficulties, the research *A Survey of Affect Recognition Methods: Audio, Visuals, and Spontaneous Expressions* [Zeng et al., 2009] focused on automatic analysis of spontaneously displayed affective behavior. This meant to gather information regarding the Human Affect (emotion) Perception, which includes psychology, linguistics, computer vision, speech analysis, and machine learning.

The *Survey of Affect Recognition Methods: Audio, Visuals, and Spontaneous Expressions* [Zeng et al., 2009] works with Affect as a concept in psychological studies. The most used approach is the prototypical (basic) emotion categories (happiness, sadness, fear, anger, disgust, and surprise), which means you measure the affect on these emotions. The basic emotions have been evaluated to be cross-cultural. Cross-cultural means that humans perceive these emotions the same way despite of different cultural inheritance. In the context of this project it is very relevant since many players and spectators come from all over the world. There are many advantages of this approach. It has been used very broadly and many cognitive and computer scientists are familiar with it. However, one disadvantage is that it only covers a rather small part of humans' emotional range.

This section has introduced the method in how to measure the affect on users when interacting with multimedia devices. Primarily it is based on the six basic emotions; happiness, sadness, fear, anger, disgust, and surprise. This means that if a multimedia device has an affect on the user while interacting with the device, it would show on these emotions. For further research it will be looked into how to test the affect on these emotions.

### 5.4.3 Physiological Reactivity

Besides the reaction observable by just looking at someone, the human body undergoes numerous physiological changes and chemical reactions when experiencing a certain emotion. The most common physiological responses associated with emotions are [Purves et al., 2001]:

- Heart rate - *increase in heart rate is often associated with fear and anger*
- Blood pressure
- Eye tracking (e.g. pupil dialation, eye fixation) - *increase in pupil dialation can be connected to user stress*
- Fluid physiology (e.g. change in hormone secretion from glands)
- Perspiration (e.g. sweating)
- Piloerection (goose bumps) - *indicates that a person is cold or experiences strong emotions such as fear, nostalgia, pleasure, euphoria, awe, admiration and sexual arousal*
- Skin conductance - *indicates the users arousal or frustration*
- Skin temperature
- Magnetic resonance imaging (brain activity scan)

Each of the physiological responses can be an indication of a certain emotion that the test participant is experiencing. As a test method, it could be a great way of backing up the empirical data collected from questionnaires, interviews or observations.

On the other hand, since emotions are such a complex subjective process consisting of multiple responses such as physiological, facial, vocal and cognitive expressions, [Barrett and Bliss-Moreau, 2009, p. 167-218] [Keltner and Lerner, p. 312-347] the information collected based of a person's emotional reaction can be non viable in some cases. One of the reasons is that different people might have slightly different reactions to the same emotions. In addition to this, the examiner might misinterpret the information [Larsen and Fredrickson, p. 40-60].

To sum up, measuring physiological response to emotions might be a great way of supporting the data, however at the same time there is a risk of it not being accurate. Besides, similarly as with facial expression recognition, tracking of any physiological response in an experiment of this project might not be sufficient considering that a great amount of equipment would be needed in order to track the whole audience, while only tracking a few individuals from the audience might not be enough to support or reject the theory.

### 5.4.4 Affective Reports

Finally, the experience can also be measured by asking the respondents to evaluate it by answering a questionnaire. Taking into consideration that experience is a rather subjective term, people might tend to describe the same situation differently. Therefore, it is a good idea to have them respond to a premade questionnaire that measures the experience between certain scales and makes the evaluation more objective. Among several affect evaluation techniques that have been researched, Positive Affects and Negative Affect Scales (PANAS) and the Self-Assessment Manikin (SAM) are two techniques that could be useful for measuring the experience of spectators of a Magic: the Gathering game.

PANAS have been developed and used in research related to social activity and satisfaction to the frequency of pleasant events. In other words, it is a scale that reflects to which extent a person feels more enthusiastic or under distress based on the dimensions of positive affect and negative affect [Watson et al., p. 1063-1070]. Therefore, depending on the positive affects and negative affects ratings on the scale, it is possible to point a certain state of mind of the one that completed



General Dimension Scales	
Negative Affect (10)	afraid, scared, nervous, jittery, irritable, hostile, guilty, ashamed, upset, distressed
Positive Affect (10)	active, alert, attentive, determined, enthusiastic, excited, inspired, interested, proud, strong
Basic Negative Emotion Scales	
Fear (6)	afraid, scared, frightened, nervous, jittery, shaky
Hostility (6)	angry, hostile, irritable, scornful, disgusted, loathing
Guilt (6)	guilty, ashamed, blameworthy, angry at self, disgusted with self, dissatisfied with self
Sadness (5)	sad, blue, downhearted, alone, lonely
Basic Positive Emotion Scales	
Joviality (8)	happy, joyful, delighted, cheerful, excited, enthusiastic, lively, energetic
Self-Assurance (6)	proud, strong, confident, bold, daring, fearless
Attentiveness (4)	alert, attentive, concentrating, determined
Other Affective States	
Shyness (4)	shy, bashful, sheepish, timid
Fatigue (4)	sleepy, tired, sluggish, drowsy
Serenity (3)	calm, relaxed, at ease
Surprise (3)	amazed, surprised, astonished

Table 5.1: The PANAS-X scale and its specific affects. Note: The number of terms comprising each scale is shown in parentheses

the scale. In 1994 Watson and Clark have revised their assessment tool and developed PANAS-X, and expanded version of PANAS, that can assess a certain emotional state through 60 items and measures 11 specific affects: Fear, Sadness, Guilt, Hostility, Shyness, Fatigue, Surprise, Joviality, Self-Assurance, Attentiveness, and Serenity (see Table 5.1) [Watson and Clark, p. 1]. The PANAS-X scales takes about 10 minutes to complete, however some of the affects might be excluded as being irrelevant to the particular research.

At the same time, the evaluation for spectator experience targets a similar self-report of entertainment, yet it allows a much shorter time for answer. This means that a scale like the PANAS will cumber the evaluation and might provoke errors in results.

The other technique that seems to be a valid evaluation method of the audiences experience has derived from Wundt's theoretical categories, that suggests the affective meaning towards stimuli can be assessed through three dimensions: Lust (pleasure), Spannung (tension) and Beruhigung (inhibition) [Wundt]. Afterwards, empirical work has repeatedly revised and confirmed that these dimensions, later renamed as pleasure, arousal and dominance are in fact present in organizing common human scenarios and their affects. Mehrabian and Russell (1974) have developed a popular assessment instrument that is based on rating a set of 18 bipolar antonym adjective pairs along a 9 point scale though all 3 dimensions of pleasure, arousal and dominance [Mehrabian and Russell]. However, this evaluation method seemed to provide a rather large set of data for analyzing as well as have a major flaw when applying to non-English speaking or non linguistically sophisticated (e.g. children) populations. For this reason, Lang has developed a picture based version of evaluation the three dimensions - *"The Self-Assessment Manikin is a non-verbal pictorial assessment technique that directly measures the pleasure, arousal, and dominance associated with a person's affective reaction to a wide variety of stimuli"* [Bradley and Lang, 1994, p. 49-59]. As seen in Figure 5.6, in the pleasure scale SAM ranges from a smiling to frowning face; the arousal dimension is illustrated as a range between an excited figure and a calm, sleepy figure; and the dominance dimension represents the amount of control a person felt during the certain experience by selecting a corresponding size of the figure [Bradley and Lang, 1994, p. 49-59].

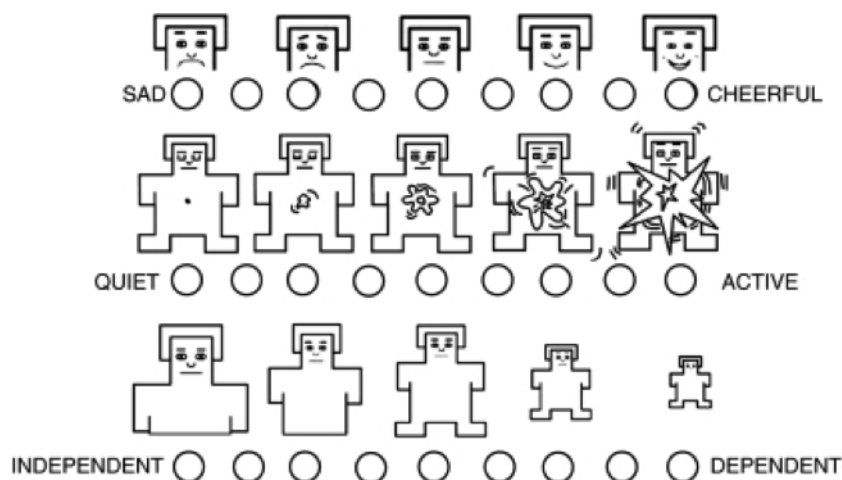


Figure 5.6: The Self Assessment Manikin scale by Lang and Bradley

To sum up, affective reports clarifies how one can research an issue through self-reporting evaluation using premade questionnaires. In this context, one can use PANAS or SAM, which are two proven effective techniques for such measurements. SAM is an alternative to the PANAS. The reason is the advantage in research of non-English speaking or non-linguistically sophisticated, due to the fact that the method is based on emotional pictures.

### 5.4.5 Observations

Observation is an ethnographic test method. In its core form, the test conductor observes the test participant and the observations are noted down or/and recorded. The test results can be organized differently; observation notes based on specific behavior and put into schemes, or descriptive observation notes concerned with all actions taking place but no models nor schemes.

The test method is very informative in terms of test results. It gives the test conductor at lot of information concerning body language, vocal cues, and physical behavior. All three components are very informative letting the test conductor know how the participants feels and thinks. However, a problem is how these components are interpreted. Observations cannot be fully objective. Whoever the observer is, the observations will be based on the person observing's history, experience, expertise, and bias. To accommodate this bias, the descriptive observation method is recommended. In that context, it is very relevant to record the test participants since it is nearly impossible to observe and note down everything without missing out on something. However, then comes another problem which is one of the clear disadvantages with this test method. A lot of quantity of data needs to be analyzed afterwards. This is why observations sometimes are performed according to models and schemes based on certain actions performed by test participants. Models and schemes make it easier to perform statistics on the test results, however it also enhances "*cherry-picking*". "*Cherry-picking*" means to pick the results that fits best within the model or scheme while other less appropriate results might be left out. If too many situations lie outside the model or scheme, the model or scheme must be revised.

Lastly, it can be a good idea to have a multiple number of observers. Since observations are very objective, it is an advantage to have several observers who differ in background, perspective, experience, or demographic factors such as age, gender, and ethnicity. Afterwards, the observation results should be compared to clear out differences or similarities to back up the results. [Lazer et al., 2010, p. 219].

### 5.4.6 Focus Groups

Normally a focus group consists of 5 to 12 people, it is often best to have two or more sessions. The test method is relatively effective and not that expensive. Furthermore, it gives a broad range of opinions. A focus group can create a highly dynamic situation where participants may raise issues they would not have thought of in a one-to-one interview.

A focus group interview is often semi-structured or unstructured. Semi-structured derives from a fully structured interview which has a rigid script and well-defined order. In the fully structured interview the test conductor cannot add questions or ask for clarification, or follow up on comments from the participant. However, this is allowed in the semi-structured interview. An unstructured interview does not have a rigid script nor well-defined order. It may have a list of topics or questions that one might choose to ask, although it is fully up to the test conductor how to do the interview.

It can be difficult to discuss sensitive topics in a focus group. Furthermore, very talkative participants might dominate the conversation too much. They might monopolize the conversation with their own points of view and crowd out other opinions. Then the wanted dynamic situation falls to the ground.

Lastly, when considering participants for a focus group, it is important to evaluate how the participants know one another. If you are examining a work related situation, it is important to consider how it will affect the interview and data if the participants are colleagues. [Lazer et al., 2010, p. 177].

### 5.4.7 Questionnaires

Questionnaires are the most common test methods of the methods mentioned here. It is defined as follows;

*“Well-defined and well-written set of questions to which an individual is asked to respond. Surveys are typically self-administered by an individual, with no researcher present; because of this, the data collected is not as deep and in-depth as with other research methods (such as ethnography)”* [Lazer, Feng, and Hochheiser, 2010, p. 100]

A questionnaire can be performed at very low costs, and it is easy to get a large number of participants. Therefore, the questionnaire is said to give the “*bigger picture*” of the certain situation.

However, the questionnaire does not make it possible to ask follow-up questions or further clarification of given answers. Another disadvantage is how participants might be separated from the test situation to some extent. This causes bias because the participant has to recall the situation and might remember something incorrectly or distorted. Furthermore, it can be hard for the test conductor to control or check this.

Lastly, the questionnaire demands the participants to read. This can be a problem if you want to test on children, or the target group does not fit with written approaches. Furthermore, there can be distortions among cultures in terms of terminology. [Lazer et al., 2010, p. 100-102].

## 5.5 Requirements

The previous sections of analysis have investigated various topics related to the FPS in order to broaden the knowledge about related subjects and help determine requirements for a prototype, which could help solve the problem faced by beginner spectators of Magic: the Gathering.

First of all, it has to be taken into consideration, that this project focuses on a particular card game from the perspective of its audience rather than the players. At the same time, it is very important that the prototype does not disturb the players. In addition to this, the natural flow of the game should also remain unchanged, meaning that the original rules of the game are preserved rather than being adjusted in regards to the prototype.

The prototype must include the following features of Magic the Gathering:

- Tapping
- Use of dice roll and coin flip
- Life counting
- Keywords

That being said, the focus should be orientated towards the audience and making their experience of spectating a game more enjoyable. On the other hand, using the knowledge from Lobunets and Prinz research [Lobunets and Prinz, 2011] shows that non interactive public display should be the best solution for providing the audience with information about the game process. Without making this experience too interactive and keeping the audience passive (see Section 3.4.2 Designing the Spectator Experience), it is made sure that the audience will keep their attention, driven by intrinsic motivation, on the game. On the other hand, making the audience semi-passive and giving it a little bit of interaction that does not directly affect the game could make the experience more enjoyable. Therefore, a simple interactive feature resembling side betting should be implemented.

The public display should be the main source of information and the primary type of feedback to the audience. Implementing audio as a secondary type of feedback (sound effects to card movements on the screen or commentator of the game) could be a nice extra feature to add to the prototype. However, since visual is the primary focus, it means that the graphics and animations on the screen must be eye-appealing and aesthetic. In addition to this, the design should be resemble the MtG color scheme for the sake of familiarity and continuity. In order to keep the design eye appealing, the grid system and mental model guidelines (familiarity, simplicity, availability, discoverability) should be taken into consideration. As for the physical part of the prototype, usability goals (effectiveness, efficiency, safety, utility, learnability, memorability) need to be followed.

From the technical point of view, the system should be responsive and have as little communication latency as possible.

To sum up, the collection of requirements for the product are as following:

- Focuses on a particular card game from the perspective of its audience
- Does not disturb the players
- Original rules of the game are preserved
- Has a non interactive public display
- Audience is semi-passive
- Involves a simple interactive feature
- Primary type of feedback is visual
- Secondary type of feedback audio (optional)
- Has eye appealing and aesthetic graphics
  - Uses the grid system
  - Familiarity, simplicity, availability, discoverability
- Effectiveness, efficiency, safety, utility, learnability, memorability
- System is responsive
- No communication latency

# Chapter 6

## Design

This chapter will go in depth with information regarding the design and setup of the prototype. Using the requirements gathered in the Analysis chapter, a general idea of what the prototype should contain was made and certain features were implemented. Firstly it will start out by creating and designing sketches of the physical part of the prototype and explain the choices of each technological solution to the requirements set above. The physical interface contains a scanner, which includes a camera and information for the player and a glass table for the battlefield. The display and web application follow shortly after the last decisions were reasoned and also contain similar information to how the design looks and which features it involves, which should help the implementation process.

### 6.1 Alternative Card Tracking Methods

When designing the setup, some issues have been encountered in regards to tracking the cards that are placed on the table. Even though the card scanner could record and store information about what cards each player has drawn and put down on the table, the question of how to keep track of the cards afterwards still remains. While the cards are on the table, it would be required to keep track of when and which cards are being tapped, discarded or go into battle. After researching on this topic, some methods that potentially could help track the cards have been discovered.

#### 6.1.1 Color Tracking

First of all, since many players tend to put their cards in protective sleeves, some of which have a solid color on the back (see Figure 6.1), image processing and color tracking seemed as a possibility to keep track of the cards, if a camera was placed under a glass table, where cards have predefined spots for different game zones (graveyard, battlefield etc.). Even so, all of the cards would seem identical, and even though they were arranged in a certain array that the computer can recall, placing the cards in a very specific assigned slot would require extra effort from the players, instead of just playing and moving their cards intuitively.

#### 6.1.2 Fiducials

Using fiducials is another way of identifying the cards through the use of image processing but in this case the different cards could be recognized by assigning certain fiducial markings to each of them. This way it would also be easy to track whether the card is tapped or not according to the orientation of the fiducial. On the other hand, even though these markings are very similar to each other (see Figure 6.2), there is a risk that after a while the players might become familiar with some certain patterns and be able to recognize each others cards held in hand. [[reactIVision](#)].



Figure 6.1: Example of different protective sleeves [OmniDreamer, 2011]



Figure 6.2: Example of different fiducials [reactIVision]

### 6.1.3 Infrared Ink

As previously mentioned, fiducials have the potential to help track position of individual cards, however, there is a risk of the markings being too obvious. Therefore, some research of tracking methods that would be invisible to a human eye has been done. Infrared (IR) ink has this potential

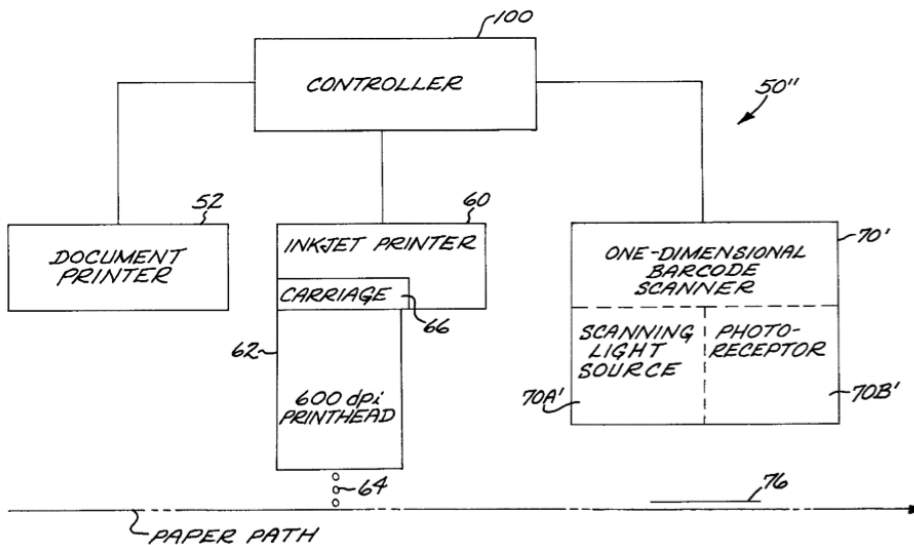


Figure 6.3: Structure of the IR ink printing/scanning system [Stephens, 2003]

of being invisible unless looked at through a digital camera without an IR filter that captures the wavelength between 720 to 1000 nm. The technology of IR ink printing is mostly used to identify

documents and ensure security [Auslander, 1997]. A system, containing of a printer and a scanner, (see Figure 6.3) has been developed to create and read the invisible markings. The printer uses a high definition inkjet printhead of 600 dpi, which allows creating high density and acuity barcodes on the documents [Stephens, 2003]. The scanner apparatus includes a light source for illumination and a camera sensitive to the non-visible light [Stephens, 2003].

The use of this technology could be a great alternative to the fiducials, seeing as it could provide a method of tracking the cards that is secure yet invisible to the human eye.

#### 6.1.4 castAR

This section will talk about castAR, which is another card tracking method. castAR works with projected augmented reality displaying holographic-like 3D projections. The 3D projection enables interaction between the user and game objects. The castAR is very fast and accurate concerning tracking, furthermore it enables the user to freely move around with the 3D projections still in place.

castAR uses three physical elements to create augmented reality (AR) and virtual reality (VR). The user can use a so-called Magic Wand to interact with virtual objects, Radio Frequency Identification (RFID) Tracking Grid is used to track and identify augmented objects, and a pair of special glasses that projects light towards the tracking grid.

The RFID Tracking Grid can be used to track objects such as miniature figures, cards or board game pieces. The Tracking Grid is made of retro-reflective sheeting material and it reflects almost all light back towards the source with very little scattering. Since the light hitting the Tracking Grid is reflected back towards the source, more than one person can use it at a time. The Tracking Grid can associate tags with physical objects so each object can be augmented to include additional information, such as a health bar or attack stats. There is also Precision Bases, which can be attached underneath the game objects, as so there are very small. The Precision Bases allows two-communication which increases the accuracy for tracking. castAR could be used as an alternative way to track cards, using the Tracking Grid. Placing cards on the Tracking Grid will make the position available on a computer and it would also be possible to track orientation. Using the AR glasses tags could be assigned to objects and it would be possible to alter health bars, attack stats and other card information digitally when looked at through the glasses. Alternatively the Tracking Grid could be used without the glasses, this would mean that the cards are just tracked using the Grid and then displayed on a regular screen. [Technical Illusions, 2013].

#### 6.1.5 Sub-Conclusion

All of the above-described alternative tracking methods could potentially be used for tracking the cards and their activity on the table without disturbing the players. Unlike color tracking (except for applying the solid colored sleeves on the cards), the use of fiducials, IR ink or castAR requires prior preparation of the cards that is permanent. Special sleeves could be developed for fiducial tracking, but the risk of players recognizing special fiducials after continuous use is too high. castAR would be also require special sleeves with Precision Bases inserted into the sleeves.

On the other hand, if this project proves to be successful and gets approved by the target audience, in the future the cards could be sold with already integrated IR barcodes, as this technology seems to provide the definite solution for tracking the cards without interfering the game and creating the risk of cheating.

## 6.2 Physical Interface

The physical interface of this project is meant to provide a better experience for the audience of a Magic: the Gathering card game without disturbing the natural flow of the game and thus not interrupting the players. In order to convey this, the physical interface must consist of two main

parts: visual display to present the information about the game and a tracking/scanning system to gather this information during the game.

Considering that this information needs to be available for multiple people at once, it has been decided to utilize one large public display rather than individual screen devices (e.g. smartphones, tablets). In addition to this, as mentioned in the analysis, the audience is expected to be passive/semi-passive, which resembles the action of watching for instance a football game, where the audience is exposed to live games as well as close ups and additional information of the big stadium screens.

In regards to the tracking/scanning system, several options have been considered. As seen in Figure 6.4, the set up could be arranged in two different ways, either having the camera tracking cards underneath or above the table. Having the camera above the table would make it easy to keep track of exactly which cards are placed on which area of the table. On the other hand, this set up requires a very high-definition camera, complicated image processing knowledge as well as a physical structure hanging above the players' heads.

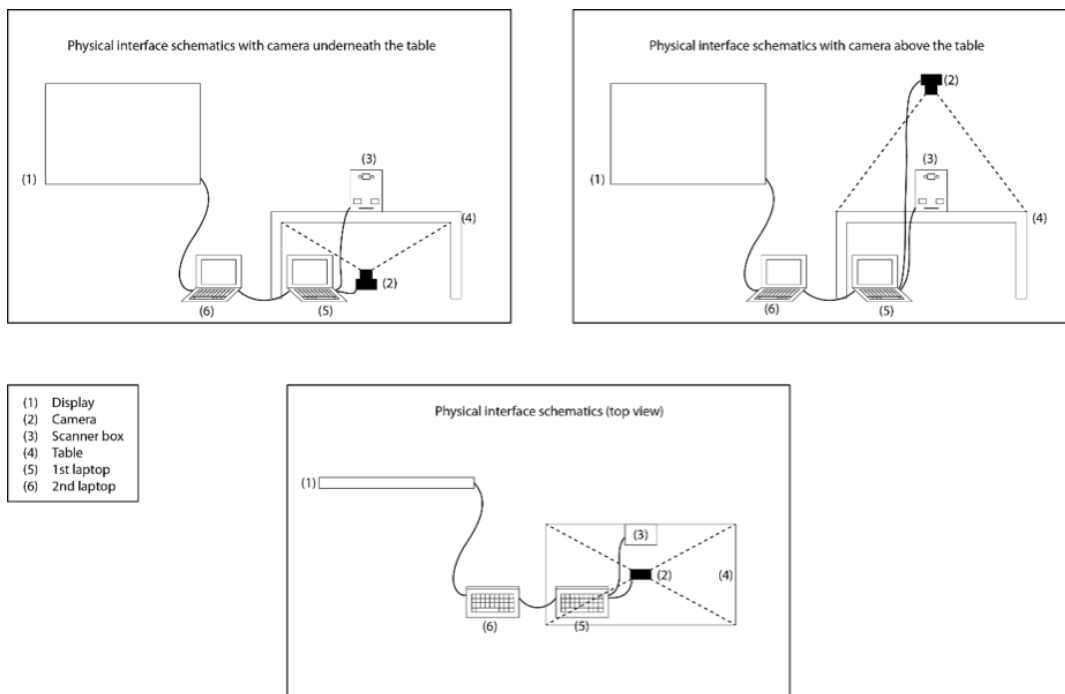


Figure 6.4: Two examples of the physical interface setup.

In order to figure out how the tracking could be utilized when placing the camera underneath a see-through table and which way would be the most appropriate in this case, several different card tracking methods have been researched and compared (see Section 6.1 Alternative Card Tracking Methods). Invisible ink was considered as the perfect solution, as it is invisible to the human eye thus does not evoke the risk of cheating. However, since this technology is not available during the period of this project, it had to be discarded. Instead, color tracking was chosen as the method of card tracking for this project. However, considering that color tracking could only detect the position of the cards and their state (whether tapped or not), another device that scans information about the cards had to be incorporated.

Scanning the card title by inserting it into an assigned slot and retrieving information about the certain card to be displayed for the public is the primary function of the scanner box. As seen, in the Figure 6.5, the device is meant to be a compact box to perform its functions. The device has been designed in this certain manner, considering various aspects and scenarios of usability. It has been considered to place the card-scanning slot on top of the box; however the front slot seemed





Figure 6.5: Example of the scanner box.

to be a more intuitive choice. The placement of the buttons as well has been designed following the same principle of intuitiveness. This design of the device requires a small, yet high definition camera to be placed inside for scanning the card title.

### 6.2.1 Features of the Scanner Box

As previously mentioned, the main function of this device is to scan cards by inserting them into an assigned slot at the bottom of the box. In the very beginning of the game each player will have to scan the cards in their hand that will be stored in the computer's memory for later reference in the game. Above the slot is a visual indicator of whether the scan was successful (green color signal) or not (red color signal). In order for the computer to know which player is scanning his cards, there are two buttons on each side of the box that make the player currently scanning one's cards active. Just like the cards scanning, this is also indicated visually by two LEDs on the front of the box on the corresponding player's side. Next to these indications are two more displays that keep track of each player's lives, that are counted automatically. This feature has been incorporated as many respondents of the initial survey mentioned it in their comments (see Section 3.5 Survey). In addition to this, as another outcome of the initial online survey, a digital dice roll and coin flip have been added to the same box. Each of the actions has an individual button that calls for a random coin flip/dice roll and its result is shown on the display on the top front of the box.

Feature list:

- Scan cards
- Switch between players
- Indicate active player
- Display and calculate lives for each player
- Push button coin flip
- Push button die roll

### 6.2.2 Setup of Physical Interface

As mentioned in the introduction to the chapter (see Section 6.2 Physical Interface) the prototype needs different physical aspects, such as electronics and a camera.

#### 6.2.2.1 Electronics

The electronics are used for user input, so a computer is not needed, or output, so a screen can be avoided. The user input can be done using various buttons or sensors and the output can be done using LED's or small displays. For the user input, buttons have been chosen as the default input method. A simple push button is preferred over a sensor such as a force-sensing resistor (FSR), because the FSR is an analog sensor, which can change, based on how much pressure is applied. A push button is a digital sensor, which does not rely on the amount of pressure applied. The push

button also gives feedback to the user in form of haptic, when the button is pressed the user can feel it, the FSR does not give any feedback.

As for output the use of LED's and small 7-segment displays are used to display information on the scanner box (see Section 6.2 Physical Interface).

To control the electronics some microcontroller has to be used. It would be ideal to either use an Arduino Uno or a Raspberry Pi, since both of these devices are easy to work with and they provide a good number of General-purpose input/output (GPIO) pins. The Raspberry Pi would be the best choice to use, since it is an actual computer in itself that can run all the software needed, compared to an Arduino Uno which still needs a computer to relay all the data to.

### 6.2.2.2 Camera

As mentioned before, there is a need for scanning the card. This can be done with a camera, however, there are different cameras that can be used when performing such task.

For the ideal design a small and compact camera would be used. An example of this could be a Raspberry Pi camera [Raspberry Pi Foundation, 2013]. As mentioned in the previous section the Raspberry Pi is preferred over the Arduino Uno because it can run all the software needed without the need for an additional computer. The Raspberry Pi camera is also small and compact and it would fit great in a small scanner box as the one designed.

The prototype does not only consist of a physical scanner box and a table, however, the most important part of the prototype is the display. The display is the actual part that will decide whether the FPS can be answered positively or negatively, since the target group focuses on beginner spectators of MtG.

## 6.3 Display (GUI)

This section will go through the design of the graphical user interface (GUI) which in the context of this project, is a screen displaying the game process in real time. It will evaluate pros and cons of design ideas. Furthermore, it will present the concept and sketches used in the process of developing the final design. The design will be developed based on the requirements established in Section 5.5 Requirements.

### 6.3.1 Layout

This section will present sketches for the layout design and the final design of the GUI. It will also go into the aesthetics of the display.

For the color, it was decided to use the same color as the cards in Magic: the Gathering. This was chosen to link the two elements, Magic: the Gathering and the application, together and keep an overall theme as well as to maintain the aspect of familiarity. The design visualizes all needed elements to make it possible for the audience to follow the game, which make them semi-active. For this purpose a grid will be used, Figure 6.6 shows an illustration of the layout used. A grid would help to visualize the needed elements and make the overall design development easier. This is related to the Final Problem Statement that states to what degree it is possible to improve how spectators follow a game. By making the audience semi-active, they get involved in the interaction which makes it possible to test how their experience is affected. In order to do so, it is furthermore important to track the game with limited latency.

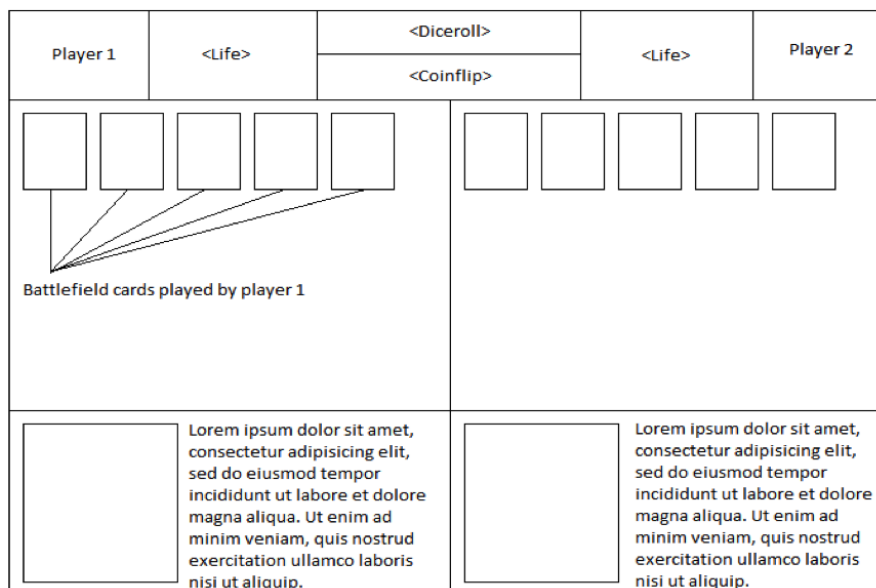


Figure 6.6: Layout used for the display.

### 6.3.2 Animations

In order to make a visual-driven design with eye-appealing graphics and animations, it was evaluated to add animations to certain game actions. This concerns coin flip, dice roll, and card actions. For the coin flip it is appropriate to visualize a coin flipping. In that sense it is important that the coin animation in fact looks like a real life coin flip since the animation illustrates that specific action. It is not important that the coin itself looks like a real coin, instead it could be e.g. a cartoon coin. The dice roll should also be illustrated visualizing a dice rolling. Same as the coin flip, the action itself should be realistic but not necessarily the dice itself.

The animations on the cards will be sliding, flipping, flying, and zooming. The card will flip around when drawn from the library, then flying up, zoomed in at (like getting closer to the audience), and then placed on the battlefield. When a card is tapped, it will be rotated by 90 degrees clockwise or counter-clockwise. Lastly, the features of the specific card drawn will show at the button of the display.

### 6.3.3 The Mental Model

The overall setup follows a basic setup of a classic menu appearance. This is due to the *Familiarity*. As stated in Section 5.3.1 Mental Model, *Familiarity* is important in context of the Mental Model. It is useful due to the fact that many potential users are familiar with such interface and knows or intuitively knows, how to navigate around it. Furthermore, it keeps the interface simple due to the *Simplicity* mentioned in the Mental Model. Especially the fact that the interface structure is consistent, it does not change a lot throughout. This means that the user at all time knows where to search for specific information, e.g. <Life>, and that no elements compete against each for the user's attention. This also makes the information nicely available due to *Availability* in context of the Mental Model. Since no elements will be interactive in context of clickable buttons for instance, it is not relevant to consider *Discoverability* to further extend.

### 6.3.4 Display Features

The display has a wide range of features that need to be taken in consideration when creating the design for it. Overall the display must represent the current game in progress, however, it

must represent it so that the viewer gets a good idea of which cards were being played. The game in progress that it presents must include the battlefield and mana pool of both players, however also show the library of each player and how many cards each has left in their libraries. Another important aspect that should be kept in mind is that it must briefly show the cards that are being used. These should be shown in larger sizes so that the viewer can read the text on the cards and keywords must be highlighted and explained. The display must also include the basic information that is required such as player's life, dice rolls and coin flips.

Summary of features:

- Shows the game in progress
- Possibility to zoom in on new cards entering the battlefield
- Shows explanation of keywords showing up on cards used
- Shows life of players, dice rolls and coin flips
- Visual feedback on cards being used
- Shows the betting status

## 6.4 Web Application

To add an interactive aspect to the project a web-application will be made. This application should make the user able to vote for their favorite player or for the player they think will win. As mentioned in the preliminary analysis (see Section 3.4.1 Levels of Spectator Engagement) users should be kept passive or semi-passive, making a voting application will make the user semi-passive and this will help make the experience more enjoyable and make the user more engaged.

### 6.4.1 Design

The web application overall can have a simple design aspect since there are not many features included in this part. Firstly, the only two main things that it must include, are two buttons or options, to let the viewers vote for their preferred player in the game they are watching. Therefore, it means that the app can have a simple yet aesthetic theme and not confuse the user. In order to keep an overall theme between the three functioning devices that are connected to create a full prototype; display, physical device and web-app, a certain color palette was chosen. This color palette is made of the main colors that the card game itself, Magic: the Gathering uses; light brown, dark brown blue/purple. In Figure 6.7, an example of the back of a general Magic: the Gathering card can be seen and the color palette chosen for it.



Figure 6.7: Backside of a Magic: the Gathering card.

Figure 6.8 shows two examples of how the application can be set up to not create confusion and be straight to the point when it comes to asking the user for betting. To the left, the first iteration of the application can be seen. A light brown color should be used for the background so that it resembles to the MtG card and for the text, it should be aimed to achieve the same look of the text in the MtG logo. In order to achieve a similar look of the text, a font specifically created to copy MtG's text style should be used, a black border should be added to the letters and the text should

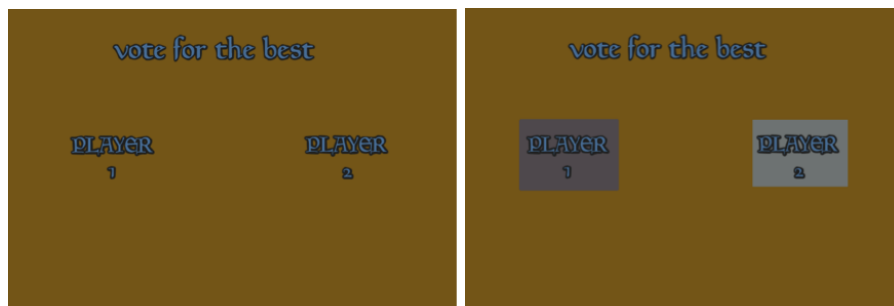


Figure 6.8: Web application concept, based on a MtG card (Figure 6.7)

be blue/purple. To the right, a slight change in design can be seen, however turning the words into two different colored buttons might subconsciously influence the voter/ user, and therefore it would be best to have both the same color. Ideally it would be best to have buttons change color according to the type of decks players are currently using in the match. For example if player one uses a red deck, the button would be red while player 2 uses a white black deck, which would imply changing the button's color to a gradient between the two colors.

Overall the design is pretty simple, in order to make the application more related to the card game that is the focus of this project, the MtG logo was added to it, which can be seen in Figure 6.9 (left), the logo is also accompanied by the 5 colors that are used as mana. In Figure 6.9 (right), the background color was changed to a gradient which goes from light brown to darker brown, thus increasing the resemblance to the MtG cards.

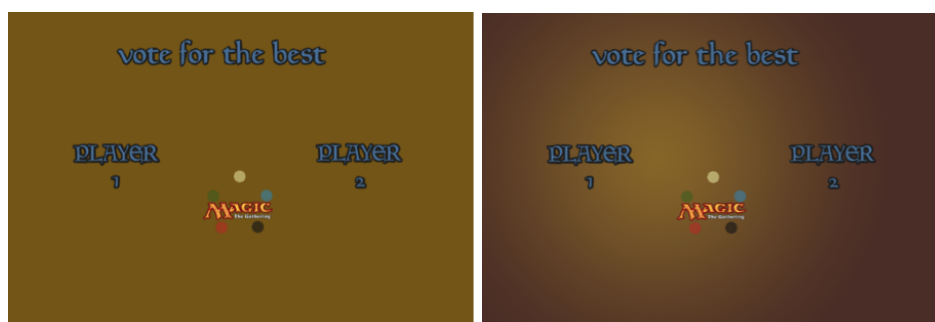


Figure 6.9: Web application concept, based on a MtG card (Figure 6.7)

### 6.4.2 Features

There are not many features required to be set for the web application which allows viewers to open it and vote for the player which they believe could win. Overall, it must allow the viewer to open a web page and show two options for voting for one of the players. Each of these options must be clear about which player the viewer is voting for and once they have pressed the player they desire to win, it must register the data and send it to the display. Additionally the application can show the amount of votes placed for each player during the game that is being followed.

Summary of features:

- options for voting
- state which player they are voting for
- intuitive
- show the current amount of people that have voted

- show who has most votes
- send data to the display showing that another viewer has voted for a specific player after a button has been pressed

## 6.5 Sub-Conclusion

Overall these ideas are created while having an ideal design in mind for a time where specific resources would have been reachable and if there would have been enough time. Since the design choices are ideal, certain changes must be considered before they can be implemented. These changes will be described in a section called Delimitation and will then include restrictions encountered and their replacements.

## Chapter 7

# Delimitation

This chapter will delimitate some of the design choices made in the chapter above and will then shortly describe alternatives that had been found with the limited time and resources. Firstly, it was started out by trying to implement the Raspberry pi camera, however some difficulties have been encountered, such as the camera needing a 60 cm focus range, which would then require to build at least a 60 cm tall box for the scanner. Not being possible to get the Raspberry Pi camera to work, it was required to use a different camera, the best choice was a Canon camera since it was possible to connect it to C++ library `openFrameworks` and use it as a data gathering method when creating the prototype.

However due to the fact that the camera had been changed, it was no longer possible to achieve the design created in the design chapter of having a small disc shaped scanner, therefore a new design was created. This can be seen in Figure 7.1, only the visual appearance of the device has been modified, but leaving the main functions the same.

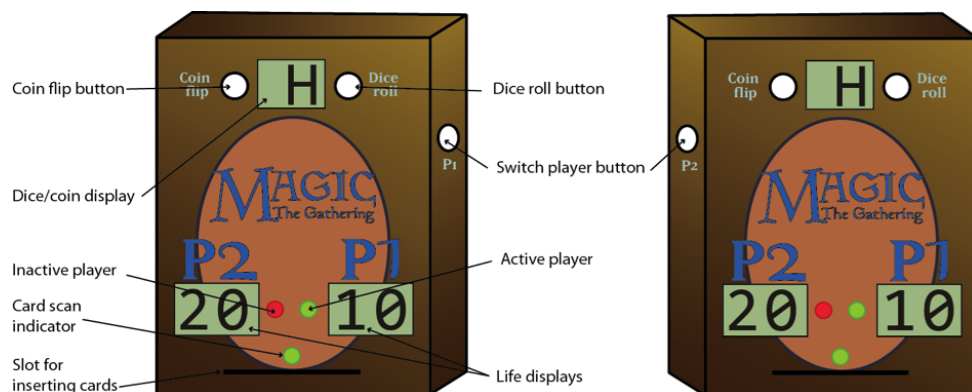


Figure 7.1: Scanner box design

Overall, the same design choices were kept however, the box is taller in order to fit the Canon camera inside and be able to read the card inserted in the slot at the bottom of the box.

Due to financial limitations, it was not possible to acquire infrared ink, therefore the optimal and reachable solution was to implement color tracking and use a see through/glass table as part of the actual prototype. With this solution in mind, it would be able to track the cards placed on each side of the table and which position it is at.

Another change from the design to the implementation was the setup designed for the display, this was slightly altered so that it can fit all the information such as cards, player life and keywords. In order to fit the cards on the screen properly and be readable at the same time, the two player zones were put one at the top of the screen and one at the bottom and the cards aligned to each other (see Figure 7.2).

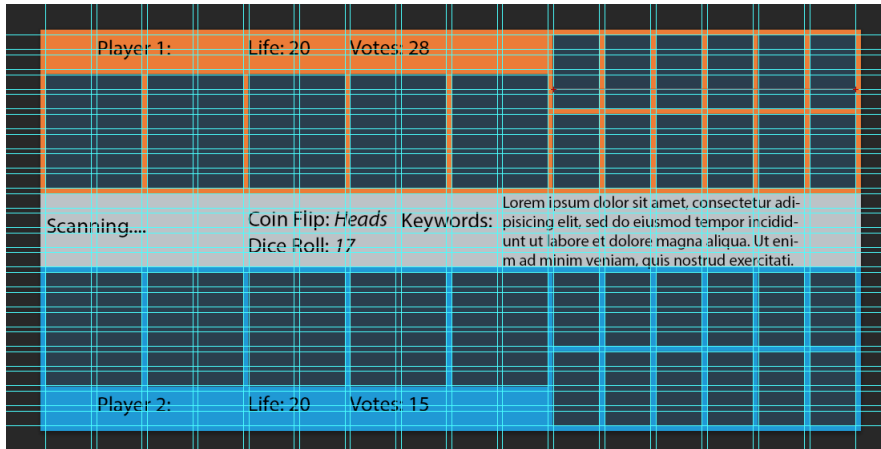


Figure 7.2: Grid used for the GUI.

The web application design was changed due to lack of knowledge in coding php and HTML however, it was matched with the display theme. The changed design only includes two buttons which stretch half/half on the website page, allowing the voter to click anywhere, on the specific side of the page, to vote for who they deem best.

Another point skipped for the implementation were animations. Due to time restrictions and lack of knowledge animations were omitted, it was considered to animate the pop up card however, after several tries it was not succeeded and time pressure forced the project to move on without the addition of animations.

## 7.1 Midterm

During the midterm more information and requirements regarding the prototype were gathered. This was done by creating a short usability test and questionnaires, however observations also played an important role in making the final design choices. Due to the fact that there are not many Magic: the Gathering players at Aalborg University, it was only possible to get six participants in total, four for the physical interface while two for the display, to use our prototype and answer a short questionnaire.

The participants were asked to use the scanning box and play a short match with one of the group members in charge of the project, while others were observing the screen for any changes. Once the participant did not want to test the prototype anymore, they answered a questionnaire. The questionnaire involved questions that regarded the aesthetics of the prototype and asking for help on how to improve it, some of which will be quickly presented below.

For the physical interface:

- “If you had to rate the feature of scanning a card in terms of ease of use, how would you rate it?”
- “If you had to rate the feature of scanning a card in terms of effectiveness, how would you rate it?”
- “What do you think about playing on the table with assigned card positions?”
- “What do you think about the slot for inserting cards?”

For the display:

- “If you had to rate the display in terms of how understandable it was, how would you rate it?”



- *“If you had to rate the display in terms of how aesthetically pleasing it was, how would you rate it?”*
- *“Was it possible to read the information about the cards?”*

These questions were all chosen in order to see the participants’ opinion on the specific design decisions made.

According to the results, three of the participants believed that the scanning feature of the physical interface was neither usable nor unusable but they believed it was ineffective, however three participants believed that it was intuitive. Which means, overall the scanning did not affect the participant’s understanding of the physical interface.

Another problem the participants encountered with the physical interface was the battlefield, which restricted them to not being able to tap the cards or move them around, which led to answers to the questions:

- *“fine but annoying you can’t move the cards when attacking and how does it work when tapping them”*
- *“Its ok, but a bit annoying unless you are able to rearrange”*

For the implementation the *lands* will not be able to tap. Because of technical limitation with how many cards can be tracked, the lands will be excluded.

For the display questionnaire, it was gathered that participants understood the display and rated it as understandable and that it was possible to read the information on the cards, however, there was not a positive feeling towards the aesthetics of the display, but rather a neutral and not aesthetically pleasing answer.

These answer have then lead to slight changes in the design, such as adding the land cards on the display as well and tapping the cards. However, due to technical restriction the tapping can only be done by pressing a button on the physical interface.

Another important aspect noticed at the midterm was that the game seemed confusing for some of the spectators due to the fact that they were not aware which player was scanning at any time, which led to the idea of adding feedback while a player was scanning the card. This feedback consists of text on screen letting the viewer know what is happening.

## 7.2 Sub-conclusion

To sum up, the Raspberry Pi camera had to be discarded due to technical issues, and instead the Canon camera was used. This caused changes in the final physical interface design. Furthermore, infrared ink tracking was also not possible to implement, and instead color tracking was used. In order to make everything work together, a final design was developed as illustrated in Figure 7.2.

There were also changes to the web application design. The final design includes two buttons, each on one half of the website page. Furthermore, animations in the display design had to be discarded due the lack of knowledge on this matter.

At the midterm, the initial display design was tested. The midterm test was used as an indication of the initial display design. This showed lacks in the aesthetics of the display, which afterwards were changed, this includes adding land cards and feedback when a card is being scanned.

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## Chapter 8

# Implementation

The Implementation chapter will start out by giving a quick overview of the physical interface implemented for the prototype. This is divided up in the three parts the prototype depends on: main computer, secondary computer and web application and each of these parts contain both descriptions of the programming part and the physical implementation. The overall setup of the working prototype can be seen in Figure 8.1. Firstly, the two different computers can be seen, wirelessly connected to one another however each of them are connected to different devices used to build the prototype. The main computer is used for information received from scanning the cards hence it is connected to the scanner, the buttons and LEDs and to the Canon camera. The second computer is connected to the display and to the web-cam, which is placed under the playing table and is used for color detection.

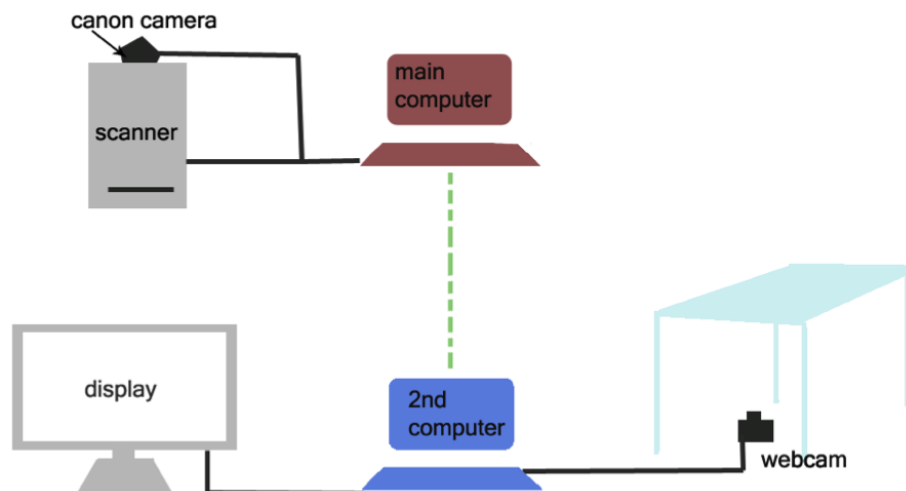


Figure 8.1: Overall setup of the prototype

The digitalized version of the game is displayed on a screen through a different computer than the one used for implementing the scanner software and physical interface. The two computers are connected using `ofxNetwork`, a built-in library of `openFrameworks`, which allows the connection between two programs via networking. Once the connection between the two computers is established, data regarding the scanned card, such as name of the card and player's turn, is then sent to the computer to be displayed (see Figure 8.2).

The main computer contains a connection to the scanner and the remaining physical connections, such as buttons, 7-segment displays and LEDs, all set on the scanner box, while the second computer connects to a web-cam, that is used to perform color detection, and a screen, which displays the cards and similar information regarding the game in progress.



Figure 8.2: Final version of the display

Figure 8.3 shows the final complete prototype, complete with table and scanner.

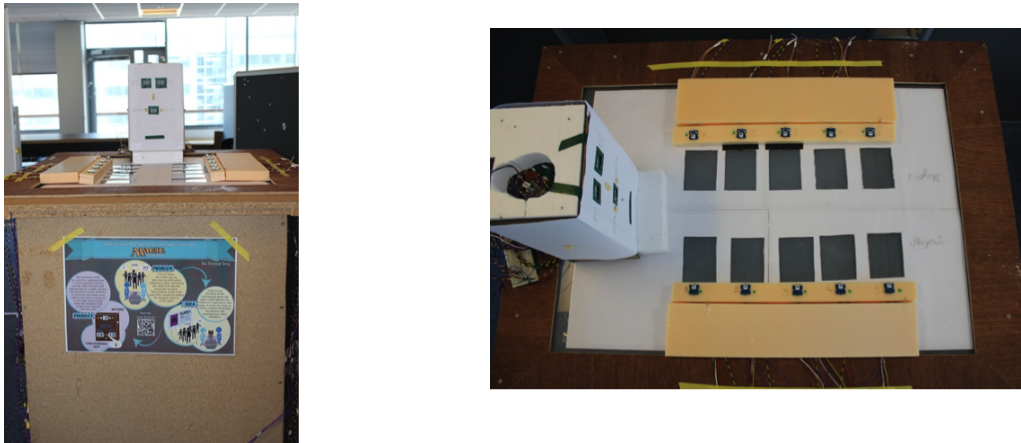


Figure 8.3: Final version of the complete prototype.

## 8.1 Main Computer

To accommodate the design requirements, a physical interface based on the design (see Section 6 Design), was created. The physical interface consists of two parts, the first part is the camera that acts as a scanner, while the second part is a combination of buttons, LED's and small displays.

### 8.1.1 Scanner

As mentioned in the design chapter (see Section 6.2.2.2 Camera), a Raspberry Pi camera would be ideal to be implemented in the scanner. However this proved to be more difficult than initially anticipated when the implementation began. First, there was some hardware restrictions on the camera, the camera's focus distance is about 60cm to 200cm, which is too much for the prototype. Ideally, it would be possible to have the camera around 10cm-15cm away from the card. A way to fix this problem would be to create a lens for the camera that changes the focus distance. In order to change the focus distance it would be possible to place glasses in front of the camera or attach a clip-on-lens [mikerr and eckythump, 2013]. These solutions (having the camera far away from the

object or creating a lens for the camera) were not ideal and it would still not fix the other problem that the Raspberry Pi camera had, which was that the software was not fully developed.

The Raspberry Pi camera works well with video and there is a good support for using video in C++ applications, but the quality of the videofeed is not great. The still-image quality, on the other hand, is much better and could work very well with our application. The problem lies in the software support for still images. In order to get still-images to work, a new library would have to be written to support it in C++ and be able to load images into a format that can be used with our existing application. The combination of software and hardware problems led to switching to a regular DSLR camera (Digital single-lens reflex camera) for the scanner.

A Canon EOS 550D camera was used. The problems that the Raspberry Pi camera had do not apply for the Canon camera. The software library for C++ is extensive and since the camera has an adjustable focus, the images can be clear even up close, the only downside is the size. The Raspberry Pi could replace the need for a laptop and be able to run the software, instead a regular computer is needed.

### 8.1.2 Components

The scanner and display need different input and output. For the scanner to work, it needs a way to register a card, change player, change life total, roll dice, display life and so on. This could be accomplished using a computer and a keyboard, but in order to make the scanner a separate object, an Arduino is used to control the buttons, LEDs and small 7-segment display. The computer that controls the display needs to be able to register when a card is tapped, this is difficult to do with a web-cam and color tracking, so instead buttons are used to indicate when a card is tapped on the display and a small LED will indicate to the player that the card is tapped. This means that the card is not physically tapped (rotated  $90^\circ$ ) but instead only moves up on the display. The display computer also uses an Arduino to control the buttons and LEDs.

The prototype displays the life count of each player and dice roll / coin flip. This can be displayed using six 7-segment displays (see Figure 8.4).

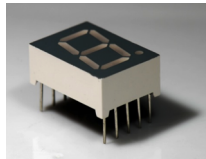


Figure 8.4: 7-Segment Display [Vishay, 2013]

These displays are paired up, so there will be three displays, each with two digits. These displays have 10 pins each, which means that in order to use them with the Arduino, 48 pins<sup>1</sup> have to be available on the Arduino. However, 48 pins is too many pins for the Arduino to run, so to minimize the amount of pins used, an 8-bit shift register [Texas Instruments, 2009] has been used to reduce the pin number to 3 pins per double-digit display, the total pin number is then 9.

The scanner also needs a way to register when a card has been placed inside. This has been done using a photocell [Advanced Photonix, Inc., 2006]. Based on the amount of light the photocell registers, it will, via analog input, tell the Arduino that a card is placed in the scanner.

Since the game will be played by two players at once, the prototype needs to know which player's card is being scanned and when the life changes, as well as which player's life is changing. For this reason there will be a button that switches between the players. To display which player is currently active, two LEDs, that turn on or off, are added.

When a card is being scanned, an RGB LED will give feedback to the player and change color to green, if the card is correctly scanned or red, if the card failed to be scanned.

<sup>1</sup>2 pins on each 7-segment display are set as ground. The remaining 8 pins are input pins.

To sum up, the physical interface consists of two Arduino Uno. The first Arduino has 3 double-digit 7-segment displays, a photocell, an RGB LED, 2 regular LEDs and a 6 buttons. The second Arduino has 10 LEDs and 10 push buttons.

### 8.1.2.1 7-Segment Displays

The three double-digit displays are set up the exact same way. Figure 8.5 shows the schematic of the setup.

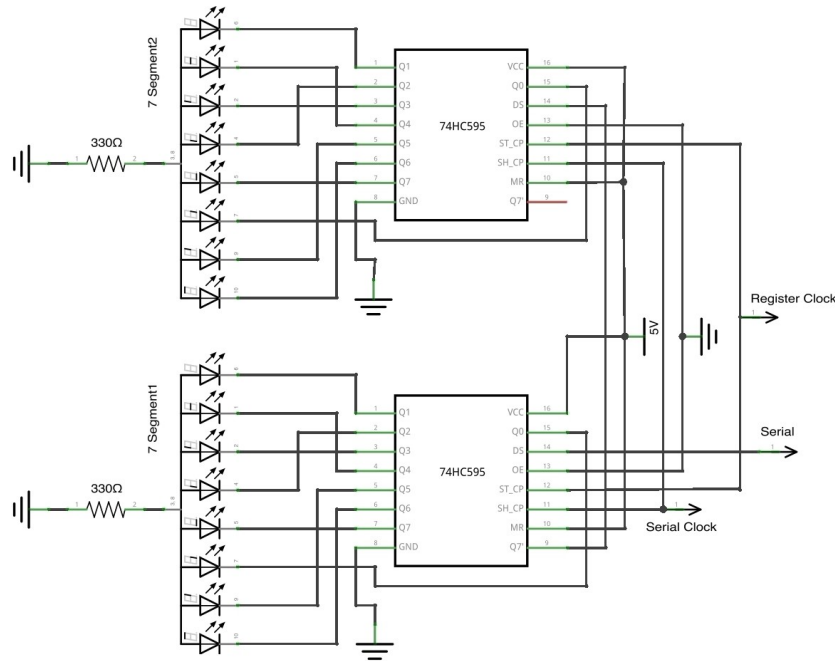


Figure 8.5: Wiring for two 8-bit shift registers and two 7-segment displays

The displays are chained together two and two, which means that the required pin count is just three pins for each double-digit. As seen on the schematic the three pins needed are Serial, Serial Clock and Register Clock, these pins are digital output pins on the Arduino. The code for controlling the displays can be seen on the CD.

### 8.1.2.2 Photocell

The photocell uses one analog pin on the Arduino. When a card is placed on top of the photocell the input will fall from around 1023 to less than 100. To figure out when a card has been placed the code from Code 8.1.

Code 8.1: Code to control the photocell

```

1  if (pinNum == Photocell.Pin && arduino.getAnalog(Photocell.Pin) < 1000
    && !cardDetected) {
2      //card detected
3      scanCard();
4      cardDetected = true;
5  }

```

Once a card has been detected it is also required to stop the `if-statement` or else it will run until the card has been removed. The boolean `cardDetected` will be set to `true` and the function `scanCard` will run.

When the card has been removed `cardDetected` needs to be `false`, so the `if`-statement can run again. This is done using the code from Code 8.2.

Code 8.2: Code to check if a card has been removed

```

1 if (arduino.getAnalog(Photocell_Pin) > 685 && cardDetected) {
2     cout << "\n---Card Removed---\n";
3     cardDetected = false;
4 }

```

The setup of the photocell can be seen in the schematic in Figure 8.6.

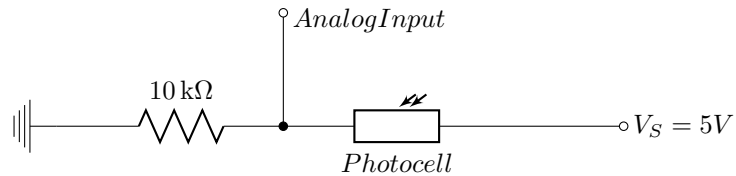


Figure 8.6: Circuit of how the photocell is connected.

### 8.1.2.3 LED

For indicating simple feedback, such as which player's turn it is and which card is tapped, a regular green LED is used. Figure 8.7 shows the schematic for setting up such as LED. The LED uses one digital output pin to turn on and off.

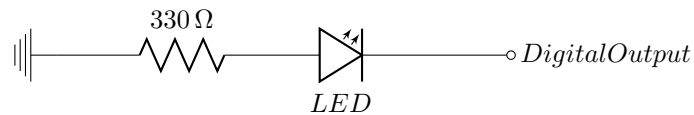


Figure 8.7: Circuit of how an LED is connected.

To display more complex information, such as the status of the card scan, an RGB LED has been used. Figure 8.8 shows the schematic of an RGB LED.

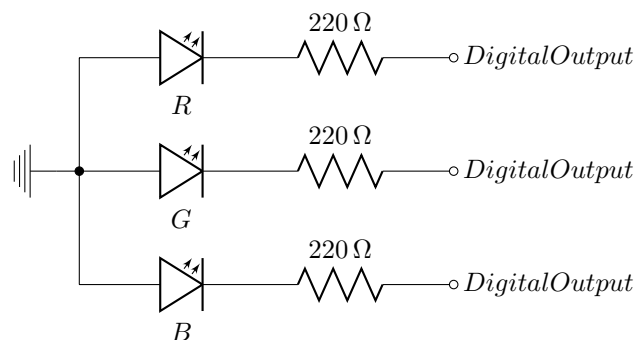


Figure 8.8: Circuit of how an RGB LED is connected.

The RGB LED uses three digital pins on the Arduino and turning each pin on and off can change the color.

### 8.1.2.4 Buttons

Since the prototype uses too many buttons there would not be enough pins on the Arduino. A way to avoid using a lot of pins and just use one pin instead is to add all the outputs of the buttons to one analog pin. Between each button and the analog input pin there should be a resistor, so each button will give a different analog reading. An example of this can be seen in the schematic in Figure 8.9.

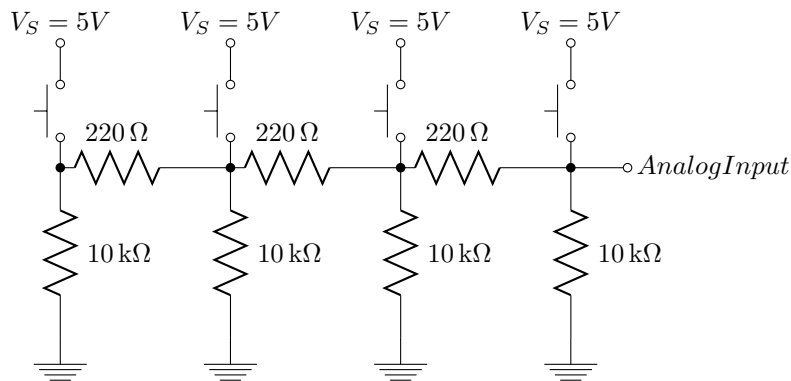


Figure 8.9: Circuit of how four buttons are connected to one input.

The code to control the button can be seen in Code 8.3. When a button is pressed the value of `temp` will be a number between 1023 and 1. When the button is released the value will be 0. To avoid debounce, a boolean has been made for each value that will be `true` when the button is pressed and `false` when it is released.

Code 8.3: Code to control multiple buttons using a single analog input

```

1  if (pinNum == button.Pin) {
2      int temp = arduino.getAnalog(button.Pin);
3      if (temp > 965 && !_button1) {
4          cout << "Do something with button 1\n";
5          _button1 = true;
6      } else if (temp > 890 && temp < 900 && !_button2) {
7          cout << "Do something with button 2\n";
8          _button2 = true;
9      }
10     if (temp == 0) {
11         _button1 = false;
12         _button2 = false;
13     }
14 }

```

### 8.1.3 Programming

The software part of the prototype consists of two parts. First there is the *display*, which displays all the information to the audience. Second there is the *scanner*, which scans the cards and controls all the electronics.

Both applications are written in C++ using openFrameworks (oF) [openFrameworks.cc, a]. The scanner is using a couple of different libraries to do optical character recognition (OCR), controlling



the camera and parsing JSON<sup>2</sup> data and recognizing the name on the card using a library called Tesseract [Google]. Tesseract is an OCR engine maintained by Google that can be used on a variety of platforms. openFrameworks has a pre-compiled version for Mac OS X, called ofxTesseract [McDonald, a], which provides easy access to the Tesseract library and comes with easy-to-use functions. The camera used for scanning had to be of a certain quality, else the OCR could not be performed optimally. After trying different cameras (see Section 6.2.2.2 Camera) it was decided to use a Canon EOS 550D. This camera can be controlled from openFrameworks using ofxEdsdk [McDonald, b], which is a library with easy access to functions that can be used for the chosen camera Canon EOS 550D. When the scanner scans a card, it returns the name of the card but there is no other data associated with the card, such as description or stats. To get additional information from the card, an http request is sent to an online database [Seitz], which returns a JSON file. This JSON file needs to be parsed into regular strings that can be used throughout the program. In order to do this, a library called ofxJSON [Crouse] is used.

### 8.1.3.1 Tesseract

To set the ofxTesseract library up, a compiled version of the Tesseract library is needed. The library can be compiled from the source [Google] to work on Windows, Linux and Mac. The library was compiled on Linux (under Raspberry Pi) and Windows but the library did not work correctly with the openFrameworks addon (ofxTesseract). Instead the pre-compiled Mac version that ofxTesseract comes with was used. This limited the scanner software to run only on Mac OS X. The library (ofxTesseract) comes with a list of functions that makes it easy to use. Code 8.4 is an example of how to set ofxTesseract up.

Code 8.4: ofxTesseract setup

```

1 ofxTesseract tess ;
2 tess.setup() ;
3 tess.setWhitelist("abcdefghijklmnopqrstuvwxyABCDEFGHIJKLMNOPQRSTUVWXYZ
   ");
4 tess.setAccuracy(ofxTesseract::ACCURATE) ;
5 tess.setMode(ofxTesseract::AUTO) ;
6 tess.findText(pixels) ;

```

**Line 1:** Create an object called `tess` of type `ofxTesseract`.

**Line 2:** Run the setup function

**Line 3:** Choose which characters will be recognized. The prototype only needs regular letters so no special characters have been added .

**Line 4:** Sets the mode which will be used. There are two modes; Accurate or Fast. As the names suggest, Fast is a fast mode but less accurate and Accurate is a slower mode and more accurate.

**Line 5:** ofxTesseract includes different modes to search for different types of text. AUTO is the default mode that just searches the whole image for text.

**Line 6:** After setting up the basic things it is just a matter of using line 6 which returns a string of the resulting text in the image.

### 8.1.3.2 Camera

As mentioned in the introduction, a Canon EOS 550D camera is used for scanning the card. This idea of using the Raspberry Pi camera was discarded because of various reasons already discussed. To get the Canon camera to work, a library called ofxEdsdk [McDonald, b] is used. This library uses

<sup>2</sup>JSON data is gathered from `api.mtgdb.info` [Seitz] and returns information about each card in JSON format.

the Canon's own camera utility for Mac to get the videofeed from the camera into openFrameworks. Code 8.5 is an example of how to setup ofxEsdk.

Code 8.5: ofxEsdk setup

```
1 ofxEsdk::Camera camera;
2 camera.setup();
3 camera.update();
4 camera.isFrameNew();
5 camera.getLivePixels();
```

**Line 1:** Create an object called `camera` of type `Camera` from the `ofxEsdk` namespace.

**Line 2:** Setup the camera and use it instead of the building web-cam.

**Line 3:** Get a new frame from the camera

**Line 4:** Returns true, if there is a new frame and it is now possible to use the frame for image processing.

**Line 5:** Returns `ofPixels` of the current frame. After the pixels has been returned they are stored in an `ofPixels` variable and can be manipulated using `ofPixels` functions.

After getting the pixels from the camera, they can be used together with `ofxTesseract` to do OCR.

### 8.1.3.3 JSON

When using the database `api.mtgdb.info` [Seitz] to get card information, the result is returned in JSON format. This needs to be decoded somehow and the easiest way to do this, is by using the library `ofxJSON` [Crouse]. Code 8.6 is an example of how to use the `ofxJSON`.

Code 8.6: ofxJSON setup

```
1 ofxJSONElement json;
2 json.open("http://api.mtgdb.info/cards/cardName");
3 json[0]["name"].asString();
4 json[0]["power"].asInt();
```

**Line 1:** Create an object called `json` of type `ofxJSONElement`.

**Line 2:** Returns true if the path has been parsed successfully. Also stores the data returned by the path in the `json` variable.

**Line 3:** Access the JSON field named "name" and return it as a `string`.

**Line 4:** Access the JSON field named "power" and return it as an `int`.

After getting the variables from the JSON fields that are needed, they are stored as strings or integers for later use.

### 8.1.3.4 Networking

As mentioned in the introduction of this section, a total of two application are being used to control the prototype. The two applications need a way to communicate with each other and the easiest way to do this is by using networking. `openFrameworks` includes a library called `ofxNetwork` [openFrameworks.cc, b], which includes two different modes for communicating: UDP and TCP. UDP (User Datagram Protocol) is connectionless, which means that it does not have to establish a connection between the two applications before sending packages, but the problem is that there is no guarantee that the sent packages, will arrive at the destination. TCP (Transmission Control

Protocol) on the other hand, is a connection based protocol, which requires that the two applications establish a connection before any packages can be sent. The good thing about TCP is that there is a guarantee that all packages sent will be received.

For this prototype TCP is used, due to the fact that there is a need for all packages to be received and a connection between the two applications can easily be established at start up.

Code 8.7 will explain the server-side of the networking. The server will run on the *scanner*. Code 8.9 will explain the client-side of the networking, which will run on the *display*.

Code 8.7: ofxNetwork server setup

```

1 ofxTCPServer server;
2 int client;
3 server.setup(8800);
4 server.setMessageDelimiter("\n");
5 for (int i = 0; i < server.getLastID(); i++) {
6     if (server.isClientConnected(i)) {
7         client = i;
8     }
9 }

```

**Line 1:** Create an object called `server` of type `ofxTCPServer`.

**Line 2:** Create a new integer called `client`.

**Line 3:** Setup the server using the port 8800.

**Line 4:** Set the message delimiter to `\n`, which means that every time `\n` (enter) is send, the rest of the message will be discarded.

**Line 5:** Run through ID's that the server has been connected to.

**Line 6:** Check if the server is connected to the ID.

**Line 7:** Set `client` to the last connected ID.

To find a message to the client, the server can use the code from Code 8.8.

Code 8.8: Sending information from the server to the client

```

1 server.send(client, "String of information");

```

Code 8.9: ofxNetwork client setup

```

1 ofxTCPClient clients;
2 clients.setup("192.168.1.10", 8800);
3 clients.setMessageDelimiter("\n");
4 if (clients.isConnected()) {
5     string str = clients.receive();
6     if (str == "\n" || str == "") {
7     } else {
8         //Use the string str here.
9     }
10 }

```

**Line 1:** Create an object called `clients` of type `ofxTCPClient`

**Line 2:** Setup the connection to the server using the IP address of the server and the correct port number.

**Line 3:** Set the same message delimiter as the server.

**Line 4:** Check if the client is connected to the server

**Line 5:** If the client receives anything, store it as a string called `str`.

**Line 6:** If the string is an `enter` (`\n`) or nothing then do nothing, else use the string.

With the two applications setup as Code 8.9 and 8.7, it is just a matter of using `if-statements` to determine what should be done with the received code.

### 8.1.3.5 Arduino

To control the electronics of the prototype, two Arduino Uno are being used. These are also programmed in openFrameworks using `ofArduino`. To get the Arduinos to work with openFrameworks it is necessary to load StandardFirmata to the Arduino, this is done by using the Arduino IDE [[Arduino.cc](#)].

Once StandardFirmata has been loaded onto the Arduino it can be setup in openFrameworks using the code from Code 8.10.

Code 8.10: `ofArduino` setup

```
1 ofArduino arduino;
2 arduino.connect("/dev/tty.usbmodemfa131", 57600);
3 void setupArduino(const int & version);
4 void digitalPinChanged(const int & pinNum);
5 void analogPinChanged(const int & pinNum);
```

**Line 1:** Create an object called `arduino` of type `ofArduino`.

**Line 2:** Connect to the port `/dev/tty.usbmodemfa131` using the baud rate 57600.

**Line 3:** Create a setup function to setup which pin numbers and modes the Arduino should use.

**Line 4:** If a digital pin has any input changes, they can be monitored here.

**Line 5:** If an analog pin has any input changes, they can be monitored here.

Once the Arduino is connected to the scanner and the other to the display. The Arduino for the scanner controls different LEDs, 7-segment displays and buttons to change player, roll dice, flip coins and change life. The Arduino connected to the display controls buttons used to tap creatures and corresponding LEDs to indicate which creatures are tapped.

### 8.1.3.6 Levenshtein Distance

When the scanner is scanning a card and doing optical character recognition on the name, there are bound to be some mistakes. This can be because the background is not a solid color, the light is a bit off, the card is dirty and so on. To avoid getting wrong names all the time, that cannot be searched for (because they do not exist), the Levenshtein Distance [[Munich](#)] [[Jurafsky](#)] is used to find the name that matches the card name most. The prototype uses two pre-made Magic: the Gathering decks, so the cards are known. A list of all the card names has been made and the Levenshtein Distance algorithm is used to match the scanned name to the list of available names.

The Levenshtein Distance creates a matrix of the least amount of edits for two strings to match up. This is used to find the distance between two strings, however, it does not check for the smallest distance between a string or a list of strings. Code 8.11 shows pseudo-code for comparing a file of strings with a single string.

Code 8.11: Pseudo-code for finding the closest match of a string and a file of strings

```

1 For each line in file
2     Add to vector
3 For each string in vector
4     Get distance
5     Store distance as smallest distance
6     If distance less than smallest distance
7         Smallest distance = distance
8 Smallest distance is the closest string that matches

```

This can be done in C++, using Code 8.12.

Code 8.12: Code for finding the closest match of a string and a file of strings

```

1 dataFile.open("path/to/file.txt");
2 while (!dataFile.eof()) {
3     getline(dataFile, line);
4     cardNames.push_back(line);
5 }
6 dataFile.close();
7 for (int i = 0; i < cardNames.size(); ++i) {
8     distance = distanceString(cardNames.at(i), cardName);
9     if (distance < min) {
10        min = distance;
11        place = i;
12    }
13 }

```

**Line 1:** Open the file.

**Line 2:** Go through the file until `eof` (end of file).

**Line 3:** Get the line of the file and store the string in `line`.

**Line 4:** Add the string `line` to the vector `cardNames`.

**Line 6:** Close the file.

**Line 7:** Go through each string in the vector `cardNames`.

**Line 8:** Store the distance between the scanned name `cardName` and the string from the vector `cardNames`. `distanceString` is a function to compute the Levenshtein Distance.

**Line 9:** Check if the distance is less than the minimum distance.

**Line 10:** Store the new distance as `min`.

**Line 11:** Store the place at which the smallest distance is found as `place`.

After the `for`-loop is finished, the string that was the closest matched the `cardName` can then be found using `cardNames.at(place)`. For the full description of the Levenshtein Distance see Appendix E Levenshtein Distance.

The programming of the main computer leads to information connected to the secondary computer. Without the information gathered from the main computer, it would not be possible to display any information of the game in progress on the display.

## 8.2 Secondary Computer

This section will go in depth with information regarding the implementation of the design of the display and the mechanics behind it. Firstly, it will start out by giving a short description of the

processes taking place on the second computer, followed by an explanation of the code and snippets examples.

### 8.2.1 Display Implementation

The second computer takes in consideration processes that include: displaying the cards on the screen alongside with basic information from the game such as life, dice rolls, coin flips and the votes each player has received from the audience. It must also categorize the scanned cards according to the information it receives from the main computer. The main computer is connected through the library `ofxNetwork` to the second computer, which receives information separated by a circumflex character. Another role of this system, is to detect cards placed on the battlefield and display them to the audience. In order to do this, color detection was implemented.

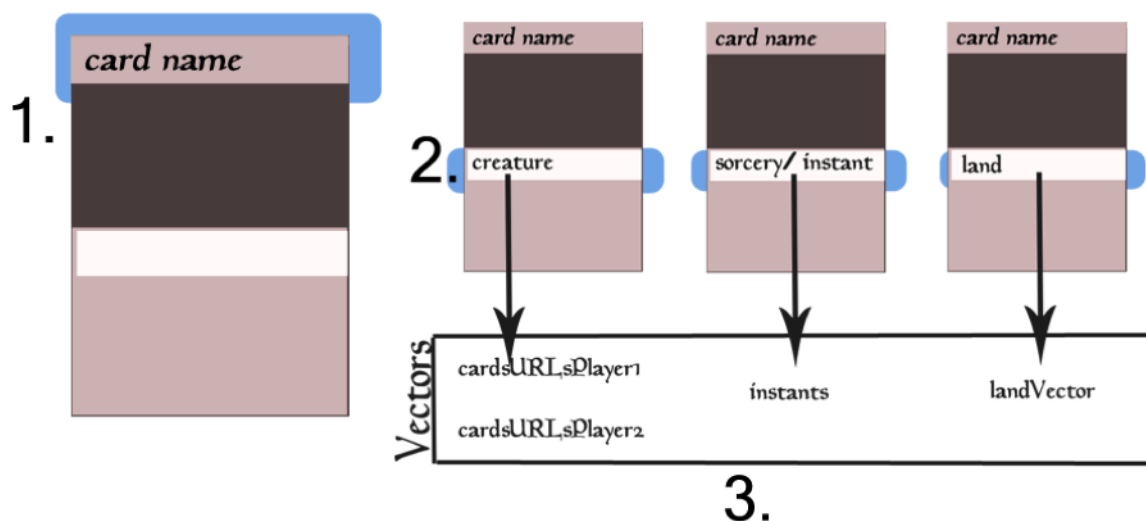


Figure 8.10: Process of displaying information received from the main system

An overview of the first three steps taking place before displaying information, can be seen in Figure 8.10. The first step is a simple step effectuated by the scanner and the main system, where the card the player has drawn will be scanned. The name of the scanned card will then be detected by the camera mounted on the physical interface and sent to the second computer along with information such as: which player (player1, player2), type of the card (creature, sorcery, instant, land) and keywords that are connected to the card. Once the information was received, it is sent through a decoding function to let the computer know what the string of information contains, then according to the players and type of cards they are, they are stored in 4 different vectors. The vector names can be seen in Figure 8.10 step 3 and the arrows point which type of cards will be saved in which vectors. Once the information is known by the second computer, a series of if sentences re-triggered in order to draw the right information onto the display.

In the first iteration of the display, only certain information was contained (creature cards, life, dice roll and coin flips), however during the midterm it was noticed that certain changes should be made (see Section 7.1 Midterm). The design and implementation of the first iteration can be seen in Figure 8.11 and later on, Figure 8.13, which contains the changed design with improved information and display.

The midterm has brought the attention on specific changes that needed to be made and improvements that were required. Such changes were to add more information that is happening on the battlefield, therefore it was decided to split the creature cards from the rest and place the land

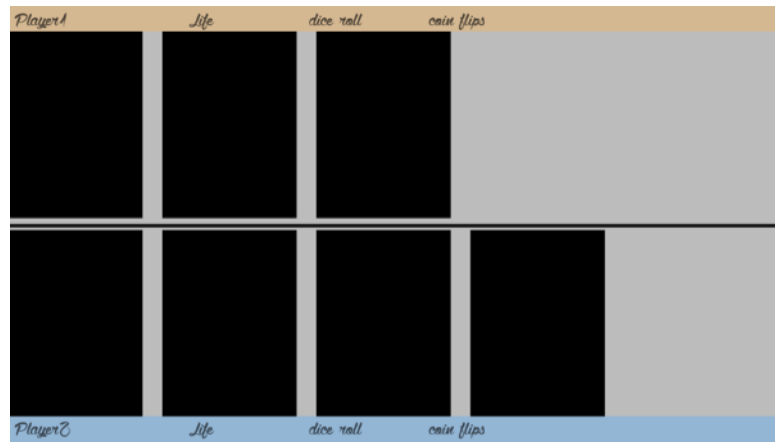


Figure 8.11: First iteration of the display. The cards take up most of the space (black rectangles) and there are not room for lands or keywords.

cards to the right of each player’s display side. Currently, the display for each player can hold 5 cards for creatures and 10 lands. These numbers were chosen in order to have clear image of the cards according to the screen size used which displays them, therefore the cards can be seen and read clearly at any time by the viewers.

player 1 scanning. . .  
player 2 scanning. . .

Figure 8.12: Graphic that will be displayed when a player scans a card.

Another feature added and improved after midterm was the popping up of the card once the player has scanned it and adding some feedback to the display while the player is scanning. Therefore, it was chosen to display written information to the display such as “*Player 1 scanning*” while the certain player’s card is being scanned (see Figure 8.12). Once the card was scanned it will pop up to the right and will remain for 50 frames. The flaw of this feature was noticed during the midterm and therefore an improvement of this was added (see Figure 8.13).

The design setup was quickly explained and how it was implemented, however the functionality behind all the design is a more complicated process, which will be explained in the sections to come.

### 8.2.2 Programming of the Display

The design is simple and is mainly built out of rectangles and text. In the display it can be noticed that there are two main rectangles, one at the bottom of the screen and one on the bottom, these were created by using the built in function in openFrameworks: `ofRect`. The code snippets used for these can be seen below, where `h` and `w` are predefined variables containing width and height of the screen;

```
ofRect (0,0,w,(h/2)-(h/9)+15);
```

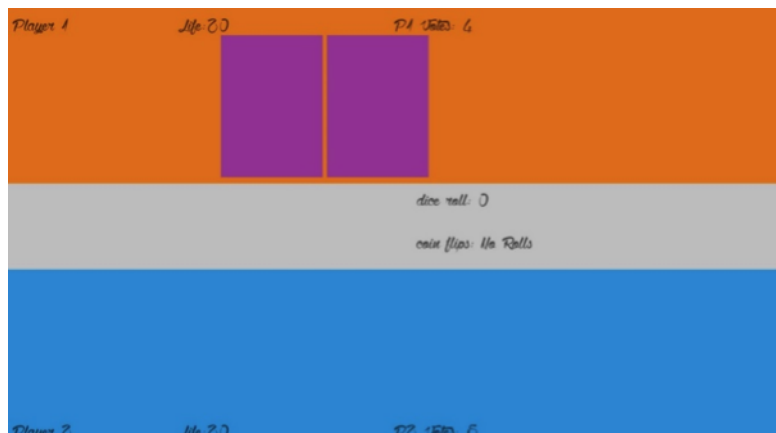


Figure 8.13: Second iteration of the display. The cards are now placed in the left side with room for lands on the right. In the middle there is also a gray area for keywords and other information.

```
ofRect (0, (h/2)-(h/11)+(h/5), w, (h/2));
```

The text is also created by using openFramework's built in function `drawString`. For each player, life, vote section, coin flip section etc. that uses text a new variable had to be declared and each of them were drawn separately at certain position on the screen.

```
player1.drawString(name1, 10, 40);
```

Since openFrameworks requires an `ofImage` variable declared for each image that is going to be drawn on the display, five images were declared for each of the two players. These images were drawn only when the right color was detected on the specific spots.

A problem however occurs when loading the right images into the declared variables that will be drawn and getting the program to know when to remove the cards and replace them with the new one scanned. This was solved by creating many booleans set to false and triggered when certain information was received from the main computer.

### 8.2.3 Decoding Functions

The information sent from the main computer was decoded by using a function and by detecting the first string character in each message sent. Below, the function used to send the name of the cards can be seen. It mainly contains a `for-loop` which goes through the characters sent and looks for the circumflex symbol, which is used to divide the characters into words. Once the positions of the symbols were detected, each of the words were set up in cases in a switch case, since most of the time, the message contains more information than just the name. In this case, it holds information about which player it is, which type the card detected is and the keywords found, regarding the card.

In the function in Code 8.13, it can be seen that, the name is set for case 2, and once it goes through all the words divided by the symbol, it counts up to the third word (`case 2`), and returns it, which is then used in the update function.



Code 8.13: Code to decode a string where each word is separated by a circumflex.

```

1 string testApp::getName(string info) {
2     string temp = "";
3     int a = 0;
4     int b = info.size();
5     int j = 0;
6     for (int i = 0; i < b; i++) {
7         for (; i < b && info[i] != '^'; i++) {
8             temp += info[i];
9         }
10        switch (a) {
11            case 2:
12                cout << "name: " << temp << endl;
13                return temp;
14                break;
15        }
16        temp = "";
17        a++;
18    }
19 }

```

There are nine decoding functions used in the programming of this prototype; `getUrl`, `getPlayer`, `getType`, `getDice`, `getCoin`, `getLife1`, `getLife2`, `getName` and `getKeywords`. All of them work similarly, however they focus on different messages and parts of the message. Each one of these functions are used to get different information from the main computer (scanner) to the secondary computer, which is used to display on the screen for the viewers.

### 8.2.4 Update Function

The `update` function is a function in `openFrameworks` that runs once each frame. Inside the update function `ofxNetwork` is placed, which creates a TCP connection between the primary and secondary computer (see Section 8.1.3.4 Networking). The networking in the update function decides which message was sent and which `if` statement to enter. For example if it is detected that the message starts with the letter "P", it will start a counter and afterwards will decide which player of the two it is, by using a similar decoding function to the one explained in Section 8.2.3 Decoding Functions. Once it knows which player it is, it sets the booleans `player10` or `player20` to true (see Code 8.14).

Code 8.14: Code showing what boolean to use, based on the string received from the main computer.

```

1 if (str[0] == 'P') {
2     received=true;
3     counter=0;
4     if (getPlayer(str).compare("Player1") == 0) {
5         player10=true;
6     }
7     if (getPlayer(str).compare("Player2") == 0) {
8
9     }
10 }

```

The cards detected while using the decoding function are stored inside different vectors, as mentioned in Section 8.2.1 Display Implementation (see Figure 8.10). The `if` statement in Code 8.15

checks whether the cards received from the main computer are *creatures*, if they are *creatures*, then the `if` statement checks which players turn it is and saves the *creature* in the specific vector for that player; `cardURLsPlayer1` or `cardURLsPlayer2`.

Code 8.15: Code to check if the card is a *creature*, then which player it is, finally the card is stored in a vector.

```

1  if (getType(str) == "Creature"){
2      if (getPlayer(str).compare("Player1")==0) {
3          for (int i = 0; i < cardURLsPlayer1.size(); i++) {
4              if (cardURLsPlayer1.at(i).compare("nothing") ==
5                  0) {
6                  cardURLsPlayer1.at(i) = getURL(str);
7                  p1Received = i;
8                  break;
9              }
10         }
11     }

```

The same happens when the type of the card detected is a *sorcery* or an *instant*, the decoding function `getType()` is used and the cards are saved in the corresponding vector, which are used to draw the cards on the display for the spectator (see Code 8.16).

Code 8.16: Code to check if the card is an *instant* or *sorcery*, then store the card in a vector.

```

1  if (getType(str) == "Sorcery" || getType(str) == "Instant" ){
2      sorcery=true;
3      for (int i = 0; i < instants.size(); i++) {
4          if (instants.at(i).compare("nothing") == 0) {
5              instants.at(i) = getURL(str);
6              cat = i;
7              break;
8          }
9      }
10 }

```

In the update function, the color detection is also done by the `videoGrabber`. The `videoGrabber` is a built-in function in `openFrameworks`, which helps get data from the camera connected to the computer. In this case `vidGrabber` is an object of type `videoGrabber`, which is used to check when the camera receives a new frame which then enters activates the `if` statement.

The code for how the color detection is done, can be seen in Code 8.17 and it uses built-in functions of `openFrameworks`' library to get frames and pixels of the videofeed. Once this information is acquired, it enters a double `for` loop, which sets three variables for the three colors with the amount of pixels detected in the image. `result_g` and `result_r` sets the color that should be detected, which in this case is red and orange.

<code>scanX</code>	0	256	512	768	1024
Position of card	1	2	3	4	5

Table 8.1: Table showing `scanX` values and the corresponding card position.

Code 8.17: Code to detect either orange or red color and then exchange the colored pixels with white and all other pixels with black

```

1  if (vidGrabber.isFrameNew()) {
2      unsigned char * pixels = vidGrabber.getPixels();
3      for (int y = 0; y < h; y++) {
4          for (int x = 0; x < w; x++) {
5              r = pixels[(y*w+x)*3+0];
6              g = pixels[(y*w+x)*3+1];
7              b = pixels[(y*w+x)*3+2];
8
9              result_g = (r > b+20 && g < b && b < 130) ? 255
10                 : 0; //checks for red
11             result_r = (r > g+10 && g > b && b < 125) ? 255
12                 : 0; //checks for orange
13         }
14     }
15 }

```

The information gathered in the update function is connected to the drawing process and immediately sent to the drawing function once it has been received. The following section will go in depth with some of the processes used to draw the cards on the display.

### 8.2.5 Drawing a Creature Card

The code for drawing a card focuses on a lot of the external information, which is received from both the scanner and the color detection. For each card that needs to be drawn, the code contains an `if statement`, which works similarly to the one what will be described below.

The `if statement` starts out by checking at which position the card is being detected by the web-cam. `scanX` decides the position by checking whether the number of the card detected at is 0, 256, 512, etc. Table 8.1 shows the numbers which `scanX` goes through in order to find the right position for the card. For example if `scanX` is detected to be 0, it means it is looking at the first position of the cards on the battlefield.

Once the program knows which position it is at, it moves on to the second part of the `if statement` and checks whether the average color of the card detected on that position is bigger than a pre-set value `colorThreshold`, which is set to 50. There are two different colors that the web-cam is set to detect, player 1 is set to have a deck sleeved with orange sleeves while player 2 uses a deck sleeved with red sleeves. This means the web-cam is set to detect orange and red (see Code 8.18).

Code 8.18: Code to detect either red or orange.

```

1  result_g = (r > b+20 && g < b && b < 130) ? 255:0; //checks for red
2  result_r = (r > g+10 && g > b && b < 125) ? 255:0; //checks for orange

```

Once the role of the color detection is finished, it moves on to the last part of the `if statement` which checks whether a card was loaded on position 1 of player 1. `p1Card1Loaded` is a boolean, set

to false in the setup function<sup>3</sup> and as long as this is set to false, it will mean there is no card on the specific position on the physical interface and once the rest of the conditions are fulfilled it will enter the if sentence which will turn this boolean and `p1Card1Draw` to true. On the other hand if the conditions are not fulfilled and these booleans are set to be true, meaning the card has been removed or there is no card detected, everything will be set to their default values. The boolean `p1Card1Draw` decides whether the card should be drawn on the screen or no, which means if this is true, the card will be drawn and removed when this will be set to false. The code for this can be seen in Code 8.19.

Code 8.19: Check whether a card should be drawn or not.

```

1  if (scanX == 0 && averageC > colorThreshold && !p1Card1Loaded) {
2      p1Card1Draw = true;
3      p1Card1Loaded = true;
4  } else if (p1Card1Loaded && scanX == 0 && p1Card1Draw && averageC <
      colorThreshold) {
5      p1Card1Draw = false;
6      p1Card1Loaded = false;
7      cardURLsPlayer1.at(0) = "nothing";
8  }

```

### 8.3 Web Application

The prototype is interactive for the players but the audience can only stand and watch. As mentioned in Section 6.4 Web Application, a web application was created as a way for the audience to interact with the game. This application is a website where the audience can vote for their favorite player and the score will then be updated on the display of the prototype. Figure 8.14 shows a flowchart over the web application.

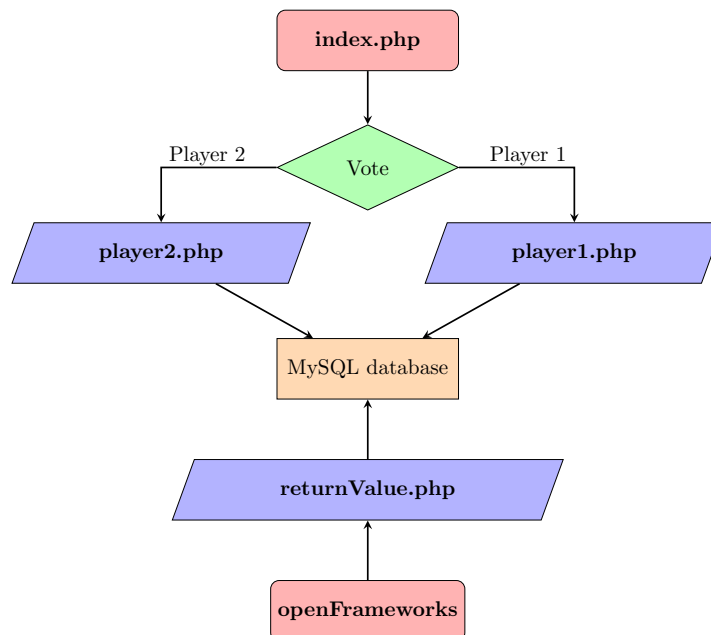


Figure 8.14: Flowchart showing the web application.

<sup>3</sup>The setup function is a function that runs once, when the program start and can be used to assign initial values to variables.

The program starts with *index.php*. This is a php file but it also contains html code, the html code is for the buttons and the layout. Code 8.20 shows a snippet of the code from the *index.php* file. The code shows how one of the two buttons is created. *turquoise-flat-button* refers to a style in a css file (*style.css*).

Code 8.20: *index.php* snippet

```

1 <div class="turquoise-flat-button">
2   <a onclick="self.location='player1.php'" class="fill-div">Player 1<
   /a>
3 </div>

```

When one of the two buttons is pressed, either script *player1.php* or *player2.php* will run. This can be seen as the green diamond on Figure 8.14. As mentioned in Section 7 Delimitation, the design of the web application was changed. The final design can be seen in Figure 8.15.



Figure 8.15: Final design of the web application, shown in the iOS Safari browser.

The scripts *player1.php* and *player2.php* are almost identical; the only difference is in what number is stored in the MySQL database.

Code 8.21: *player1.php* snippet

```

1 mysql_connect("$host", "$username", "$password") or die("Cannot Connect
   ");
2 mysql_select_db("$db_name") or die("Cannor select db");
3 $sql="INSERT INTO '$tbl_name' ('p1') VALUES ('1')";
4 $result=mysql_query($sql);
5 if ($result) {
6     echo "Successful";echo "<br>";
7 } else {
8     die('Error: ' . mysql_error());
9 }
10 mysql_close();

```

**Line 1:** Connects to the database, if the connection fails it exits and prints "Cannot Connect".

- Line 2:** Selects the database, if it fails it exits and prints, "Cannot select db".
- Line 3:** Inserts the value 1 into column p1 for the table \$tbl\_name. For *player2.php* the value would be 2 and the column p2.
- Line 4:** Stores the result of the query as \$result.
- Line 5:** If \$result is true then the values have been stored correctly.
- Line 6:** "Successful" is printed on the screen with a breakline.
- Line 8:** If the \$result fails, the script exits and prints the error.
- Line 10:** Finally the script closes the connection to the MySQL database.

When the data is stored in the database, it looks like Figure 8.16. Whenever someone votes for player 1, it is stored as a 1 and votes for player 2 are stored as a 2. This is done so it will be easier to receive each vote with openFrameworks.

	p1	p2
<input type="checkbox"/> Edit Copy Delete	1	0
<input type="checkbox"/> Edit Copy Delete	0	2
<input type="checkbox"/> Edit Copy Delete	1	0
<input type="checkbox"/> Edit Copy Delete	0	2
<input type="checkbox"/> Edit Copy Delete	0	2
<input type="checkbox"/> Edit Copy Delete	1	0
<input type="checkbox"/> Edit Copy Delete	1	0
<input type="checkbox"/> Edit Copy Delete	0	2
<input type="checkbox"/> Edit Copy Delete	0	2
<input type="checkbox"/> Edit Copy Delete	1	0

Figure 8.16: Screenshot of the MySQL database with 5 entries (votes) for player 1 and 5 entries for player 2.

The last script is *returnValue.php*, this script returns all the votes from both players. openFrameworks sends an HTTP request to the script, which then returns the votes. The script returns a string that looks like: 1010011001 0202200220. All the 1's are player 1 votes and all the 2's are player 2 votes. All the 0's can be ignored. Since one value is added a time, the column that does not get a new value will get a 0. A snippet *returnValue.php* can be seen in Code 8.22.

Code 8.22: *returnValue.php* snippet

```

1  mysql_connect("$host", "$username", "$password") or die("Cannot Connect
   ");
2  mysql_select_db("$db_name") or die("Cannor select db");
3  $get=mysql_query("SELECT * FROM 'counter '");
4  while($row = mysql_fetch_array($get)){
5      echo $row[0];
6  }
7  echo " ";
8  $get=mysql_query("SELECT * FROM 'counter '");
9  while ($row = mysql_fetch_array($get)) {
10     echo $row[1];
11 }
12 mysql_close();

```

**Line 1:** Connects to the database, if the connection fails it exits and prints "Cannot Connect".

**Line 2:** Selects the database, if it fails it exits and prints "Cannor select db".

- Line 3:** Make a query to the server for all the values in the table *counter*. Then store it in *\$get*.
- Line 4:** While there is still rows in *\$get*,
- Line 5:** print the rows for column 1.
- Line 7:** Print a space, so the two columns are separated.
- Line 8:** Repeat Line 3.
- Line 9:** Repeat Line 4.
- Line 10:** Print the rows for column 2 this time.
- Line 12:** Close the connection to the MySQL database.

The script has now printed the string 1010011001 0202200220, which can be returned to openFrameworks using some C++ code from the display application.

Code 8.23: openFrameworks code to get player votes

```

1 ofHttpResponse resp = ofLoadURL("http://drudoo.com/counter/public_html/
  returnValue.php");
2 string temp = resp.data;
3 for (char c : temp) {
4     if (c == '1') {
5         p1Votes++;
6     }
7     if (c == '2') {
8         p2Votes++;
9     }
10 }
11 cout << "\n—p1Votes: " << p1Votes << endl;
12 cout << "\n—p2Votes: " << p2Votes << endl;

```

- Line 1:** Queue the server at the provided address and save the result as *resp*.
- Line 2:** Create an object called *temp* of type *string* and store *resp*'s data.
- Line 3:** Using a for-each loop to run through all the characters in the string.
- Line 4:** If the loop encounters a 1.
- Line 5:** Then increment *p1Votes* my 1. *p1Votes* is an integer.
- Line 7:** If the loop encounters a 2.
- Line 8:** Then increment *p2Votes* my 1. *p2Votes* is an integer.
- Line 11:** Print *p1Votes*.
- Line 12:** Print *p2Votes*.

The audience can go to *index.php* on their smartphone and vote for each player. Based on which button is pressed, either *player1.php* or *player2.php* is called. Both of these scripts stores a value (either 1 or 2) in a MySQL database. openFrameworks can then make an HTTP request to *returnValue.php* which returns a string of all the votes. Using a for-each loop it is possible to loop through the string and count all the votes. To test the web application go to [http://drudoo.com/counter/public\\_html/index.php](http://drudoo.com/counter/public_html/index.php) or use the QR code in Figure 8.17.

The full code for both the main and secondary computer can be seen on the CD.



Figure 8.17: QR code redirecting to the web application.

## 8.4 Conclusion

To sum up, the prototype needs to use a special implemented table that can cooperate with the display to show the information to the spectators. The scanner box is necessary to notify the secondary computer or the display about the cards the players use during the game. Overall the prototype tries to implement the features set during the Design chapter, either by keeping the design set in mind or by trying to adapt the implementation techniques to a new design, which can cut on time usage.



# Chapter 9

## Testing

This chapter will cover the evaluation process of the prototype developed during this project. First of all, it will go through the testing methods introduced in the methodology section and pick the ones that would be most relevant when evaluating the digitalized MtG game. Afterwards, the test setup will be introduced and test execution process explained. This will be followed by a description of the pilot test and its results. After discussing the outcome of the pilot test, the actual test results will be presented and analyzed. The chapter will be concluded with an overall evaluation of the test's outcome as well as a discussion based on the results.

### 9.1 Hypothesis

The goal of this test is to evaluate the formulation of the FPS which goes as following:

*“To what degree can spectator’s experience improve while following a game of Magic: the Gathering, if they are presented with visual representations that keep them updated about the game process, in comparison to the existing methods of spectating?”*

In order to determine how the digitized version of an MtG game will impact the spectator’s experience the following hypotheses have been formulated:

- **Null-hypothesis:** There is no change in the experience of a beginner MtG spectator when visual representations are used.
- **Alternative hypothesis:** There is an improvement in the experience of a beginner MtG spectator when visual representations are used.

Since the null hypothesis is asking about a specific type of difference rather than evidence of any difference at all, the test is considered a one-tailed T test. Taking into consideration, that the participants will not be expected to take part in both of the testing sessions (with and without public display), the test will be performed on two different samples. This means that each test session will be performed on an equal amount of people, and will be conducted as a between group experiment.

### 9.2 Testing Methods

Section 5.4 Methodologies previously introduced several different methods that might be used for the evaluation of this test. After having compared and considered each of them, it has been decided to use the following methods during the testing:

- Questionnaire has been chosen as a way of collecting quantitative data for statistical analysis about the subject. On the other hand, the questionnaire has been designed in such a way that a few open-ended questions were included for a qualitative perspective on the topic.

- PANAS will be used to analyze the emotional state of participants, which could help determine whether the spectating was a positive or a negative experience.
- Observations will be used for collecting information about the participants' behaviour during the test sessions as a comparison to the rest of the methods.
- GSR has been chosen as the most effective physiological measurement that could be useful in following the participant's reactions towards the game. Ideally it was thought that audio measurements would have been a better approach at analyzing data from a crowd of people, which is the audience of the game in progress. It was not possible to get the specific program (openEAR<sup>1</sup>) to work in order to be able to analyze audio data recorded, therefore an alternative solution was thought of. However, this solution does not cover a large audience and focuses on one person at a time. This solution is also more burdening for the participants since they would have GSR equipment attached and are asked not to move around too much. If audio measurements had been possible, participants would not need to be bothered by the setup of the tools.

### 9.2.1 Questionnaire

This section will go through the some of the questions of the questionnaire for the final tests, each of the questions explained will also be briefly mentioned in the text, however in order to get an idea of the full summary of the questionnaire handed out see Appendix A and Appendix B. The full set of answers can be seen on the CD.

The questionnaires used for both the display and non-display test setups, included a consent form at the beginning of the questionnaire informing the participants about the scope of the project, what the data will be used for and asked whether the data can be used for these purposes. The majority of the questions chosen for the questionnaire containing Likert scale ranging from 1 to 7.

The first question to be asked which plays an important role to the goal of the project, was whether the participant would rate their spectating experience with the display prototype from very difficult to very easy (see Figure 9.1). This information is then used to be compared to the same type of information that will be received from the non-display questionnaire.

**How would you rate the overall experience in terms of how easy or difficult it was to follow the game of Magic: the Gathering? \***  
*Mark only one oval.*

	1	2	3	4	5	6	7	
very difficult	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	very easy

Figure 9.1: “How would you rate the overall experience in terms of how easy or difficult it was to follow the game of Magic: the Gathering?”

The question seen in Figure 9.2 below has been chosen to be added only on the questionnaire for the display since it addresses to a digitized content of MtG and the experience of the participant with it. This question was asked in order to get the participant's opinion on how much they think of this idea being able to influence their experience and whether it is in a good way or in a bad way.

Another point to be taken in consideration was the importance of adding the 3 extra stacks of cards on the display. It was done in order to see how much the lack of these 3 piles could have affected the participant's experience of spectating the game since it did not include all the piles you would usually be able to look at during the game. The question is simple and gives the participants two answer options, this can be seen in Figure 9.3.

<sup>1</sup>openEAR is the Munich open-source emotion and recognition toolkit, which provides efficient feature extraction algorithms [Eyben]

**In your opinion, how much did the display with digitized game process contributed to improving your spectating experience of this Magic: the Gathering game? \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
not at all	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	very much

Figure 9.2: “In your opinion, how much did the display with the digitized game process contributed to improving your spectating experience of this Magic: the Gathering game?”

**Would you like to be able to see the graveyard/library/exile pile of cards on the display? \***

*Mark only one oval.*

Yes

No

Figure 9.3: “Would you like to be able to see the graveyard/library/exile pile of cards on the display?”

Another important question, which could point to what type of feelings, the participant might have felt during the experiment and the PANAS. This scale asks the participant to rate a number from not at all to extremely, what type of emotions they felt while watching the game in progress. The non display also contains a PANAS scale, the two can then be compared to get an idea of the state of mind the participants might have had during the spectating of the games and make an assumption of a conclusion to the FPS. Figure 9.4 shows how the PANAS scale was setup and which emotions it involved. It was chosen only to include the relevant 20 emotions that can be used in this case.

In order to get an idea whether the simplicity or complexity of the display might have affected the experience of the spectators, a question regarding these points was added to the questionnaire. The same occurs when a question regarding the familiarity was added. This was asked due to the MtG notions and symbols used on the display and it is a way to make sure the spectators understand what it is meant by them.

Lastly, questions that point to the age group, gender and MtG knowledge were added, and these were used to point the data gathered to specific type of players/spectators. For example to see what kind of rating a beginner MtG spectator would give the prototype compared to an experienced/professional MtG spectator. The options offered to the participants to this question can be seen in Figure 9.5.

As the questions have now been explained the next section will go in-depth with the test setup and then the test execution.

### 9.3 Test Setup

This section will go in depth with information regarding how the test should be set up during the testing phase. Ideally, it would be required for the physical prototype to be set in a different room than where the display with the game in process will be projected. Since the test consists of two parts, one to test the display with the implemented prototype and one to compare to, which will be performed as a regular game, each of the parts will be shortly presented in this section. The two tests can be performed either at the same time or once the first setup is completed. However, this would mean that we would have to ask and wait for more participants to visit the shop, since the test was meant to a between group experiment. According to how many people will be visiting the shop during the time the prototype has been set up, it can be decided if the tests should take place at the same time. The test will have two groups, the experimental group and the control group.

**Please rate the following emotions regarding how present they were while you were spectating the game of Magic: the Gathering. \***  
 Mark only one oval per row.

	1 - not at all	2 - a little	3 - moderately	4 - quite a bit	5 - extremely
Afraid	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Scared	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Nervous	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Jittery	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Irritable	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Hostile	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Guilty	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ashamed	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Upset	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Distressed	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Active	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Alert	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Attentive	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Determined	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Enthusiastic	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Excited	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Inspired	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Interested	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Proud	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Strong	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Figure 9.4: “Please rate the following emotions regarding how present they were while you were spectating the game of Magic: the Gathering?”

**How long time have you been playing Magic: the Gathering? \***  
 Mark only one oval.

1-6 months

6-12 months

1-2 years

2+ years

Figure 9.5: “How long time have you been playing Magic: the Gathering?”

The experimental group will also be called the display version and the control group will also be called the non-display version.

### 9.3.1 True Experiment

The test setup is aimed to be a true experiment. When conducting a true experiment a few different conditions have to be met:

- The experiment needs to test at least one hypothesis
- The experiment must have at least two condition
- The experiment dependent variables are measured through quantitative data
- The experiment results are analyzed using statistical tests
- The experiment should aim at removing potential biases
- The experiment should be replicable at different locations, with different participants at other times by various test conductors

[Lazer et al., 2010, p. 42]

These requirement needs to be taken in to consideration when conducting the experiment and also when creating the test setup.

### 9.3.2 Display Test Setup

This is the experimental group, exposed to independent variable being tested, and to the variable of study.

As mentioned before the display test setup should be divided into two parts in two different rooms. This set up is made of the physical prototype, which contains the implemented table, the scanner box, and the two computers sending the data. On the other hand, the secondary computer connects to a projector or screen, which is placed in a different room. This is where participants are asked to spectate the game in progress, which would then not allow them to see the actual physical game in progress.

The test would preferably be conducted at a local Magic: the Gathering store or place where MtG players meet and play.

The participants will be chosen for the test according to which area of the shop they approach, if they seem to pay an interest to the Magic: the Gathering section. One of the group members will ask the shop visitors whether they would like to participate in a test. If they accept to do so, they will be explained the main idea behind the experiment and what they need to do. Once they are notified about the important information, if no game had been in progress meanwhile, a new game will be started. Participants will then watch the game for 5-10 minutes or until the game is finished, according to how long the game will take. Once the test is over, they are handed a questionnaire. Since the prototype involves a voting application, QR codes that lead to the website with the possibility for voting with either of the players during the game, should be set up around the room which streams the display. Participants should also be reminded that such a function exists and that their votes are updated on the display.

Another aspect that needs to be taken in consideration is the fact that GSR data needs to be logged from participants in order to gather more information regarding the participant reactions to the display. It was decided that each third participant to be asked to join in the test should be connected to a GSR. Every third person will then have a GSR attached and a camera will also be recording the participants and the display, to be able to connect the data from the GSR with the action happening on the display at the certain time.

#### 9.3.2.1 Setup Steps

1. Certain shop visitors are asked whether they are willing to participate in the test
2. If they accept, they are introduced to the test using the manuscript below:
  - *“This test is conducted for our bachelor thesis in Medialogy. We are aiming to improve the spectator’s experience when watching a game of Magic: the Gathering by digitalizing the game and displaying the game process on the screen. What we ask from you is to hang around and watch the game for 5-10 minutes, afterwards we would like you to answer a short questionnaire.”*
3. If the participant is one of the third participants, a GSR will be attached to them and explained that:
  - *“You do not have to worry about this, it is for our sake so we could have more data to analyze. But please try not to move too much while you’re hooked up to the equipment.”*
4. Once the GSR is attached the camera will be started together with the logging of the GSR data

5. The game will run for 5-10 minutes while participants are spectating
6. They will be handed out the questionnaire after 10 minutes maximum

### 9.3.3 Non-Display Test Setup

This is the control group that was not exposed to any variables. The non-display test, should be set up similarly, however, it will only take one room, where the players are surrounded by the spectators/participants, which will then follow the game for 5-10 minutes. Once the time is over they are asked to answer a questionnaire, similarly to the display test setup.

#### 9.3.3.1 Setup Steps

1. Gather participants
2. Start a game of Magic: the Gathering
3. After 5-10 minutes, questionnaires are handed out to the participants

## 9.4 Pilot Test

Before starting the actual testing, a pilot test session has been carried out on May 2nd. The pilot test was meant to validate our testing methods and eliminate any noticeable flaws in it. Due to this reason the test was conducted using the methods described above (see Section 9.2 Testing Methods) as if it was the actual test.

Overall the pilot test had four participants, which were fellow medialogy students that play MtG. There were two sessions in total, each having two participants. The participants were introduced to the concept of the project and purpose of the testing before preceding. Afterwards one of the two participants was randomly chosen to be monitored with GSR sensors. Once the game began, the GSR sensors were activated and the camera recording the display was started. Each of the sessions took around 5-7 minutes (the time it took the players to finish one game). Throughout the testing session one of the group members was making observations and taking notes about the participants' behavior. After the testing session the participants were asked to answer a questionnaire.

### 9.4.1 Questionnaire Results

General questions about their overall experience showed that all of the participants found it easy to follow the game (an average of 5.5 on a scale of 7). The participants stated that the display with digitized game process has to some extent contributed to improving their experience of spectating the game (an average of 5 on a scale of 7). Two of the respondents mentioned that they would like to have audio feedback along with the visual display. All of the respondents seemed to have no problem seeing and reading the cards on the screen, which shows that the images on the display are not too small. On the other hand, it seems that all the participants found it slightly difficult to follow the players' lives as well as dice rolls and coin flips. Before the final testing, these features should be changed so they are more noticeable for the spectators. All of the respondents thought it was relevant to have the keywords on the display. As for the lack of tapping of cards, two of the respondents found it neutral, while the rest two had different opinions on lack of this feature.

In terms of visual design, it seems that the simplicity of the design did not influence the participants' experience, however they did not find the display design too familiar to the original theme of MtG.

Regarding the voting application, three out of four respondents used it, however it did not seem to make them feel more involved in the game (an average of 3 on a scale of 7), although the concept itself was considered somewhat useful (an average of 5 on a scale of 7).

Judging from their general opinion, the participants seem to be fond of the idea of digitalizing the card game, however it might be the execution of the prototype at this stage that does not provide the full satisfaction. Most of the tests subjects mentioned being confused about which player was who and whose turn it was. In addition to this, some participants have shown interest in having the remaining players' cards in the library, graveyard and exile displayed on the screen as well.

#### 9.4.1.1 GSR Results

Galvanic Skin Response (GSR) is a way of measuring participant's arousal or frustration. To measure GSR on participants, two electrodes must be attached to the skin to measure the conductivity between the two. When a participant feels different emotions, the skin conductivity increases or decreases. This can be measured as analog signals that can be converted to numbers and plotted to a graph. The GSR data can show if the participants are feeling any emotional response during a test and at which point of the test the response was observed. [Lazer et al., 2010, p. 344+352+359].

A clear advantage to this method is how the change of an emotional state can be measured physiologically. An increase in skin conductance can be a sign of these changes and can therefore back any quantitative results from e.g. a questionnaire. One of the main reasons to this advantage is how the results are neither subjective nor separated from the testing task itself. The measurements are made during the test not afterwards, which means participants do not have to recall any specific situation. Furthermore, the results are not subjective, this means they are not self-evaluated. The participant does not have to think about nor describe how they feel. This is an advantage since self-evaluated responses can be highly biased due to the subjective angle.

That being said a lot of factors can affect one's emotions and feelings and thereby cause the curve to spike out biasing the results. Almost everything can point to one's mood, the people around, your current health state or your initial skin temperature before the test etc can affect these factors. This can make GSR's highly unreliable and therefore you need to back up your data with e.g. questionnaires, observations or similar. Furthermore, it is recommended to test participants' initial temperature to measure the exact change and ensure reliable results.

To test the GSR, they were set up and tested in two pilot tests. Unfortunately the system had a bug in the first pilot test, resulting in the GSR results not being logged. However, the bug was fixed for the next pilot test and the results are shown below in Figure 9.6.

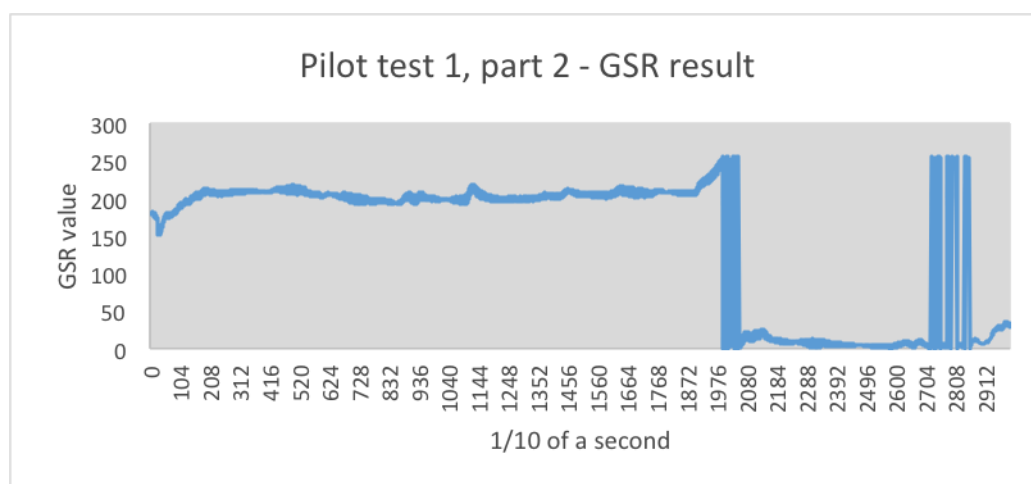


Figure 9.6: GSR results from one participant from the pilot test.

The results are displayed as a curve diagram. Time is represented on the x-axis (1/10 of a second), and the GSR sensor values are represented on the y-axis. The GSR sensor values show

whenever the skin conductance increases or decreases due to a possible emotional stimulus. The higher the GSR sensor values is, the more skin conductance and vice versa.

At first the curve seems rather steady and stable, but suddenly, the GSR values drop remarkably. The drop can have several explanations, for instance, the test took from five to seven minutes, which is a relatively long time when you have to keep your hand in the same position. This could have caused the sudden drop.

Different problems occurred when using the GSR sensors. Firstly a pair of sensors were created from scratch however the results were not consistent and the data showed a lot of inconsistent spikes. Afterwards, with hopes of getting better and consistent results, a pair of Seeed Grove GSR sensors were bought, however, these sensors were also showing inconsistent results which were very hard to analyze due to unpredictable spikes. The results seen in Figure 9.6 start out seemingly consistent but spike out unexpectedly and are therefore considered unreliable. Having the sensors show unreliable data during the pilot test phase, makes it impossible to trust the data collected during the final test. Because of the results gathered during the pilot test, GSR sensors were completely discarded for the final test.

#### 9.4.1.2 Observations

As mentioned, the test lasted for approximately 5-7 minutes. To some people, this can be a relatively long time to sit still and quietly observe a display that may or may not interest the participants as much, however, this was not a problem. All four participants sat still and quietly the whole time showing no signs of boredom or absence. In fact, sitting still and quiet dominated all observations made for the pilot test. During the pilot test several test participants had facial expression indicating certain emotions/feelings. The main facial expressions were confusion, awaiting, anticipating, happiness and joyful. These emotions were expressed by smiling, laughter, sustained eye contact, wrinkled forehead and silence. There were also minor behavior such as yawning and cheering. The latter occurred frequently while one participant yawned once. Another interesting aspect is how the participants cheered for the players. This led to a sudden engagement in the voting application. Furthermore, the test participants talked with one another during a few moments during the game. This encouraged a shared experience, which highly seemed to improve the spectator experience (participants were smiling and laughing). Participants also quietly discussed players' movements at few occasions. Conclusively, there were not any observations that can explain the sudden drop in the GSR curve mentioned in Section 9.4.1.1 GSR Results.

#### 9.4.1.3 Sub-Conclusion

The pilot test resulted in pointing out the basic flaws of the prototype. In general, these are the features that could be changed/added to the prototype before the actual testing:

- A font that is easier to read
- Better representation of players' lives, dice rolls and coin flips
- More familiarity to the original MtG theme
- Indication of which player's turn it is
- Indication of which player is who (possibly including live feed of their faces on the screen)
- Improving the voting application (possibly adding more features to it)

In regards to the testing methods, the questionnaire seemed to not cause any misunderstandings and resulted in useful feedback. In addition to that, the observations mostly matched and backed up the results gathered from the questionnaires.

On the other hand, the GSR sensors did not give any usable data. It did not provide any noticeable indications about the state of the subject during certain events of the game nor match the observation results. GSR sensors could verify and validate the observation and questionnaire



results but due to its proven inefficient, it was decided to disregard the GSR sensors and not to use this method during the actual test.

As for the duration of the test, it seemed that five to seven minutes were long enough for the spectators to get an idea of how the prototype works and gather enough knowledge to fill out the questionnaires.

## 9.5 Test Execution

The test took place during the week of 5th to 9th of May and took five days to gather enough participants for both the display and the non-display prototypes. The data was gathered from 60 participants, where 30 of them have been chosen at Faraos Cigarer and the rest online. The prototype was installed at Faraos Cigarer, a shop in Copenhagen that sells Magic: the Gathering cards and accessories. The shop has a floor divided in two rooms; one with tables and one with sale items. The table room is meant for tournaments and similar events which is used by MtG players to come and play MtG games and meet other players. The other room is designed as a regular shop with shelves and a sale counter. However, there is also a long table and a projector. The prototype was setup in the table room divided from the projector displaying the application in the other room. It was not possible for spectators to follow the game on the prototype along with the game displayed on the projector. An image of how the physical prototype was setup in the store can be seen in Figure 9.7.



Figure 9.7: Image of the prototype setup at Faraos Cigarer. The table is placed in a room of the shop where people come and play Magic: the Gathering.

The test participants were shop visitors, not necessarily to buy anything but maybe just to play Magic: the Gathering. Participants were chosen according to which store area they were looking at, if they were playing or looking at Magic: the Gathering, indicating that they played Magic: the Gathering in general, they were potential test subjects. Test participants were introduced to the test by one of our two conductors. The test participants were seated in front of the display and after five or ten minutes, according to how the game had been going, then handed out the questionnaires (see the full questionnaire in Appendix A Experimental Group (Display) Questionnaire). The test was conducted with one to four participants at the same time, this depended a lot of the amount of people joining the shop. After filling out the questionnaire, the test was over and the participants were thanked for participating. Some participants had questions about the prototype and the

overall project, these participants' data is described in the sections below as unstructured informal interviews.

Once the display experiment had reached 30 participants it was time to start testing the non-display test setup, however, due to the fact that the first test took more time than expected, it was no longer possible to wait for participants at the Faraos Cigarer shop, so instead it was decided to set up the test online and hope it would reach 30 participants during the weekend.



Figure 9.8: Filming of two test conductors playing a game of Magic: the Gathering for the non-display version (control group).

This was done by filming two of the group members playing a game of MtG with the same deck of cards that was used for the display test setup. The filmed game took around five minutes and was added at the beginning of the questionnaire, which means it allowed the participants to watch the video and when done to answer the specific questionnaire (see Section 9.2.1 Questionnaire). Figure 9.8 shows how non-display test was set up and recorded to be uploaded online on [Reddit.com](https://www.reddit.com).

The test execution has been explained and the test has been conducted. The next section will present the test results and afterwards analyze and discuss them.

## 9.6 Test Results

In this section the results from the final test will be presented. Not all results are presented here, but the full test results can be found in Appendix C Test Results. For the final test, two different questionnaires were given out to two different groups of participants. The first questionnaire was given to the audience of the prototype, experimental group, while the second questionnaire was given to audience of a regular game, the control group.

### 9.6.1 Experiment Results

This section will present the results from the experimental group. The results will be divided into sections corresponding to each section from the questionnaire.

#### 9.6.1.1 General Experience

The first question the participants are asked, after the consent form, is about their overall experience. This question is a Likert scale from 1 to 7 where 1 is very difficult and 7 is very easy.

- *“How would you rate the overall experience in terms of how easy or difficult it was to follow the game of Magic: the Gathering?”*

The answers can be seen in Figure 9.9. The negative part of the scale (1-3) contains 26.6% of the answers (nobody answered 2), whereas the positive side of the scale (5-7) contains 53.3% of the answers. The middle of the scale (4) 20% of the answers.

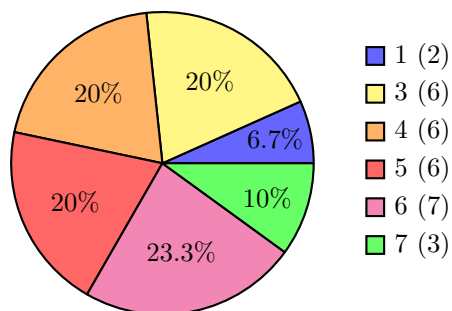


Figure 9.9: Overall Experience with display, on a scale from 1 (very difficult) to 7 (very easy) ( $n = 30$ )

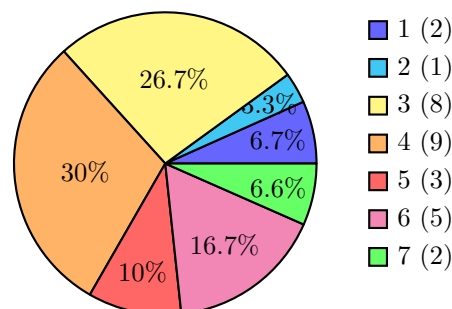


Figure 9.10: Influence of the display towards spectator experience, on a scale from 1 (not at all) to 7 (very much) ( $n = 30$ )

The next question is about how the spectator experience was improved based on the contribution of the digitized game. Again the scale was a Likert scale from 1 (not at all) to 7 (very much).

- *“In your opinion, how much did the display with digitized game process contributed to improving your spectating experience of this Magic: the Gathering game?”*

Figure 9.10 shows the answers for the question. The answers are almost equally divided between 36.6% negative (1-3), 30% neutral (4) and 33.3% positive (5-7).

#### 9.6.1.2 PANAS Scale

To see the participants emotional response to the prototype a PANAS scale was used. This means that the participants had to rate different emotions on a scale from 1 to 5. Table 9.1 shows an example the emotional response from one participant and the scale on which to rate each emotion on.

The PANAS scale compares each participants the negative emotions to their positive emotions (see Section 5.4.4 Affective Reports). Figure 9.11 shows the result of the PANAS scale from 4 random participants. The results can vary from 10 to 50.

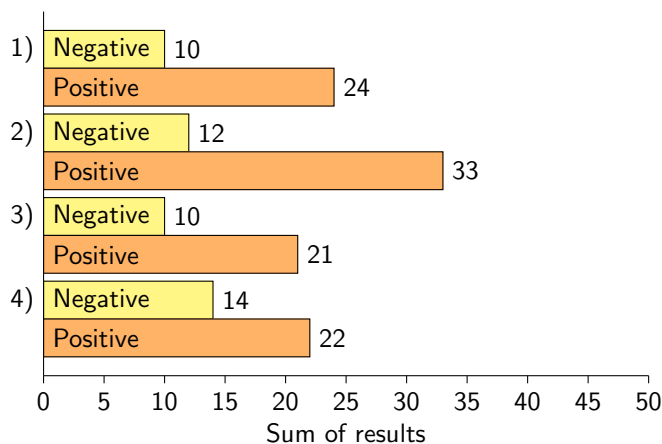


Figure 9.11: PANAS results from 4 random participants.

	1 - not at all	2 - a little	3 - moderately	4 - quite a bit	5 - extremely
Afraid	x				
Scared	x				
Nervous	x				
Jittery	x				
Irritable			x		
Hostile	x				
Guilty	x				
Ashamed	x				
Upset			x		
Distressed		x			
Active				x	
Alert				x	
Attentive					x
Determined				x	
Enthusiastic			x		
Excited			x		
Inspired		x			
Interested				x	
Proud		x			
Strong		x			

Table 9.1: Example of a participants emotional response in a PANAS scale.

### 9.6.1.3 Rating Features

After the PANAS scale the participants were asked to rate different features of the display. The section contains nine questions and their answers. All the questions use a Likert scale from 1 (negative) to 7 (positive).

The first question is about the representation of the cards.

- *“The representation of the cards that were being played (1-difficult to see — 7-easy to see)”*

The answers can be seen in Figure 9.12. The answers show that the majority of the participants liked the representation.

- *“The readability of the cards on the display (1-difficult to read — 7-easy to read)”*

The answers can be seen in Figure 9.13. Again the majority of the results are positive and around 1/4 of the participants are neutral.

Next there are two questions about the keywords shown on the screen. These keywords are special abilities that some cards have. There exist more than a 100 different keywords so it can be hard to remember them all.

- *“The representation of the keywords on the display in terms of how easy it was to see it (1-difficult to see — 7-easy to see)”*

Figure 9.14 shows that only a few participants think it is somewhat difficult to see the keywords and the majority are positive about the representation of the keywords.

- *“The relevance of displaying the keywords on the display (1-very unnecessary — 7-very helpful)”*

Figure 9.15 shows the answers for the relevance of displaying the keywords. The answers are not consistently positive, compared to the previous question, some participants find it very helpful while others think it is unnecessary.

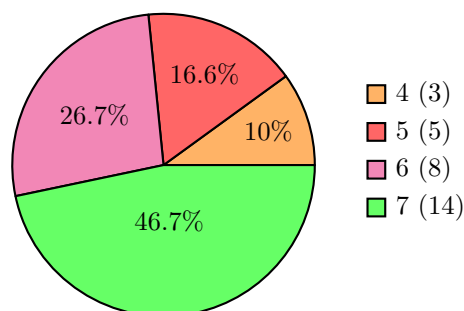


Figure 9.12: Representation of the cards, on a scale from 1 (difficult to see) to 7 (very to see) ( $n = 30$ )

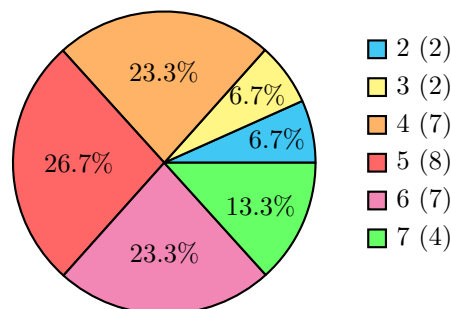


Figure 9.13: Readability of the cards, on a scale from 1 (difficult to read) to 7 (easy to read) ( $n = 30$ )

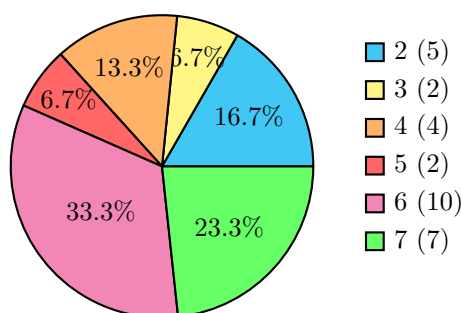


Figure 9.14: Representation of the keywords, on a scale from 1 (difficult to see) to 7 (easy to see) ( $n = 30$ )

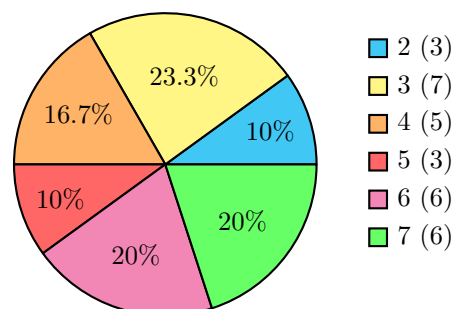


Figure 9.15: Relevance of displaying the keywords, on a scale from 1 (very unnecessary) to 7 (very helpful) ( $n = 30$ )

The next question is about *tapping*. Tapping is a feature of the game that discussed how to implement. The card needs to be turned  $90^\circ$  which was not possible as the prototype does not track where the lands are placed (see Section 7 Delimitation).

- “The lack of tapping of the lands in terms of how much it influenced your experience (1-not at all — 7-very much)”

As Figure 9.16 shows, the majority of the participants found that it influenced their experience a lot.

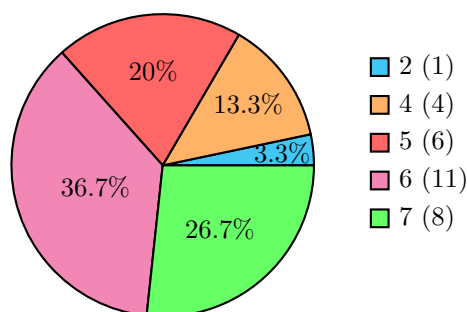


Figure 9.16: Lack of tapping lands, on a scale from 1 (not at all) to 7 (very much) ( $n = 30$ )

The last two questions in this section are about the design and familiarity of the display.

- “The simplicity of the design in terms of how much it affected your experience of watching a game of Magic: the Gathering (1-not at all — 7-very much)”

Figure 9.17 shows the results of the question. About 1/3 are neutral about the question and the other 2/3 are slip between negative (26.6%) and positive (36.6%).

- “The familiarity of the display in terms of the original theme of Magic: the Gathering (1-not familiar at all — 7-very familiar)”

The result of the last question is can be seen in Figure 9.18. The majority of the answers were positive (70%), with 26.6% answering *very familiar*.

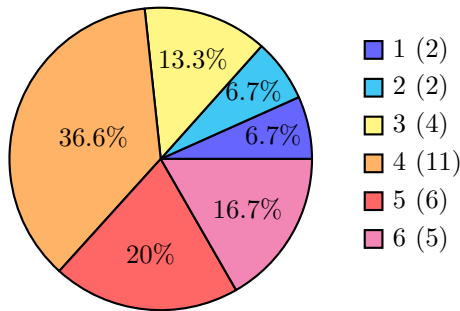


Figure 9.17: Simplicity of the design, on a scale from 1 (not at all) to 7 (very much) ( $n = 30$ )

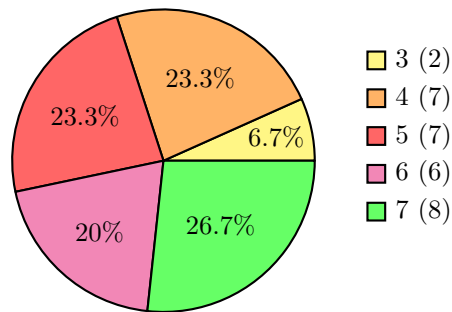


Figure 9.18: Familiarity of the display, on a scale from 1 (not familiar at all) to 7 (very familiar) ( $n = 30$ )

#### 9.6.1.4 Web Application

This section will go through the results of the questions about the web application. This is the application where the user can vote for the player they believed would win.

The first question is an intro question that asks if the participant used the web application.

- “Did you use the web application? (Yes/No)”

Only 5 participants used the web application. This means that the next two questions only have 5 participants answering.

- “In regards to the online betting application, how much involved in the game did it make you feel? (1-not at all — 7-very much)”

Figure 9.19 shows the results.

- “How did you feel about the concept of voting for the player you favor? (1-very useless — 7-very useful)”

Figure 9.20 shows the results.

With both of these questions, it is impossible to come with any conclusions since there are too few participants that actually used the web application.

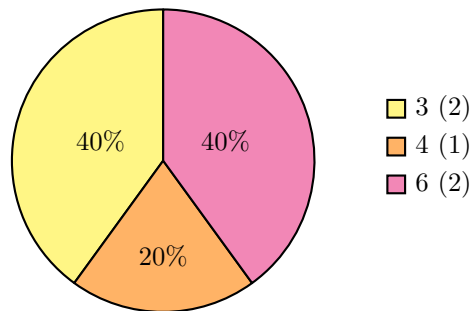


Figure 9.19: Involved in the game, on a scale from 1 (not at all) to 7 (very much) ( $n = 5$ )

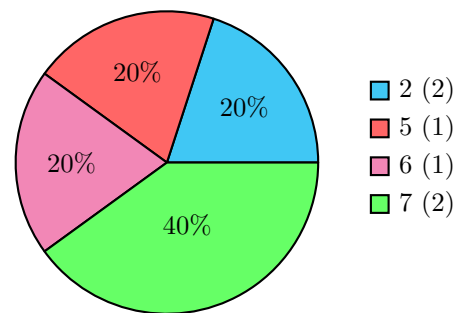


Figure 9.20: Feelings about the concept of voting, on a scale from 1 (very useless) to 7 (very useful) ( $n = 5$ )

### 9.6.1.5 Basic and Demographic Questions

The last sections is about basic questions that can be helpful in identifying the target group that have tested the prototype.

- “What is your age?”
- “What is your gender?”

The participant’s age can be seen in Figure 9.21. As for their gender, the participants consist of one female and 29 males.

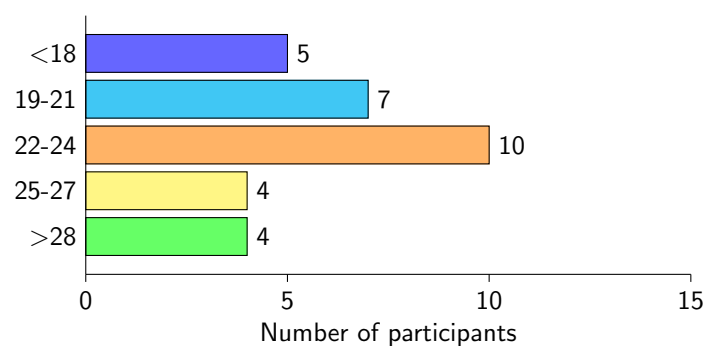


Figure 9.21: Age ( $n = 30$ )

- “How long time have you been playing Magic: the Gathering?”

As seen in Figure 9.22 most people have been playing for more than two years.

The last question is about how often the participants are playing Magic: the Gathering

- “How often do play Magic: the Gathering?”

The answers can be seen in Figure 9.23.

## 9.6.2 Control Results

This section will talk about the control group and their results.

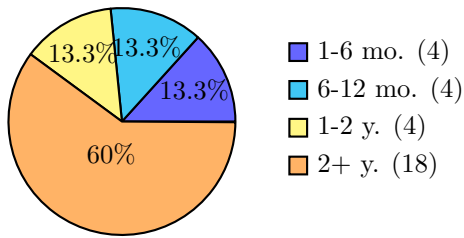


Figure 9.22: How long have you been playing ( $n = 30$ )

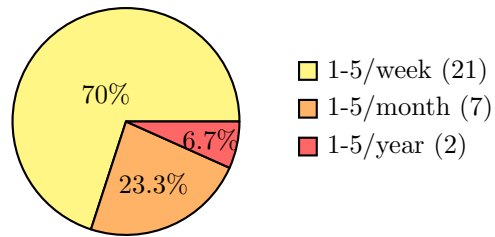


Figure 9.23: How often do you play ( $n = 30$ )

### 9.6.2.1 General Experience

As with the experimental group (see Section Section 9.6.1 Experiment Results), the control group’s questionnaire starts out with a question about the spectators overall experience.

- “How would you rate the overall experience in terms of how easy or difficult it was to follow the game of Magic: the Gathering? (1-very difficult — 7-very easy)”

The answers to the question can be seen in Figure 9.24. The negative part of the scale (1-3) contains 56.7% of the answers.

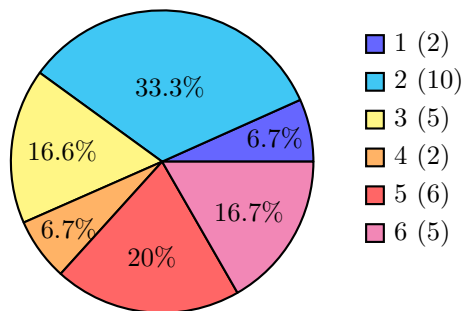


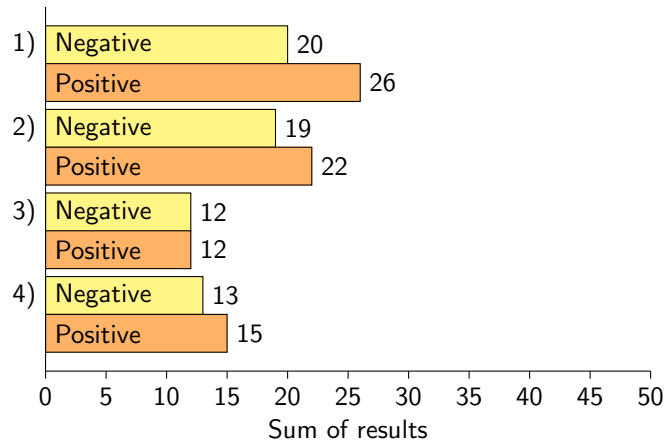
Figure 9.24: Overall Experience without display, on a scale from 1 (very difficult) to 7 (very easy) ( $n = 30$ )

### 9.6.2.2 PANAS Scale

The PANAS scale for the control group is the same as the experimental group. An example of the scale can be seen in Table 9.1 on Page 82.

Figure 9.25 shows an example of four random participants answers.



Figure 9.25: PANAS results from 4 random participants. ( $n = 30$ )

### 9.6.2.3 Concept Evaluation

The control group answered two questions about the concept of digitizing Magic: the Gathering. The first question was an open ended question where the participants could write notes and comments about the idea.

The other question was a close-ended question.

- “Would you like to have a digitalized version of the game that you are spectating displayed on screen? (Yes/No)”

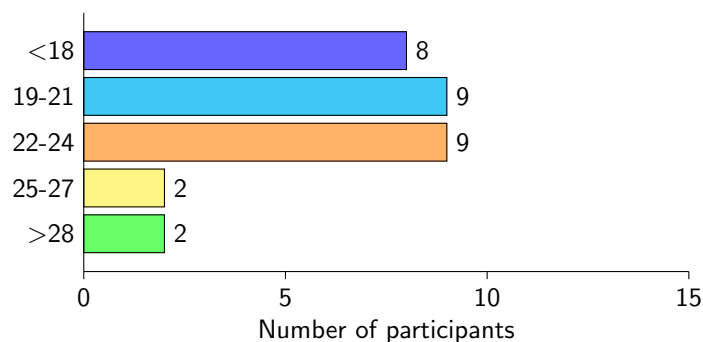
$\frac{1}{3}$  (33.3%) of the participants did not like the idea of a digital version but  $\frac{2}{3}$  (66.6%) did like the idea.

### 9.6.2.4 Basic and Demographic Questions

The last sections is about demographic questions, as in the experimental results.

- “What is your age?”
- “What is your gender?”

The result of these two questions can be seen in Figure 9.26 and the gender distribution was two females and 28 males.

Figure 9.26: Age ( $n = 30$ )

- “How long time have you been playing Magic: the Gathering?”

As seen in Figure 9.27 most people have been playing for more than two years. The amount of participants that have been playing for two or more years are the exact same as in the experimental group (see Figure 9.22).

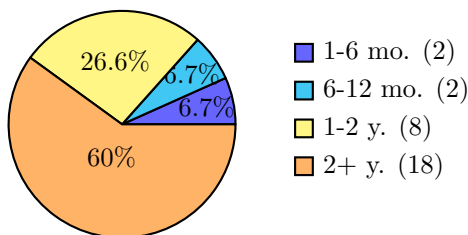


Figure 9.27: How long have you been playing ( $n = 30$ )

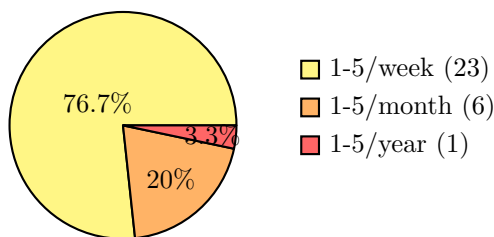


Figure 9.28: How often do you play ( $n = 30$ )

The last question is in regards to how often the participants are playing Magic: the Gathering.

- “How often do play Magic: the Gathering?”
- “How often do watch others play Magic: the Gathering?”

The answers can be seen in Figure 9.28.

Both the experimental group and the control group had a box for general comments. These comments will be discussed in the result discussion.

## 9.7 Test Discussion

After presenting the test results in the previous section, this section will start out with presenting the test statistics, which were used to compare some of the test results. Afterwards the test results will be discussed and the PANAS scores will be calculated and analyzed. A section about interviews that were conducted and the questionnaire’s general comments will be looked at, ending with a section about biases which will be presented.

### 9.7.1 Statistics

As mentioned in the test introduction (see Section 9 Testing), two hypotheses were made: a null hypothesis and an alternative hypothesis.

To see if the null hypothesis can be rejected an independent-sample t test was made. This t test compares the means of two sample groups. The two sample groups in this study are independent of each other and no participant has been in both the experimental group and the control group. The control group including the participants that tested the non-display version of the prototype, while the second sample, the experimental group including the participants who tested the display version. The data that is going to be compared are the answers from the question:

- “How would you rate the overall experience in terms of how easy or difficult it was to follow the game of Magic: the Gathering?”

The answers from the question can be seen in Figure 9.29 where the orange bars are from participants that used the display and the yellow bars are from participants that did not use the display.

By looking at the graph it is possible to see that a lot of participants are more negative (answer 1-3) about the non-display prototype whereas the participants that tested the display prototype are more positive. The mean of the two datasets are 4.5 for the display and 3.5 for the non-display, while

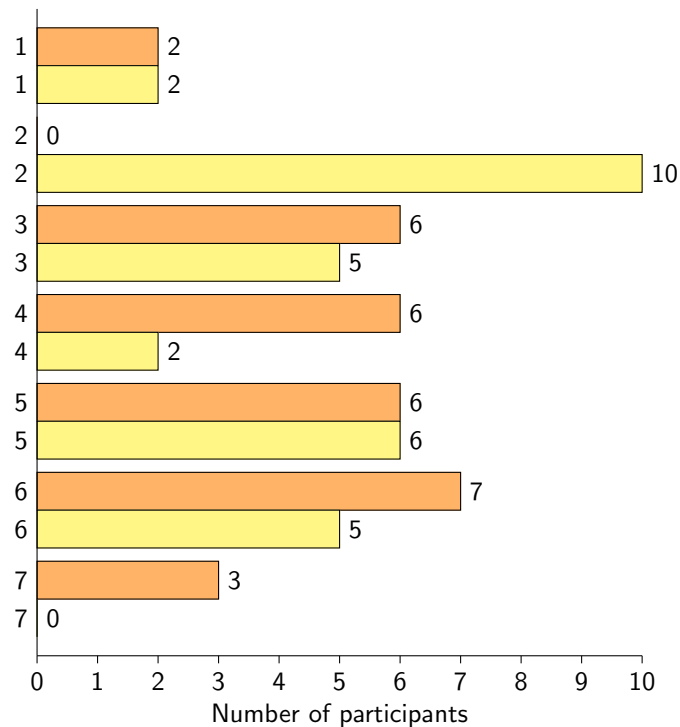


Figure 9.29: Overall experience with display ( ■ ) and without display ( ■ ), on a scale from 1 (very difficult) to 7 (very easy) ( $n = 30$ )

the median for the display is 5 and 3 for the non-display. So far this indicates that the experience with the display is overall more positive than the non-display. Before concluding anything based on our questionnaire, a statistical test testing the null hypothesis has to be conducted. As mentioned earlier, an independent-sample t test will be made and a Mann-Whitney U test. The t test will compare the means of the two datasets to see if the null-hypothesis can be rejected [Lazer et al., 2010, p. 76] whereas the Mann-Whitney U test compares the median of the two datasets [Mathworks.se].

Running a t test on the data from Figure 9.29 using Equation 9.1 will result in a t value of 2.5120.

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

where

$\bar{X}_1$  = mean of display samples

$\bar{X}_2$  = mean of non-display samples

$n_1$  = numbers of samples from  $\bar{X}_1$

$n_2$  = numbers of samples from  $\bar{X}_2$

$$s_1^2 = \frac{\sum(X_1 - \bar{X}_1)^2}{n_1}$$

$$s_2^2 = \frac{\sum(X_2 - \bar{X}_2)^2}{n_2}$$

(9.1)

Looking at a t table [Gerstman, 2007], with a degree of freedom (df) at 58, the p-value will be between 0.01 and 0.005 for a one-tailed test and between 0.02 and 0.01 for a two-tailed test. The hypothesis (and FPS) states that we want an improvement in spectator experience and therefore a one-tailed test have to be used.

To make sure the calculations are correct the code from Code 9.1 can be run in matlab.

Code 9.1: Matlab code to run a one-tail t test.

```
1 [h, p, ci, stats]=ttest2(exp_dis,exp_non,'Tail','Right')
2 //where exp_dis is the dataset for participants using the display and
   exp_non is for non-display participants.
```

The t value is the same and we get an exact p-value of 0.0074. This means that the null-hypothesis can be rejected at the 5% probability level<sup>2</sup>. For an independent-samples t test to be valid, a few assumptions need to be fulfilled. One of these assumptions is that the errors need to be identically distributed. The test conducted here, cannot assume that the errors are identically distributed. When giving instructions to the participants, two group members instructed it the participants on how the test will be conducted and what the participants should do. Guidelines were made for the test conductors to follow, but a script was not used to make sure the instructions were identical. This could cause some of the participants to get more information than other and therefore create different errors [Lazer et al., 2010, p. 86]. To make sure the null hypothesis can still be rejected, another statistical test can be made. The Mann-Whitney U test is a non-parametric statistical test that does not assume the errors are identically distributed, which is why it is ideal to conduct a Mann-Whitney U test to test the null hypothesis [Lazer et al., 2010, p. 94]. The Mann-Whitney U test can be run in Matlab using the code from Code 9.2.

Code 9.2: Matlab code to run a one-tail Mann-Whitney U test.

```
1 [p,h,stats] = ranksum(exp_dis,exp_non,'Tail','Right')
2 //where exp_dis is the dataset for participants using the display and
   exp_non is for non-display participants.
```

The result is a z-value of 2.4160 and a p-value of 0.0078, which is almost identical to the result from the t test. This means that the null-hypothesis can also be rejected using a Mann-Whitney U test.

This means that the null-hypothesis can be rejected when using either a parametric t test or a non-parametric Mann-Whitney U test. Rejecting null hypothesis we can assume there is a change in the experience of a beginning spectator when visual representations are used. Since the null hypothesis is rejected we can accept our alternative hypothesis and assume there is an improvement in the experience of the spectator.

## 9.7.2 Overall Questions

After asking the questions about the participant's overall experience with the prototype, the participants that used the display were asked about how much the display improved their spectating experience. As mentioned in Section 9.6 Test Results, the answers were divided into three parts. The question is structured as a Likert scale from 1 (negative) to 7 (positive) the answers are 37% negative (1-3), 30% neutral (4) and 33% positive (5-7). Even though the answers to the question seem to be mostly negative, the previous question's t test and Mann-Whitney U test shows that the null-hypothesis can be rejected and there is an improvement to the spectator experience.

Both the participants that used the display and the non-display version were asked about the reason for thinking it was easy to follow a game. For the display version, most participants said they could both recognize and read the cards (21) and a few only said that they could read the cards (6). This is good since one of the focuses of the prototype was for the participants to be able to read the cards during the game if they did not already know them. For the non-display version, most participants said they could recognize the cards (14), while only 1 participant said it was possible to read the cards and just 2 participants said they could both recognize and read the cards. This

<sup>2</sup>The probability level indicates the possibility of observing the same or more extreme results again.

shows that during a non-display game, it is very hard to read the cards and if you cannot recognize the cards then it is very tough to follow along with the game. The display seems to fix this problem as a lot of participants could properly read the cards.

After asking about the participants' experience with the prototype, two questions regarding the display version and additional features to the prototype, were asked. The first question is about feedback types, such as audio and haptic, almost half of the participants (47%) wanted some kind of audio feedback, however, 37% did not want any type of feedback. There was no opportunity for the participants to elaborate on which type of audio feedback they would prefer, so it is unknown if they would like audio cues or commentators. Four participants, however, chose *other* and two of them mentioned commentators as feedback type they want to see in the prototype. Commentating was not possible in the scope of this project, because it might have been disturbing for the people shopping in the store and people playing other games when the prototype was being tested, this is also the same reason why audio cues were not implemented.

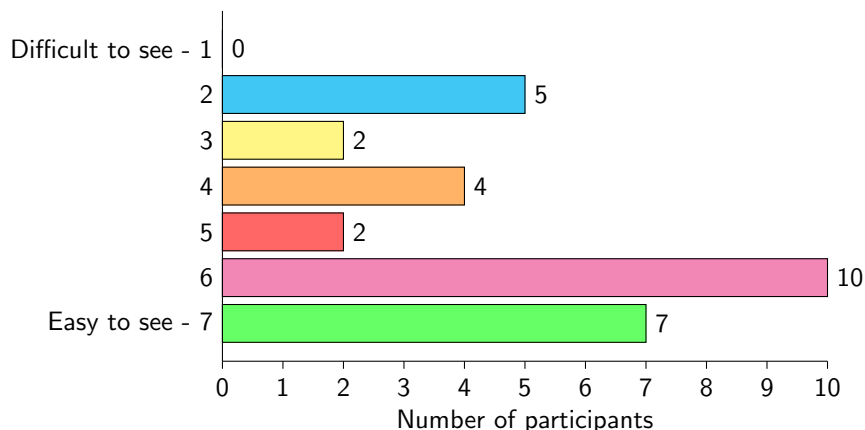
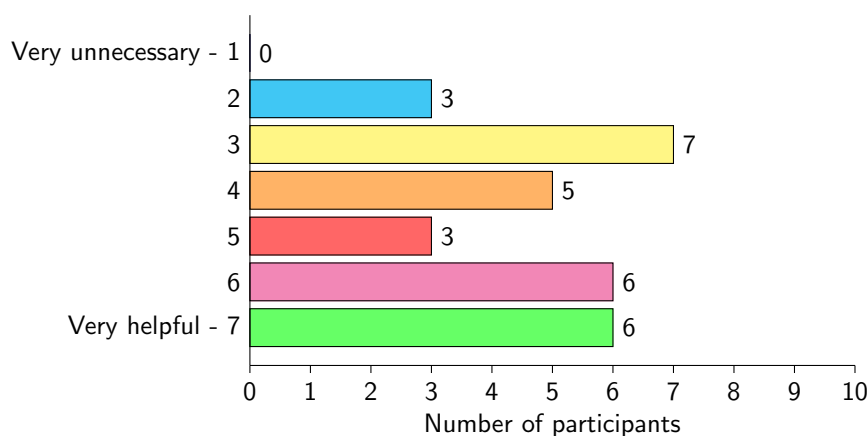
Another question to the participants was asking about additional features. Some of the additional features suggested were; the inclusion of the graveyard, library and exile pile. All but one participant wanted to see this implemented. This sort of feature was discussed before as a feature to be implemented in the prototype, however due to time constraints and technical knowledge, it was chosen not to implement it for the final test.

In order to get some feedback on the display version of the prototype, participants were asked to rate aspects, such as readability of the cards, representation of player life, relevance of displaying keywords, on a scale from 1 to 7. When asked about the representation and readability of the cards, 47% answered that the cards were easy to see (rated it a 7 on the scale). Nobody gave a negative (1-3) answer and very few, 3 participants, answered neutral. The readability of the cards has a more distributed answer. Four participants are negative about the readability of the cards whereas 19 participants are positive. These two questions show that, the idea of having a big version of each card was a good approach but not everyone thinks the cards are easy to read, which means the text might be too small or too blurry. One of the reasons this could have happened is the use of the projector offered by Faraos Cigarer, which seemed to have a bad quality when presenting the information on canvas. However, overall the participants like both the readability and representation of the cards.

A question that has a strong positive answer is the representation of the player life. In total 22 participants rated the representation of the life as positive (5-7) and over half (16) of the participants rated it with a 7 (easy to see). Life is often represented using dice, which can be hard to see from afar, using a large font to display the player life of the display proved to be a success, therefore allowing each spectator to see when life was being added or removed to which player. Dice roll and coin flip is represented almost the same way as player life, but the ratings to the question about the representation of dice roll and coin flip have very mixed results compared to the question about player life. Seven participants answered that it was difficult to see (rated it as a 1) and half the participants were negative about the representation, only four participants answered that it was easy to see (rate it as a 7) and just seven participants in total were positive about the representation of the coin flip and dice roll. This could mean, that the position of these two was not ideal and could have been placed in a better view, however it could also be due to the fact that these two were not used as often during the game play.

Card keywords have a big emphasis in the display version. As mentioned in Section 9.6.1.3 Rating Features there are over 100 different keywords and it is almost impossible to keep track of them all. 19 participants are positive about the representation of the keywords with seven participants rating it a 7 (easy to see), however seven of the participants in total are negative about the representation. Figure 9.30 shows the distribution of the answers.

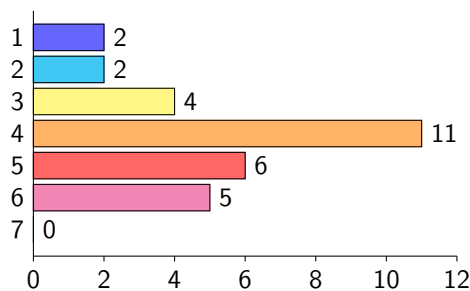
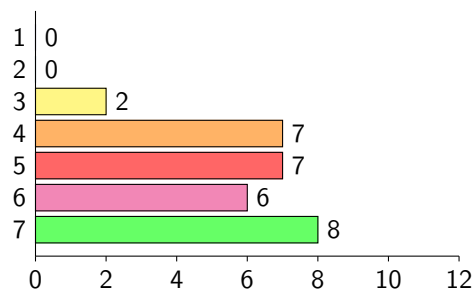
On the other hand, when looking at the relevance of the keywords more people are negative or neutral than in the previous question. Figure 9.31 shows a representation of the answers. Looking

Figure 9.30: Representation of keywords on display. ( $n = 30$ )Figure 9.31: Relevance of keywords on display. ( $n = 30$ )

at the two figures (9.30 and 9.31) it is clear to see that the representation of the keywords is good but the relevance of displaying them is less helpful than anticipated. One of the other reasons could be that the cards used in the decks for the prototype, might have included common cards that most MtG players know about, which could have led the participants to rating the keywords as unnecessary. That said, there are still more participants that find it helpful (15) than unnecessary (10).

One feature that was not implemented was the ability for lands to tap. It was considered that this feature might not change the experience of the spectator since the focus falls mainly on the attacking cards. This feature, however was considered as a task to be implemented together with the graveyard/exile/library piles though this would have required a more time than it was available. Therefore, the participants using the display version were then asked if the lack of tapping the lands influenced their experience. Seven participants said it influenced their experience very much and overall 25 participants agreed that it somehow influenced their experience. Only one participant did not find that it influenced their experience, this could mean that the ability to tap lands could have improved their experience, however the lack of it did not seem to worsen it.

The display tries to create familiarity and simplicity (see Section 5.3 Building a Graphical User Interface) so the participants were asked two questions. As seen in Figure 9.32 and Figure 9.33 the answers from the question about simplicity are evenly split and follow a normal distribution, whereas the answers from the question about familiarity leans more towards the ratings of 5, 6 and 7 (very familiar).

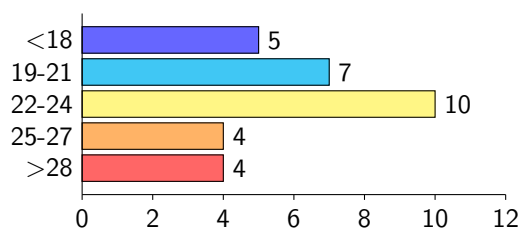
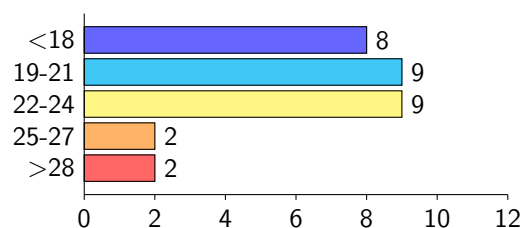
Figure 9.32: Simplicity of the design ( $n = 30$ )Figure 9.33: Familiarity of the display ( $n = 30$ )

The simplicity or familiarity could possibly influence their overall experience, if the simplicity and familiarity had low scores that could possibly mean that the design negatively influenced their overall experience. However, in this case, participants seemed to have a neutral feeling towards the simplicity of the display. This could mean that they regard the display as being complex or crowded with information and could use some improvements. On the other hand, the majority found the usage of symbols, text and such familiar, which could imply it was easy to understand as separate features.

A lot of participants (25) did not use the web application. Only 5 participants tried it and, as mentioned earlier, this could be because the instructions were not similar for every participant. This means that the answers provided for the next couple of questions have very few responses and nothing can really be concluded based on them. When asked how involved in the they were, participants rated it a 3, one participant rated it neutral and 2 participants rated it a 6. When asked about their feeling about the concept of voting, the response was positive with four participants rating 5, 6 and 7 and just two participants with 2.

The participants that used the non-digital version of the prototype (the control group) were asked about the concept of a digitized version and their opinion on the matter. 20 participants answered that they would like a digital version and just 10 participants said they would not like one. They did not get any information regarding what a digital version would include or what it could do, but the response overall was still positive.

The last sections of the results were demographic questions. To make sure the results come from the same target group, questions like age, gender and experience were asked. Figure 9.34 and Figure 9.35 shows the difference in ages between the two groups.

Figure 9.34: Age (display) ( $n = 30$ )Figure 9.35: Age (non-display) ( $n = 30$ )

Plotting the normal distribution for the age (see Figure 9.36) shows that the distribution of the target group age is very close to each other. The gender distribution is also very close to each other. The display version has 1 female and 29 males testing it whereas the non-display version has 2 females and 28 males.

Since the FPS describes the target group as beginner spectators the participants are asked how long time they have been playing Magic: the Gathering. As seen in Figure 9.37 and Figure 9.38

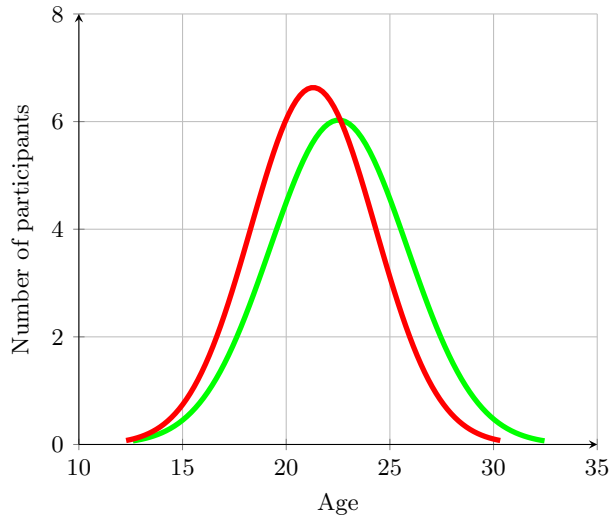


Figure 9.36: Normal Distribution of ages for Display ( — ) and Non-Display ( — ) ( $n = 30$ )

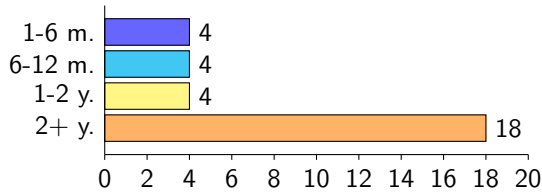


Figure 9.37: How long have you been playing (display) ( $n = 30$ )

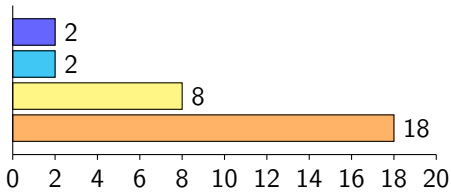


Figure 9.38: How long have you been playing (non-display) ( $n = 30$ )

most participants have been playing MtG for more than two years, this is a bit longer than what our optimal test group would have, but since the distribution of the participants in the two different group samples (display and non-display) is close to each other, it is all right considering they both contain a similar amount of 2+ years players.

### 9.7.3 PANAS

The goal with PANAS is to compare positive affect (PA) with negative affect (NA) from both sample groups - with display and without display. First the PANAS results will be presented; the five most positive answers and the five most negative answers from each sample group will be shown. Then the mean and standard deviation will be calculated for each group and the results will be compared and analyzed. The results for positive and negative answers can each culminate to a maximum of 50 points and a minimum of 10 points.

#### 9.7.3.1 Display Results

The five most positive answers from the questionnaire given to the participants that used the display can be seen in Figure 9.39, whereas the five most negative answers can be seen in Figure 9.40. The maximum positive score from the display version is participant 18, which had a positive score of 34. The negative score from participant 18 is at 15, the different in the positive and negative score shows that the participant had a positive experience and did not feel a lot of negative emotions when testing the prototype.

Generally the results of the PANAS scale for the display version were positive. The mean (see Table 9.2) was at 21.7 for the positive answers compared to the mean of the negative answers, which



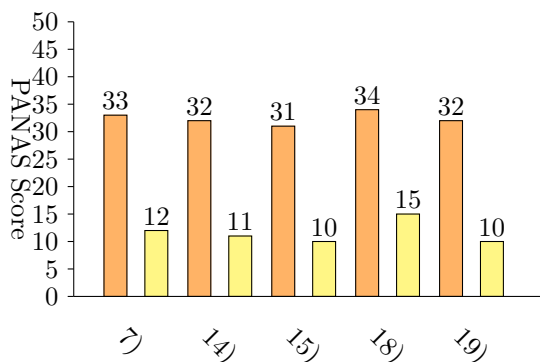


Figure 9.39: Five most positive PANAS answers for users of the display version of the prototype, showing positive affect (PA) ( █ ) and negative affect (NA) ( █ )

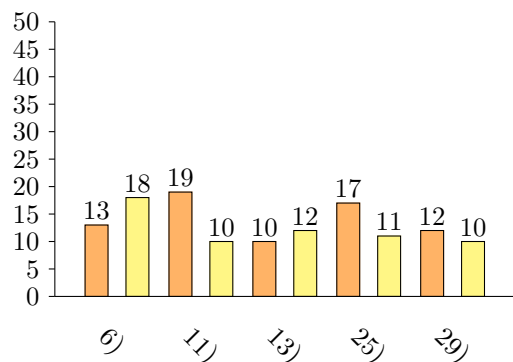


Figure 9.40: Five most negative PANAS answers for users of the display version of the prototype, showing positive affect (PA) ( █ ) and negative affect (NA) ( █ )

were only 11.0. The very low mean for the negative answers shows that the participants almost did not feel any negative emotions. As Figure 5 shows, the highest negative emotion was participant 6, which had a score of 18. The standard deviation for the negative scores is also very low (1.97), which means that the participants' answers were very close to each other. On the other hand, the standard deviation for the positive answers was somewhat larger at 7.47, indicating that the answers were further from each other.

### 9.7.3.2 Non-Display

In Figure 9.41 the five most positive answers from the non-display can be seen, likewise Figure 9.42 shows the five most negative answers.

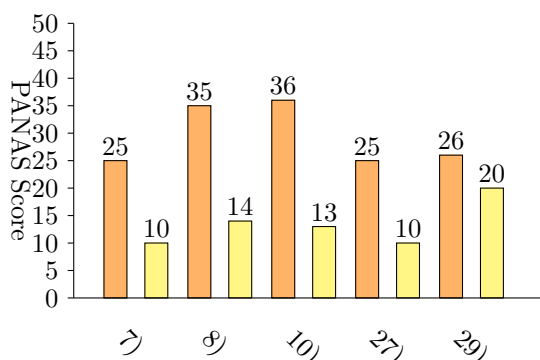


Figure 9.41: Five most positive PANAS answers for users of the non-display version of the prototype, showing PA ( █ ) and NA ( █ )

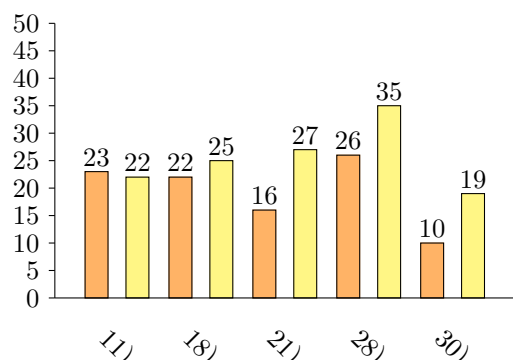


Figure 9.42: Five most negative PANAS answers for users of the non-display version of the prototype, showing PA ( █ ) and NA ( █ )

Especially one participant seems to feel very conflicting emotions. Participant 28 (see Figure 9.42) have a negative score of 35 and a positive score of 26. Looking at Figure 9.42 and Figure 9.41, the negative answers in both figures are very different, this is also reflected in the standard deviation as seen in Table 9.2. The standard deviation of the positive answers is 6.44 and the standard deviation of the negative answers is 6.02, this means that the participants' affect are spread out a lot. Comparing the standard deviation of the negative answers from the experimental group and control group shows that the experimental group felt more the same negative emotions,

compared to the control group, where the participants' have more spread emotions.

Test group		Mean	Standard Deviation
Experimental	PA	$\mu = 21.7$	$\sigma = 7.47$
	NA	$\mu = 11.0$	$\sigma = 1.97$
Control	PA	$\mu = 19.4$	$\sigma = 6.44$
	NA	$\mu = 14.6$	$\sigma = 6.02$

Table 9.2: Overview of mean and standard deviation of PANAS scale.

### 9.7.3.3 Sub-Conclusion

To sum up the results, the experimental group (display) showed more positive emotions in general but also had a higher variance in the answers, whereas they felt less to none negative emotions with little variance in the answers.

The control group (non-display), on the other hand, had higher negative emotions and than the experimental group and lower positive emotions. The standard deviation of both positive emotions and negative emotion were quite high at around 6, which means the participants felt a lot different emotions from each other.

## 9.7.4 Informal Unstructured Interviews

During the test phase, people approached the prototype expressing interest in the project. Interviews were conducted about the prototype and its features, however, without having any interview structure. The interviews started out with the participants approaching the prototype and asking what it was or how it worked.

The general response was positive. From around ten interviews nobody had a negative reaction to the concept, although a few people had comments about improvements to the prototype. One person commented that the prototype was great but that it lacked necessary features before it would be ready for a tournament. Most notably the prototype lacked three different piles of cards that are used in the game: the graveyard, the library and the exile pile, as it was mentioned before. Another participant did not have any problems with the missing piles, but instead he would have preferred that it would be possible to see which creature was attacking or blocking.

These additional things were discussed during implementation, but because of time constraints it was not feasible to implement.

However, we did get some negative feedback for a specific feature. A few people did not like the way the creatures were tapped. As mentioned in Section 8 Implementation the creatures did not actually tap, instead they were moved up/down and the word tapped would be written beneath/above the card. This was done because the display layout did not account for cards rotation  $90^\circ$  and when creating the prototype it was not thought to be an annoyance for the spectators. It turned out that some spectators did not like this idea.

The coin flip and dice roll was placed in the center of the display (see Section 7 Delimitation) for them to be easy to see. Some people commented that it was unnecessary to see these things all the time and the placement should be out of the way and only shown when they were actually used.

The feedback from these interviews has shown that the concept is completely new for everyone and the implementation was so far a success. The interviews have also shown that features that we found important or well implemented could have been done differently.

## 9.7.5 General Comments

Besides the statistical data, the questionnaires contained a few open-ended [Lazer et al., 2010, p. 111] questions which allowed collecting qualitative data. One of the questions from the first test session

with the display version of the prototype evaluating the concept of digitizing MtG for the sake of spectators (“*What is your general opinion about the concept of digitizing the Magic: the Gathering game on behalf of the spectators?*”) received a lot of positive responses such as the following and others alike:

- “*I liked it a lot it is a great idea, cause it makes spectating a lot easier. MTG can be displayed for a greater crowd.*”
- “*Good concept. Direct filming often has problems with unknown cards.*”
- “*Sounds like a great idea, better then on tv where a camera is placed above the board.*”
- “*I like the concept, but there is plenty of room for improvement.*”
- “*it is a great idea, interesting concept!*”
- “*I liked it, it will make competitive play a lot easier to watch and follow.*”
- “*I think it is great and interesting.*”
- “*Makes the experience more enjoyable and easier to see.*”
- “*Great idea! Needs a little fine tuning, but it clearly works.*”
- “*Very good idea, to make magic a spectator sport.*”
- “*It was helpful and made it easier to spectate.*”

These comments express a clear fondness towards the concept of the project and its potential to improve spectator experience at MtG tournaments. On the other hand, many respondents noticed that there is room for improvement - some of their experiences have been influenced by technical issues of the system or the lack of flow in the game. However, there were many suggestions of what could make this prototype even more efficient. The respondents had an opportunity to share their ideas for improving the project (“*Do you have any general comments/suggestions in regards to the overall testing experience?*”) and many came up with helpful suggestions. A general trend was noticed in regards to the current way of tapping the cards, as many spectators seemed slightly confused about it (relate to question: “*The lack of tapping of the lands in terms of how much it influenced your experience*”). Another thing that was mentioned numerous times (relate to question: “*Would you like to be able to see the graveyard/library/exile pile of cards on the display?*”) was the need of displaying other areas of the game (graveyard/library/exile/player’s hand) as well as displaying more obvious interactions between the cards and how the spells are countered. In general, some participants found the layout of the display a bit messy. In addition to this, several respondents mentioned a need for a commentator to clarify the game and keep its flow. This can be related to the question about an alternative type of feedback (relate to: “*Would you like to have any other type of feedback about the game other than visual?*”), as majority (45%) stated a desire for audio as a secondary feedback. The following lists collected suggestions of improvements from the test participants:

- “*Proper tapping of the cards and lands*”
- “*Better visualization of what cards are being targeted and how spells are countered*”
- “*Better visualization of which player is active and what phase they are in*”
- “*Display the remaining areas of the game (graveyard, exile, library and possible player’s hand or at least its size)*”
- “*Improve the display layout - make sure objects do not overlap*”
- “*Better flow in the game - faster scanning process*”
- “*Implement animations for dice roll and coin flip, otherwise remove them from screen when irrelevant*”

In regards to the simple design of the display, some respondents evaluated it positively, while others thought it was overly simple. One of them stated, “*The screen is over simplified. Optimally*

*as a viewer, you would be able to zoom in on the card of your choice.*". This comment suggests that it might be a possibility to expand the web application by having the whole game displayed there as well, however the spectator would be able to zoom in on cards if one did not catch something on the big display. This way the spectators would be given more individual freedom, while still keeping the public display as the main source of information. To sum up, the concept received a positive response, however a great deal of improvement is still needed to make the spectator experience enjoyable.

### 9.7.6 Biases

During the test and by observing the prototype, some biases have occurred. These biases can overall affect the results and conclusions that can be made upon the responses. This section will go in depth with some of the biases encountered, both during the test phase and the prototype itself. It will start out by making general comments on the bias that can be noticed for the demographic of the participants gathered and continue with problems occurring with the test.

It was noticed that the majority of the participants for both the display and non-display had been males, while only a small amount of females. This could generally bias the results since in order to get unbiased results, an even equal amount of both genders in both group samples would have been required. However, in this case it was expected that the majority of the participants to be males, since MtG community has been consisting mainly of males and a small percentage of female players.

Another bias noticed to be the age range of the participants, which varied from participants with age below 18 until ages above 28. The results used for the analysis were not just of the participants with ages ranging between 18 and 27 as stated in the characterization of the target group, which means it was not focused on specific age for the target group.

Because the target group is very specific (beginner Magic: the Gathering players) judgment sampling was used. This sampling method allowed the test conductor to judge if the participants are suited for the test. As mentioned the test was conducted at Faraos Cigarer and while the store sells a lot of Magic: the Gathering cards and accessory it also sells a lot of other things. The test conductors scouted potential test participants by observing what they were looking at in the store. When a participant was chosen he or she was approached and asked to participate in the test. This sampling method is easy to use and should get a better results than convenient sampling, since the researcher chooses participants based on judgment. That said, the sampling may not represent the whole population and it can cause stereotypes.

Having one of the tests performed on participants gathered online compared to having the participants gathered at Faraos Cigarer can also be a cause for a bias hence the participants online do not get a similar treatment to the participants gathered in the store. For example, when speaking of the results gathered online, the participant could feel more comfortable to answer the questionnaire and is also set in a comfortable position compared to participants meeting the group member's and being disturbed from their time at Faraos Cigarer. In the case of meeting the actual participants there is no longer a feeling of anonymity. Another point to be taken in consideration when it comes to approaching shop visitors and asking them for help in performing the experiment, is the fact that the majority of the people do not willingly approach us to help on the test as it happens online when the questionnaire is posted on a website where people willingly open up the link and join in the experiment. Therefore, by approaching costumers it could come off as bothering them from their playtime in Faraos Cigarer in order to help us test, which could lead them to not spending enough time on answering the questionnaire. For example in the case of the PANAS scale, some participants rated the same number for all emotions which could mean that either they were not being patient or actually felt that way about the prototype.

The results of the display test can also have been affected by the fact that there was not a consistent manuscript describing each step of the test and what the participant's addition to the

test would involve. Therefore, some of the participants have not been informed about the QR codes, seen on the walls next to the display, purpose, which could lead explain the fact that many of the participants did not use the web application. However, another reason to why they might have not used it, could have been the lack of a QR code scanner on their phone or lack of network connection, which was necessary in order to reach the web application.

A bias that had an influence on the results gathered for the prototype was the sudden unexpected technical difficulties, which had forced us to restart games that have been played for more than 5 minutes or caused us to abruptly end the game and the streaming on the display. Therefore these kinds of difficulties had forced us to restart the game while the participants were following the stream, which caused them to see the beginning of the game twice and answered a questionnaire based on this information. Another point to be mentioned when thinking of streaming games is that some of the games can be boring and some a lot more entertaining than others, this means that the participants might have had different levels of entertainment when watching the game on the display which could have highly influenced the participants spectating experience.

Another important point that can change the experience of a player is the type of decks played during the game, if the decks would have interesting new cards or unexpected usage of common cards, the game can become more interesting to watch. In our case, the decks used for the testing, contained mainly common cards that have been released for at least a year, which would be easy to recognize for players that have been playing MtG more than a year. On the other hand, this was done in order to simplify some of the features that required to be implemented in the time expected. However, due to the fact that the two prototypes, display and non-display, both used the same decks during the games for the test, and because the data is compared between the two, some biases can be removed.

As mentioned before in Section 7 Delimitation, the lands on the display did not tap when they were being used as would happen in an actual game, which is also the game recorded for the non-display test setup. This can cause a bias in the results gathered for the spectating experience since the game displayed on the projector did not completely simulate an actual game.

Lastly, a bias that can change the results to the test on a large scale is the fact that the majority of the participants were not, as stated in the final problems statement, beginners in MtG. It was noticed that most participants had a wide knowledge on Magic: the Gathering and it is then expected they had recognized the majority of the cards and that the keywords feature was not as useful to them as it would have been to a beginner MtG spectator.

## 9.8 Sub-Conclusion

The Final Problem Statement asks to what degree the spectator's experience is improved. Based on the questions from both the experimental group and the control group questionnaires, it is possible to see that the experimental group has a generally positive response with a mean of 4.5667 and a standard deviation of 1.6121. Comparing that to the responses from the control group (mean of 3.5 and standard deviation of 1.6764), it can be seen that the responses from the experimental group are higher than the control group; the standard deviation on the other hand is almost the same. It was confirmed with a t test and a Mann-Whitney U test that the null hypothesis can be rejected, which accepts the alternative hypothesis and the fact that by using visual representations with features that simplifies the game, it is possible to improve the spectator's experience. Therefore, according to the results it can be seen that the visual representations improved the experience on a small scale. If we consider the medians of the Likert scales asked in the first question of the questionnaires as the degrees of improvement, it can be seen that the median of the answers from the participants, rating the display, was 5 while the median for the answers, from the non-display participants, was 3 instead. Therefore, it can be noted that there are two degrees of positive difference between the two means of showing a game of Magic: the Gathering.

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# Chapter 10

## Discussion

This chapter will go in depth with points that should have been taken in consideration earlier and points that could have been approached differently. In this case it will touch upon flaws, mistakes and their solutions.

### 10.1 Has the Research Been Sufficient?

An overall point for the research that should be considered as a topic of discussion is whether the focus on the certain research topics presented throughout the report have been sufficient. Has there been enough theoretical points considered when working on the project and have these points been a help into building the prototype as it is now and testing its functionality?

The report is considered to contain a sufficient amount of information regarding Magic: the Gathering, the card game that is in focus throughout the report. The research about MtG in the analysis, which goes in depth with most of the relevant features that can be used for the prototype, has played an important role when designing the prototype. It is considered that the research had been sufficient to an extent that the important and most common rules of the game had been researched into and added as features to the final prototype. However, it probably would have been a good approach to also consider the information gathered in the State of the Art inside the Preliminary Analysis. The State of the Art section contains short descriptions of online card games which have the same rules as Magic: the Gathering. It would have been a good idea to use similar approaches as Magic Online, such as having important information to the side and make smaller cards, but this could mean the spectators might have troubles reading the cards.

There is a high amount of information when it comes to interactivity throughout the report, however we believe that interactivity has not played an important role in building the prototype, since the prototype itself had not been designed with interaction in mind but merely as a way of conveying visual information. However, some of the information gathered about interaction had been used to create the physical prototype, which is used to send the information to the display. Even though the physical interface was not the focus of the final test, it was a necessary step in order to be able to digitize a live game of MtG.

The theory of the grid systems has been of great use throughout the creation of the display. However, a more preferable idea would have been to further focus on the significance of each part of the grid system. This way it would be possible to place certain features according to the importance of the viewers' needs to see the information and in compliance to which areas of the grid system usually receive more attention. The research could have, however, been more thorough when it comes to information regarding the creation of an aesthetically pleasing design. In order to be able to understand how the choice of colors can influence the viewer's experience, theory regarding colors, contrasts and their relationship would have been an useful topic to look into. The same applies to having a theoretical approach of when to use text or when to use symbols while representing data.

At the moment, the display uses various information presented as text when this could have been represented as symbols and would make the display seem less crowded. As some participants have stated, a place where text could have been replaced by a symbol was when a card was being tapped. Therefore, by giving more thought into gathering research about the creation of the display, it would have been possible to create a better representation of an MtG game.

Section 5.4 Methodologies has covered interesting points that could have been taken in consideration when testing the prototype, however, most of the points presented in the certain section have not been given much attention due to the fact that initially it was thought to perform the test on a larger audience, than 2 to 3 people per test. However, a lot of research has been gathered on other ways of getting more data from a test and one of these topics was the Physiological Reactivity which explains how asking participants about their feelings affect them. This information has not been used as intended and it would have been a good idea to give this information more thought when using the PANAS, for example.

## 10.2 Were the Design and Implementation Phases Optimal?

In general, the design setup was acceptable but not optimal, however, the design should have focused more on arranging the features in a way that can become easier for the spectators to understand and not seem crowded to the eye, as some spectators have stated. Perhaps it would have been a good idea to use more information from the section State of the Art, where examples of online MtG games are given and described. By looking how they show the information, it could change the design slightly so it becomes more familiar and pleasant to the eye. However, even though some of the information could have been used to improve the design of the display, it would not be as easy to work with a non-interactive display to show all that information.

Designing and implementing a better approach of the problems encountered, would have changed the way the prototype works and improve the general experience of both the player and the spectator. It would have been ideal to skip the implementation of a card scanner and not bother the player with taking time to scan each card. When looking back at Section 6.1.3 Infrared Ink and Section 6.1.4 castAR these two alternative card tracking options seemed like a good idea, however, they were unavailable. IR Ink seemed like an easy solution to card tracking, and by combining it with fiducials, it might be possible to create invisible infrared tracking. During the initial research of the topic it was discovered that the price for IR Ink was rather high and the availability was low. It was not easy to get hold of IR Ink and on top of that, we also required a way to track the infrared ink. Since common cameras and web-cams do not detect infrared, it would require us to get another camera, which can actually use infrared detection. castARs tracking grid also seemed like a feasible solution but again there where availability problems. The castAR system has been running as a Kickstarter campaign [Technical Illusions, 2013] and the pre-orders are not shipping before September 2014, even if it was possible to get the system before time, the price for a tracking grid and precision base is running up to hundreds of dollars, which is outside the scope of this project.

As mentioned before, ideal solutions would have been the IR Ink or the castAR system. This could have then improved the design and usage of the prototype. By spending more time and financial resources, on trying to implement a similar approach to the ideal solution of using IR Ink, it would have led to a better prototype implementation, rather than having to work with color detection, which happened to encounter various problems at times. Since it was not possible to implement any of the solutions above, a different approach should have been taken in consideration, such as trying to achieve a smaller scanner box as the design initially created. This could have been possible by doing more research on acquiring a working smaller camera. Purchasing a high quality web-cam could have diminished the box size and made it more appealing to the player, however such a camera would have a high cost. Another solution would have been to implement our own software in order to get the Raspberry Pi camera to work with our program and by also adding a lens to the



Raspberry Pi camera; it would have been possible to get the camera to focus properly. Overall, by using a Canon camera with built-in software, it was possible to have more time for implementing the actual prototype, which was not restricted by financial resources.

During the design phase, Section 6.3.2 Animations talks about the importance of eye-appealing graphics and animations, which should include things like coin flip, dice roll and card actions. These animations were not implemented even though they should have been given more attention. The animation part of the implementation was very low on the priority list and postponed until everything else was working. Since the animations were not a requirement for the prototype to function it was not given a higher priority and when there was no more time left to implement and the animations were not done, the idea was discarded. The animation might have changed the overall experience of the spectators or it might have changed their emotions, but it is only possible to speculate about such things.

The implementation phase can be considered incomplete due to the fact that there are so many restrictions encountered when using the prototype. Some of these restrictions are the lack of tapping lands and cards on the display, similarly to an actual game of MtG, the fact that it is only possible to place five cards at a time on the battlefield, while in an actual game of MtG it is possible to place unlimited amount of cards. Another restriction of the display which altered the results was the fact that the *blocking* and *targeting* of creatures was not shown on the display, which made the game seem rather confusing to the spectators. The addition of graveyard was also an important feature that was lacking in the final display, however it was considered to be added, but due to time and technical restrictions it was not possible.

### 10.3 Was the Testing Approach Optimal?

Generally the test setup has been well prepared, however some problems had been encountered and in order to get better results to conclude upon, some changes to the testing approach would have been ideal. Some of these changes would have been to gather a large audience when testing the display rather than having one to four participants at a time to spectate the game in progress. This would have then been a better reenactment of a crowded MtG gathering where it is not possible to follow the game as easily. This could have also allowed gathering of audio data from a large crowd and connect it to information happening on screen. As mentioned in Section 5.4 Methodologies, audio measurement is possible and could have been used to gather qualitative data that can be related to the display and the action happening on it. By using the audio information gathered it could have been possible to point out which moments of the display have impacted their experience and it would also be possible to measure their experience according to how much noise or discussion it would have initiated. A software package called openEAR that supposedly can analyze audio was looked at, but after futile attempts to compile it, even with helps of the developers, the idea was discarded.

The test execution could have been more precise, as mentioned in Section 9.7.6 Biases section there is an error in the test, which occurs when the concept of the test was explained to the participants. The test conductor did not read from a script, which means that the test description was not the same every time. This can cause differences in the test results and is also why a Mann-Whitney U test was conducted together with a t test. The test conductor could have been more precise when detailing the test to avoid these errors. One of the concrete errors that were discovered from this was that not a lot of test participants tried to use the web application.

It was also not optimal to have gathered participants for the non-display test setup online, this could have a high influence on the results and in order to have gathered proper data, it would have been required to organize a similar test setup as the display. In order to create a true experiment, it would have been required to use a randomizing method to randomly assign participants for both the display and the non-display tests and not focus on acquiring participants for the display only.

For example, it could have been chosen to have a deck of cards with black and red cards and the participants that drew a black card would have to test the non-display while participants with a red card would be used for the display. This would have been a better approach at achieving a true experiment and better, unbiased results.

By looking at Section 9.3.1 True Experiment section, there are certain requirements to be met when performing a test in order for this to be a true experiment. The first point to be considered requires us to have an experiment based on a hypothesis, which can be accepted. As mentioned in the Statistics, the null hypothesis set for the experiment had been rejected due the results achieved and therefore the alternative hypothesis was accepted. Another requirement that points the experiment into the direction of becoming a true experiment is the usage of minimum two conditions, which in this case are the experimental group and the control group. The following points that lead to a true experiment are also fulfilled and quantitative data is gathered and t test and a Mann-Whitney U test conducted. However, the last two conditions to be fulfilled in order to have a true experiment are not met. Even though the test was designed with the goal of avoiding biases, various biases have been encountered, as mentioned in Section 9.7.6 Biases, which have could have a big impact on the results. Lastly, the experiment was not conducted in different places under different circumstances, which means that the experiment conducted is not a true experiment and is then a quasi-experiment.

## 10.4 Did We Fulfil Our Final Problem Statement?

*“To what degree can a beginner spectator’s experience improve while following a game of Magic: the Gathering, if they are presented with visual representations that keep them updated about the game process, in comparison to the existing methods of spectating?”*

Overall, the implementation and testing of the prototype is not considered a proper reenactment of an MtG game in progress and therefore several biases had been discovered. This means that the majority of the results are biased and cannot be considered as valid data and a representative sample of the population. However, if we assume that the results are not affected by the biases and that the testing approach was valid, it is considered that the final problem statement has been fulfilled and that there is a two degrees positive difference between the implemented prototype and the traditional method of spectating a game of MtG (see Section 9.8 Sub-Conclusion). There is a significant statistical difference between the two methods of spectating a game of MtG, which means that visual representations on a screen, which keep viewers updated about the game, can improve the experience of an MtG spectator.

# Chapter 11

## Conclusion

This chapter will shortly sum up all the chapters presented throughout the report and describe the overall progress of the report. These descriptions will lead to a conclusion of the report and the results gathered during the testing. Firstly, the analysis chapter gave an in depth presentation of the focus of the report, which is Magic: the Gathering, followed by theoretical points on how to create a proper GUI. The methodologies section inside the Analysis covered basic methods that can be used in order to test the different types of data gathered when testing the FPS. The Analysis ends with a sum up of the requirements and a list of the features that should be included when creating the prototype.

With the help of this information, it was possible to design the three different parts of the prototype: physical interface, display and web application. The Design chapter starts with various solutions for tracking cards on a table, which then chooses an ideal solution to be implemented to the prototype. Once the research regarding this decision has been completed, design sketches and feature lists for each of the parts of the prototype are created.

Since, it was not possible to achieve the ideal design created in the Design chapter, a delimitation section was created, which explained the changes done from the Design to the implementation and points out the reasons for this. The lack of time and financial resources led to creating a larger scanner box, therefore a new design was introduced in this chapter and information regarding a first iterative test, conducted at the Midterm, is given. With the help of test participants gathered at the Midterm, the prototype had to undergo a major change both functionality wise and design wise.

The Implementation chapter contains descriptions of each step of the process done in order to achieve the final prototype. The section is divided in two sections, which represent the two computers: main computer and secondary computer, which receive and send data for the display. The physical interface focuses mainly on information regarding the scanner and the electronics choices done in order to achieve the final product. LEDs and buttons have played an important role in creating the physical interface and thus also simplifying some of the processes required in order to simulate a game of MtG. The secondary computer was connected with the help of networking to the main computer and receives data that triggers information to be placed on screen. The program used to create the prototype involved openFrameworks and was written in C++, however external libraries such as Tesseract<sup>1</sup> and EDSDK<sup>2</sup> were used. Lastly, the web application implementation was described and presented as the final result.

The experiment was conducted as a between group experiment and the participants were selected using judgment sampling and half of the results were collected at Faraos Cigarer while the rest of the participants were gathered online. The data was collected using quantitative methods and statistical tests on the data were conducted. The test showed that the null hypothesis had been rejected and

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<sup>1</sup>Using the of library ofxTesseract

<sup>2</sup>Using the of library ofxEdsdk

therefore, it was considered that there is a positive difference between the implemented prototype and other spectating methods. However, it was argued that the results might not be valid due to the existing biases caused by the testing approaches and decisions.

It was also discussed that the lack of research might have influenced the outcome of the prototype and therefore makes the final result less pleasant to the viewer. The fact that the test had only been conducted in a single location with various conditions and the amount of biases, have led to believe that the experiment conducted was a quasi-experiment. The fact that the null hypothesis has been rejected, the alternative hypothesis was accepted and therefore there is an improvement in the experience of a beginner MtG spectator when visuals are used, and the difference is of two degrees between the two.

# Appendix A

## Experimental Group (Display) Questionnaire

### A.1 Improving MtG spectator experience

The purpose of this research project is to create an interactive prototype for playing and spectating Magic: the Gathering. This is a research project being conducted at Aalborg University - Copenhagen, Denmark. You are invited to participate in this research project because you play Magic: the Gathering. Your participation in this research study is voluntary. You may choose not to participate. If you decide to participate in this research survey, you may withdraw at any time. If you decide not to participate in this study or if you withdraw from participating at any time, you will not be penalized. The procedure involves filling out an online survey that will take approximately 5-10 minutes. Your responses will be confidential and we do not collect identifying information such as your name, email address or IP address. The survey questions will be about spectating Magic: the Gathering and how to improve this experience. The results of this study will be used for scholarly purposes only and may be shared with Aalborg University representatives. If you have any questions about the research study, please contact [kl14ml604@create.aau.dk](mailto:kl14ml604@create.aau.dk). **ELECTRONIC CONSENT:** Please select your choice below. Clicking on the "agree" button below indicates that: you have read the above information you voluntarily agree to participate

- *"If you do not wish to participate in the research study, please decline participation by clicking on the "disagree" button."*
  - Yes
  - No
  
- *"Participant type"*
  - Regular
  - GSR

### A.2 General experience

- *"How would you rate the overall experience in terms of how easy or difficult it was to follow the game of Magic: the Gathering?"*
  - 1) Very Difficult
  - 2)
  - 3)

- 4)
  - 5)
  - 6)
  - 7) Very Easy
- *“In your opinion, how much did the display with digitized game process contributed to improving your spectating experience of this Magic: the Gathering game?”*
  - 1) Not at all
  - 2)
  - 3)
  - 4)
  - 5)
  - 6)
  - 7) Very much
- *“If you think it was easy to follow the game, what in your opinion was the main reason of it?”*
  - I recognized the cards
  - I could properly read the cards
  - I could both recognize and read them
  - Other:
- *“Would you like to have any other type of feedback about the game other than visual?”*
  - Yes, audio
  - Yes, haptic (e.g. vibration)
  - No
  - Other:
- *“Would you like to be able to see the graveyard/library/exile pile of cards on the display?”*
  - Yes
  - No

### A.3 PANAS scale

- *“Please rate the following emotions regarding how present they were while you were spectating the game of Magic: the Gathering.”*

### A.4 Rating Features

- *“The representation of the cards that were being played”*
  - 1) Difficult to see
  - 2)
  - 3)
  - 4)
  - 5)
  - 6)
  - 7) Easy to see
- *“The readability of the cards on the display”*

	1 - not at all	2 - a little	3 - moderately	4 - quite a bit	5 - extremely
Afraid					
Scared					
Nervous					
Jittery					
Irritable					
Hostile					
Guilty					
Ashamed					
Upset					
Distressed					
Active					
Alert					
Attentive					
Determined					
Enthusiastic					
Excited					
Inspired					
Interested					
Proud					
Strong					

- 1) Difficult to read
- 2)
- 3)
- 4)
- 5)
- 6)
- 7) Easy to read

- *“The representation of the player life in terms of how easy it was to see it”*

- 1) Difficult to see
- 2)
- 3)
- 4)
- 5)
- 6)
- 7) Easy to see

- *“The representation of dice roll/coin flip in terms of how easy it was to see it”*

- 1) Difficult to see
- 2)
- 3)
- 4)
- 5)
- 6)
- 7) Easy to see

- *“The representation of the keywords on the display in terms of how easy it was to see it”*

- 1) Difficult to see
- 2)

- 3)
  - 4)
  - 5)
  - 6)
  - 7) Easy to see
- *“The relevance of displaying the keywords on the display”*
  - 1) Very unnecessary
  - 2)
  - 3)
  - 4)
  - 5)
  - 6)
  - 7) Very helpful
- *“The lack of tapping of the lands in terms of how much it influenced your experience”*
  - 1) Not at all
  - 2)
  - 3)
  - 4)
  - 5)
  - 6)
  - 7) Very much
- *“The simplicity of the design in terms of how much it affected your experience of watching a game of Magic: the Gathering”*
  - 1) Not at all
  - 2)
  - 3)
  - 4)
  - 5)
  - 6)
  - 7) Very much
- *“The familiarity of the display in terms of the original theme of Magic: the Gathering”*
  - 1) Not familiar at all
  - 2)
  - 3)
  - 4)
  - 5)
  - 6)
  - 7) Very Familiar

## A.5 Web app

- *“Did you use the web application?”*
  - Yes
  - No



- *“In regards to the online betting application, how much involved in the game did it make you feel?”*
  - 1) Not at all
  - 2)
  - 3)
  - 4)
  - 5)
  - 6)
  - 7) Very much
- *“How did you feel about the concept of voting for the player you favor?”*
  - 1) Very useless
  - 2)
  - 3)
  - 4)
  - 5)
  - 6)
  - 7) Very useful
- *“Did you experience any technical issues while using the application?”*
  - Yes
  - No
- *“If yes, please elaborate on your previous answer”*

## A.6 Concept evaluation

- *“What is your general opinion about the concept of digitizing the Magic: the Gathering game on behalf of the spectators ?”*
- *“Would you like to have a digitalized version of the game that you are spectating displayed on screen?”*
  - Yes
  - No
- *“Did any technical issues interrupt your spectating of the game?”*
  - Yes
  - No
- *“If yes, please elaborate on your previous answer”*

## A.7 Basic and demographic questions

- *“How long time have you been playing Magic: the Gathering?”*
  - 1-6 months
  - 6-12 months
  - 1-2 years
  - 2+ years
- *“How often do play Magic: the Gathering?”*

- Never
- 1-5 times a week
- 1-5 times a month
- 1-5 times a year
- *“How often do watch others play Magic: the Gathering?”*
  - Never
  - 1-5 times a week
  - 1-5 times a month
  - 1-5 times a year
- *“What is your gender?”*
  - Male
  - Female
- *“What is your age?”*
  - <18
  - 19-21
  - 22-24
  - 25-27
  - >28

## A.8 General comments

- *“Do you have any general comments/suggestions in regards to the overall testing experience?”*

## A.9 Further testing

- *“If you wish to participate in further testing of this project and take part in a focus group some time next week, please leave us your contact email in the text field below.”*

## Appendix B

# Control Group (Non-Display) Questionnaire

### B.1 Improving MtG spectator experience

The purpose of this research project is to create an interactive prototype for playing and spectating Magic: the Gathering. This is a research project being conducted at Aalborg University - Copenhagen, Denmark. You are invited to participate in this research project because you play Magic: the Gathering. Your participation in this research study is voluntary. You may choose not to participate. If you decide to participate in this research survey, you may withdraw at any time. If you decide not to participate in this study or if you withdraw from participating at any time, you will not be penalized. The procedure involves filling out an online survey that will take approximately 5-10 minutes. Your responses will be confidential and we do not collect identifying information such as your name, email address or IP address. The survey questions will be about spectating Magic: the Gathering and how to improve this experience. The results of this study will be used for scholarly purposes only and may be shared with Aalborg University representatives. If you have any questions about the research study, please contact [kl14ml604@create.aau.dk](mailto:kl14ml604@create.aau.dk). **ELECTRONIC CONSENT:** Please select your choice below. Clicking on the "agree" button below indicates that: you have read the above information you voluntarily agree to participate

- *"If you do not wish to participate in the research study, please decline participation by clicking on the "disagree" button."*
  - Yes
  - No

### B.2 General experience

- *"How would you rate the overall experience in terms of how easy or difficult it was to follow the game of Magic: the Gathering?"*
  - 1) Very Difficult
  - 2)
  - 3)
  - 4)
  - 5)
  - 6)
  - 7) Very Easy

- “If you think it was easy to follow the game, what in your opinion was the main reason of it?”
  - I recognized the cards
  - I could properly read the cards
  - I could both recognize and read them
  - Other:

### B.3 PANAS scale

- “Please rate the following emotions regarding how present they were while you were spectating the game of Magic: the Gathering.”

	1 - not at all	2 - a little	3 - moderately	4 - quite a bit	5 - extremely
Afraid					
Scared					
Nervous					
Jittery					
Irritable					
Hostile					
Guilty					
Ashamed					
Upset					
Distressed					
Active					
Alert					
Attentive					
Determined					
Enthusiastic					
Excited					
Inspired					
Interested					
Proud					
Strong					

### B.4 Concept evaluation

- “What is your general opinion about the concept of digitizing the Magic: the Gathering game on behalf of the spectators ?”
- “Would you like to have a digitalized version of the game that you are spectating displayed on screen?”
  - Yes
  - No

### B.5 Basic and demographic questions

- “How long time have you been playing Magic: the Gathering?”
  - 1-6 months
  - 6-12 months

- 1-2 years
- 2+ years
- *“How often do play Magic: the Gathering?”*
  - Never
  - 1-5 times a week
  - 1-5 times a month
  - 1-5 times a year
- *“How often do watch others play Magic: the Gathering?”*
  - Never
  - 1-5 times a week
  - 1-5 times a month
  - 1-5 times a year
- *“What is your gender?”*
  - Male
  - Female
- *“What is your age?”*
  - <18
  - 19-21
  - 22-24
  - 25-27
  - >28

## **B.6 General comments**

- *“Do you have any general comments/suggestions in regards to the overall testing experience?”*

## **B.7 Further testing**

- *“If you wish to participate in further testing of this project and take part in a focus group some time next week, please leave us your contact email in the text field below.”*

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# Appendix C

## Test Results

This appendix will contain the full test results in chronological order, however, some of the results including both text and charts are duplicated in the report (see Section 9.6 Test Results) as well as here.

In this section the results from the final test will be presented. For the final test, two different questionnaires were used on two different groups of participants. The first questionnaire was given to the audiences of the prototype, after they had been a spectator to a game. The second questionnaire was given to audiences of a regular game. The first questionnaire was the experimental group and the second questionnaire was the control group.

### C.1 Experiment Results

This section will present the results from the experimental group. The results will be divided into section corresponding to the section from the questionnaire.

#### C.1.1 General Experience

The first question the participants are asked, after the consent form, is about their overall experience. This question is a likert scale from 1 to 7 where 1 is very difficult and 7 is very easy.

- “How would you rate the overall experience in terms of how easy or difficult it was to follow the game of Magic: the Gathering?”

The answers can be seen in Figure C.1. The negative part of the scale (1-3) contains 26.6% of the answers (nobody answered 2), whereas the positive side of the scale (5-7) contains 53.3% of the answers. The middle of the scale (4) 20% of the answers.

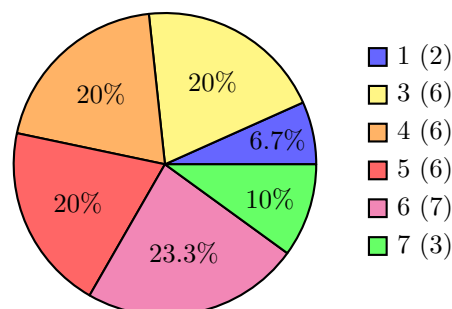


Figure C.1: Overall Experience with display ( $n = 30$ )

The next question is about how the spectator experience was improved based on the contribution of the digitized game. Again the scale was a likert scale from 1 (not at all) to 7 (very much).

- “In your opinion, how much did the display with digitized game process contributed to improving your spectating experience of this Magic: the Gathering game?”

Figure C.2 shows the answers for the question. The answers are almost equally divided between 36.6% negative (1-3), 30% neutral (4) and 33.3% positive (5-7).

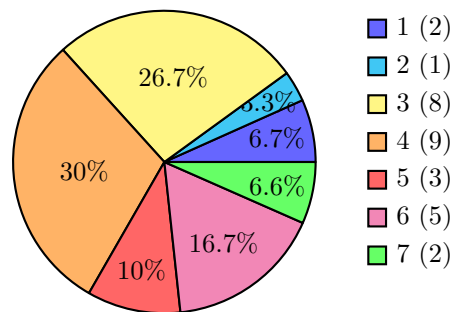


Figure C.2: Spectator experience with display ( $n = 30$ )

The third question is a bit different from the two first ones. It asks why it was easy to follow the game. The question does not use a likert scale but instead is a multiple choice question with an *other* option.

- “If you think it was easy to follow the game, what in your opinion was the main reason of it?”
  - 1) I recognized the cards
  - 2) I could properly read the cards
  - 3) I could both recognize and read them
  - 4) Other:-----

The question is not mandatory and should only be answered if the participant “*think it was easy to follow the game*”. This means that not everyone answered the question. In total, 27 participants answered the question.

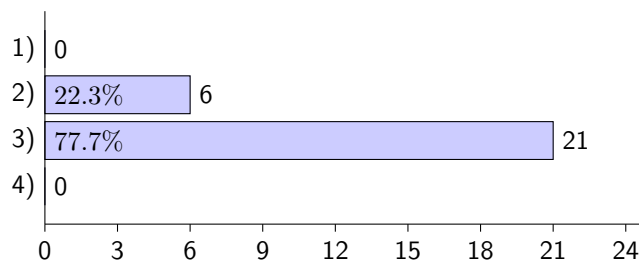


Figure C.3: Reason for thinking it was easy to follow a game. ( $n=27$ )

As seen in Figure C.3 nobody answers 1) *I recognized the cards* or 4) *Other*. The majority (77.7%) answered that they could both recognize the cards and read them. A small percentage (22.3%) answered that they could properly read the cards.

The next two questions are about additional features for the prototype. As mentioned in Section 7 Delimitation the ideal design and the implementation are different. The next questions ask about features that were thought of, but not implemented.



- “Would you like to have any other type of feedback about the game other than visual?”
  - 1) Yes, audio
  - 2) Yes, haptic (e.g. vibration)
  - 3) No
  - 4) Other:-----

Figure C.4 shows that half of the participants would like either audio (46.7%) or haptic (3.3%). About 1/3 of the participants did not want any other type of feedback. 4 participants answered other. Their answers were the following:

- Handsize for each player
- Commentating
- comments on game play choices
- text explanations

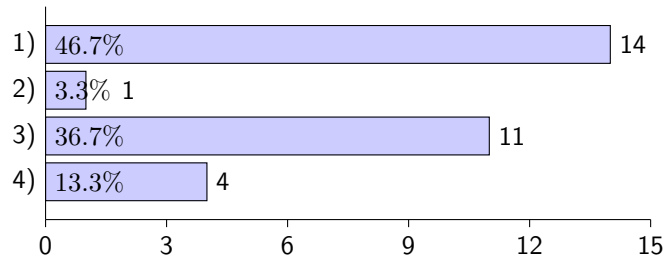


Figure C.4: Other types of feedback. ( $n = 30$ )

The other question about addition features is about the *graveyard*, *library* and *exile pile*. This is three piles of cards in the game that the players can draw cards from or put cards in to.

- “Would you like to be able to see the graveyard/library/exile pile of cards on the display?”

The question is a mandatory yes/no question and the results can be seen in Figure C.5.

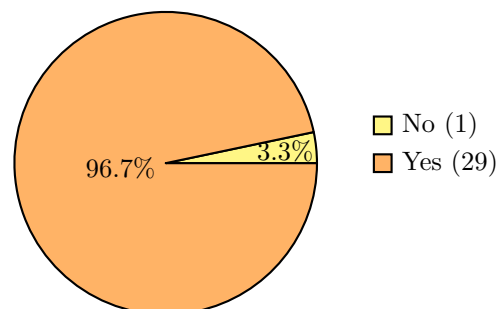


Figure C.5: Additional features such as graveyard/library/exile pile ( $n = 30$ )

	1 - not at all	2 - a little	3 - moderately	4 - quite a bit	5 - extremely
Afraid	x				
Scared	x				
Nervous	x				
Jittery	x				
Irritable			x		
Hostile	x				
Guilty	x				
Ashamed	x				
Upset			x		
Distressed		x			
Active				x	
Alert				x	
Attentive					x
Determined				x	
Enthusiastic			x		
Excited			x		
Inspired		x			
Interested				x	
Proud		x			
Strong		x			

Table C.1: Example of a participants emotional repsonse in a PANAS scale.

### C.1.2 PANAS Scale

To see the participants emotional response to the prototype a PANAS scale was used. This means that the participants had to rate different emotions on a scale from 1 to 5. Table C.1 shows an example the emotional response from one participant and the scale on which to rate each emotion on.

The PANAS scale compares each participants the negative emotions to their positive emotions. Figure C.6 shows the result of the PANAS scale from 4 random participants. The results can vary from 10 to 50.

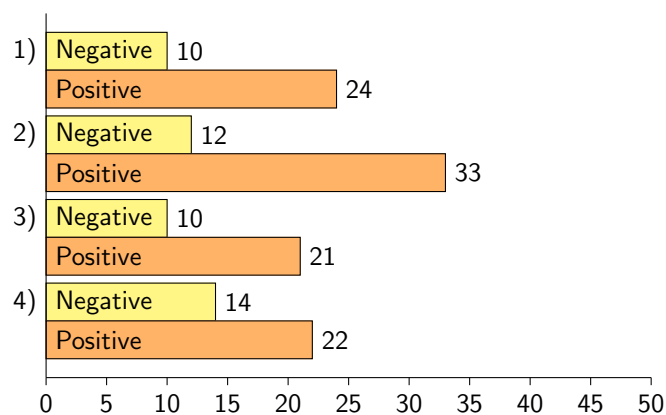


Figure C.6: PANAS results from 4 random participants. ( $n = 30$ )

### C.1.3 Rating Features

After the PANAS scale the participants were asked to rate different features of the display. The section contains nine questions and their answers. All the questions use a likert scale from 1

(negative) to 7 (positive).

The first question is about the representation of the cards.

- “The representation of the cards that were being played (1-difficult to see — 7-easy to see)”

The answers can be seen in Figure C.7. The answers shows that the majority of the participants liked the representation.

- “The readability of the cards on the display (1-difficult to read — 7-easy to read)”

The answers can be seen in Figure C.8. Again the majority of the results are positive and around 1/4 of the participants are neutral.

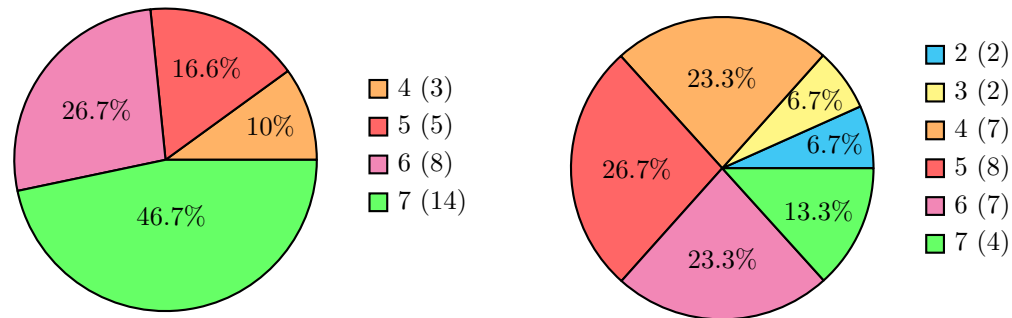


Figure C.7: Representation of the cards (n = 30)      Figure C.8: Readability of the cards (n = 30)

- “The representation of the player life in terms of how easy it was to see it (1-difficult to see — 7-easy to see)”

The answers can be seen in Figure C.9. The results shows that more than half the participants thought it was very easy to see the player life very few (2 participants) thought it was somewhat difficult.

- “The representation of dice roll/coin flip in terms of how easy it was to see it (1-difficult to see — 7-easy to see)”

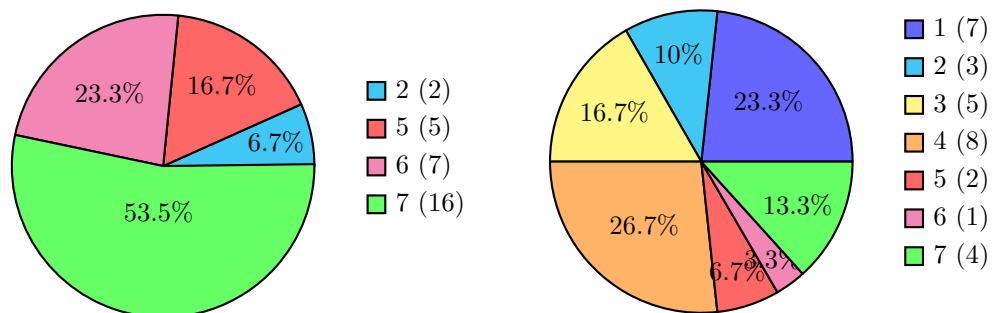


Figure C.9: Representation of player lift (n = 30)      Figure C.10: Representation of dice roll/coin flip (n = 30)

The answers can be seen in Figure C.10. There are very mixed feeling about the representation of dice roll and coin flip. Half of the participants are negative about the representation but still around 1/4 are positive the rest (1/4) are neutral.

Next there are two questions about the keywords shown on the screen. These keywords are special abilities that some cards have. There exist more than a 100 different keywords so it can be hard to remember them all.

- “The representation of the keywords on the display in terms of how easy it was to see it (1-difficult to see — 7-easy to see)”

Figure C.11 shows that only a few participants think it is somewhat difficult to see the keywords and the majority are positive about the representation of the keywords.

- “The relevance of displaying the keywords on the display (1-very unnecessary — 7-very helpful)”

Figure C.12 shows the answers for the relevance of displaying the keywords. The answers are not consistently positive, compared to the previous question, some participants find it very helpful while others think it is unnecessary.

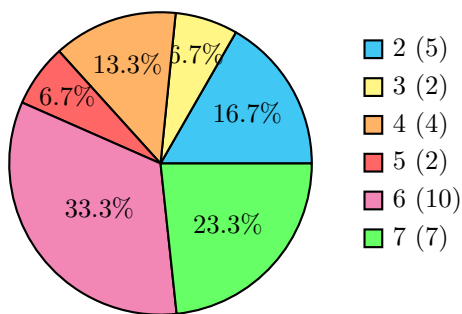


Figure C.11: Representation of the keywords (n = 30)

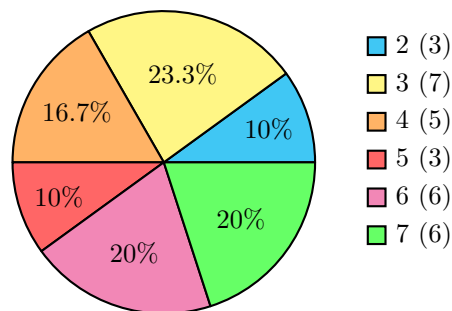


Figure C.12: Relevance of displaying the keywords (n = 30)

The next question is about *tapping*. Tapping is a feature of the game that discussed how to implement. The card needs to be turned 90° which was not possible as the prototype does not track where the lands are placed.

- “The lack of tapping of the lands in terms of how much it influenced your experience (1-not at all — 7-very much)”

As Figure C.13 shows, the majority of the participants found that it influenced their experience a lot.

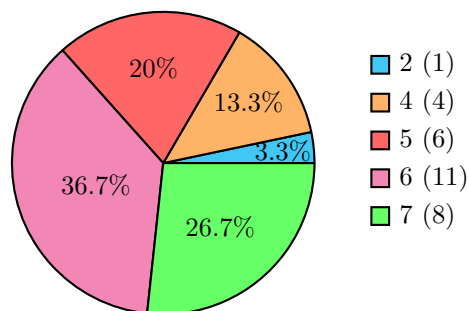


Figure C.13: Lack of tapping lands (n = 30)

The last two questions in this section is about the design and familiarity of the display.

- “The simplicity of the design in terms of how much it affected your experience of watching a game of Magic: the Gathering (1-not at all — 7-very much)”

Figure C.14 shows the results of the question. About 1/3 are neutral about the question and the other 2/3 are slip between negative (26.6%) and positive (36.6%).

- “The familiarity of the display in terms of the original theme of Magic: the Gathering (1-not familiar at all — 7-very familiar)”

The result of the last question is can be seen in Figure C.15. The majority of the answers were positive (70%), with 26.6% answering *very familiar*.

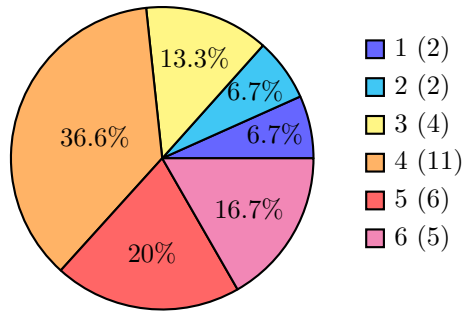


Figure C.14: Simplicity of the design ( $n = 30$ )

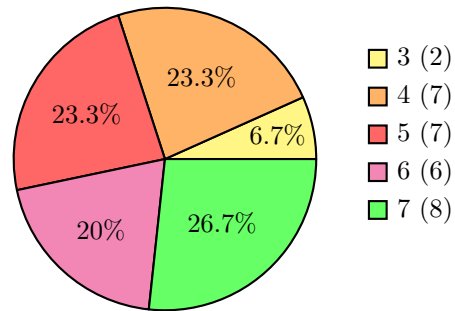


Figure C.15: Familiarity of the display ( $n = 30$ )

### C.1.4 Web App

This section will go through the results of the questions about the web application. This is the application where the user can vote for the player they think will win.

The first question is an intro question that asks if the participant used the web application.

- “Did you use the web application? (Yes/No)”

As seen in Figure C.16 only 5 participants used the web app. This means that the next two questions only have 5 participants answering.

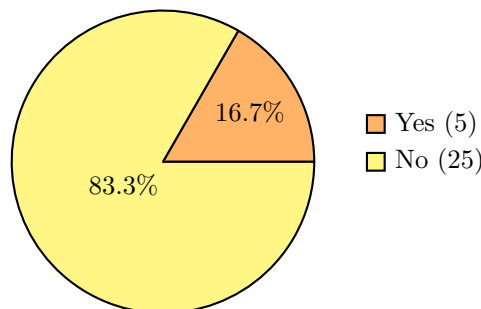


Figure C.16: Participants that used the web app ( $n = 30$ )

- “In regards to the online betting application, how much involved in the game did it make you feel? (1-not at all — 7-very much)”

Figure C.17 shows the results.

- “How did you feel about the concept of voting for the player you favor? (1-very useless — 7-very useful)”

Figure C.18 shows the results.

With both of these questions it is impossible to come with any conclusions since there are too few participants that actually used the web application.

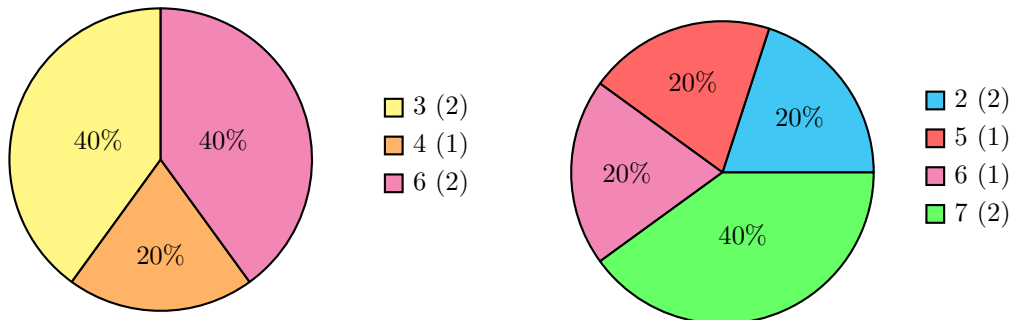


Figure C.17: Involved in the game (n = 5)

Figure C.18: Feelings about the concept of voting (n = 5)

### C.1.5 Concept Evaluation

The concept evaluation asked an open questions regarding the participants general opinion about the concept.

- “What is your general opinion about the concept of digitizing the Magic: the Gathering game on behalf of the spectators ?”

The result from this question will be looked at in the result analysis later in this chapter.

The next two questions is about technical issues that might have interrupted the game play. The first question is a yes/no questions whereas the second one is an open question were the participants should explain what happen and if it affected their experience.

- “Did any technical issues interrupt your spectating of the game?”

The results can be seen in Figure C.19

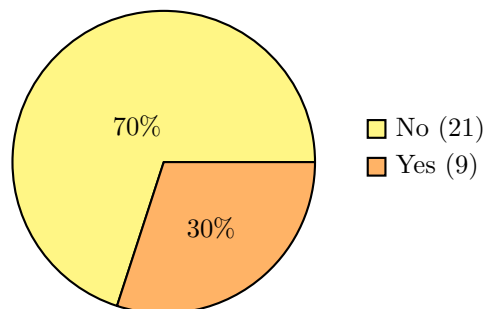


Figure C.19: Technical issues intertupt the game (n = 30)

- “If yes, please elaborate on your previous answer”

### C.1.6 Basic and Demographic Questions

The last sections is about basic questions that can be helpful in identifying the target group that have tested the prototype.

- “What is your age?”
- “What is your gender?”

The result of these two questions can be seen in Figure C.20 and Figure C.21.

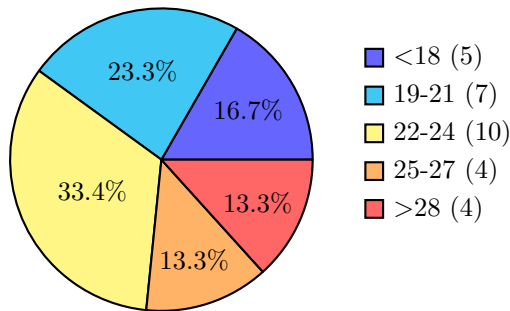


Figure C.20: Age ( $n = 30$ )

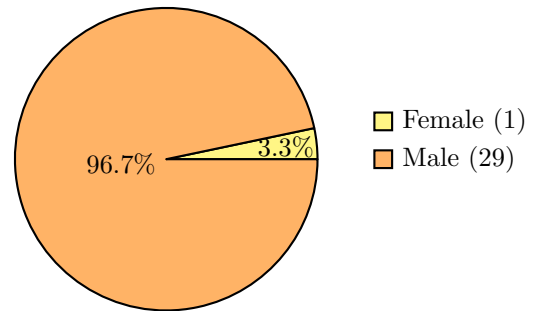


Figure C.21: Gender ( $n = 30$ )

- “How long time have you been playing Magic: the Gathering?”

As seen in Figure C.22 most people have been playing for more than two years.

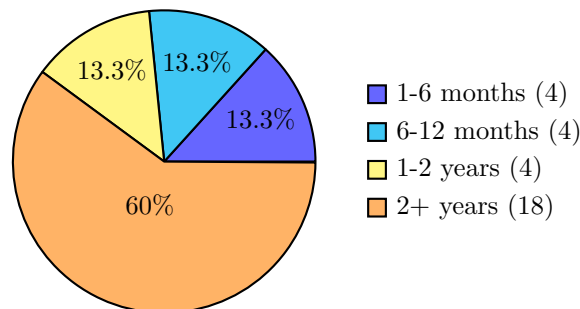


Figure C.22: How long have you been playing ( $n = 30$ )

The last two questions is about how often the participants are playing Magic: the Gathering and how often they watch others play.

- “How often do play Magic: the Gathering?”
- “How often do watch others play Magic: the Gathering?”

The answers can be seen in Figure C.23 and Figure C.24.

## C.2 Control Results

This section will talk about the control group and their results.

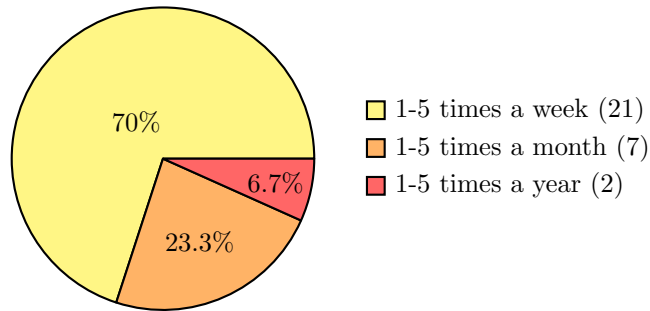


Figure C.23: How often do you play ( $n = 30$ )

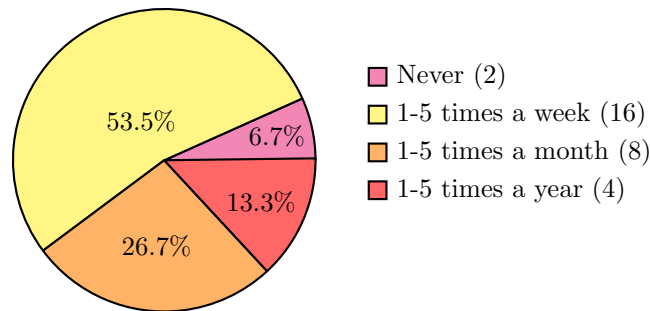


Figure C.24: How often do you watch ( $n = 30$ )

### C.2.1 General Experience

As with the experimental group (see Section Section 9.6.1), the control group’s questionnaire starts out with a question about the spectators overall experience.

- “How would you rate the overall experience in terms of how easy or difficult it was to follow the game of Magic: the Gathering? (1-very difficult — 7-very easy)”

The answers to the question can be seen in Figure C.25. The negative part of the scale (1-3) contains 56.7% of the answers.

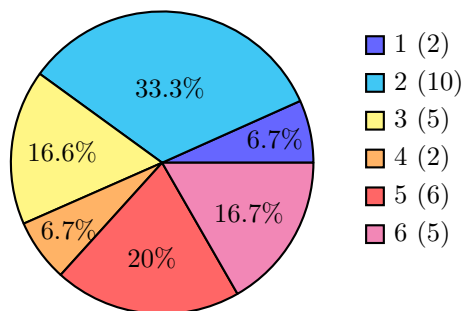


Figure C.25: Overall Experience without display ( $n = 30$ )

The next question was also asked to the experimental group.

- “If you think it was easy to follow the game, what in your opinion was the main reason of it?”
  - 1) I recognized the cards



- 2) I could properly read the cards
- 3) I could both recognize and read them
- 4) Other:-----

In total, 19 participants answered this question. The answers can be seen in Figure C.26.

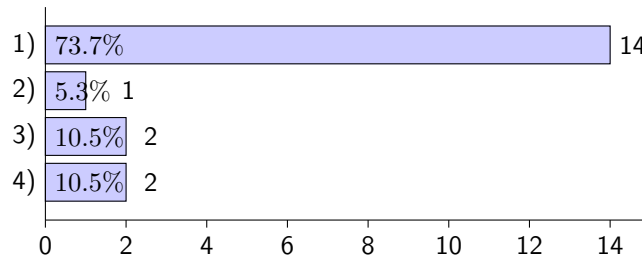


Figure C.26: Reason for thinking it was easy to follow a game. (n=19)

### C.2.2 PANAS Scale

The PANAS scale for the control group is the same as the experimental group. An example of the scale can be seen in Table C.1 on Page 120.

Figure C.27 shows an example of four random participants answers.

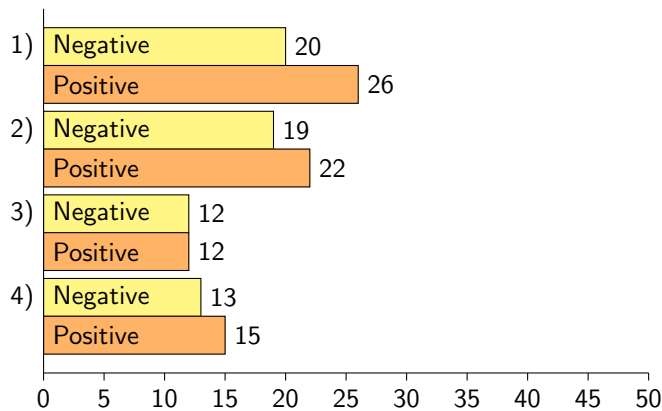


Figure C.27: PANAS results from 4 random participants. (n = 30)

### C.2.3 Concept Evaluation

For the control group there were two question about the concept of digitizing Magic: the Gathering. The first question was an open question where the participants could write notes and comments about the idea. The other question was a yes/no question.

- “Would you like to have a digitalized version of the game that you are spectating displayed on screen? (Yes/No)”

The answers can be seen in Figure C.28. 1/3 of the participants did not like the idea of a digital version but 2/3 did like the idea.

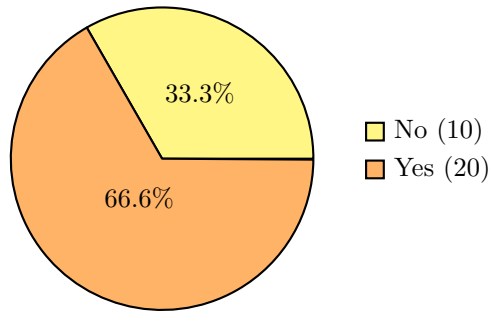


Figure C.28: Would you like a digital version? ( $n = 30$ )

### C.2.4 Basic and Demographic Questions

The last sections is about demographic questions, as in the experimental results.

- “What is your age?”
- “What is your gender?”

The result of these two questions can be seen in Figure C.29 and Figure C.30.

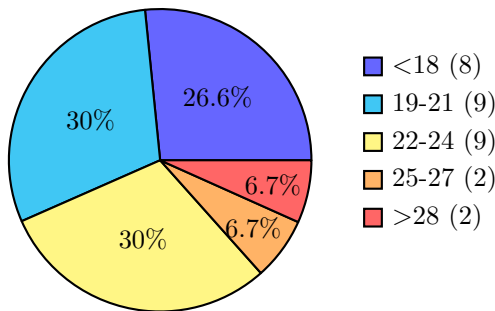


Figure C.29: Age ( $n = 30$ )

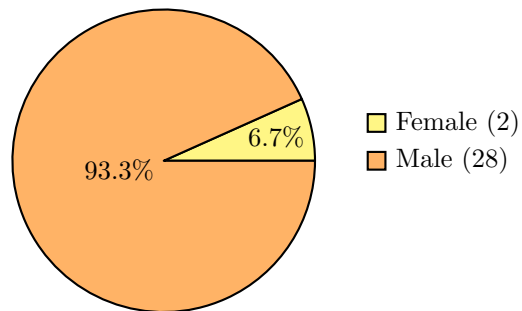


Figure C.30: Gender ( $n = 30$ )

- “How long time have you been playing Magic: the Gathering?”

As seen in Figure C.31 most people have been playing for more than two years. The amount of participants that have been playing for 2+ years are the exact same as in the experimental group (see Figure C.22).

The last two questions is about how often the participants are playing Magic: the Gathering and how often they watch others play.

- “How often do play Magic: the Gathering?”
- “How often do watch others play Magic: the Gathering?”

The answers can be seen in Figure C.32 and Figure C.33.

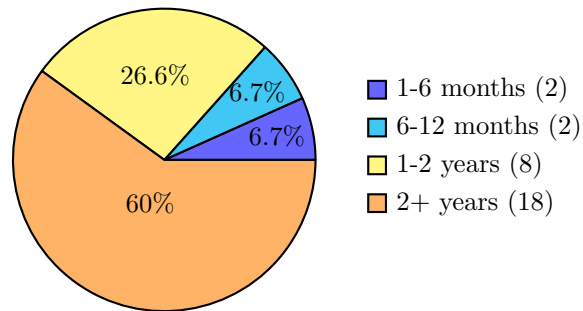


Figure C.31: How long have you been playing ( $n = 30$ )

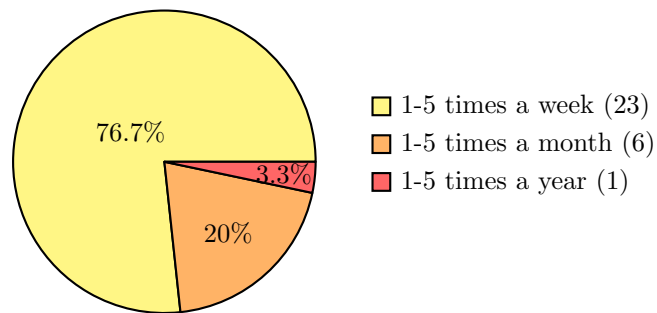


Figure C.32: How often do you play ( $n = 30$ )

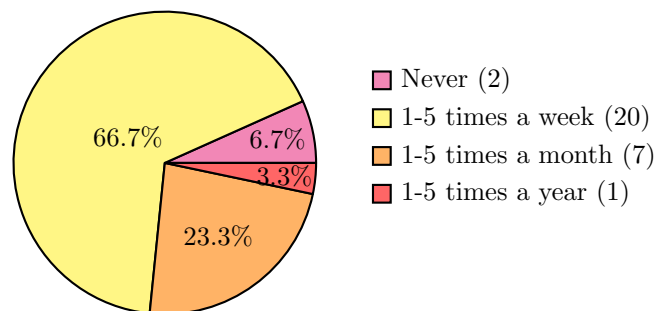


Figure C.33: How often do you watch ( $n = 30$ )

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# Appendix D

## Interactivity

This section researches into interaction in card games and how such can be used in Magic: the Gathering. It is based on a similar study done by Oleksandr Lobunets and Wolfgang Prinz [Lobunets and Prinz, 2011]. It is highly relevant to evaluate the methods used in the Lobunets and Prinz experiment, as this project also aims to implement interactive devices into a traditional card game. Their focus is described as follows:

*“[...] develop guidelines for applying surface based interaction devices as a platform for collaborative working environment”* [Lobunets and Prinz, 2011, p. 674]

Lobunets and Prinz uses the card game UNO. Since their focus is the implementation of the interactive devices, it was evaluated not to be a problem that it is two different card games.

Lobunets and Prinz also evaluate real world game action gestures such as shuffling a deck. This matter in their project will not be used for further evaluation, and instead their results on developing guidelines for the creations of an interaction design will be used in designing the Graphical User Interface.

Their research focuses to aid the interaction both in the physical and digital domain in card games. An important part is not to lose the attractiveness of the game to the players while adding these extra digital features. This also includes the interaction with physical game objects such as dice.

The research points out three interactive/non-interactive devices:

- Interactive player (smartphone)
- Interactive table (tabletop and tablet)
- Non-interactive display (public display)

This project aims to do the same thing, which means as with Lobunets’ and Prinz’ study, the wireless network is important for the devices to communicate. The Lobunets and Prinz study has some general game controlling functions such as; start a game, reset a game, shuffle cards, and pick a card. These are elementary features for a simple card game. In the context of this project Magic: the Gathering is much more complicated and needs a lot more features. This means that a set of requirements will be established in terms of creating a final design for the interactive devices.

The three devices are used in the following manners. The interactive table serves as a game table, say displaying a deck and a pile, which the user can interact with, e.g. draw a card. The interactive player displays a set of tangible cards, which is private and visible only to that player. Furthermore, the interactive player is mobile because of the size and weight of the device. The non-interactive display is public and visible to all players and spectators. This is connected to the mobile devices and displays the game table. In that context, the Lobunets and Prinz study suggests to enable a visualization of the game in other places e.g. public places. In the context of this project, it is relevant to use this possibility. Since this project focuses on how to affect the spectators experience

and follow the game process, such displays could help to ease this experience by visualizing the game process.

Lobunets and Prinz tested the interactive devices on 8 participants using questionnaires containing 40 questions. The results of this test showed that 79% thought the system was easy and fun to use. 85% thought that it was easy to learn the system. This could mainly be due to the simplicity of the GUI, which was kept rather simple. The test also showed that the physical interactions made the game more fun to play. This mainly showed in the low ratings of the non-interactive displays showing the game process. In that sense, it proves that it is highly important to use the game process display very carefully. It should only show useful and relevant information to the spectator, and if possible make the display interactive instead of non-interactive through one's mobile device. It could be if the spectator could use the information displayed on the screen on one's mobile device. Furthermore, Lobunets' and Prinz's participants were asked their opinion in free form. In that sense the most popular features of the system was; good graphical design and animations, fun interacting with virtual objects, and useful automatic scores calculations. Especially the latter part is relevant in the context of this project. Finally, Lobunets and Prinz evaluates the most important aspect in their design:

- Responsiveness (keeping in mind network communication latency)
- Visual-driven design (eye-appealing graphics and animations)
- Natural mapping (avoid confusion between system and user mental models (see Section 5.3.1 Mental Model))
- Usage of multi-modality - if possible, to automate routine tasks

These bullet points serve as the developed guidelines for applying surface based interaction devices as a platform for collaborative working environments. They will be used in the design of the GUI in the application.

# Appendix E

## Levenshtein Distance

The best way of explaining how the algorithm works is by looking at an example. Table E.1 shows the Levenshtein Distance matrix for the words *Hello* and *Holle*.

		H	e	l	l	o
	0	1	2	3	4	5
H	1	0	1	2	3	4
o	2	1	1	2	3	3
l	3	2	2	1	2	3
l	4	3	3	2	1	2
e	5	4	3	3	2	2

Table E.1: Levenshtein Distance matrix for the words *Hello* and *Holle*. The yellow highlights is the shortest distance between the two words.

The first row contains the string; *Hello*, in the first column contains the second string; *Holle*. The second row and the second column gives the distance for each character to an empty string. This means that if the first string is *Hello* and the second string is nothing, then the distance from nothing to nothing is 0, *H* to nothing is 1, *He* to nothing is 2, *Hel* to nothing is 3 and so on. Every *insertion* for a new character *cost* 1. The same is true for the column with *Holle*.

The pseudo-code for this can be seen in Code E.1, where *d* is a 2D matrix of integers.

Code E.1: Pseudo-code for Levenshtein Distance matrix, step 1

```
1 d[i][0] = i
2 d[0][j] = j
```

When the first row and column has been filled out, another part of the algorithm has to be used. This time there are three ways of finding the shortest distance to the new character.

1. Inserting a value
2. Deleting a value
3. Replacing a value

Both *inserting* and *deleting* a value has a *cost* of 1 whereas *replacing* a value can either have a cost of 1 or 2 or even more if that is needed. For this application the replacement cost is 1. The pseudo-code for this can be seen in Code E.2.

Code E.2: Pseudo-code for Levenshtein Distance matrix, step 2

```
1 d[i-1][j]+1
2 d[i][j-1]+1
3 d[i-1][j-1]+cost
```

```

4 if x[i] == y[j] then cost = 0
5 if x[i] != y[j] then cost = 1

```

Looking at the Table E.1, the result of Line 1 from Code E.2 will be  $1 + 1 = 2$ , Line 2 will be  $1 + 1 = 2$  and Line 3 will be  $0 + 0 = 0$ . This gives us three results, 0, 2, 2, taking the smallest of the three is the distance between the first two letters in the two words. The value 0 is then highlighted in Table E.1.

Taking the next letter *e* from word *Hello* and compute the distance from *H* in *Holle* (see the red highlight in Table E.2) gives the three results;  $2 + 1 = 3$  (yellow and red),  $0 + 1 = 1$  (cyan and red) and  $1 + 1 = 2$  (purple and red). The smallest value is then 1, which means that from *He* to *H* there is a distance of 1.

		H	e	l	l	o
	0	1	2	3	4	5
H	1	0	1	2	3	4
o	2	1	1	2	3	3
l	3	2	2	1	2	3
l	4	3	3	2	1	2
e	5	4	3	3	2	2

Table E.2: Levenshtein Distance matrix for the words *Hello* and *Holle*.

This can be computed for all the characters in the two strings using the code from Code E.3.

Code E.3: Code snippet for Levenshtein Distance matrix.

```

1 for (int i = 1; i <= n; i++) {
2     for (int j = 1; j <= m; j++) {
3         int cost = (t[j-1] == s[i-1])?0:1;
4         d[i][j] = min(min(d[i-1][j]+1,d[i][j-1]+1),d[i-1][j-1]+
5             cost);
6     }
}

```

- Line 1:** Run through the first string where *n* is the string length.
- Line 2:** Run through the second string where *m* is the string length.
- Line 3:** Calculate the cost. If the two characters are identical the cost is 0 else it is 1. *t* is the first string and *s* is the second string.
- Line 4:** Calculate the cost to be placed in the matrix *d*. Find the minimum between *insertion* and *deletion* then check the result against the *replacement* and find the smallest value. The result is stored in *d*.

The final code for the function can be seen in Code E.4.

Code E.4: Code implementing Levenshtein Distance.

```

1 int distanceString(string s, string t) {
2     int n = s.length();
3     int m = t.length();
4     int d[n+1][m+1];
5
6     if (n == 0) {
7         return m;
8     }
}

```



```
9     if (m == 0) {
10         return n;
11     }
12     for (int i = 0; i <= n; i++) {
13         d[i][0] = i;
14     }
15     for (int j = 0; j <= m; j++) {
16         d[0][j] = j;
17     }
18     for (int i = 1; i <= n; i++) {
19         for (int j = 1; j <= m; j++) {
20             int cost = (t[j-1] == s[i-1])?0:1;
21             d[i][j] = min(min(d[i-1][j]+1,d[i][j-1]+1),d[i-1][j-1]+cost);
22         }
23     }
24     return d[n][m];
25 }
```

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