Board Game Accessibility for Persons with Visual Impairment

by

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The above committee determined that the thesis is acceptable in form and content and that a satisfactory knowledge of the field covered by the thesis was demonstrated by the candidate during an oral examination. A signed copy of the Certificate of Approval is available from the School of Graduate and Postdoctoral Studies.

Abstract

Despite the huge popularity and benefits of traditional board games, they present serious accessibility issues to players, particularly those with visual impairments, due to the heavy use of visuals to communicate gameplay information. Limited research investigating the inherent issues present in board game elements and in the potential solutions to these issues has been conducted so far. In this thesis, an in-depth investigation in the field of board game accessibility for those with visual impairment is conducted, investigating three main aspects: i) the inherent accessibility issues of game components and mechanics, ii) the reliability of board game guidelines for the identification of accessibility issues, and iii) the development of a digital assistive technology for board game gameplay. The findings of this thesis are discussed and compiled, in order to provide a general guide regarding the development or adaptation of accessible board games.

Keywords: Board Game, Accessibility, Visual Impairment, Heuristic Evaluation, Assistive Technology

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Chapter 1

Introduction

1.1 Overview

This thesis presents an investigation into guidelines and assistive technologies that improve the accessibility of tangible non-digital board games for persons with visual impairments. While modern board games are gaining in popularity, these styles of games present serious accessibility barriers for those with visual impairments due to the heavy use of visuals alone to communicate gameplay information [1]. Persons with visual impairments, such as those with low vision, color blindness, or blindness, are either completely unable to play these games or face serious accessibility barriers which negatively affects their gaming experience when trying to play. When gameplay is enabled to this audience, it is often through the aid of friends or family assisting the player with impairment by communicating visual information present in components and managing the player's interaction, which hinders participant's enjoyment due to their limited interaction and autonomy with the activity.

Due to publishers lack of awareness or interest, games are still released tailored to the overall audience (i.e., those without impairments) without special concern regarding those with visual impairment, an audience which comprises over 250 million persons worldwide [2, 3]. There is also very limited research currently conducted in the field of board games accessibility, being a pertinent area that

requires further development of solutions and alternatives to make modern board games accessible irrespective of one's visual ability.

This thesis presents the investigation of the current state of board game accessibility for those with visual impairment, conduct an in-depth analysis of the accessibility barriers present within board game mechanics and components, evaluate the reliability of a set of board games' accessibility guidelines developed in past research [4], and document the development of an assistive technology targeted to enable users to play non-accessible board games.

1.2 Introduction

Games have been part of our society for thousands of years. One of the first documented games, Senet, is a two-player game of luck and strategy that dates back to Ancient Egypt before 3,100 BC [5, 6]. Games were initially non-digital and comprised of tangible components such as wood, stone, and later plastic, and often required the presence of multiple players in the same physical environment. The advent of digital technologies has led to a massive transformation (paradigm shift) of games whereby beginning in the 1950s, games have shifted to the digital domain, and currently, the majority of new games are being developed for computers, video game consoles, and mobile devices [7].

Despite the massive popularity of video games, traditional board games (defined here as all non-digital games) have increased in popularity since the release of the commonly called "German-Style games", or Eurogames, in the late 1970s and early 1980s [8]. This genre of games was responsible for introducing new types of themes and gameplay mechanics, distinguishing them from traditional abstract strategy games and other popular mass market games. These new games offered gameplay opportunities that diverged from common tropes found in traditional board games, such as relying mainly on luck, present in games like Snakes and Ladders, or on heavy strategy, found in games like Chess. Eurogames sought to cater to the general audience by providing medium complexity games that

allowed players to make strategical decisions, while avoiding direct conflict between players. Additionally, these games present specific characteristics such as succinct rule books, gameplay mechanics that are directly related to the game's theme, and gameplay systems that are composed of multiple interconnected sub-mechanics [8]. The most important game of the genre, The Settlers of Catan[1], was initially released in 1995 in Germany and obtained huge success in the North American market, consequently setting the scene to the publishing of other titles from this genre. The Settlers of Catan has sold over 25 million copies worldwide, with a film adaptation in the making by Sony Pictures [9].

While originally the majority of these games were designed in European countries (hence the name "Eurogames"), in the past two decades designers from a variety of other countries, such as the United States, Canada, Brazil, China, Korea, and Japan, have been influenced by these games and also contributed with the development of games that share their characteristics. Due to the current globalized nature of these games, they are currently referred by the overall public as Modern Board Games, or Hobby Games [8, 6].

The board game industry is considered to be in its golden age, continuing to grow each year and registering almost $1.2 billion dollars in sales during 2015 just in Canada and the United States alone [10]. These styles of games are ensuring that not only designers, publishers or businesses that sell them thrive, but also new related industries such as Board Game Cafés including the Canadian Snakes and Lattes, where customers are able to enjoy gaming while eating and drinking [11]. Unique board game related words and components have also been recently officially recognized and added to English dictionaries, such as the case of the word "Meeple", a recurrent playing piece in a variety of games [12]. The popularity of these games does not appear to be showing any sign of slowing down, with a constant yearly market growth of over 15% [13], and thousands of new games being designed every year; 2017 alone over 3,700 new games released [14].

[1] https://boardgamegeek.com/boardgame/13/catan

In the past few decades, online board game communities have also emerged, such as the BoardGameGeek website[2], which contains game-specific information, news, and discussion forums, connecting hundreds of thousands of enthusiasts around the world [8]. Board Game conventions, such as the Spiel Essen Game Fair and Gen Con, also attract a increasing number of attendees each year [15].

Aside from fun and enjoyment, playing board games leads to positive and formative contributions to players. More specifically, board games have demonstrated to be an effective tool for improving communication, problem solving and social skills, and to promote effective social interaction between players [16]. Board games are also valuable to the psychological, cognitive and social development of young kids [8]. In addition, it is worth noting that the act of playing board games has a strong emphasis on the socialization of its players, with constant interaction between players that are sharing the same physical environment. In a research conducted with board game players, the majority of participants considered this social aspect of the activity one of its primary sources of enjoyment [8].

Similar to video games, board games have also transcended their status as pure entertainment media, with serious board games designed for purposes such as learning, simulation, training, and raising awareness regarding different topics. For example, the game "CODE: Programming Game Series" teaches young kids basic programming concepts, such as loops and conditionals, through puzzles [17]. Freedom: The Underground Railroad [18] provides an immersive experience that simulates the early history of the United States in the 19th century, where players are part of the abolitionist movement trying to end slavery. The game received an extensive list of awards, praised by how it respectfully dealt with the topic and how the gameplay aligned with content that is usually taught in US schools [19]. The game Meltdown contains game pieces made of ice that melts while playing to promote awareness about global warming and its effects [20].

[2]https://boardgamegeek.com

1.3 Accessibility Barriers and Visual Impairment

Despite their growing popularity and benefits, the act of playing board games is an activity that poses many accessibility barriers for those that have some form of impairment, particularly for those with visual impairments. Board games share similar accessibility issues to those found in video games, as most of their gameplay information is presented exclusively through the use of visuals [1]. However, digital games have the advantage of being able to provide greater flexibility when communicating information, as they can employ sound and they simulate the sense of touch through haptic interfaces-devices, as an alternative to visuals. In board games, not only does the exclusive use of visuals in components present a big accessibility barrier when visualizing information, but also the need for players to physically interact and manipulate real objects during gameplay presents an additional layer of difficulty for those with visual impairment to achieve complete autonomy while playing.

Due to such characteristics, those with visual impairment have severely limited experiences when playing board games, or are completely unable to play them without constant assistance from other participants. According to the World Health Organization (WHO) in 2017, the number of persons with visual impairment was over 250 million people globally, with this number potentially tripling as the world population grows older [2, 3]. Visual impairment is defined as the functional limitation of the visual stimulus that cannot be corrected even with the use of corrective glasses or lenses [21]. There are varying degrees of visual impairment, ranging from blindness (visual acuity of less than 3/60), to low vision (visual acuity of less than 6/18), and conditions related to difficulty in perceiving specific colors or spectrums of colors (i.e, color blindness) [21, 2]. Visual impairments can also be described as the visual limitation that negatively influence one's ability to conduct daily life tasks and activities.

As discussed earlier, the act of playing traditional board games brings valuable contributions to its players, with many of these being particularly important

to people with visual impairment. For example, the improvement of social and communication skills through play of these games is highly beneficial to this group, as persons with visual impairment tend to present a higher level of social isolation and difficulties in interpersonal relationships [22].

It is important to highlight the significance of autonomy for players with visual impairment. Autonomy can be defined as the individual ability to fully conduct activities or tasks irrespective of one's impairment, and it is considered one of the main rights for persons with impairments according to the international Convention on the Rights of Persons with Disabilities [23]. The increased sense of autonomy in a person's daily lives greatly promotes their social interaction, improves quality of life, and personal fulfillment [24]. Although players with visual impairment may be capable of playing some games through the help of others, such as family and friends, the ability to conduct the activity with complete independence is highly important for their enjoyment of it.

In order to promote effective inclusion of participants, designing games that are exclusively played only by persons with visual impairment is not enough, as it prevents interaction with others that do not have visual impairments limiting their social reach. When designing for accessibility those with impairments must be able to engage with the activity in the same manner as those without impairments, making it "equivalently accessible" [25]. Therefore, it is pertinent that accessible games enable gameplay for both those with and without visual impairments to interact in gameplay with any person irrespective of any impairments.

1.4 Board Game Accessibility Approaches

Unfortunately, solutions to games' accessibility for persons with visual impairment is challenging. One of the biggest difficulties to design universally accessible games for this audience relates to the varying degrees of visual impairment that people experience. For example, low vision can include characteristics such as tunnel vision, sensitivity to light, blurred or distorted vision, absence of peripheral vision,

among others. Legally blind persons have a wide variance of visual acuity, and color blindness may refer to individuals that either have difficulty recognizing or are unable to completely visualize specific color spectrums [2, 3, 26, 21].

Therefore, accessibility solutions must account for the specific needs of the individuals, while concurrently allowing gameplay between players with a variety of visual abilities. In order to improve inclusion and benefit the largest number of individuals it is also important to explore solutions that are low cost and with ease of access, to avoid hindering the reach of the selected approach to the main audience.

Potential solutions for board game accessibility often can be categorized into two main areas: a) design modifications of games' components and rules, and b) the use of digital assistive technologies that enable or facilitate play.

1.4.1 Design Modifications

Design modifications of game elements, particularly when carried during the conceptual stages of the development process, often require low financial and time costs as even small decisions such as the use of specific colors, shapes, typographies, patterns, icons, and layout can already thoroughly improve the accessibility of visual elements, and consequently the game itself [27].

This approach requires the assessment of each individual game regarding their specific issues and accessibility barriers in order to carry changes, often resulting in a more optimal solution to its accessibility issues. Although an initial assessment needs to be conducted for each individual game, solutions often are reusable for other games of similar components or mechanics, making future accessibility planning steps for games faster and easier to conduct.

Design modifications often involve improving upon the visualization of game elements so that players that have a low or moderate degree of impairment are able to more easily interact with the game, and sensory substitution, providing an alternative sensorium to communicate information, which in the case of tangible games is often achieved through the use of touch (haptics).

While this approach is generally cost effective, it requires the skills or knowledge regarding visual accessibility in order to properly identify issues and conduct adjustments. Some solutions can be carried to similar games, but these must still be implemented separately for each game, as the exact set of game components are not usually shared between different games. While this does not infer any extra work if done during the initial development of the game, it can be time consuming if conducted retroactively to adapt pre-existing games into becoming accessible.

1.4.2 Digital Assistive Technologies

The second approach, digital assistive technologies, seeks to improve upon board games accessibility in a variety of ways, such as the design of companion applications to enable specific games via automatization, or facilitation of the overall tasks related to playing these games, such as the visualization of game components.

One such promising approach has been the investigation of the use of immersive technologies, that is, technologies of video games, virtual reality (VR), augmented reality (AR), virtual worlds and social networks that have the ability to engage users of all ages, and attract, capture and retain our attention [28]. In recent years, immersive technologies have become more accessible through the release of cheaper headsets (also known as head-mounted displays or HMDs), such as the HTC Vive or Google Glass. The use of such devices has presented potential strategies that can improve accessibility for users with visual impairment, with approaches tackling both vision enhancement [29], which uses image processing to apply different filters in the device's display to improve the visualization of elements, and sensory substitution, such as communicating visuals through the use of audio [30].

Digital assistive technologies may require less responsibility and upfront effort from the players in order to enable board game gameplay, as applications can easily be designed to be compatible with a variety of different games that share similar elements and components. They can help players through moderation of the activity, automatizing parts of gameplay and facilitating information commu-

nication, tasks that would otherwise require constant assistance from a participant without visual impairments or design adjustments. Applications that seek to improve visualization of game components can also be used to easily enable games that would otherwise be too difficult or tiresome to conduct adjustments, such as games with a big variety of unique gaming pieces.

The use of digital assistive technologies also has the upside of allowing easier sharing of solutions between end-users, as applications can be published in online repositories and instantly shared across the internet. Users can also engage into shared efforts into shaping a more complete open-source assistive technology for board gaming.

However, the use of overly general digital assistive applications may not seamlessly provide an optimal accessible gameplay experience, as accessibility solutions designed with consideration to the specificities of each game are able to deliver a better and more polished user experience, without interaction hiccups [31]. The use of complex technologies also limits the reach to which the overall end-user community can participate in the generation of these solutions, as it requires greater technical skills from users.

1.5 What Problem is This Thesis Solving?

Unfortunately, research and development of accessible board games for persons with visual impairment in either aforementioned approaches is still very limited. The majority of games published in the market are not accessible for those with visual impairment, and accessible versions of these are almost non-existent. Given the growth of board games, their importance for the society, and the non inclusivity associated with them, the accessibility of these games is now more pertinent than ever.

This thesis seeks to explore pertinent aspects to board game accessibility that can be used by game designers, publishers, players, and any interested group, with the goal of enabling tangible tabletop board games to be played by partici-

pants irrespective of visual impairments. It is also vital that accessibility solutions preserve players' autonomy and the ability of playing with participants without visual impairments. It is also important to highlight that this thesis seeks to complement and expand upon previously conducted research that has originated with the author's undergraduate thesis, which has already contributed with an initial investigation in the field and currently has a publication currently under review in a peer-reviewed conference.

This thesis contributes with the fields of Accessibility and Human-Computer Interaction (HCI), more specifically in the area of tabletop board games. In addition, some of the strategies discussed in this thesis regarding the communication of visuals to those with visual impairment can also be applicable to the related field of video games. This thesis contributions to improve upon board game accessibility are present in the form of:

1. An in-depth investigation of the accessibility issues present in these games most recurrent mechanics and components;

2. The evaluation of the reliability of board games accessibility guidelines as a tool for the identification of issues present in individual board games;

3. And the exploratory investigation of an assistive technology that seeks to enable or improve board game gameplay to the wide variety of users with visual impairment.

This thesis initially conducts an investigation of the most recurrent accessibility issues present in board games, employing a list of board game accessibility guidelines that have been developed in past research by the author of this thesis [4], in order to identify issues present in recurrent game elements. These issues are organized under two main categories: i) accessibility issues of game components, and ii) accessibility issues of game mechanics. These findings are then compiled into a master list, providing insight on problematic game elements and tasks.

Based on these findings, the guideline list is improved and updated, and a heuristic evaluation of the new guidelines is conducted to test its reliability for the identification of issues present within individual games. These guidelines will provide assistance to those interested in the task of identifying and solving accessibility issues present in these games.

Finally, we explore the initial development of a digital assistive technology prototype that considers the specific context of board game gameplay and its related tasks is conducted. This prototype experiments with both visual enhancement and sensory substitution techniques to facilitate non-accessible board games to be played by those with visual impairment without requiring extensive design modifications to games.

As this thesis seeks to investigate a wide variety of pertinent topics regarding board game accessibility, each chapter discusses the pertinence of its own specific subject, presenting the current research gaps of the topic, methods investigated, and individual contributions. Albeit with different focuses, these topics are intertwined, with the overall discussion of board game accessibility being conducted across different chapters and finally compiled in the final chapter of the thesis. Ultimately, This thesis seeks to drive further academic research in the field, and to act as a guide to aid any interested person to conduct the development or adaptation of board games in order to make them accessible for those with visual impairment.

This thesis is influenced and motivated by the following research questions:

1. What are the inherent accessibility issues present in the genre of traditional tabletop board games for those with visual impairment?

2. What is the reliability of accessibility guidelines in the identification of issues present in board games?

3. How can we design a digital technology that enables players to engage with board game gameplay with ease?

1.6 Thesis Outline

Chapter 2 discusses related work pertinent to board games accessibility. Due to the current limited amount of formal discussion present in the field, the topic is expanded to include accessibility efforts conducted on similar and related fields, such as video games and guidelines accessibility. Related work is organized into different categories based on their approaches and main accessibility focus, with these works being assessed according to their strengths, weaknesses, and the reach of the investigated studies to enable participants with visual impairment to conduct a variety of different tasks and activities. As most of the research is conducted in different fields, many of the approaches are also translated to consider the specificities of board games, in order to create a foundation for the field.

Chapter 3 presents a detailed analysis regarding board games accessibility issues. An analysis of the recurrent games' components and mechanics is conducted using a set of accessibility guidelines as a framework to identify pertinent issues for participants with visual impairment. These findings are then compiled into a comprehensive board game accessibility issues list, presenting the different issues organized into categories, and how they have a negative effect on board games gameplay for different forms of visual impairment. Improvements to the current set of board game accessibility guidelines are also discussed, improving upon the initial list to accommodate new insights from the analysis.

Chapter 4 presents an evaluation of the improved guidelines list to assess its reliability as a tool for the identification of accessibility issues. Two investigators, with varied degrees of expertise regarding accessibility, analyzed separately two board games using the same guidelines list in order to identify all potential accessibility issues present in these games. Their results are then compared to identify the degree of overlap between problems identified.

Chapter 5 presents the exploratory development of a digital assistive technology prototype to facilitate board game gameplay. The chapter presents the development of an image recognition system that is compatible with devices such

as mobile phones, personal computers, and virtual reality headsets, and seeks to enable gameplay of board games through vision enhancement and sensory substitution approaches.

Chapter 6 discusses this thesis findings and summarizes them in the form of a list of pertinent topics when considering overall aspects regarding to the accessibility of board games and their components. This thesis' shortcomings and limitations are also discussed, with future improvements and areas of research being suggested.

1.7 Summary Chapter 1

This chapter presented an overview of the field of board games and its presence in human society, and discussed the current struggles faced by persons with visual impairment in regards to the access to gameplay. Unfortunately, the field presents poor accessibility, particularly to those with visual impairment, as these games heavily rely on the use of visuals alone to communicate important gameplay information. Accessibility efforts in the field are often carried under two main categories: design modifications, with direct changes to game components and its presentation; and digital assistive technologies, with the usage of digital technology, such as sensory substitution, designed to adjust the communication of information to facilitate gameplay. Unfortunately, research conducted in this area is limited in either categories.

This thesis research goals are also presented, which include: i) the in-depth investigation of accessibility issues related to board game mechanics and components, ii) the assessment of the reliability of board game accessibility guidelines, and iii) the investigation of a digital assistive technology prototype that considers the context of board games.

The next chapter provides further context regarding the field of board game accessibility, and, due to the scarcity of efforts in the area, also includes research that has been conducted in related fields, such as video games accessibility.

Chapter 2

Related Work

2.1 Introduction

This chapter explores the related literature pertinent to board game accessibility for persons with visual impairment. Considering that the spurt in popularity and growth of the hobby of board games has only happened in the past few years, there is still extremely limited formal academic research conducted in regards to board games, or more specifically in the area of board games accessibility. The relevance of providing accessible alternatives to engage with this new entertainment hobby together with the absence of proper research conducted in the field reiterates that further research is required.

As the current efforts towards board game accessibility are still insufficient to provide a solid foundation for this research, this literature review was expanded to include research conducted in similar related fields, such as video game accessibility, accessibility guidelines, and digital assistive technologies that support persons with visual impairment.

The goal of this literature review is to provide a better understanding of the different approaches that have been conducted to improve upon the development of accessible designs. The following section (Section 2.2) presents the selection criteria used to collect the different papers that compose this literature review, and how these papers have been organized through this chapter. Sections 2.3, 2.4, 2.5, and

2.6, explore the different categories of papers investigated. Each category presents discussion on different accessibility related works, discussing their strengths and weaknesses, including the feasibility of such approaches when considering that solutions should include diverse conditions related to visual impairment and the likelihood that the overall audience is able to obtain the technologies employed. The final section (Section 2.7) comments on the overall papers explored, presenting a summary of relevant points identified in these works.

2.2 Selection Criteria and Organization

In order to conduct this analysis of literature, academic articles from peer-reviewed conferences and journal databases were selected, and more specifically the ACM Digital Library, Google Scholar and SpringerLink. Articles were selected based on whether they investigated the topic of board games accessibility, particularly those that proposed solutions for the target audience of persons with any type of visual impairment (including low vision, legal blindness and color blindness). In addition, internet forums and websites that discussed board game accessibility were also investigated, such as posts from the BoardGameGeek [32] and the subreddit r/boardgames [33] forums, as the community itself demonstrated to be a huge driving force for the proposal and discussion of accessibility solutions.

Unfortunately, as Woods [8] describes, there is limited formal research done regarding the specific aspects of board games, and even less about board game accessibility. The search conducted was able to identify only one study related to board game accessibility which discussed the inclusion of persons with visual impairments in the aforementioned conferences and journals databases. Considering this limitation, the scope of this literature review was then expanded to include works conducted in areas that share similar characteristics to board games or that propose the use of digital assistive technologies to facilitate tasks that could directly or indirectly facilitate board game gameplay. Although not directly related to board games, these efforts are valuable to provide an initial foundation and veri-

fication of current accessibility methods and approaches, which ultimately provide insight that can be translated to the context of board games gameplay.

This literature review was organized along the following four categories:

i) Accessible Digital Games: The primary interface of interaction of this type of game and its presentation is fairly distinct from traditional board games, as it requires the use of external controllers to manipulate digital avatars and most of the game rules are automatically handled by the video game console, in contrast with a more direct tangible interaction and manual control of the game states. However, digital games share a collection of similar characteristics to board games, such as goals, rules, multiplayer, interactivity with a product and gameplay loop. Both styles of games also share similar use of visual analogies and metaphors to communicate information, such as through the use of specific icons and user interface presentation. As previously commented, digital games also face many of the same accessibility issues present in board games regarding communication of gameplay information, as both types of games heavily employ visuals to communicate a variety of gameplay information to players. This category discusses papers that investigate approaches to enable non-accessible digital games to become playable irrespective of players' visual abilities, and games that were designed from the ground up with the goal of being accessible to both participants with and without visual impairments.

ii) Accessible Board Games: This category investigates the literature directly focused on the aspect of tabletop board game accessibility for persons with visual impairment. As formal research in the topic is still rather limited, the review includes community-driven strategies and recent game publishers efforts to make these games accessible. These efforts range from low-tech design adjustments to digital non-immersive assistive technologies that seek to improve board game accessibility.

iii) Games Accessibility Guidelines: Accessibility guidelines are an effective way of providing a basic structure and guidance on how to identify and handle

accessibility issues. Guideline lists are considered a standard in different fields, as they can provide structured knowledge to assist proper development of products that comply with norms and expectations. In regards to accessibility, guideline lists are able to provide assistance to developers and designers from the start to conduct the development of accessible products, or to evaluate and conduct required design modifications needed to make pre-existing non-accessible products accessible. In the case of video games, considerable progress has been made in regards to accessibility guidelines, with different collections providing support with respect to general games accessibility or about specific genres, technologies and mechanics. Unlike digital games, however, there are currently no comprehensive list of accessibility guidelines specific to board games. In this section, the main collections of digital game accessibility guidelines are explored with the goal of investigating how many of these recommendations can be translated to the domain of tangible board games, and how can they serve as a initial foundation to the potential creation of board games accessibility guidelines.

iv) Immersive Technologies (VR and AR) and Related: As previously commented, immersive technologies are one of the promising accessible technologies to improve visual accessibility due to their current reach in the market and flexibility of features. This category investigates efforts related to visual accessibility when employing technologies such as VR and AR, with or without the use of HMDs. The investigation of immersive systems focus on strategies that improve accessibility through the use of vision enhancement or sensory substitution to communicate information to users. A few non-immersive systems are also investigated, as they make use of similar technologies to communicate information to users with visual impairment. Although most papers discussed in this category are not focused on board games, they present pertinent efforts regarding the use of these technologies in ways to improve visual accessibility to users for a variety of different tasks, which can ultimately provide initial guidance in how the technologies can be developed towards enabling board game gameplay.

In all four different categories, the strengths and weaknesses of the approaches are discussed, including their suitability considering the variety of different visual impairments. The reach of the approaches is also highlighted, or how feasible these solutions are in regards to enabling the general target audience. It is also important to point out that the majority of persons with impairment also live in low-income settings [2], and while there may exist a variety of technologies that are able to effectively enable users to perform tasks such as playing games, some of these technologies can be hardly accessible to the target audience that needs it, due to financial reasons.

In addition to the different academic works investigated, a variety of efforts from publishers of board games and the community that seek to make games more accessible are explored.

2.3 Accessible Digital Games

While the main mechanism of interaction of digital games is different when compared with board games (digital and analog, respectively), these two genres make use of a shared pool of game elements, such as rules, points, themes, metaphors, and most often similar graphical elements, such as icons and the layout of visual elements. When considering the overall topic of game accessibility for persons with visual impairment, the majority of efforts can be found in the digital domain, targeted towards games available for video game consoles, smartphones, and personal computers. While the amount of design and development of accessible digital games is still minimal when compared to the digital gaming industry as a whole, considerable progress has been achieved in the past few years in regards to an overgrowing catalogue of games accessible for persons with visual impairment [34].

The design of games for persons with visual impairment gave rise to the genre of "blind-accessible" games called audio-games, which replace visual feedback with sound and haptics, such as controller vibrations and force feedback, to communicate information. However, access to mainstream games is still rather

scarce, and most accessible games only allow gameplay exclusively between participants that have visual impairments, limiting the possibilities of engagement between players with and without visual impairments. Most research conducted in the field has aimed to close the gap between players with and without visual impairments or to allow access to popular mass-market titles, in order to achieve more effective inclusion and access of this audience to the hobby.

Yuan and Folmer [35] designed the accessible game "Blind Hero", an adapted version of the commercially popular digital rhythm game Guitar Hero, which enabled gameplay for those with visual impairment via use of a custom designed glove capable of providing haptic feedback through small pager motors. Each motor was attached to a finger of the glove, buzzing when users should press buttons corresponding to the gameplay. The game was tested by four participants (two blinds, one blindfolded sighted, and one sighted), with all users being able to play the game, considering it fun, and having a similar level of performance after continuous play.

Gutschmidt et al. [36] developed a hybrid analog-digital adaptation of the puzzle game Sudoku for persons with visual impairment. The approach explored the use of sensory substitution through a tangible haptic display connected to a computer that communicates information to players via touch. The developed prototype, "BrailleDis 9000", is a tactile display containing rows of dots that can be raised or lowered, supporting features such as vibrations or pulsations, and accepting gestures or touch as input. The system was designed to facilitate play by users with visual impairment, allowing them to customize different ways to receive feedback through the tactile display, while at the same time it sought to preserve the game's level of challenge and complexity.

Rector, Bennett and Kientz [37] explored the design of accessible exergames (digital games used for exercise) for persons with visual impairment. They designed a game for yoga learning/practice called "Eyes-Free Yoga", which employs the Microsoft Kinect in order to track players' poses and to provide audible instructions

and feedback to players. The prototype was tested with 16 visually impaired participants, and was considered positive by the majority of them. Although the game was praised, it was unable to simulate a real-world yoga class, given the limitations imposed by the Kinect made it impossible for the system to provide completely accurate feedback for users regarding their poses.

Although the aforementioned studies do not approach traditional board games and their specificities, they provide useful insight regarding the possibility of designing accessible games via sensory substitution. In all studies, the majority of participants reported the ability to experience the intended gaming experience, regardless of their impairment, and that they enjoyed the activity of playing these games even though the original visuals that the developers used to communicate information had been replaced by another modality, such as touch or sound [35, 37]. These studies demonstrate not only the feasibility of translating common visual feedback into other sensory modalities, but also that participants were able to understand the alternate approach with sufficient ease to actively engage with the games with enjoyment and autonomy.

Solutions that employed custom or proprietary technology, such as Gutschmidt's BrailleDis 9000, and Yuan's Haptic Glove, were deemed effective in allowing gameplay for participants with visual impairment. However, these approaches have limited reach to most of the population, as they require the development of complex and often expensive custom devices, and therefore may not be an ideal mass market accessibility approach [38]. The design of an assistive system or game that utilizes a more commonly available technology, such as the Microsoft Kinect in the work of Rector et al. [37], constitutes a more feasible step in the direction of bringing that solution to the general intended audience.

Unfortunately, in most studies there are limited considerations regarding participants that have a lower degree of visual impairment, such as low vision or color blindness, with most solutions only addressing the needs of blind individuals,

even though persons with impairments such as low vision account for the largest share of individuals with some sort of visual impairment [2].

2.4 Accessible Board Games: Community and Industry Efforts

Most of the accessibility efforts to design or adjust board games prominently come from the community of players. Handmade solutions for a variety of popular games are discussed on Internet forums, primarily via the BoardGameGeek website [32]. Users collaboratively and informally discuss approaches on how to enable games for persons with visual impairment, and the state of accessibility in the hobby and popular games. Some pertinent discussion to board games for persons with visual impairment include users sharing their experience on how to play games with players that have some form of visual impairment, without having to adapt these games [39]; and players' personal experiences in playing with those with visual impairment [40]. While most of the information discussed is presented in a very casual and informal manner, with limited analysis or robustness, the various discussions threads from the community are able to highlight the presence of persons with visual impairment within the hobby, and their outcry for more accessible board games.

In addition to the overall discussion regarding accessibility within the hobby, a few users have also conducted initial analysis in regards to accessibility issues found in the games. The user DeFrisco [41] compiled with assistance from the community a list of examples from commercial games to assess the level of colorblind "friendliness" each game has, showing comparison pictures of games' components and how different forms of colorblind audiences perceive them. DeFrisco and other users also discuss different approaches that could be used to enable games that make poor use of colors into becoming accessible for persons with color blindness.

The blind player Eddie Timanus shares his personal experience within the hobby of board games, discussing a variety of approaches explored by himself and

friends when adapting games, physically changing components in order to make them inclusive [42]. Timanus also comments on the pros and cons of different adaptation strategies, and recommends different low-cost tools to conduct the necessary changes to components, such as the use of white glue and velcro.

In recent years, board game publishers have taken the first steps towards making their games more accessible, especially in regards to issues related to color blindness. For example, the first edition of the game Splendor[1] used color alone to represent resources, making the game unplayable to players who could not differentiate the colors depicted in cards. The addition of iconography in the second edition to differentiate each color made the game accessible for this audience. The classic game Uno, published by Mattel, received a colorblind accessible edition via addition of small ColorADD [43] icons to represent the cards' colors, 46 years after the release of its original edition [44]. Nevertheless, publisher initiatives in regards to accessibility are still limited, particularly when considering the amount of non-accessible published games every year.

Other companies, such as 64 OZ Games [45], have approached the development of "toolkits" as a product to allow specific board games to become accessible specifically for blind persons. 64 OZ Games sells kits that employ use of Braille and QR Codes stickers to be attached to game components, communicating written information through touch and audio, respectively.

The constant community discussion regarding board game accessibility helps to gauge overall interest from diverse users in the topic of accessible games, and provides an initial view and understanding regarding the needs and barriers faced by this audience. The recent efforts by board game publishers to improve visual accessibility may be reflective of the growing outcry for solutions by community users. While most solutions from publishers have focused only on the issue of color blindness, these efforts and considerations can be deemed a step in the right direction that can potentially evolve to also account for visual impairments

[1] https://boardgamegeek.com/boardgame/148228/splendor

beyond color blindness. For example, graphic design changes to improve the size and contrast of elements can be highly beneficial to persons with low vision.

Outside the discussions from the community of users or board game publishers, previous formal investigation in regards to board games accessibility has been conducted. The author of this thesis conducted an initial investigation in the development of accessible board game prototypes and board game accessibility guidelines, employing a participatory design approach [4]. Two accessible game prototypes were developed using various design modification strategies to facilitate the visualization of game elements and with complementary haptics feedback for communication of visual information through touch. Four playtest sessions of the prototypes were conducted with seventeen participants, eight of whom have various types of visual impairment. The results indicated that all participants were able to freely engage in board game gameplay with autonomy and competitiveness. The findings contributed to the initial development of a board game accessibility guideline list, providing a list of recommendations and examples to improve the accessibility of board games. The complete guideline list with suggestions is presented in the appendix A, and its usage is further explored in later chapters of this thesis.

Other formal academic contribution can be seen via the work of the website Meeple Like Us, directed by researcher Michael James Heron [46]. The website Meeple Like Us provides "accessibility teardowns": reviews of popular board games in order to assess their level of accessibility for persons with visual, cognitive, and physical impairment. Contributors also comment on barriers for those with communication, emotional and socioeconomic issues. Games analyzed receive an accessibility score on each of these different categories, representing how easily someone with that specific disability would be able to enjoy the game without any adjustments to the game or use of special assistive technology.

Unfortunately, other than the author's prior work, and the work by MeepleLikeUs, which focuses on a variety of different accessibility issues, there's an ab-

sence of formal academic research on the topic of board game accessibility. Although the community brings a plethora of contributions in many different aspects, most of the approaches discussed are still rather primitive: little is discussed regarding the use of digital technologies or more advanced design techniques. There is also no observable "unity" regarding solutions proposed, or the availability of a list of best practices, as the discussions are scattered across multiple different posts and webpages.

2.5 Game Accessibility Guidelines

One of the strategies employed to improve the accessibility of games has been through the development of guidelines that aid developers on the identification of potential accessibility issues, and at the same time also provide solutions to those, enabling the design of games that have lower barriers for those with impairments. As games that account for accessibility at the beginning of the design phase do not require the use of expensive technologies or resources, guidelines have the overall benefit of being a cheap and effective toolkit to guide the development cycle. While ideally guidelines should assist the development of games as early as possible, they can also be used as a checklist in later stages, or as heuristics to evaluate the level of accessibility of a given already published game, in order to carry changes.

For digital games, researchers sought to develop a comprehensive list of accessibility guidelines to become an industry standard, similar to the W3C Web Accessibility guidelines [2]. The "Game Accessibility Guidelines" list [47] is a collaborative living document developed by professionals from the digital game industry and research academics, being one of the prime lists of guidelines on how to enable video games to be more accessible for persons with motor, cognitive, vision, speech and hearing impairments, providing specific examples and details for each guideline. The list is divided into three main categories: i) Basic, with easy to implement solutions and general techniques; ii) Intermediate, requiring some planning, but

[2] https://www.w3.org/standards/webdesign/accessibility

beneficial to all users irrespective of impairments; and iii) Advanced, which present complex adaptations to account for more profound impairments and a more universally accessible design.

Other organizations and researchers have also designed their own sets of recommendations regarding digital games accessibility. Araujo et al. [48] proposed a set of guidelines focused on the development of audio games for persons with visual impairment, addressing the ability to allow effective gameplay between persons with and without impairment. The International Game Developers Association (IGDA) prepared an accessibility report on digital games with statistics derived from surveys to assess the current degree of accessibility in the industry, discussing potential accessibility strategies that can aid with the inclusion process of players[49]. The "Includification" guide [27] discusses the presence of players with impairments in the community and lists different approaches to allow for a better inclusion of those in the hobby of playing digital games. Cheiran and Pimenta [38] grouped and evaluated many of these accessibility guidelines for digital games using content analysis, in order to develop a more concise list, dividing the final list of guidelines in categories based on the W3C: Perceivable, Operable, Understandable and Robust.

There is continuous improvement on recommendations, best practices and guidelines to enable accessible digital games, accounting for different devices and technologies. These approaches help designers and developers during the production phase of games, or even after the release, with accessibility updates being able to quickly be delivered to users at home. Most collections, such as the work of Includification and the IGDA, are not limited to only design and development recommendations, instead they also aim to raise awareness to the overall public and game companies about the topic of games accessibility, providing statistics and information about users with a variety of impairments and their presence in the market.

Unfortunately, with the exception of the suggested guideline list resulting from past research done by myself, similar collections of recommendations, guidelines, or best practices cannot be observed regarding the topic of accessible board games. Although some of the recommendations found in guidelines for digital games could be easily adjusted to fit within the board game context (e.g., proper use of visuals, such as correct use of color, contrast, elements size, etc.), guidelines that discuss the overall digital interaction present in digital games are not as easily translated, such as considerations to adaptive customization or alternative communication systems. Board games also have specificities that require them to be directly addressed, such as the materiality of game components, spatiality, and the stronger social aspect of the activity, with players sharing the same physical surroundings.

The discussion regarding board game accessibility is scarce, and although it can be found in discussion forums, as commented previously, there is still a lack of formal development of lists or guidelines that guide how to tackle the accessibility barriers present in board games.

2.6 Immersive Technologies

The recent release of cheaper and commercially accessible virtual and augmented reality headsets has enabled immersive technologies to reach end-users, and has been investigated as a promising tool to improve accessibility for a variety of impairments. These headsets have the flexibility of being compatible with a variety of devices, and allow for applications that focus on visuals, audio, gestures, haptics, movement, or a combination of them. While at the consumer level the technology has become popular for its use in the gaming industry, researchers have been investigating the development of accessible applications for these systems, and their use as an assistive technology, intended to support persons with impairments by facilitation of specific tasks.

Although there is a lack of studies focused on the use of these technologies for the play of board games, several studies have investigated the use of this technology to improve overall accessibility for persons with visual impairment, enabling users to perform a variety of different tasks. Some of these tasks include the ability to perceive the presence of visual elements, and to visualize details in them, which are pertinent to be discussed as these abilities could potentially enable board game gameplay.

AR and VR technologies for accessibility have been explored mostly throughout two different main approaches: providing visual enhancement, which seeks to improve the visualization of elements; or sensory substitution, which replaces visual feedback with alternate sensory systems, most often audio or touch.

Zhao, Szpiro and Azenkot [31] explored using head-mounted displays (HMDs), such as the Oculus Rift, to enhance the vision of persons with low vision. They devised a video see-through (VST) system called ForeSee, which contained customizable video enhancement methods and display views, and evaluated users experience using the system to conduct daily life tasks. They found that ForeSee was effective for a variety of persons with different types of low vision, with the exception of those that had either a severe degree of impairment or too little impairment. The researchers also noticed that the functionality to mix and customize different enhancements was essential for the system, observing that different enhancements worked better for different types of users and/or tasks.

Zhao et al. [50] sought to discover the ability of persons with low vision to perceive virtual elements using AR smart glasses. They conducted a series of user tests involving participants with low vision using mainstream commercial AR glasses, the Epson Moverio BT-200. The test's tasks sought to assess users' abilities of perceiving the glasses' projected elements (texts, shapes, sizes, contrasts, colors) in two different scenarios: walking, and stationary. They found that low vision participants were able to identify the projected elements, and listed characteristics that made elements easier to be identified, such as: luminance contrast being

better than color contrast; white and yellow colors; thick borders; sans serif fonts; etc.

Maidenbaum et al. [30] explore the use of sensory substitution devices (SSDs) for blind persons in the context of VR environments, in order to discover the possibilities of using this approach for navigational training and the level of immersion experienced by participants within these environments. Blind participants used the SSD EyeMusic device, which converts visual image characteristics (including distance, colors, brightness, etc.), into different sound instruments, in order to conduct different tasks. The results were highly positive, showing that all blind participants were able to effectively complete all required tasks and reported increased level of immersion in the VR environment as tests progressed.

Other related approaches explore the design of systems that use smartphones' cameras and sensors in order to identify and substitute visuals to audio. Kacorri et al. [51] discuss the possibility of developing a personal object recognizer app for persons with visual impairment, removing the need for expensive or crowd-powered alternatives. The authors designed an app for smartphones that allows users to take photos and label different objects, with the app being able to process and identify images using an adapted version of Google's Inception image recognition system. The authors found that the biggest challenge for personal object recognizers is how to ensure that users are able to properly take photos of the objects following the system's instructions, as photo consistency highly affects the system's accuracy. Regardless, the average accuracy observed in tests conducted with blind participants was of 75%, close to sighted participants' accuracy of 96.9%.

Regal et al. [52] explored the inclusion of persons with visual impairment on the activity of brainstorming, by using tangible cards with near field communication (NFC). The system developed, named TalkingCards, sought to allow persons with visual impairment to use these cards in a similar fashion to written cards and post-its that are used during brainstorming sessions, maintaining the

user experience involved with tactile brainstorming methods. The input methods to register information on cards were either speech-to-text or recording audio through a smartphone app. The authors conducted a series of four different user tests to assess the system, and results indicated that all participants considered it useful and easy to use.

Although the studies presented in this category do not directly address the context of board games, many of the investigated approaches provide valuable insights regarding technologies that have the potential to lower or even remove some accessibility barriers for those with visual impairment. For example, systems such as ForeSee aim to provide an overall enhancement of one's vision and, therefore, would improve accessibility of any activity that involves the visual stimuli, including playing games [31]. For a variety of board and card games, gameplay could be enabled by simple identification of cards by users, which could, for example, be quickly achieved through the use of audio. For persons with severe visual impairments, such as those that are legally blind, the use of cameras or sensors, such as the NFC, to identify elements and translate them into different sensory systems constitutes a low-cost approach that has been shown to be effective to communicate information or provide general feedback when conducting tasks [52].

The decision regarding which specific assistive system to be used must consider the task at hand and the specific group of visual impairment to which the technology will be assisting. For example, vision enhancement approaches can be highly beneficial to those affected by conditions of low vision or color blindness, as corrections can be customized and personalized to the user's display, while on the other hand users with severe degrees of impairment may be hardly able to improve their visualization of elements. Sensory substitution may be effective to a more wide range of visual impairments, but may also require an increased amount of training [30], or not be suitable for tasks that involve large quantities of textual information. A hybrid system, which allows for the combination and customization of both approaches may be ideal when exploring these technologies.

It is important to highlight that while vision enhancement or sensory substitution systems can be produced to facilitate a multitude of activities and tasks, assistive technologies when designed considering a specific activity often are able to perform better, providing a more polished and complete accessibility experience, as it takes into consideration different case scenarios pertinents to the activity and its tasks [31]. Developing an assistive technology designed specifically for board game gameplay will contribute to a better and more complete user experience.

2.7 Summary Chapter 2

This chapter investigated the efforts related to board game accessibility and related fields, structured into four different categories. The topic of board game accessibility is unfortunately rarely discussed and explored in academia, lacking in-depth analysis of its different issues and how to solve these issues. The inherent accessibility barriers of the activity for persons with visual impairment prevents a large number of persons worldwide to be involved with the activity that could otherwise wield great benefits to them.

Due to the absence of studies directly related to this field, works from related fields were also investigated, such as those from digital games, immersive technologies, and games accessibility guidelines for those that have visual impairments. While the aspect of accessibility is also a work in progress in these fields, substantial progress has already been achieved in regards to technology, guidelines, techniques and awareness.

Although there is no single silver bullet to improve upon visual accessibility, most studies have focused on investigating either sensory substitution, which relates to communicating visuals through another sensory system, or vision enhancement, which seeks to improve and facilitate the visualization of visual elements. While approaches explored in related fields are mostly focused on digital media devices, they fundamentally seek to solve the same communication prob-

lem present in non-digital board games: the exclusive, or heavy, use of visuals to communicate relevant information.

A variety of different approaches have been investigated and discussed, ranging from low-tech solutions, such as graphic design changes, to heavily technological, such as the use of immersive technologies, image recognition systems and sensors. The results from these studies were discussed in this chapter and aim to shed light on the strengths, weaknesses and reach of different approaches that seek to improve accessibility. Efforts from related fields were analyzed with lens of how they can serve as foundation for similar studies that can be conducted, or technologies that can be employed, when addressing the specificities of board games and its components.

Chapter 3

Investigating Board Games Accessibility Issues

3.1 Introduction

As discussed in Chapter 2 (Related Work), contributions to the field of board game accessibility are still few and far between, with limited formal or academic research being conducted to assess the accessibility issues present in these games. While research conducted in similar fields, such as digital games, can provide initial guidance on overall accessibility strategies, recommendations, and approaches, further work still needs to be carried in regards to the specific characteristics of traditional analog games.

As previously mentioned, this thesis seeks to improve upon the field of board games accessibility for those with visual impairment with the following major main contributions: an in-depth analysis of the different accessibility issues present in board games that may prevent or hinder the gameplay experience of persons with visual impairment; the evaluation of the use of board game accessibility guidelines for the identification of accessibility issues; and the proposal of different accessibility solutions to commonly found issues, through the use of design modifications and assistive technologies.

This chapter focuses on the first contribution of this thesis, the investigation of accessibility issues present in board games, focusing on the issues innate to these games' gameplay mechanisms and game components.

3.2 Persons with Visual Impairment and Accessibility Issues

Some overall accessibility issues for those with visual impairment can be fairly straightforward to identify and solve, many being already widely discussed in accessibility guidelines or standards. One such example is the universal recommendation of avoiding the exclusive use of color to communicate information, as not all persons are able to perceive colors in the same way and the original meaning may be lost if not accompanied by auxiliary elements. However, the diversity of instances of impairments, even within the same overall category, requires the use of different lenses when analyzing any given product in order to perceive potential accessibility barriers to groups of users. For example, low vision includes problems such as tunnel vision, distortion of vision, spots before the eyes, extreme sensitivity to light or glare, absence of peripheral vision, and night blindness, amongst others [26], all of which require different strategies to overcome. In addition to considerations to the varied target audience, in order to fully identify a variety of issues pertaining to a product, it is important to understand and analyze the tasks that are related to the specific use of each product.

As briefly mentioned in Chapter 2, discussion regarding board games accessibility issues, albeit most informally, is already taking place and is specially predominant in community forums. Users conduct analysis of issues present in games and share their personal experiences of playing having a visual impairment, with many suggesting handmade improvements or providing feedback directly to game publishers in hopes that changes can be carried to future printings of the same game or for new games yet to be designed. Among the different analysis of accessibility issues for board games, the website Meeple Like Us [46, 53] stands out

as one of the first and most predominant ventures that seeks to conduct structured accessibility "teardowns" reviews, where popular board games are assessed considering a variety of different impairments, with each analyzed game being compiled into a master list. New reviews are periodically published and added to the master list, becoming an invaluable resource for those with impairments to be able to have an initial assessment whether a given game is playable or not for them.

While the current overall discussion and analysis conducted on the field of board games accessibility demonstrates progress in regards to the diffusion of information of accessibility problems found within the board games hobby, there is still an absence of unity from these collected works to visualize the greater picture of accessibility pertaining the field. Most accessibility analysis conducted by the community and researchers are often done on a game-by-game basis, whereby one specific game is evaluated in its entirety, considering the specific components, mechanics, and tasks, that are pertinent to its gameplay. This approach is often effective to provide an in-depth understanding of the specific game at hand, allowing the investigator to identify and carry any needed accessibility change in order to enable the analyzed game, as demonstrated by the work of Yuan's Blind Hero [35]. While the analysis of one specific game may provide the unsolicited benefit of the insight on strategies to enable similar games that share overlapping elements, a game-by-game analysis is limited to a more specialized view of accessibility to a certain family of games, rather than a wider general view of the issues found in this genre of games. Although the specialized understanding of specific game issues is not negative by any means, there is an absence and need for a more general view of the core board game elements.

It is important to note that, in contrast to digital games, board games currently do not have accessibility standards or guidelines to assist designers and publishers through the development of more accessible games, or to provide an overall view of the different issues. Such collection can provide an initial foundation

and unity, allowing interested individuals to be able to identify recurrent aspects that require proper attention when developing accessible games.

3.3 Scope of Accessibility Analysis

It is based on the aforementioned needs that an analysis and documentation of board game accessibility issues is conducted, considering the wide variety of board games and their elements. This analysis seeks to generate a master accessibility issues list, organized by the two core aspects pertinent to every game: game mechanics, the set of rules that guide the gameplay interactions and goals; and game components, which in the case of board games stands for the game pieces present within the game box which players use alongside the game rules in order to effectively play the game.

Historically, the development of board games has initially followed a limited manifestation of mechanisms and game components. Ancient classic abstract strategy games such as Chess, Checkers, Go, Senet, the Royal Game of Ur, among others, all commonly present a similar game structure, often employing a simple game board in which player pieces are positioned across a predetermined grid. Although game rules vary slightly among these games, the overall look and tasks related to these games have been similar, with players taking turns into moving pieces along the grid. In the 20th century, toy companies, such as Hasbro, were responsible for the initial return of board games, bringing mass market games to the general audience, such as Monopoly and The Game of Life [8, 6]. While different from original abstract strategy games, these games also presented limited variation in their game rules and components, with a predominant focus on dice rolling accompanied by moving pieces through a path present in the board. However, these scenarios have drastically changed since the release and predominance of modern board games. Board games have since then become more akin to video games, whereby designers constantly experiment with different gameplay mechan-

ics, rules, interactions, and themes, often revisiting and providing new twists to those.

Board games nowadays provide a wide variety of game mechanics and complexities, catering to a much larger audience. Some examples include: cooperative games, where players have to work together in order to solve a set of different goals; real-time games, in contrast to the traditional turn based action; games that require users to write or draw; among many others. Not only a wide variety of gameplay mechanics are being explored, but also different and unique board game components are being experimented, with games ranging from the use of traditional board, cards, and pawns, to companion digital devices that are required to allow play.

In order to gather more information of the different game mechanics and components, the BoardGameGeek (BGG) database website[1] was investigated. The BGG website, released in 2000, is the principal international database for board games, containing over 90 thousand unique games being organized each with their own information page, gallery, and discussion forums. The website gathered more than 4 million monthly unique visitors throughout 2015, with over 400 thousand registered members [8, 54]. The website presents a comprehensive collection of published games, and a crowd-sourcing model, similar to Wikipedia, in which end-users are able to shape the website by providing additional content, such as new entries of games or supporting additional material in the form of pictures and videos. The large collection of games present in the website are categorized based on different features, such as release date, mechanics, rating score, genre, among others, allowing for advanced search using different filters.

[1] https://boardgamegeek.com/

3.4 Selection Criteria

Considering the size and scope of this thesis, a selection criteria was devised to determine the choice of both game mechanics and game components to be analyzed in regards to their accessibility issues.

3.4.1 Game Mechanics

The game mechanics category page at the BGG website presents an overall categorization of core mechanics divided into 51 categories. Figure 3.1 shows the complete list of game mechanics as of August 2018. The sheer variety of unique game mechanics makes analyzing accessibility issues present in the core elements of all mechanics a lengthy and daunting task. Therefore, for the purposes of this thesis work the analysis focused on the accommodation of only the most popular game mechanics, as accessibility recommendations to those will potentially aggregate more immediate benefits, enabling persons with visual impairment to engage and play the same family of games that the general player community is currently playing.

The BGG website database was used to assist in the identification of the most recurrent board game mechanics, collecting data pertaining to each individual 51 core board game mechanics, and the corresponding games that make use of them. For each category of game mechanics, the following data was collected:

- The total number of games published that employ the specific mechanic, in order to gauge overall presence in the market.
- The total number of owned games that employ the specific mechanic, in order to gauge consumer ownership and popularity of games.

In order to collect this data from the website, a Python script [55] was modified to parse the data pertinent for this analysis. The script employs a Python API [56] that connects with the official XML API provided by the BGG website [57, 58]. The Python script was configured to parse the entire database of games,

Acting	Action / Movement Programming
Action Point Allowance System	Area Control / Area Influence
Area Enclosure	Area Movement
Area-Impulse	Auction/Bidding
Betting/Wagering	Campaign / Battle Card Driven
Card Drafting	Chit-Pull System
Commodity Speculation	Cooperative Play
Crayon Rail System	Deck / Pool Building
Dice Rolling	Grid Movement
Hand Management	Hex-and-Counter
Line Drawing	Memory
Modular Board	Paper-and-Pencil
Partnerships	Pattern Building
Pattern Recognition	Pick-up and Deliver
Player Elimination	Point to Point Movement
Press Your Luck	Rock-Paper-Scissors
Role Playing	Roll / Spin and Move
Route/Network Building	Secret Unit Deployment
Set Collection	Simulation
Simultaneous Action Selection	Singing
Stock Holding	Storytelling
Take That	Tile Placement
Time Track	Trading
Trick-taking	Variable Phase Order
Variable Player Powers	Voting
Worker Placement	

Figure 3.1: List of Board Game Mechanics on the BoardGameGeek database.

writing data about each individual game from the website into a .CSV file. The collected file contains 89999 games from the database, with information about each game's genre, mechanics, and quantity of users that own the game.

Before assessing the mechanics' popularity based on the data collected, each of the individual 51 core mechanics was analyzed, researching their innate gameplay elements and tasks to check for:

- Overlap: Some of the mechanics have revealed to be subsets of other mechanics. For example, "Roll and move" and "Dice Rolling" are presented as different categories, when the first is just one of the approaches when implementing the latter. While these subsets of mechanics have their own individuality in the original list as different categories due to their recurrent use in a variety of games, these mechanics seemingly present the same task related features and components.

- Non-visual related: Some of the observed mechanics have a complementary nature, with their usage requiring another principal mechanic, and not presenting specific game related tasks that require the use of visuals innate to them. These are in a sense overly generic, and could be considered specific features present in games that do not change the overall interaction used in the game. For example, "Cooperative Play" or "Player Elimination" are mechanics that influence users' end goal, but these by themselves do not dictate specific interactions or visual-related tasks to which these games follow. Some mechanics involve the need for other senses, such as "Singing", but those are outside of the scope of this current work.

Mechanics that presented overlap were aggregated together into individual categories, as this analysis seeks to investigate the most general and core elements present in these mechanics. In addition, categories of mechanics were excluded if they did not infer the specific use of components, interactions, or tasks that require players to use or identify visual elements, as those already present an overall accessible nature to those with visual impairment. Eleven game mechanics were then merged into other similar, more general mechanics, and twenty-four were excluded from the master list due to non-visual related tasks and components, bringing the total number of unique game mechanics to sixteen. Individual lists were created for the remaining sixteen game mechanics, incorporating on each list all games that presented that specific mechanic. It is important to point out that most games from the database had multiple mechanics associated to them, rather than

a single one. These games were included in multiple listings simultaneously, as analyzing each individual game to identify which given mechanic is predominant, if any, is unfeasible due to the large amount of games. For each list, the total number of published games and the total combined quantity of games owned by users are compiled. The aforementioned data collected is sufficient to provide a general overview of mechanics popularity and presence for the purposes of this study. The mechanics where ranked based on the number of games owned, selecting the five mechanics with the highest ownership to carry out the accessibility analysis. Table 3.1 presents a summary of the selected mechanics.

Mechanic	Num. User ownership
Hand Management	12,487,185
Dice Rolling	8,965,493
Area Movement	5,606,565
Auction/Bidding	4,635,455
Tile Placement	3,182,699

Table 3.1: Board game mechanics ranked according to the number of unique users that own games with the specified mechanics on BoardGameGeek.

3.4.2 Game Components

Game components, also known as the playing pieces, are a fundamental interface for which players are able to interact with the game, its sets of mechanics, rules, and the other players. In contrast to mechanics, there is currently no categorization for board game components in the BGG database. In order to select the most recurrent game components, an initial list of components was compiled based on their presence on the most popular games from each of the previously mentioned popular game mechanics. A selection of the ten most popular games from the final list of each of the game mechanics discussed in the previous section (refer to Table 3.1) was carried out to analyze their accompanying components. A total of 34 games were selected, as some games were present in multiple mechanics lists. In each of the selected games, it was investigated: i) its rulebook, a form of

product user manual; and ii) its BGG game page; in order to identify the game' components, their function, and overall usage. The game components were then categorized based on their form and function, with closely related pieces grouped together despite minor differences, such as aesthetics. Table 3.2 presents the final list of selected components for the accessibility review, including the number of times the pieces were present across the different games.

Game components	Presence in selected games
Rulebook	34
Cards	28
Game Board	25
Pawns / Miniatures	22
Tiles	18
Dice	13
Cubes / Resources	10

Table 3.2: Board game components ranked according to the number of games that contain the specified components.

3.5 Accessibility Analysis Methodology

Table 3.1 and 3.2 present the overall list of mechanics and components selected for the focus of the accessibility analysis, which seeks to identify innate accessibility issues present in these elements to players with visual impairment which can hinder or prevent gameplay of this audience. As previously mentioned, the variety of components and mechanics present in the genre of board games goes well beyond the ones discussed in this list. However, the selected list is reflective of popular and recurrent elements within the hobby of board games, and that the analysis of those will yield broad, and immediate, accessibility contributions to the field as a whole.

The heuristics evaluation methodology [59, 60] was selected for the accessibility analysis of these game elements. The heuristics evaluation methodology traditionally consists on the use of guidelines or heuristics by a number of investigators to identify issues present in a variety of systems and products. The

investigators carrying the evaluation can be stakeholders, such as the product developers and consumers, or experts from the field. Investigators refer to guidelines and heuristics in order to focus on specific features from the application, but may also use their own expertise as a complementary factor when conducting the evaluation. The heuristic evaluation provides a series of benefits, including not requiring user testing with participants, being effective for the identification of major issues present within a product, can be conducted on early prototypes, and do not require the use of a multitude of investigators to generate results [61, 62].

The heuristics evaluation was conducted by the author of this thesis, assessing each of the selected game mechanics and components considering their core characteristics and tasks related to their use. As discussed in the related work chapter, the author of this thesis previously designed a list of board game accessibility guidelines [4], which was proposed as part of his undergraduate thesis. This list of guidelines was selected as the heuristics list to guide the evaluation, presenting important board game themes and related aspects to which the selected game elements were assessed. These guidelines present the ongoing effort of providing an initial guidance for the improvement of the overall accessibility of board games, being developed through the combination of pertinent accessibility guidelines from related fields and the collected qualitative data of players' needs, experiences, and feedbacks, before and after playtesting accessible board game prototypes. Table 3.3 presents a short summary of the guidelines, and appendix A presents an excerpt of the author's past research with the description of individual guidelines and its applications.

As suggested by the heuristics evaluation methodology, the evaluator was free to discuss findings based on his own expertise of the field, and to highlight issues that were related to specific guidelines.

The procedure for the analysis of accessibility issues present in game mechanics and components involved the following steps:

Tactile Feedback
TF1 - Use tactile patterns to delimit, identify, or describe components
TF2 - Use pieces with different physical forms to represent different resources or player ownership
TF3 - Use tactile patterns to differentiate pieces that must preserve their original form
TF4 - Use storage compartments to keep components organized on the play area
TF5 - Fix game components to prevent accidental moving
TF6 - Use Braille for identification and description of game components
Color and Contrast
CC1 - Avoid using color alone to convey meaning
CC2 - Prioritize the use of color blind friendly palettes
CC3 - Use highly contrasted colors
Information Design
ID1 - Use fonts with larger size and higher readability
ID2 - Enlarge game components whose size does not directly influence gameplay
ID3 - Re-write text to make it concise and/or employ keywords and tags
ID4 - Highlight important graphical elements related to gameplay
ID5 - Use iconography complementary to text
Game Rules
GR1 - Provide accessible rulebooks
GR2 - Provide audible feedback about actions performed by players and changes on game state
Assistive Technologies
AT1 - Use assistive technologies to identify and read aloud game elements
AT2 - Translate game components and/or analog actions to accessible digital apps

Table 3.3: Tomé et al. board game accessibility guidelines

- A careful research of the myriad of visual impairments and their characteristics, in order to understand the variety of players' visual ability;
- The investigation of overall board games' mechanisms and components, breaking them down into their core functions and the tasks involved with their utilization.

- The application of the guideline list in order to identify core issues related to the standard tasks and aspects often found within these elements.

In the following section, overall information about each of the analyzed categories is presented, with a detailed discussion about the findings. Subsequent to the analysis of these elements, the usage of the guidelines list is discussed, and improvements to the list are carried out to reflect the findings that arise as result of the evaluation, incorporating newly observed pertinent aspects to the accessibility of board games. At the end of this chapter, the updated guideline list is presented along with the summary of all accessibility issues found when conducting the evaluation.

3.6 Analysis of Board Game Accessibility Issues

This section presents the findings of the accessibility analysis of the selected game mechanics and components. A brief explanation is provided, including the main characteristics of the analyzed game elements and popular games that employ such elements, followed by the potential accessibility issues or limitations present in these game elements considering the broad audience of individuals that have low vision, color blindness, or are legally blind. A summary of the findings of the analysis is presented at the end of this chapter. Each selected game element and their assessment is presented in no particular order.

It is important to highlight that some game components and mechanics go hand in hand, and are quite impractical to dissociate. For example, dice is, by definition, a fundamental and always utilized component in games that employ the dice rolling mechanism. The same can be said for tiles in tile placement games. In these scenarios, these elements were grouped together within the same section, assessing both elements and their relationship together. It is also important to point out that not every game that employs a particular component will necessarily employ a specific game mechanic related to that component. For example, while all dice rolling games employ dice as a component, not all games that use dice employ

it with a dice rolling mechanism, as this component can be used as a numerical tracker of information in the game, among other fringe utilizations. Overall, the analysis of the accessibility issues of mechanics and components was conducted considering the wide diversity of their utilization, presenting considerations based on their general or specific uses.

3.6.1 Dice Rolling

Definition

Dice rolling, as the name suggests, is a game mechanism that employs the use of dice as a component that produces a random outcome, often this outcome being a random number within an expected range. Dice rolling is one of the most common and oldest game mechanisms, being present in both Senet and the Royal Game Of Ur, two of the oldest known board games. While the standard dice presents a cubic shape, with sides numbered from one to six, there are a variety of other dice made with polyhedral shapes to accommodate more diverse number ranges. One such dice is the icosahedron dice, with twenty sides, which is commonly used in traditional roleplaying games as it allows more diverse, and flexible, outcomes from rolls due to its number range often represented from one to twenty-one.

As previously mentioned, the submechanic of dice rolling games, "roll and move", was particularly predominant in mass-market games, due to the popularity of games such as Monopoly, by the company Hasbro [8, 6]. The roll and move mechanic was often the major game mechanism in those games, and involved the movement of player pieces a random number of spaces in a board according to the results of the dice roll. Nowadays, dice rolling incorporates a wider variety of tasks, and can be found as a major game mechanic, or complementary to other game mechanics. Dice have also been used for alternative tasks to rolling, such as tracking game progressions (e.g. number of rounds left) and variable elements (e.g. resources cost). Popular games that incorporate dice and dice rolling includes the

renowned trading game Catan, the yahtzee-style King of Tokyo, and the territory building The Castles of Burgundy.

Task Assessment

The common tasks involved with dice rolling during board game gameplay often require players to: i) identify specific dice within or near the play area, ii) collect and hold a given number of them, iii) throw, or drop, them into the play area, and iv) be able to visualize the outcome of the rolled dice. Slight variations exist depending on the game, which may alter some, or all, of these steps. For example, In some games players collect dice from a hidden compartment, such as bag, and are not able to identify them prior to rolling; or require the use of complementary devices to roll the dice, such as the Dice Tower, a structure with bumps that influences the rolling of the dice; or may be required to throw the dice following specific rules, or targeting specific regions in the playing area, adding dexterity skills to the task. When using dice as a tracker of other game elements, players are required to constantly identify the current dice value, and carry any required changes regarding its positioning based on changes of the game state.

Accessibility Issues

The dice rolling mechanic presents potential accessibility issues in three of the four aforementioned common tasks related to this mechanic.

The first task, identifying specific dice in the play area, presents accessibility issues especially when multiple dice of the same shape are treated as different game elements, presenting only minor visual differences. This is most common in games which dice of the same shape presents different value on their sides, and games in which players have ownership over specific dice sets, with these sets presenting small visual differences to set them apart. In these games, color is commonly used as the element to group and differentiate dice. Unfortunately, using color alone to communicate information is often problematic, as the information can be lost to those that are not able to properly visualize it, such as persons with color blindness.

Employing the same shape to represent different groups of dice also hinders the possibility of identifying this distinction through touch. Dice found in games are also often small in size, with the common size measuring only 16 mm for each side. This small size can further difficult the identification of the element for those that are not able to visualize details present in small objects. These issues relate with guidelines CC1 and CC2, which suggest that color should be avoided as the sole element to convey meaning, and recommends that color blind friendly palettes be used to improve the game experience for persons with color blindness; guidelines TF1, TF2, TF3, and TF6, which suggests a variety of approaches in regards to re-shaping, or adding tactile patterns, for the identification of the object; and with guideline ID2, which recommends enlarging components to make them easier to visualize and to create distinction based on size.

This task may also pose small issues in regards to the identification of the position of the object in the game area. This issue relates with guideline TF4, which suggests storage compartments for the game components, which can assist players to identify the location of the intended object.

The second task, collecting and holding a number of dice, do not present any inherent accessibility issues, as it directly relates with the first task, and players should be able to collect and hold dice as long they can be localized in the play area and identified in regards to its characteristics.

The third task, throw or drop the collected dice, present varied degrees of issues, depending on the defined set of rules of each game in regards to how this task is carried. Most commonly, the throw of the dice does not require players to account for specific regions of the play area, as long as it is dropped into an unobstructed region. Minor issues can occur, especially to players who are blind, when trying to identify a region in the play area to conduct the dice roll, as the rolling should preserve the positioning of the other game elements. Irrespective of a player's visual ability, dice when thrown may accidentally fall off the playing area, and the retrieval task may be lengthy or bothersome, hindering the players

experience. These issues relates with guideline TF4, which suggests compartments for organization of the overall game components, which may include a distinct region to carry out the dice rolling task and to minimize related problems. In the case of game rules that require players to aim their throws towards or into specific positions of the playing area, the playing area requires elements to provide players the ability to fully locate and identify the target position prior to realizing the throw, in order to preserve the intended game experience.

The fourth task, visualizing the outcome of the roll, presents many of the same issues found in the first task. This task, however, also requires players to be able to identify the outcome of the roll, which is presented in the opposite face of the resting side. This presents accessibility implications to players that require to use haptics to be able to identify information. While standard dice commonly presents a degree of tactile feedback in the form of pips with high- or low-relief, players may unknowingly influence the dice result when physically interacting with it. In addition, identifying the outcome of multiple dice may be a lengthy task for games that require large amounts of dice to be simultaneously rolled.

3.6.2 Hand Management

Definition

Despite the name, hand management refers to the majority of games that are broadly defined as card games. In this mechanic, players have individual collections of cards, often secretly held in hand, and are required to strategically evaluate their use according to the current game state in order to achieve specific game goals. Hand management is a prominent game mechanism for games that use cards as a relevant game component. It is employed in a multitude of board and card games, being incorporated as the main or complementary element in a variety of game genres and mechanisms, such as trick-taking, card drafting, deck building, among others. Popular games that incorporate this mechanic includes the cooperative Pandemic, the deck-building Dominion, and the drafting game 7 Wonders.

The hand management mechanic has a direct connection with the game component cards, as it is the core element used by the mechanism to carry its tasks. Cards, also known as playing cards, often have a simple design, commonly being card stock paper with standard size and shape, and printed visual information on it. A collection of cards grouped together is known as a "deck" of cards, and a multitude of games uses cards as their only component to enable gameplay.

Task Assessment

Although the overall gameplay and use of the cards heavily varies depending on the game's goal, this mechanism often involves three main tasks: i) the identification of cards and their content, ii) the acquisition of new cards, and iii) the play, or disposal, of previously owned cards into the playing area. The hand management mechanism also incorporates a notorious sub-mechanic widely present in modern games: card drafting. Card drafting presents a specific approach for the task of acquiring new cards, emphasizing on giving players more control over their acquisition. Players investigate a limited common pool of cards and strategically decide which they want to acquire, in contrast with the random draw from a face-down deck of cards.

Accessibility Issues

Each of the three previously mentioned main tasks presents potential accessibility issues to players that can provide annoyance during gameplay or completely hinder their ability to engage with the game. The first task, card identification, is directly related to the game component of cards itself. Unfortunately, traditional playing cards pose serious accessibility barriers for gameplay, as almost the entire information communicated by the physical object is represented through the visuals printed on the cards. Cards have little to no tangible aspects innate to them, and these are hardly used to communicate gameplay information. For persons that can't see, cards are completely non-accessible, as any visual meaning will be lost and can't be reached through other sensory system. This issue relates

with guidelines TF1, TF2, and TF6, which suggest different tactile approaches to be used as a complementary non-visual form of communicating the content of the object.

Card identification can also be difficult for persons with low vision in a game-by-game basis, depending on card size and layout design. Most cards present in board games follow the two most common industry standards for playing cards: the wide "poker" size, which consists of 63.5 mm by 88.9 mm, and the narrow "bridge" size, which consists of 56 mm by 88.9 mm. Identification of visual elements present in these cards can be potentially troublesome when games present a poor user interface, high load of information, or small visual elements, such as icons and text. This issue relates with guidelines from the "Information Design" category, which suggests enlarging the physical component, the visual information presented on it, and prioritization of the relevant gameplay elements.

The second task, card acquisition, relates to the necessary steps to how players are able to acquire new cards to their hand. Games which cards are randomly obtained, such as drawing from a bag or deck of cards, do not pose serious accessibility issues as long as the source of cards can be physically interacted with, and is visually identifiable, avoiding being confused with other game components. Games which employ decision making when acquiring new cards, such as drafting, require that cards be easily identifiable, directly relating to the accessibility issues of the first mechanism task. In addition, games that employ spatiality in the card acquisition process, such as Century Spice Road[2], which limit player options based on the specific position of cards, may present issues with non-intended repositioning of cards by players when handling them, especially via those that may require direct touch in order to identify the card's content. This issue relates with guideline TF4 and TF5, which discusses using storages and fixing components in place to prevent accidental movements.

[2]https://boardgamegeek.com/boardgame/209685/century-spice-road

The third task, play or disposal of cards, relates to how users carry out the action of revealing a card from their hand, and the posterior positioning of it following specific placement rules. The action of revealing a card when playing demands that not only the individual owner of the card be able to identify it, but also the other involved players, in order for them to account for changes in the game state. It is important to point out that the identification of the revealed card should not be a laborious task to the other players. While a universally accessible card may allow the identification of its contents by all players, if the task of identifying revealed cards is complex or lengthy, it may hinder the intended user experience for games that require it to be frequently performed. The action of positioning the card requires players to be able to identify the intended card's target location. In some games, cards when played need to be gathered into a collective pile, often referenced as the "discard pile", while in other games players have their own personal boards or regions in which the card should be allocated. In either use cases, the target location should be easily identifiable by players and are required to support the collection of these cards, preserving any additional spatiality that may be required when performing the action (e.g.: positioning the card sideways or face-down). Issues may arise if cards played are not disposed correctly, as they may be accidentally mixed with other game elements across the playing area. This issue relates to guideline TF4, which discusses organizing the play area with compartments to properly collect components, and with guidelines TF1 and ID4, which recommend non-visual strategies or highlighting important gameplay elements, for easier identification of the intended element destination.

3.6.3 Tile Placement

Definition

This mechanic has a direct connection with the game component tiles, being the core element that guides gameplay. Games that employ the tile placement mechanism, also known as tile laying or tile-based games, require players to strategically

position tiles following grouping rules in order to achieve game goals. Traditional tile placement games include games such as Dominoes and Mahjong. The tile placement mechanism features a considerable degree of spatiality, as tiles are organically arranged in the play area during gameplay, rather than in a standard default manner, with players seeking to acquire rewards by placement of tiles often through the connectivity between adjacent tiles, or the creation of clusters. This spatiality is often employed in two main approaches: i) boardless, with placement happening free-form in the play area, starting from an initial point or tile, or ii) constrained, with auxiliary boards and grids defining possible placement fields. Popular games that incorporate the tile placement mechanism include the area control Carcassonne, the abstract strategy Patchwork, and the grid movement Takenoko.

Task Assessment

The common tasks involved with tile placement during gameplay often require players to: i) identify the tiles content, be it ones individually owned by players or that have been placed in the playing area, ii) identify tiles' positions in the play area and the available placement options, and iii) be able to play a tile in an intended target position.

Accessibility Issues

The tile placement mechanic presents potential accessibility issues in two of the three aforementioned common tasks related to this mechanic.

The first task, identifying tiles' content, presents a variety of accessibility issues to players due to the tiles' size, shape, and the spatiality required during gameplay. Games that use small tile pieces provide increased difficulty for the visualization of the tiles' content, being especially troublesome for players with decreased visual acuity, as there is limited space available within the tile to display visual information. While this issue is recurrent for a variety of game components when devised in a small size, it is greatly enhanced when considering tiles, as these

components often lack other tangible or visual identifiers, with all tiles presenting the same shape and size. In addition, the use of the same shape and size for different pieces makes these components not accessible for those that require the use of touch to identify the game elements. These issues relate with guidelines TF1, TF3, and TF6, which suggest different tactile approaches to provide additional haptics feedback complementary to visuals, and guidelines ID2, which recommends enlarging game components to improve upon visualization of the elements. It is also important to highlight that tiles' shape and size are commonly used in direct relationship with gameplay aspects, often delimiting how pieces connect to each other, the space they occupy, among other factors. In such games, these components also present limitation in regards to physical changes and alterations that can be done. This presents an additional layer of complexity when considering accessibility adaptation approaches for these elements, and require in-depth consideration for each game specific rules, if intended to preserve the original gameplay experience. This issue relates specifically with guideline TF3, which suggests tactile patterns to differentiate pieces that must preserve their original form.

The identification of tiles also presents additional obstacles due to the spatial use of these components during gameplay. This process can be inconvenient for players that require the use of touch to perceive information, as there is an increased importance in regards to preserving the correct positioning of tiles in the playing area. Players need to be able to touch and identify tiles without accidentally altering their original positions, as this directly influences core gameplay aspects. This issue also requires special consideration based on the tile placement approach utilized by the game, as boardless games lack the use of specific grids or boards to define placement restrictions, while constrained games present well defined regions where tiles can be allocated. This issue relates with guideline TF5, which suggests the fixing of game components to prevent accidental movement.

The second task, identifying tile position and placement options, requires players to be able to perceive the collection of tiles that have been played, and

to visualize the different available placements based on these tiles. This poses different considerations and barriers depending on the approach used by the game for tile positioning.

Games that present pre-established constraints for placement often make use of boards with grids or delimited regions in which tiles can be located. In these games, players must be able to clearly identify the borders between different regions, and to understand the delimited space that composes a single region. The use of low contrastant colors, background pictures, or thin lines to delimit such regions, can result in frustration to players seeking to discern the individual grid spaces during the assessment of the different placement options. This issue relates with guidelines CC3, which suggests highly contrasted colors, and guidelines ID4, that recommends highlighting important graphical elements related to gameplay. These boards often employ heavy use of visuals to communicate the information regarding the different areas, often completely lacking tangible feedback, and as a result are completely non-accessible to participants that need to employ touch in order to identify the placement options available. This issue relates with guidelines TF1 and TF6, which suggest varied tactile approaches in order to delimit and communicate elements of game components.

In regards to boardless games, these present accessibility issues in a game-by-game casis, depending on game rules. In a multitude of such games, placement options are delimited based on a starting point in the playing area, where an initial tile is located and further placement expansion grows adjacently from previously played tiles. In these games, all tiles in the play area are connected from at least one side, and, consequently, players should be able to identify all possible placement options as long as they are able to perceive at least one individual tile placement. In these cases, issues in this task are directly related to the accessibility of the first task, being identifying tiles. In other games, however, players are able to emerge from multiple non-connected points, or posterior removal of played tiles can create islands. In these games, players that rely on touch to visualize elements may face

frustration when trying to identify all tiles previously positioned in the playing area and the available placement options, as there is no grid or board to cover the range of positions to which tiles may be.

The third task, playing a tile in an intended target position, is directly related with the first two tasks, being able to identify tiles content, their position, and available placement options, and does not pose inherent accessibility issues, as players should be able to conduct this task as long as the first two are made accessible.

3.6.4 Area Movement

Definition

The area movement mechanic refers to games where the spatial positioning of pieces in the playing area is considered for gameplay aspects, and players are able to carry actions to move these pieces from one specific area, or region, of the playing area to another. The areas allowed for movement are often represented in a game board, with visual representations of the different regions and their divisions. One recurrent form of representation of this mechanic is the depiction of a map with different regions, such as countries or cities, where players are able to move their pieces through neighboring areas and connections. Other specific recurrent representations of area movement include: point-to-point movement, which presents a series of dots connected through lines, where players can only move through these connections; and grid movement, where the entire board is uniformly divided by a grid formed by a geometrical shape, such as squares or hexes, often commonly present in traditional abstract strategy games, like Chess. Popular games that incorporate the area movement mechanism include the area control Small World, the cooperative Forbidden Island, and the abstract strategy Hive.

Task Assessment

While the movement rules of the individual pieces slightly differs from game to game, this mechanism involves three main tasks: i) the identification of players' pieces and their position on the game board, often requiring players to perceive the relative position of their pieces in comparison with other game elements, ii) the identification of the distinct areas within the board, considering any movement restrictions and iii) to physically carry the action of moving game pieces from one location of the playing area to another.

Accessibility Issues

The area movement mechanic presents potential accessibility issues in two of the three aforementioned common tasks related to this mechanic.

The first task, identifying player pieces and their position, is completely dependent on the game's components used to represent each player, as this mechanism is general and does not dictate the use of specific pieces. It is important to note, however, that the majority of games in this genre employs sets of components to each player with almost identical characteristics, with these only being distinct from each other through minor visual differences, such as the use of color. For example, the mass market game Risk uses army miniatures to represent players, which are scattered across a map depiction of the world. These miniatures present the same haptic characteristics irrespective of player ownership, including shape and size, and can only be differentiated through observation of their colors. This identification issue of components that present similar appearance is specially enhanced in these games, as pieces from different players are often mixed and gathered into close proximity, providing an additional layer of difficulty in regards to strategies in how to differentiate them. This issue affects players that are unable, or have difficulty, visualizing the entire game piece or its coloring. This issue relates with guideline TF2, which suggests that pieces have different forms to

represent player ownership, and with guideline CC1, which recommends avoiding the use of color alone to convey meaning.

The process of identification of game pieces can also be troublesome for players that require the use of touch to perceive information, as there is an increased importance in regards to the correct positioning of the elements in the playing area in games that use this mechanic. Players must be able to touch and identify game components without accidentally altering their original positions, as this directly influences core gameplay aspects. This issue relates with guideline TF5, which suggests the fixing of game components to prevent accidental movement.

The second task, identification of the areas of the board, requires that players be able to clearly identify the borders or connections between different regions, and to understand the delimited space that composes a single region. This task is directly related with the component used to represent the different regions, often being a game board, and may present potential accessibility issues to the wide variety of players with visual impairment. One such issue is game boards that employ the use of color alone to code meaning between different areas, using colored borders, lines, or infill, may difficult the ability of players with color blindness or low vision to clearly differentiate the areas of the board. This issue relates with guideline CC1, which recommends that color should be avoided as the only element to convey meaning, as the meaning can be completely lost if the person cannot differentiate specific colors. Another issue relates with difficulty with the identification of the different regions in the game board as a consequence of the overload of graphical elements or use of small visual elements, which can be troublesome to persons with lower visual acuity. This issue relates with guidelines ID1, ID2, and ID4, which suggest strategies regarding enlargement of visual elements or the highlight of important graphical elements related to gameplay. To players that are legally blind, boards often rely on the heavy use of visuals alone to represent the different areas and lack any haptic feedback to communicate this information

through touch, making them completely non-accessible to this audience. This issue relates with guideline TF1, which recommends the use of tactile patterns in order to delimit and describe components and the visuals present in them.

The third task, moving game pieces from one area to another, is directly related with the first two tasks, being able to identify the pieces and the regions of the board, and does not pose inherent accessibility issues, as players should be able to carry this task as long as the first two tasks are made accessible.

3.6.5 Auction/Bidding

Definition

The auction mechanism, also known as the bidding mechanism, requires players to compete in various rounds for the acquisition of items or other in-game benefits, such as priority in turn order, through the offering of an in-game currency. The player that manages to offer the most currency in a given round receives the benefit being auctioned, with future rounds offering new items. Although this mechanic often uses money as the currency in which auctions are paid, it presents a twist in the form of a sub-mechanic known as area control. Area control, also known as area influence, refers to the game mechanic which players seek to conquer specific regions of the game board in order to achieve their goals, doing it if they manage to achieve the majority of their player pieces in the specific region. Area control is considered to a sub-mechanic of auction, as the player pieces, often represented as miniatures, can be considered currency in which players can use to outbid others in a given region, with the player that has the majority of their pieces in a region being the winner of the benefit provided by that region. While it presents slight differences with respect to the traditional auction mechanism, as multiple auctions happen simultaneously in the form of different regions in the board, it maintains the core elements of players attempting to outbid each other.

The auction mechanism is often carried in games through two different approaches: open bids or closed bids. In open bids, players take turns explicitly

revealing how much currency they are willing to spend in the item being auctioned, with the next player having the option of increasing the bid, or passing on the offer, with play continuing until all players besides one pass on the offer. In closed bids, all players secretly select the amount of currency they are willing to spend, with a simultaneous reveal of this amount by all players, with the player that spent the most winning the item. Popular games that incorporate the auction mechanism include the economic Power Grid, the political Twilight Struggle, and the set collection Five Tribes.

Task Assessment

As previously commented, this mechanism is often present in the form of either open or closed bids, with these approaches slightly altering some of the tasks involved with it. The core tasks require players to: i) identify the items being auctioned, ii) identify the bids of other players, and iii) decide and communicate their own bid.

Accessibility Issues

The auction mechanic presents potential accessibility issues in one of the three aforementioned common tasks related to this mechanic.

The first task, identifying the item being auctioned, does not pose inherent issues related to the mechanic, and is accessible as long as the auctioned items can be identifiable irrespective of participants visual acuity or color perception.

The second task, identifying the bids of other players, poses potential accessibility issues for games that use the approach of closed bids. In these games, players are required to hide their bids and reveal them once all players have decided upon their individual bids. Bids are commonly hidden in closed fist, with players simultaneously revealing the hidden amount. This task can be problematic, especially in groups composed only of blind players or those with severe low vision, as the identification of other players' bids is required to happen at the same time to prevent players from changing their bids based on new acquired information.

The third task does not pose inherent accessibility issues to the task itself as it ultimately depends on the accessibility of the specific component used as in-game currency. In addition, in most open bid games players only need to verbally express the amount of money they are willing to bid, which is communicated irrespective of players visual abilities. As long as the currency used in the auction is accessible, players that win bids should be able to effortlessly spend the required amount.

3.6.6 Game Boards: Fixed and Modular Boards

Definition

A Game board, a surface that presents or hold gameplay elements, is one of the most predominant game components within the genre. Traditionally, game boards were an essential component in order for a game to be categorized as a board game, hence the name of the genre. Nowadays, the term incompasses the wide variety of non-digital games, including boardless games like numerous card or tile based games. While traditional game boards were made of wood and shaped in the form of a rectangle or square, these components are currently found in a wider variety of forms, sizes, and materials.

While this component has various uses and differ from game to game, the most prominent function of game boards is to facilitate gameplay, by communicating game rules, important gameplay information, and providing organized play via a well defined areas. In addition, the game board is often used to provide feedback to players based on their actions, to display available options, and to hold or store game components. Despite few exceptions, the majority of game boards can also be categorized under two general categories: fixed boards, where the disposition of the game board in the playing area and its layout is constant; and modular boards, where the board is composed of multiple separated parts and is effectively built prior or during gameplay, presenting different possible configurations for gameplay.

Task Assessment

The general tasks involved with the utilization of game boards during gameplay often require players to: i) display the game board in an intended position of the play area and organize components atop of it, ii) identify and manage elements and components present in its surface.

Accessibility Issues

The interaction with game boards presents potential accessibility issues in both of the aforementioned common tasks related to this component.

The first task, displaying and organizing the game board in the play area, is often done prior to commencing gameplay, during the game setup phase. This task presents a varied degree of accessibility, depending on the necessary precision involved with the positioning of the game board, their auxiliary components, and the number of game boards used for the game. Displaying the game board in the playing area poses little issue in games that use a single board with fixed configuration, as players commonly only need to position it in an even surface, preferably within reach all players. However, In the case of games that make use of multiple boards, or modular boards, players must be able to identify and differentiate boards, organizing them following the specific setup rules of the game, which often considers spatial aspects. As game boards often rely on the use of visuals alone to communicate information, with little to no tangible aspects to communicate its information, players that are blind or have low visual acuity may find it troublesome to conduct this task due to difficulties with the identification of the content printed in the surface of the board. This also greatly affects the ability of organizing auxiliary components on top of the game board, as the defined regions to those components are commonly represented through visuals. This issue relates with guidelines TF1, TF2, TF3, and TF6, which propose various tactile alternatives to communicate visual information through touch.

The second task presents two main aspects: the identification of elements and components, which relates with players' ability to perceive the printed elements in the board and the auxiliary components displayed in specific regions on top of it; and the handling and management of these elements. The first aspect is an essential task not only during gameplay, but also during setup of the game board. The issues pertaining this aspect relate to heavy use of visuals, and have already been discussed above.

The second aspect, the identification of the auxiliary components on top of the game board, greatly depends on the level of accessibility of the components themselves. However, their usage in the context of game boards often demand a degree of spatiality, requiring that these components be positioned in specific regions of the playing board due to organization or gameplay features. This can be troublesome for players that require the use of touch to perceive information, as they need to be able to touch and identify components without accidentally changing their original positions. This issue relates with guideline TF5, which suggests the fixing of game components to prevent accidental movement, and guideline TF4, which suggests the use of compartments to store game components.

3.6.7 Playing Pieces: Resources and Player Representative

Definition

This section discusses a variety of game components that fall under the broad category of playing pieces. These are components used by players in order to carry actions in the playing area and can be divided into two distinct categories based on their functions: player representative pieces, and resource pieces.

Player representative pieces are components owned and used by players in order to do specific in-game actions or track players' progress. Players own a similar set of these components during gameplay, with each set having small variations so that they can be differentiated, such as the use of color. A common variation of this approach is also found in the form of neutral representative pieces: components

shared and collectively manipulated by all players. Regardless of ownership, these components are commonly represented in the form of small models, such as pawns, miniature figures, and Meeples, an abstract stylized human miniature.

Resource pieces are components often acquired by players throughout gameplay, and are commonly used as a form of currency or as commodities. These components are available to all players in a shared pool, and are managed according to specific gameplay rules. These components are commonly represented in the form of small geometrical objects, such as cubes, discs, stones, or abstractly shaped in the form of their real counterparts, such as is the case of money bills and coins.

Task Assessment

While these components may present variations regarding the specific tasks related to their use, as their management is directly related to the specific gameplay rules and interactions set by each game, the general tasks involved with the utilization of playing pieces during gameplay often require players to: i) identify and differentiate pieces, including representative pieces from players and resources, and ii) the management of the playing pieces, including the collection, positioning and/or storage of pieces into specific areas of the playing area.

Accessibility Issues

The interaction with playing pieces presents potential accessibility issues in both of the aforementioned common tasks related to this component.

The first task, identifying and differentiating pieces, presents serious accessibility issues to the wide variety of persons with visual impairment, due to industry standards regarding size, shape, and color of these components. Player representative pieces most commonly have the exact same size and form, employing color as the only element to differentiate similar sets and to define ownership among the different players. For example, while regular chess pieces present distinct shapes to differentiate pieces based on their function, both players use the exact same set of pieces, with color being the only element used differently in each

set. This poses complications to people that are color blind as they may be unable to differentiate similar components, especially in games that utilize a large variety of components and do not use colorblind friendly palettes, making gameplay difficult or completely non accessible. The lack of particular shapes to represent distinct sets of pieces also makes these components non accessible for those with a lower visual acuity and require touch in order to perceive the components. The same problem is also commonly found in regards to resource components, with recurrent non accessible approaches such as the use of identical coins and bills that have the same tangible characteristics, such as size and shape, and cubes or discs that symbolize various resources employing only color to differentiate them. This issue relates with guidelines TF2 and TF3, which suggests the use of different physical shapes or tactile patterns in order to differentiate components, and guidelines CC1 and CC2, which reiterates the importance of avoiding the use of color alone to convey meaning and to prioritize the use of color blind friendly palettes.

It is also important to highlight that the size of these components can also provide an additional layer of difficulty to the task of identifying these elements, as these pieces are often considerably small. This is especially problematic in the case of games which pieces carry additional visual information, such as text or icons, which can be hard to clearly visualize. This issue relates with guideline ID1 and ID2, which suggests the use of larger and more readable fonts, if textual information is present, and the enlargement of components which size does not directly influence the gameplay interaction.

The second task, managing playing pieces, presents a varied degree of accessibility, being highly dependant of specific gameplay rules, number of components, and the presence of auxiliary components such as game boards and storage options. Playing pieces are often arranged into three different positions of the playing area: i) on top of a shared game board, with its spatial positioning being highly related to gameplay interactions, goals, to track player's progress, ii) on top of a player's individual game board, communicating meaningful gameplay informa-

tion pertinent to that player, and/or iii) positioned anywhere within reach of each player, as a reserve in which pieces will later be disposed somewhere. While the degree of spatial importance of these elements wildly vary depending on the aforementioned arrangement options, a basic amount of spatiality is always required to ensure that playing pieces maintain adequate proximity or distance from each other. This aspect can be problematic to those that require the use of touch to perceive information, as players need to interact with pieces while preserving the specific or overall positioning of them in the playing area. This issue relates with guideline TF5, which suggests the fixing of game components to prevent accidental movement. Collecting, or disposing, resources can also provide minor annoyance depending on the number of components used on the game, as they may be scattered across a multitude of different regions in the playing area. While this aspect directly relates with the ease of identification of these components, games that employ a large variety of playing pieces in a shared area without the use of organized storage compartments can demand extensive time from players, even when components are accessible. This aspect can be especially demanding for those that need to physically touch the pieces in order to perceive them. This issue relates with guideline TF4, which suggests storage compartments for the game components, which can help players to identify the location of different pieces for quick collection, or to return the piece to the shared pool after using it. Other management aspects, such as the translation of pieces from one position to another, do not pose inherent issues regarding the playing pieces itself, being directly dependant of the accessibility of auxiliary components such as game boards to present clear guidance in regards of the intended positioning of these elements, and to be able to properly accommodate them in place in the intended target location.

3.6.8 Game Rulebook

Definition

Game rulebooks are indisputably the most recurrent component of board games, being present in the wide majority of games. Rulebooks are a form of a product user manual, presenting overall information regarding the game, including elements such as rules explanation, index of components, gameplay scenarios examples, game narrative and storytelling, designer notes, clarifications, among others. While game rulebooks present a wide variety of content, their main goal is regarding rules teaching, and is present in all rulebooks through the form of explanations about gameplay goals, tasks, and interactions. These rulebooks are often found in the form of physical booklets or pamphlets, with digital versions of these also being available for download in publishers' websites.

Task Assessment

The usage of game rulebooks revolves around a single tax: collecting textual and visual information, often occurring any time before or during gameplay. Prior to actual gameplay, users are required to read the rulebook in order to understand all the game elements and their interactions. Users are also required to collect information regarding the game's setup in order to know how to organize all components based on the number of players into their initial intended position, which is often present in the form of textual instructions and images. During gameplay, rules may be revisited for clarification purposes, to provide guidance, or when fringe scenarios and new game elements arise.

Accessibility Issues

The degree of accessibility of game rulebooks is completely dependent of the accessibility employed in both mediums that these components are present: physical and digital.

Physical rulebooks often present very little accessibility to persons that have a lower visual acuity, as there is a preference to the heavy use of text in order to

communicate the majority of information present within them, with images often being used only to provide complementary information to the written content. The lack of tangible aspects to communicate information also make these components completely inaccessible to blind people.

Digital rulebooks are identical copies of physical rulebooks, but provided in the digital medium. These are often made available to users in the form of .PDF files that can be accessed online or downloaded. Unfortunately, .PDF files are notorious for providing poor accessibility when not developed considering universal usability. Issues range from text not being searchable, images not containing alternative text, tab orders not following document structure, among others [63]. Many of such issues prevent users from being able to use assistive technologies, such as screen readers, in order to collect information from the document. Digital game rulebooks are often not fully accessible, as the provided files were not designed to be used in digital devices. These files are commonly the exact same files used by publishers to print physical rulebooks, and are often released to the wide audience with non-optimal sizes and many being image-only PDFs, which are incompatible with a myriad of assistive tools.

These issues, both in the physical and digital versions, regarding game rulebooks are related with the guideline GR1, which suggests that rulebooks need to be made accessible to audiences irrespective of visual abilities, due to the core importance of this game component.

3.7 Discussion

This section presents and discuss the findings from the analysis, including a summary of the aforementioned board game accessibility issues, insights arising from the identified issues, initial thoughts regarding the use of the accessibility guidelines to elucidate the inherent issues, and improvements to the guideline list.

3.7.1 Insights and Summary of Board Game Accessibility Issues

The analysis of the accessibility issues present in board games incorporated five main game mechanics and seven game components, which were selected according to the main criteria of their presence and popularity within the hobby of board games. From these selected game elements, the in-depth analysis of its related tasks have suggested a total of 33 recurrent accessibility barriers to persons with visual impairment when engaging with board game gameplay. Based on the identified issues, the occurrence of overlap between issues is observed in different categories, with specific issues being recurrent among different game elements. These include aspects ranging from poor accessibility practices found in the industry, to the innate lack of non-visual communication from game components and interactions, among others. It is important to point out, however, that while many of these issues share similar underlying causes that negatively affects their accessibility, solutions still require to account for the particular tasks of each of these elements in order to assess optimal approaches that better support and enable their use.

A summary of these aforementioned accessibility barriers can be found in Table 3.4, which presents the list of game components and mechanics, the related tasks that present accessibility barriers, and a brief description of those issues.

Mechanic / Component	**Related Task**	**Accessibility Issues**
Dice Rolling and Dice	Identifying specific dice in the play area	**i)** Dice can be hard to differentiate, due to aspects such as lack of tactile feedback and distinct shapes, small size, and use of color alone to differentiate.

Table 3.4 continued from previous page

	Throw / Roll collected dice	**i)** Players need to constantly identify region in the play area which does not conflict with other game elements; **ii)** Dice retrieval can be difficult due to random start and end positions of dice;
	Visualizing roll outcome	**i)** Share the same issues related to the task "Identifying specific dice"; **ii)** Players that need to employ haptics to identify information may unknowingly influence dice result; **iii)** Identifying outcome of multiple dice may be lengthy
Hand Management and Cards	Card identification	**i)** Heavy use of visuals to communicate information, little to no tactile feedback; **ii)** Small standard card size, poor interface, high load of information, and small elements, can make it difficult to visualize information
	Card acquisition	**i)** Relates with task "Card identification" and its issues; **ii)** Games that employ spatiality in this task may present issues with non intended repositioning of cards by players
	Play / Disposal of cards	**i)** Relates with task "card identification" and its issues, with the addition that other players should also be able to visualize the card's content; **ii)** Issues may arise in regards to card mixing if cards are not disposed correctly

Table 3.4 continued from previous page

Tile Placement and Tiles	Identifying tiles' content	**i)** Small tile size, poor interface, high load of information, and small elements, can make it difficult to visualize information; **ii)** Little to no tactile feedback; **iii)** Limited changes to tiles sizes and shapes can be carried without changing gameplay.
	Tiles spatiality	**i)** issues with non intended repositioning of tiles by players when employing haptics;
	Identifying tiles position and placement options	**i)** low contrast, information overload, and thin lines may pose difficulties in the identification of borders between regions and to understand the delimited space that composes a single region; **ii)** Lack of connectivity between tiles in boardless games may make it difficult for blind players to identify all tiles and connections.
Area Movement	Identifying player pieces and their position	**i)** Distinct similar pieces share the same areas, and can be hard to differentiate due to aspects such as lack of tactile feedback and distinct shapes, small size, and use of color alone to differentiate; **ii)** issues with non intended repositioning of pieces by players when employing haptics;

Table 3.4 continued from previous page

	Identification of the areas of the board	**i)** Areas in the game board can be hard to differentiate, due to aspects such as the use of color alone to code meaning between different areas, overload of visual information, and use of small visuals; **ii)** heavy use of visuals, with little to no tactile feedback
Auction / Bidding	Identifying other players' bids (closed bids)	**i)** visual cues are commonly used to allow players to simultaneously reveal hidden bids, being difficult to conduct the task for those with little to no visual acuity.
Game Boards: Fixed and Modular Boards	Displaying and organizing the game board in the play area	**i)** spatial organization of game boards in the play area can be difficult due to little to no tactile feedback communicating information present in these boards;
	Identification of elements and components	**i)** spatial organization of components on top of game boards can be difficult due to little to no tactile feedback communication information present in these boards, and lack of storage compartments; **ii)** issues with non intended repositioning of pieces by players when employing haptics;
Playing Pieces: Resources and Player Representative	Identifying and differentiating pieces	**i)** Pieces can be hard to differentiate, due to aspects such as lack of tactile feedback and distinct shapes, small size, and use of color alone to differentiate.

Table 3.4 continued from previous page

	Managing playing pieces	**i)** spatial organization of components on top of game boards can be difficult due to little to no tactile feedback communication information present in these boards, and lack of storage compartments; **ii)** issues with non intended repositioning of pieces by players when employing haptics; **iii)** lack of organized storage compartments can demand extensive time from players to dispose pieces, such as resources.
Game Rulebook	Physical rulebooks	**i)** heavy use of text to communicate information, images used only to provide complementary information; **ii)** lack of tactile feedback
	Digital Rulebooks	**i)** Available in non accessible formats, with lack of compatibility with screen readers. Same content (and issues) of physical rulebooks due to being a digital copy.

Table 3.4: Summary of board game accessibility issues.

While these findings are still exploratory in nature, and do not cover the entire spectrum of board game gameplay and its nuances, the above list of accessibility issues represent an important contribution to improve upon board game accessibility. It presents an overall view in the tasks involved with the most popular game mechanics and components, providing a framework in which future research can use as a starting point to guide the development of accessibility solutions. The list also represents the first formal academic investigation into the general elements of board game gameplay and their accessibility.

In addition to contributing with future academic research, the list of issues constitute a practical tool that can be used by designers, publishers, or interested stakeholders in general, as a learning guide or checklist during the development (or adaptation) of accessible games. While the current list does not tackle solutions to the discussed issues, it contributes into providing awareness in regards to difficulties faced by those with visual impairment when engaging in gameplay, and explicitly pointing the different aspects that can pose these difficulties.

3.7.2 Identifying Issues Using Board Game Accessibility Guidelines

As previously commented in the analysis methodology section, in order to identify the issues present in the selected game elements, the core tasks involved with their usage were investigated using the previously developed board game accessibility guidelines as the principal framework that guided the analysis for issues. The guideline list was used both as a checklist to assess if the analyzed elements complied with expected accessibility standards, and to emphasize pertinent aspects related to board game accessibility that should be verified. While the use of the list was overall helpful to the analysis, it also presented some limitations.

One such limitation is regards to recommendations that are too generic, unclear, or not particularly helpful for the specific task of analyzing mechanics and components. For example, guideline AT1 suggests the use of "assistive technologies to read aloud game elements". As the guideline only suggests an approach in a rather general manner, it fails to quickly provide proper instruction regarding which specific accessibility issues, game elements, or pertinent aspects require proper care, and were not advantageous for highlighting problems during an analysis.

It was also observed the presence of overlap between guidelines, particularly with the ones that provide considerations regarding tactile feedback. Guidelines such as TF1 and TF6 both suggest the same approach: the utilization of tac-

tile patterns to provide haptic feedback alternative to visual, with guideline TF1 presenting an overall view of this strategy, and TF6 specifically addressing the use of Braille as one of the approaches. The specificity of guidelines such as TF6 did not provide any additional assistance to the analysis which would justify its individuality in the list.

The investigation of a wide variety of mechanics, components, and their related tasks also presented specific, although recurrent, scenarios involved with some of these elements that have not been properly addressed by the guidelines list. For example, the process of simultaneous action present in auction games with closed bids poses considerations regarding how to manage the task of each each player presenting individual hidden information to all other players at the same time, without relying on the use of visuals. Some of these scenarios present clear accessibility implications and should be addressed by the list in order to increase its reach.

Despite the aforementioned limitations, the guidelines employed were able to fulfill their main goal of providing assistance with the identification of potential issues, being essential to provide proper structure to the analysis, leading to the significant identification of a total number of 33 issues. While some issues may have been left unnoticed in the evaluation, especially when considering more fringe aspects of the analyzed game elements, the discussed issues account for the majority of the more common expected problems that can be faced by those with visual impairment, and accessibility considerations regarding those will already present significant effort into the improvement of the accessibility of this genre of games.

Based on the findings of the analysis, the guideline list was updated to address the aforementioned shortcomings discussed. The following changes were conducted:

- Merge between two categories, and changes in all categories names.
- Combination of three guidelines into two others, merging guidelines that presented a considerable degree of overlap.

- Removal of two guidelines and rename of seven guidelines, to provide additional clarification, or to break it down into more intuitive and specific recommendations.

- Inclusion of two new guidelines, being either derivative of previously existing guidelines or covering pertinent board game accessibility aspects that were not properly addressed by the original list.

Appendix C shows the detailed changelog, presenting the specific modifications and explanation of changes. Table 3.5 presents the updated list of guidelines, reflective of the improvements conducted.

Tactile Feedback and Organization
TFO1 - Use tactile feedback to delimit, identify, or describe game elements.
TFO2 - Explore distinct physical shapes to differentiate game elements.
TFO3 - Use storage compartments or game boards to keep game components organized on the play area.
TFO4 - Fix game components to prevent accidental moving.
TFO5 - Ensure all pertinent gameplay information can be communicated through touch.
Color, Layout, and Visuals
CLV1 - Do not use color alone to convey meaning.
CLV2 - Prioritize the use of color blind friendly palettes.
CLV3 - Use contrasted colors between background and visual elements.
CLV4 - Highlight important graphical elements related to gameplay.
CLV5 - Use fonts with larger size and higher readability.
CLV6 - Enlarge game components and elements whose size does not directly influence gameplay.
CLV7 - Re-write text to make it concise and/or employ keywords and tags.
CLV8 - Use iconography complementary to text.
Gameplay Rules and Interaction
GRI1 - Provide accessible rulebooks.
GRI2 - Provide audible feedback about gameplay actions and state changes.
GRI3 - Provide alternative means to gameplay tasks, while preserving the original experience.

Table 3.5: Updated list of board game accessibility guidelines

3.8 Conclusion

As previously mentioned, the list of accessibility issues resultant from the analysis conducted in this chapter provides this thesis first contribution for the field, assisting with future investigation in the development of solutions that seek to enable board game gameplay to those with visual impairment. Chapter 5 documents the development of a digital assistive technology that seeks to facilitate a myriad of gameplay tasks, influenced by the overall findings of this analysis. These findings not only support further academic research into the field of accessibility and board games, but also represent a practical tool for those in the industry. In addition, the analysis also contributed with the improvement of the previously designed list of board game accessibility guidelines, with the improved list being evaluated in the next chapter (Chapter 4) in regards to its reliability for issue identification.

However, the current analysis presented some limitations. In order to better validate these results, it is recommended that more expert evaluators are involved with the investigation of these game elements and tasks, in order to account for the majority of potential issues, as not all main issues may have been identified. Nielsen suggests that a number between three to five evaluators is recommended to cover the major issues present in a given system [61].

3.9 Summary Chapter 3

This chapter presented the first research contribution of this thesis: the documentation of an in-depth investigation of the major accessibility issues in board games mechanics and components when considering the wide variety of persons with visual impairment. To do so, data was collected from the largest online database of board games, capturing data regarding user ownership of over 89 thousand board games, to select the most popular board game mechanics and components. A total amount of five game mechanics and seven game components were selected to be analyzed via a heuristics evaluation methodology, with myself acting as the principal investigator. The analysis employed the use of a previously developed

list of board games accessibility guidelines, devised by this thesis author, acting as a framework to guide the identification of pertinent points that could present gameplay barriers to participants.

For each analyzed element, a brief definition is presented along with information about popular games that employ these elements, the tasks involved with their utilization, and the list of potential accessibility issues presents in them. The analysis of these elements revealed 33 accessibility issues related to game mechanics and components. These findings are summarized in the form of a table that presents the collection of issues, a brief description of each, and their related gameplay tasks. A brief discussion regarding the identified issues is presented, and it's highlighted its utilization for future research in regards to solutions to accessibility barriers and the development of accessible games in the industry.

The use of the guideline list is also discussed, pointing out its shortcomings and strengths when conducting the analysis. Shortcomings include overly generic guidelines, overlap, and lack of recommendations regarding pertinent gameplay aspects. Despite these problems, the guideline list demonstrated sufficient assistance with the goal of identifying major accessibility issues and providing a structure to the analysis. In order to strengthen the list, the list was updated to address the aforementioned problems, through the merger of existing overlapping guidelines, the renaming and removal of unclear guidelines, and the addition of new ones addressing aspects not previously discussed that were found during the analysis.

Chapter 4

Assessing Board Game Accessibility Guidelines For Issue Identification

4.1 Introduction

As documented in the past chapter, the analysis of accessibility issues present in board games was fundamentally guided by the utilization of previously developed accessibility guidelines. The original guideline list was developed during past research related to board game accessibility via the thorough analysis and compilation of pertinent accessibility and game accessibility guidelines, combined with data collected from a user study that involved players with a myriad of visual impairments [4]. The study involved the playtest of two adapted modern board games, with players providing direct feedback about relevant aspects to these games accessibility. The guideline list was developed with the main goal of providing a foundation for the field of board game accessibility, acting as a tool to provide interested individuals initial guidance during the development or adaptation of games in order to improve their accessibility. The original full guideline list included a multitude of examples to facilitate understanding the context surrounding board game gameplay, and sought to address a variety of problems present in these games.

As Chapter 3 demonstrated, although the utilization of the guidelines for the identification of issues in mechanics and components presented a few constraints, they demonstrated to be a useful tool for the structured identification of the major issues present in these game elements. In order to improve the list's performance for future analysis, an update of the guidelines was conducted to better address the limitations found during the analysis described in the past chapter. In this chapter, a further step is taken into improving upon these board game accessibility guidelines by seeking to evaluate the list's reliability to generate consistent results. A study is conducted with two investigators who perform a heuristic evaluation of two different board games, using the updated guideline list as a framework in the identification of potential accessibility issues present in those games. The results of their evaluations is compared in order to measure inter-rater reliability, with the goal of further strengthening the proposed guideline list.

4.2 Heuristic Evaluation and Inter-Rater Reliability

Besides their original use as a list of recommendations or requirements, heuristics and guidelines have been widely adopted in usability test methods such as heuristic evaluation or expert evaluation, with these being considered strong discount usability methods: approaches that produces cheap, quick, and fair results, due to aspects such as the lower number of required investigators or infrastructure, and being flexible to be used at any time during the product development cycle, including for the evaluation of conceptual ideas or early prototypes [60, 62]. The basis of this methodology involves the use of any number of evaluators to investigate a given product using of a list of heuristics. Evaluators check whether the product complies with the predefined heuristics, and create individual lists of problems found in the product. Investigators may present varied levels of expertise and, depending on the goal of the study, may or may not employ their own expertise when conducting the evaluation [64].

While these methods have been extensively used to assist the usability and accessibility evaluations of products from a variety of different fields, evidence from fields such as video games have suggested that evaluators' results tend to present low inter-rater reliability scores, which points to low overlap between different evaluators' results when investigating the same product. These findings are deemed to be reflective of the overall subjective nature of the method, due to aspects such as the degree of evaluators' comprehension of the heuristics or guidelines, expertise of the evaluator, complexity of the product analyzed, use of different classification for issues, among others. This effect is also known as the 'Evaluator Effect', and is common to a plethora of usability methods [65]. Evidence has suggested that the degree of structure and organization when conducting the evaluation and reporting also heavily influences inter-rater reliability scores, often by alleviating the evaluator effect. Cockton et al. [66, 67] found that the use of structured reports presented 60% of evaluators consensus, in contrast to 31% of consensus from less rigid approaches to the method, in regards to the task of assigning heuristics to the issues identified. Gareth et al. [68] also discusses that despite achieving low inter-rater reliability scores, a statistical analysis of evaluators' findings may be able to reveal common patterns between reports, and those are helpful to identify and address important design themes.

While the utilization of the proposed guidelines provided sufficient support with the task of identifying accessibility issues related to board games mechanics and components, conducted in the past chapter, further evaluation is required to properly validate the list. It is pertinent to measure the list's reliability to produce similar results across different investigators. The findings resulting from such evaluation can highlight its efficacy, especially when assessing for issues in a game-by-game basis, and suggest improvements that can be carried upon the current list, which may enhance its overall assistance for the development or adaptation of games.

4.3 Evaluation Methodology

4.3.1 Overview and Evaluators

In order to analyze the reliability of the results produced when using the updated guideline list (Table 3.4), a heuristic evaluation was conducted by two evaluators using the list for the analysis of two different board games for their potential accessibility issues. The selected evaluators are researchers involved with this thesis development, including myself. Evaluator A is 22 years old, female, and presents games user research and human-computer interaction experience; Evaluator B is 26 years old, male, and presents human-computer interaction and accessibility experience. Both evaluators are master graduate students in computer science, and present different levels of expertise regarding accessibility of games and related products. Each evaluator was required to conduct their evaluation individually, with posterior comparison of their results to compute inter-rater reliability conducted by the main researcher of this thesis.

Two games were selected to be analyzed among the most popular games according to the BoardGameGeek database: Carcassonne, a competitive tile placement area control style game; and Pandemic, a cooperative hand management and area movement style game. These games were selected due to the wide variety of game mechanics and components implemented in them. Additionally, each game is from a distinct genre, being competitive and cooperative respectively. This selection criteria sought to alleviate the limitation regarding the number of games analyzed by selecting games that are representative of a multitude of gameplay tasks and elements, in order to open the possibility for a more rich discussion regarding their accessibility flaws.

4.3.2 Heuristic Evaluation Process

Prior to the start of the evaluation, a training session was conducted to present:

- An explanation of the different types of visual impairment, and their characteristics;
- A brief description and explanation of each individual guideline from the list, in order to discuss and clarify the meaning of individual guidelines;
- An overall explanation regarding the heuristic evaluation process, including initial instructions and details about the reporting format.

In addition, evaluators received printed supporting material with the content discussed at the training session to be used if needed during the evaluation, which included the full list of guidelines with a brief description explaining each individual guideline (appendix D).

Each evaluation involved the analysis of a single game at a time, and was composed of two rounds: in the first round, evaluators were instructed to investigate the game's core elements without specifically looking for accessibility issues, in order to get a good feel of the product and its characteristics, similar to how end users interact with products, as suggested by Nielsen [61]. They investigated game elements such as rules, mechanics, components, player interactions, among others. Each evaluator was also required to play the game once, in order to better understand the gameplay experience and the involved tasks, as suggested by Gareth [65].

In the second round, evaluators focused on analyzing the specific parts of the game and the gameplay related tasks, in order to identify problematic aspects that can prevent or disrupt gameplay for those with visual impairment. Evaluators had complete freedom to analyze game elements in any order they saw fit, and could report issues found in the games any time they encountered one. Evaluators were instructed that the reporting of issues should be initially done informally, with just sufficient information to locate the issue afterwards. This was incentivized so that the evaluators could focus on identifying issues first, and then in the process of writing a formal report afterwards.

At the end of the evaluation, the identified issues were re-checked by the individual evaluator so they could re-analyze the problem if needed, and for the posterior writing of the structured formal report regarding the found issue. This report required the following aspects to be included on each identified issue: i) a brief description and explanation of the issue, including information regarding where it is found, and ii) which specific guidelines the identified issue relates to, if any. When reporting the issues, evaluators were also incentivized to break down issues into specific elements of the game, rather than in a general manner, to improve the process of comparing evaluators' results after the heuristic evaluation.

At the completion of the evaluation sessions, the report data from both evaluators was collected to generate a master list of accessibility issues present in each game, and to compute the inter-rater reliability scores, or how much of the identified issues were present in both evaluators reports.

4.4 Data Analysis and Results

The heuristic evaluation report for the game Pandemic revealed a total of 82 issues identified by the evaluators, 47 issues found by evaluator A and 35 issues found by evaluator B. Carcassonne presented a total of 44 issues identified, with 21 issues identified by evaluator A, and 23 issues identified by evaluator B.

In order to compute the inter-rater reliability score of the evaluation, first it was conducted the comparison of the identified issues found by each evaluator, denominated as "problem matching" [65], to gauge the amount of overlap in both reports. As discussed by Gareth [65], this task is commonly conducted in an informal and subjective manner, with lack of details regarding the criteria used in the comparison process to define which identified issues are considered similar or distinct. Often researchers only present limited information on the process conducted, or employ subjective criteria, which hurts the reproducibility of the experiment, and can influence the computation of inter-rater metrics [65].

In order to minimize the subjectiveness and related issues of the problem matching process, It was used both the grouping process proposed by the playthrough evaluation framework [65], which develops upon the standard heuristic evaluation methodology, and the definition by Nielsen [59, 61] regarding usability inspection methods. This approach suggests that problems found should relate to individual aspects of the design, and should subsequently be grouped into categories based on the tasks in which the problem appeared in. This strategy facilitates the problem matching task, as it provides a more structured basis to which issues from different evaluators are analyzed in regards of their similarity or overlap [65]. As previously mentioned, evaluators were instructed to focus on breaking down identified issues into individual and specific design aspects. The compiled list of issues identified by each evaluator was then organized into categories by myself, based on which board game aspects they relate to, according to the descriptions provided by the evaluators about the issues. The created categories include game elements such as specific game components, mechanics, or tasks, in which the issue was identified present.

The problem matching process of both evaluators reports generated two master list of 48 and 28 unique accessibility issues, found in Pandemic and Carcassonne respectively. The disparity of the number of identified issues between both games is reflective of the different levels of interactions and components present in each game, with Pandemic presenting a wider number of game components and interactions required by players, through the use of game boards, different decks of cards, cubes, trackers, and pawns, in contrast with Carcassonne, which mostly uses tiles and pawns.

Any-Two [69] was calculated as a measure for inter-rater reliability, verifying the degree of overlap between issues identified by raters. A value of 0% indicates complete lack of overlap, and a value of 100% denotes complete agreement and identification of the same issues. Any-Two is obtained by dividing the number of issues a pair of evaluators have in common, divided by the number of unique

issues they collectively detected, averaged over all possible pairs of two evaluators [69]. In the context of this research study, Any-Two is the recommended metric to compute agreement between evaluators findings, as evaluators are responsible for the entire problem-finding task and may identify different amounts of issues. The usage of metrics such as Cohen's Kappa or Krippendorff's Alpha produces more reliable results when each evaluator assess a predetermined fixed number of issues [65, 69, 70]. Overlap occurring by chance was not accounted for in the calculation, as each evaluator independently identified issues after conducting an analysis of the games, and therefore identified problems should be reflective of major accessibility problems present in the games and unlikely to have been found by chance.

Any-Two values over 50% represent high reliability, while values lower than 10% demonstrate poor reliability [65]. Similar studies from related fields have identified Any-Two values between 10% to 30% on heuristic evaluations conducted with novice evaluators. Calculations indicate an Any-Two percentage agreement of 56.3% for Pandemic, and 57.1% for Carcassonne, in regards to the overlap of issues identified by the evaluators, representing great reliability and higher than similar fields. Appendix E presents supplemental data, including each master list of issues and individual reports of the evaluators, with issues color coded based on the specific categories they pertain, which issues have been reported by which evaluators, the guidelines each issue is infringing according to the evaluators, and the total percent agreement of identified issues. The findings also point to great reliability in regards to the task of assigning which guidelines are related to the identified issues, with 88.9% percentage agreement for the game Pandemic, and 93.8% for Carcassonne. Such a task is often the recommended approach when using heuristics evaluation along with data collected from user playtesting [65], and thus presents additional valid approaches when using the guideline list for board game accessibility.

Further individual considerations regarding these findings and the insights that arise from the problem matching task of each game are discussed in the following sections.

4.4.1 Problem Matching and Percentage of Agreement

The problem matching process for the game Pandemic combined the 35 and 47 issues found individually by each evaluator into a combined total of 48 unique accessibility issues. As previously mentioned, the identified issues were organized into categories based on specific design aspects and were identified after analyzing the description of the issues reported by the evaluators. For Pandemic, nine categories were created to organize the identified issues, ranging from game components to interaction tasks presents in the game. Each category presents a varying amount of issues, with the specific categories and their respective number of issues represented in Table 4.1. The percentage of agreement between evaluators for the game Pandemic revealed a total of 56.3% agreement across all categories, with categories such as Managing Pieces and Gameplay (100%), Game and Player Communication (100%), Storage (100%), and Game Board (75%), achieving the highest amount of overlap, and categories such as Disease Cubes (42.8%), Cards (41.7%), and Rulebook (25%), achieving the lowest amount of overlap.

Category Name	Number of Issues	Percentage Agreement
Storage	2	100%
Managing Pieces and Gameplay	3	100%
Game and Player Communication	3	100%
Game Board	8	75%
Player Pawns	3	66.7%
Cure Markers	2	50%
Disease Cubes	7	42.8%
Cards	12	41.7%
Rulebook	8	25%

Table 4.1: Pandemic defined categories, unique issues, and percentage agreement per category.

The problem matching process for the game Carcassonne combined the 23 and 21 issues found by each evaluator into a combined total of 28 unique accessibility issues. Similar to Pandemic, categories were created based on the reports by evaluators, generating seven categories with varying number of issues regarding game elements and interaction. The percentage of agreement between evaluators for the game Carcassonne presented a total of 57.1% agreement, with categories such as Managing Pieces and Gameplay (100%), Storage (100%), and Player Pawns/Meeples (60%) achieving the highest amount of overlap. In contrast with Pandemic, only the Rulebook category presented extremely low percentage of overlap (33.3%), with the other three categories presenting 50% or 60% of agreement. Table 4.2 presents the list of categories, the number of issues in each category, and the percentage of agreement of each category

Category Name	Number of Issues	Percentage Agreement
Storage	2	100%
Managing Pieces and Gameplay	4	100%
Game and Player Communication	2	100%
Player Pawns (Meeples)	5	60%
Tiles	4	50%
Scoring Board	2	50%
Rulebook	9	33.3%

Table 4.2: Carcassonne defined categories, unique issues, and percentage agreement per category.

One pertinent aspect to point out regarding the degree of overlap within each category relates to the poor scores attributed to the Rulebook category, being the category with lowest agreement in both games: 25% and 33.3%, for Pandemic and Carcassonne respectively. This is reflective of the emphasis that one of the evaluators provided in regards to the specific elements present in the rulebook, in contrast with the other. For Pandemic, evaluator B identified three accessibility issues in this category, which were general in their nature (i.e., rules not accessible to blind persons, not written considering those with visual impairment, and

poor use of visuals and small text size). Evaluator A identified thirteen issues in this category, which presented a more detailed look into the specific problematic elements within the rulebook (i.e., the material of the rulebook, specific visual elements poorly used, layout of the information, among others). Similar results were also observed for the game Carcassonne, with evaluator B identifying four general issues, while evaluator A identified ten issues with specific details regarding elements present in the rulebook. This discrepancy of the amount of issues identified in this category and the general/detailed nature of the issues reported explains the low percentage of agreement identified in the category.

It is also important to point out that while the rulebook is a recurrent component of board games, being present in every game and its usage important for rules explanation, this specific component is not part of the core gameplay loop of board games. If not considering the identified issues discussed by the evaluators in the Rulebook category, a substantial increase of 6.2% for Pandemic, and 11.3% for Carcassonne, is observed, bringing the total percentage of agreement to 62.5% and 68.4%, respectively. As previously mentioned, the percentage agreement of both games, of 56.3% and 57.1% (or 62.5% and 68.4%, disregarding rulebook issues), are substantially higher than the average values identified from related fields, such as video games. Improvements to the process of when conducting heuristic evaluation of board games accessibility may lead to even higher reliability scores.

One of the major aspects that influenced the evaluators agreement relates to the amount of specificity when breaking down the design aspects of the game, for the analysis and reporting of the issues. When reporting identified issues, evaluators provided varying degree of specificity about these issues in the different categories. For example, when discussing the accessibility of the pawn components in the game Pandemic, one evaluator identified only a single issue, explained with the rather general description of "Player pawns are not distinguishable from one another except with color". The second evaluator, however, pointed to more specific characteristics related to the players' pawns, identifying three specific issues

related to lack of distinct physical shapes, tactile patterns, and the use of color as single element to differentiate. In both games the same can also be observed with other game components, such as cards, tiles, and tokens. While both evaluators identified a similar amount of problematic elements in these games (with both evaluators describing at least a single issue on each of the identified categories), the amount of consideration regarding the specific characteristics of these problems varied between evaluators and components. This may be reflective of the lack of rigidity of the heuristic evaluation regarding the identification process, teardown, and explanation of the identified issues. Another aspect that may have contributed to these findings relates to the varying degree of expertise of each evaluator, resulting in the more thoroughly analysis of the roots and characteristics pertaining to some issues.

4.4.2 Guidelines Usage and Overlap

Another pertinent aspect to highlight from the evaluation relates to the use of the guidelines by evaluators during the heuristic evaluation, and the relationship of specific guidelines and the identified issues. Both evaluators considered the guidelines to be helpful in providing guidance during the process of identifying issues, albeit their use presented slight limitations. Evaluator A expressed that the categories dividing the guidelines list felt restrictive, as guidelines from one category could also be applicable to other categories. For example, guideline TFO2, under category "Tactile Feedback and Organization", recommends that the game "Explore distinct physical shapes to differentiate game elements". While the guideline specifically suggests the use of physical shapes to address tactile issues, the strategy of using different shapes for printed visual elements could also be explored, and is not covered by other guidelines. The evaluator felt confused on how to interpret the guideline at the start of the evaluation, and suggested that the guideline be adjusted to be more general, or a second similar guideline covering shapes for print be added. In addition, the evaluator also considered other guidelines to be too general, recommending that they could be divided into multiple guidelines to better

cover issues. One such example relates to guideline CLV5, which suggests “fonts of larger size and higher readability”, suggesting that the readability aspect of the guideline could be broken down into multiple recommendations, each discussing aspects such as line spacing, character spacing, styling, among others. Regardless, both evaluators considered that the guidelines were able to be linked to all identified issues, attributing each issue to one or multiple pre-existing guidelines.

It was also noticed in both final master lists that when specific issues were identified by both evaluators, evaluators linked these issues to the same specific guidelines in most times. For Pandemic, 88.9% of the issues that overlapped were linked to the same guidelines, and 11.1% of mismatches happened within the same category. Carcassonne had 93.8% of guidelines overlap, and 6.2% of mismatches within the same category. These results point to great reliability in the task of assigning guidelines to the issues, and suggest that despite the limitations of the current list, both evaluators came upon similar conclusions regarding issues guided by the same individual guidelines, with little discrepancy. Mismatches were also often representative of slight variations in regards to which guideline better dealt with the identified issue. For example, the issue in pandemic of “Small font used in player cards“ was attributed to be related to guideline CLV6 by one evaluator, which suggests to “enlarge game components and elements whose size does not directly influence gameplay”, and attributed to guideline CLV5 by the other evaluator, which suggests the “use of fonts with larger size and readability”. Although different, both guidelines discuss similar problems and suggestions, dealing with the size aspect of game elements.

Finally, the presence of specific guidelines in the reports should be pointed out. Each evaluator assigned from 13 to 15 unique guidelines to the issues identified on both games, pointing to the unfortunate diversity of accessibility issues present in these games. While most guidelines were mentioned by the evaluators, few guidelines were responsible for the majority of the issues identified, which may suggest a few of the major accessibility aspects that are less attended by designers

and publishers. Appendix F shows the list of guidelines present on each evaluators reports, ranked by the number of times in which the guideline relates to an issue.

4.5 Discussion

The preliminary findings suggest that the guideline list presents great reliability for both the task of issue identification, and for the assignment of guidelines to already previously identified issues. In addition, it also presents further insight to the potential causes that contribute to these results and elucidates to the current benefits of this method for tasks related to board game accessibility. As previously mentioned, both games presented substantially higher percentage agreements when compared to similar research conducted in the field of video games, with average agreement in the field measuring from approximately 10 to 30% [69], in contrast with the identified 56.3% and 57.1%, for Pandemic and Carcassonne respectively, in this study. The high reliability scores are reflective of the quality of the guideline list and the heuristic evaluation conducted. More specifically, the list went through multiple iterations in past research, employing user data from playtesting with persons with visual impairment, and in this current research, through the heuristic evaluation conducted as part of this thesis in the past chapter (Chapter 3). In addition, the rigidity of this study's heuristic evaluation method, albeit still not ideal, helped to alleviate the evaluator effect, through the use of proper instructions and assisting documentation to evaluators at the beginning of the evaluation sessions.

It is also important to point that when disregarding issues related to the rulebooks of the evaluated games, which can be deemed as separate products and deserving an individual analysis of their own merits, the percentage agreement of these games increase to 62.5% and 68.4%, presenting a considerable increase in the degree of reliability. As discussed in the past section, the lack of overlap between evaluators findings most often related to the degree of specificity in which issues were reported, with problematic tasks or components being tear down into

more or less parts by each evaluator, while the same overall themes were pertinent across both findings. It is anticipated that providing more rigidity to the process, through the use of a more in-depth training and directions with respect to the reporting aspect of the evaluation will translate into even higher reliability scores.

The results also suggest great reliability to the task of attributing specific guidelines to the identified issues. Both evaluators linked the exact same guidelines to the shared issues identified in 88.9% of the cases for the game Pandemic, and 93.8% for Carcassonne, with all mismatches happening within the same category of guidelines. These findings suggest that despite the evaluator effect, with evaluators having distinct degrees of expertise about accessibility and board games, both evaluators came upon similar conclusions regarding the same issues, influenced by the same specific guidelines.

4.6 Limitations and Future Work

The study presents limitations that need to be addressed to improve upon the validity of the results identified. While the single pair of evaluators identified a considerable number of issues in each game, Nielsen and Molich recommends that usability evaluations involve at least three to five investigators in order to better identify the main the main themes and issues present in a given product or application [61, 60]. For future work, this opens up the possibility of conducting additional rounds of evaluation similar to the ones carried out in this chapter. Future evaluation can also further investigate the evaluator effect, comparing the results that arise from individuals of varied degrees of expertise regarding board games and accessibility, to those that are experts in the field. These findings may shed further light into the reliability of the guideline list for issue identification when considering diverse individuals. In addition, future evaluations should also involve the collection and analysis of user testing data from participants with visual impairment, in order to compare the issues identified through playtesting

with the ones identified via heuristic evaluation, and to assess if the heuristics are representative of expected issues and solutions related to board games in general.

4.7 Summary Chapter 4

This chapter investigated the current list of board game accessibility guidelines regarding its reliability in the identification of accessibility issues present in these games. A heuristic evaluation was conducted employing two evaluators with distinct expertise regarding board games and accessibility, assessing two popular games: Pandemic and Carcassonne. Evaluators sought to identify issues that could be deterrent to the experience of persons with visual impairment when playing these games, using the guideline list as a guide in the identification of these issues. Individual issues identified by each evaluator were then compared, in order to compute the degree of overlap, or agreement, between evaluators. Any-two was computed presenting values of 56.3% agreement for Pandemic, and 57.1% for Carcassonne, representing good reliability and being substantially higher than the average reliability found in similar fields, such as video games. Further investigation in these results also showed that when disregarding Rulebooks from the analysis, percentage of agreement increases 6 and 11 points to each respective game, and that lack of overlap was most commonly resultant of a varied degree of specificity when reporting issues. The results also present great reliability in the task of relating guidelines to the identified issues, with 88.9% and 93.8% reliability for Pandemic and Carcassonne respectively, suggesting that evaluators came upon similar conclusions guided by the same guideline. Further investigation should be conducted in order to better support these findings, involving additional evaluators. Future evaluation should also further investigate the evaluator effect in order to discover the degree of influence in which evaluators expertise of the field influence in their results. The analysis and comparison of playtest collected user data from persons with visual impairment with the data collected from heuristic

evaluations also presents additional possibilities to better strengthen the results of these findings.

Chapter 5

Digital Assistive Technology for Board Game Gameplay

5.1 Introduction

As previously discussed, the use of digital assistive technologies represents a promising approach to improve board game accessibility. These technologies can reveal new strategies that would be otherwise manually unfeasible or too demanding, such as the automation of gameplay related tasks, auditory feedback regarding game state, and further flexibility of exploring additional user senses, such as complex sound and haptics. It also presents the added benefit of potentially requiring less long term effort for the task of adapting previously non-accessible games to make them accessible, as the coding used to enable a game may be quickly adapted for reuse in games that share similar elements.

This chapter documents the initial investigation and development of an assistive technology prototype which seeks to enable board game gameplay without the need for in-depth modifications of games' visual elements and components. The different variations of digital assistive technologies are discussed, while design decisions, characteristics of the application, limitations, and future improvements that can be conducted to improve the prototype are presented.

5.2 Digital Assistive Technologies

Significant effort has been conducted into the development of digital assistive technologies that enable those with visual impairment to use general visual products, employing vision enhancement [31, 50] and sensory substitution [35, 1, 34, 30] techniques. Unfortunately, there is little to non-existent investigation of solutions that considers the use of digital technologies to enable board game gameplay. While digital accessibility to the field is still scarce, It is important to point out that digital applications related to board games have been developed, and although these have not been made with special consideration regarding accessibility or those with visual impairment, these still occasionally contribute with improving the game's accessibility in a game-by-game basis. These applications, often referred as "companion apps", are increasingly more common in the industry and are developed with the goal of providing complementary gameplay assistance to players. Companion apps often translate specific tangible game elements or components to the digital media, seeking to facilitate the management of activities or communication of information. Additional content is also commonly distributed through these apps, such as digital-only gameplay interactions and voice acted narration.

These apps, especially those that translate physical components into digital, provide alternative or complementary approaches of interacting with the game, with some of these approaches being more accessible when compared with their original form, such as the addition of audio when communicating written text. It also allows users to make use of pre-existing assistive technologies, such as screen readers, filters or magnifiers, without need for adaptation. However, limitations are still strongly in place when using companion apps, as these applications are developed without proper consideration for those with visual impairment and may impose new accessibility and usability barriers related to their implementation.

Applications similar to companion apps, but with a clear focus on providing proper accessibility support, can be categorized as a specialized assistive technology, as the available features, tasks, and interactions present in the sys-

tem are designed in order to support a specific task at hand. Specialized assistive technologies have the principal benefit of often providing a more optimal user experience or accessibility for the given product. However, these technologies often demand a considerable amount of resources and time invested.

Another approach can be found in the form of more general assistive technologies, which seek to improve accessibility by acting directly on the overall characteristics of the given impairment, rather than on a specific task. For example, digital assistive technologies such as the ones by Zhao et al. [31, 50], which provides general vision enhancement, and by Maidenbaum et al. [30], which translate visual inputs into audio outputs, do not focus on enabling specific products by removing their barriers, but rather to change or "adapt" users' perception in a way that decreases the amount in which the characteristics related to their impairment influence their interaction with non-accessible objects. These general assistive technologies have the principal benefit of flexibility, with interactions and features seeking to accommodate a large variety of scenarios at once. On the other hand, these technologies may present issues such as a higher learning curve, especially in applications that require users to re-learn basic tasks [30], and non-optimal interaction when used to conduct too specific tasks, with more specialized assistive technologies being able to better handle these [31].

5.3 System Goals and Requirements

Considering the importance of investigating a digital assistive technology to enable board game gameplay for those with visual impairment, the development of an assistive application was explored, seeking to improve games' accessibility without complex or in-depth modification of their elements and components. This application seeks to be a hybrid general-specialized assistive technology, providing generic accessibility improvements to users, while still considering the context and nuances involved with board games. While accessibility solutions in a game-by-game basis are still optimal, especially when developed during the game's development cycle

and in a way to seamlessly complement the original gameplay experience, users still need a faster and easier way to participate in the hobby. While complying with accessibility standards during the development of games often does not incur additional development time or costs, the same may not be true when doing it retroactively [27], and the task may be demanding to end users, particularly when trying to enable complex games, or a large quantity of them. An application that improves gameplay accessibility in a more general way, accommodating a wide variety of game components and mechanics, provides a more immediate benefit to the target audience. Such an application also contributes by laying a basic foundation for which future applications can develop in a more specialized way, with solutions considering specific genres or tasks found in these games.

In light of the characteristics of board games, the accessibility issues pertaining to them (previously discussed in Chapter 3), and the needs of our target audience, the following list of requirements for the system was devised:

- Players should be able to conduct generic games' tasks through the assistance of the system, such as rolling dice, and tracking players' scores, among others.

- Sensory substitution is available, with visual information present in game components being also communicated via alternative senses, enabling gameplay for those with a severe degree of visual impairment.

- Visual enhancement is available, via augmentation of the visuals of game elements, facilitating their visualization for those with a less severe degree of visual impairment, such as those with low vision and color blindness.

- Users should have the freedom to customize accessibility parameters and set preferences, in order to best suit the system to their specific needs.

- The system needs to be affordable, and usable without the need of expensive accessories to increase its reach to the target audience, as the majority of those with visual impairment also live in low income settings [2].

In addition to the specified requirements, the developed system should support the activity of board games by being easy to use during gameplay, as the majority of game interactions will still occur via the manipulation and management of tangible components. Consequently, players must be able to use the system without increasing the complexity or intended length of the gameplay in such a manner that affects their experience.

5.4 System Development

The system was conceptualized by the author of this thesis, which was responsible for defining its core goals, functionalities, and interactions, while considering the previously discussed requirements. The functional prototype of the conceptualized assistive technology for board game gameplay was consequently developed by two programmers, including myself and an external developer [1]. The majority of the system was developed using HTML5 and Javascript, making it natively compatible with a myriad of devices that support the use of browsers and web applications, including mobile smartphones and personal computers, facilitating its distribution and reach to the target audience.

The system contributes with the improvement of the accessibility of general board games via real time recognition of visual game elements, which are enhanced and displayed in the devices' screen, communicated through audio, or through a combination of both. In addition, it also allows for a variety of general recurrent gameplay-related tasks to be conducted digitally, in order to better support tasks that would be otherwise too bothersome or lengthy. In the following sections, further details about the core aspects of the developed prototype are presented, and future work is discussed, such as additional features and user testing.

[1] The external developer was Viviane Sampaio Maia. Both myself and Viviane were responsible for implementing the major prototype functionalities together, including filters and the overall user interaction. Viviane was also the main contributor to the investigation and implementation of the ArUco API.

5.4.1 Detecting Game Elements

The main aspect of the system involves the need for itself to act as a link between game elements and players, augmenting the way in which pertinent gameplay information is perceived and communicated. The system must automatically identify and process game elements and context, providing feedback to users without being disruptive. As discussed earlier in this chapter, it is pertinent that the development of an assistive technology that does not require users to conduct extensive modifications to game elements, and that inexpensive approaches to that end should be prioritized. One approach for the low-cost identification of physical game objects involves the use of small sensors, such as NFC or RFID tags. NFC tags for accessibility applications have been previously explored by Regal et al. for its use to communicate information present in cards with satisfactory results [52]. On the other hand, while these small sensors are fairly inexpensive, they still require the use of specialized equipment such as tag readers, which represent additional costs and are not commonly found in popular consumer stores, with its acquisition potentially being a daunting task to end users. An alternative low-cost approach involves the use of image recognition algorithms, capable of identifying physical objects through the use of a device's camera and a processor. This approach was selected for the system due to the presence of mobile phones, personal computers, and miscellaneous devices, natively supplied with a camera, and it is likely that the majority of the interested individuals will already have the necessary equipment to use the system. In addition, the absence of extra devices to use the application improves its distribution and decreases the required setup time by users.

5.4.2 Fiducial Markers and ArUco Library

In order to identify the physical game elements using a camera, the use of binary square fiducial markers was investigated. These markers are used to facilitate the computer vision task of pose estimation, with binary square markers being effective at providing sufficient correspondence through the use of four corners,

and presenting a robust inner content that allows for error detection and correction techniques to be used [71]. Fiducial markers also have the added benefit of being low-cost to produce and easy to manipulate, allowing end-users to generate and directly incorporate them in objects without major constraints. Users can produce markers at home using consumer printers at an insignificant cost, and are able to produce them according to their needs and the number of unique game components [72].

Upon investigation of the different available libraries of fiducial markers, the OpenCV based ArUco library was selected to conduct the marker recognition [73, 72, 74]. The ArUco is an open source library written in C++, which uses a square shaped fiducial marker dictionary, with these markers containing a inner binary matrix with a default internal grid of 5×5 cells, which represents an id of the marker [74] (Figure 5.1).

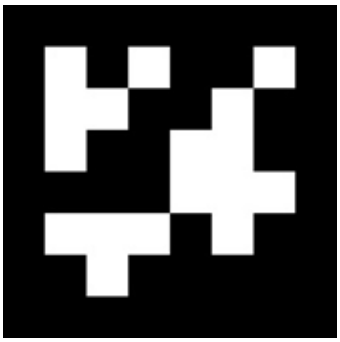

Figure 5.1: Example of ArUco fiducial marker.

The ArUco dictionary is popular for being able to quickly and reliably detect markers, being up to 40 times faster than other state-of-the art methods, and with experiments showing that it has better performance on aspects such as inter-marker distance, number of bit transitions, and false positive rates, when compared with other marker-based dictionaries [72, 74]. In addition to being able to detect its own dictionary of markers, it also fully supports the detection of markers from other dictionaries such as Chiltags, AprilTags, and ARToolKit+, and as of version 3.x, has made available automatic detection of markers from any dictionary [72]. For the development of the system the official Javascript port,

js-ArUco [75], was used due to easy integration and compatibility with web-based applications and browsers.

5.4.3 System Setup, Overview, and Modes

To enable the recognition of real life game components, at least one ArUco fiducial marker must be incorporated somewhere in their composition, such as near the corners of these objects, prior to gameplay. The addition of markers can be achieved through approaches such as the production of new components with markers, or the adaptation of previously existing components through use of stickers. The recommended placement of markers wildly varies based on the size of the component and its gameplay related interactions and handling, with the general guideline of avoiding placement in regions that may be constantly obstructed, as the device's camera requires clear visualization of the markers in order for the system to function properly. The specific amount of markers required in components depends of which accessibility options are enabled, and may range from the need of a single generic marker in each component, to multiple unique markers to differentiate unique game components.

Regardless of which accessibility features are enabled, users always have the freedom to customize the system as they see fit. Supporting evidence has shown that user customization is one of the most important features in assistive systems to increase their usage and provide proper accessibility [31, 50]. In the developed system, users are able to combine the different accessibility options and to fine tune their values through sliders present in the user interface, without requiring alterations to the source code, in order to best fit their needs and to improve the overall user experience.

To use the core system's modes, users are required to position a camera towards components that contains the markers, which are identified and communicated back through an enhanced visualization or audio. Cameras can be positioned in a needs basis, or be fixed with the assistance of a tripod to constantly cover specific regions of the play area. The utilization of video see-through

HMDs will likely facilitate the usability of the task during gameplay. The system uses standard 'point and click' (or touch) controls, and operates by displaying the real time feed of the device's camera along with a minimal interface, which users are able to select and customize a series of different accessibility options. The accessibility options are divided in three main categories: i) visual enhancement, which present different video filters and augmentation modes, in order to make game components easier to be visualized; ii) audio feedback, which allows different modes for the communication of visuals through audio, and iii) gameplay related tools, which contains a series of mini-tools that seek to automatize and facilitate specific board game tasks. All three main categories can be used individually, or together in any combination.

5.4.4 Visual Enhancement Through Video Processing

In the visual enhancement mode, the ArUco markers are used to track the current position and occupied area of the game components to perform visual modifications in the screen region that overlaps with components' surfaces. This is achieved through the identification of the X and Y positions of the four corner pixels of the fiducial marker present in a given component, this task being automatically handled by the ArUco library, and by users defining the component's width and height in the system settings, which is used to delimit the region in the video feed which the component currently occupies while considering the current marker position. The distance between each marker's corners is calculated to account for component rotation, camera distance, and overall changes in perspective, making that the selected region always overlap with the observed game component. The selected region is used to create a real time mask in the video, where modifications are directly applied on each pixel present within the mask, based on the enabled visual enhancement options. The system was designed to only enhance the component's area, rather than to apply visual changes to the entirety of the feed. This was done to avoid issues such as break of users' immersion, confusion, and discomfort, which have been documented in works that investigated enhancing the entire feed

[31] and were present in some video game titles, such as overwatch, being heavily criticized by players [76].

The visual enhancement mode allow users to select and edit the following options to improve the accessibility of game components: contrast, brightness, acutance (sharpness), color replacement (color blind options), zoom, and digital augmentation. Many of these filter options, such as contrast and brightness, are recommended accessibility filters which have demonstrated to be effective at improving the users' ability to identify visual elements[77, 31]. To enable a filter mode, users are able to either quickly select predefined template profiles which contain settings tuned to accommodate specific recurrent types of impairment, such as "deuteranopia friendly"; or to manually adjust the specific settings and values for each option, such as increasing or decreasing the amount of contrast of the component. All the filters are also non-exclusive, allowing multiple filters to be enabled simultaneously, and the settings to be adjusted with changes being reflected in the devices' display in real time (Figure 5.2 and 5.3).

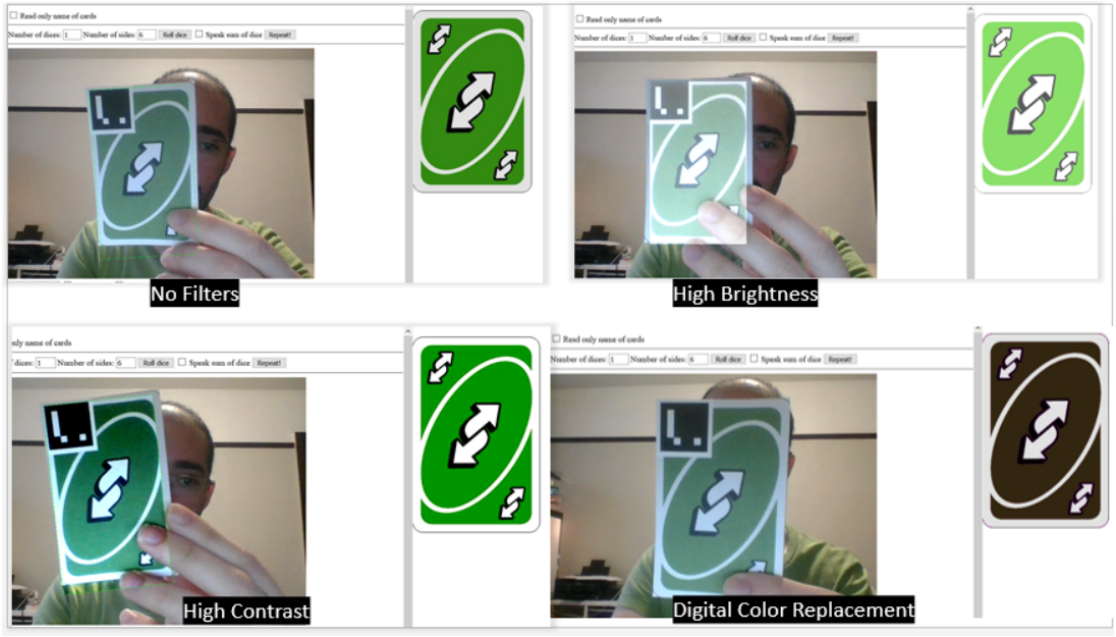

Figure 5.2: Different filters present in the application, including high brightness, high contrast, and digital color replacement.

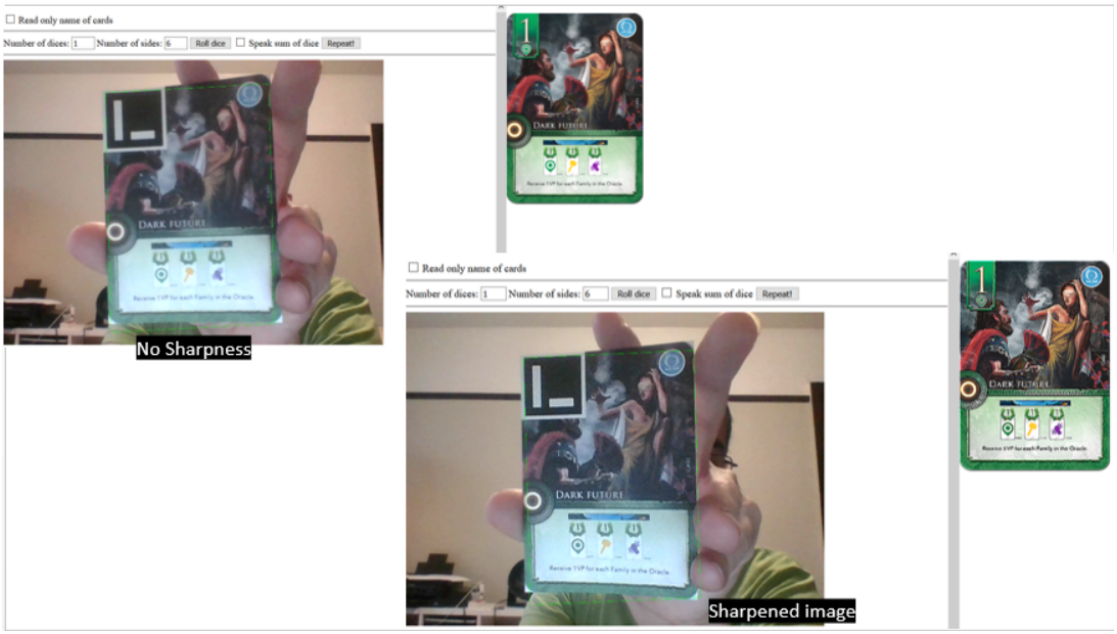

Figure 5.3: Sample of enhanced sharpness.

The majority of filters only require the usage of a single marker on components, which can be identical on all of them, as the markers are used only to calculate the current position of the component in the screen. Different markers can be used to further customize the accessibility options, as specific markers can be linked with specific profiles, enabling different filters on different components.

While most filters only present direct changes in the displayed pixel properties, the digital augmentation option was designed to enable users to visualize and interact with a digital version of the identified component. To use this mode, additional setup is required prior to gameplay, as users need to digitize the game components and to attribute unique marker IDs to each unique game component. This is done through the management of a simple local database file, where users are able to add entries for each unique game components, linking each entry with an image and a specific fiducial marker ID for posterior recognition. The entries can also contain additional information regarding the game component, such as name, descriptions of its visuals, and textual information, which can be accessed through the audio feedback mode.

With this mode, a digital version of the component is displayed in the screen when it is identified by the camera, and when multiple objects are identified simultaneously users are able to freely navigate between different objects using the systems controls (Figure 5.4). All previously mentioned filters are also compatible with the digital augmentation option, with the digital representation of the components also being able to be further enhanced.

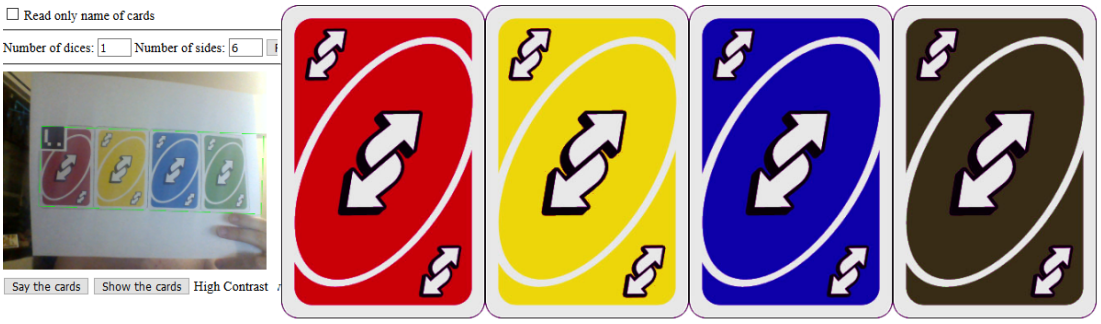

Figure 5.4: Interactive digital augmentation of a game component. Color filter replacing green currently on in the augmentation.

5.4.5 Using Audio To Communicate Visual Information

In the audio feedback mode, sensory substitution is employed to communicate visual information through audio. The ArUco markers are used to provide an identification point to which the system is able to recognize and differentiate individual game components. In contrast with the visual enhancement mode, this mode requires that each unique game component also makes use of a unique fiducial marker in their composition to properly communicate information pertaining to the visualized component. As previously discussed, a local database is used for the system to store pertinent information regarding components, and allowing components to be linked with specific marker IDs. This mode behaves as a form of screen reader: when the device's camera identifies fiducial markers, it communicates the information stored in the database that matches its ID through text-to-speech, effectively "reading" the components' content to users.

The communicated information is presented to users through the device's speakers, and the interaction can be configured to operate in two different modes: i) automatic detection, which the system communicates the newest visualized component's information whenever a new fiducial marker is detected by the camera; and ii) manual detection, requiring user input (the press of a button) to read information regarding all components currently found in the field of view of the camera. Regardless of the operation mode, users can customize the amount of information they want to receive, and modify the delivery of the information, using options available in the system's interface. For example, players can select whether they want the complete description of the observed components, including aspects such as its title, visual appearance, type, and written text, or a more condensed description, such as title only, depending on how familiar they are with the specific game components. In addition, users are able to define the speed to which the information is read, can change between different communication modes at any given time, and are able to define communication operations to cover all components, or create individual sets of rules to specific components.

5.4.6 Board Game Related Tasks

It is important to highlight that both of the aforementioned accessibility modes, visual enhancement and audio feedback, were designed to communicate information to players considering the specific context of board game play, with their usage supporting the commonly faced gameplay tasks. This is reflected through the required user interactions and the different preset settings profiles available to be selected, which have been designed to assist with common types of impairment. Some of these interactions and settings include:

- As previously commented, providing visual enhancement of only game elements, rather than the entire field of view, to make gameplay related information easier to be perceived.

- Preset recommended color blind friendly palettes when using the color replacement option, with suggested colors considering common types of color blindness and the recurrent colors used in board games [78].

In regards to the preset settings, these will not be able to always provide the optimal experience to all users, due to the variety of different visual impairments, and thus users are able to fully customize most of these options, which can be done through controls in the interface of the system.

In addition to the aforementioned aspects, the system also presents a series of small accessibility tools to assist with specific gameplay tasks present in games. These tools were developed directly acknowledging some of the accessibility issues in gameplay related tasks which have been previously discussed in chapter 3. Different from the previous discussed features, these tools do not facilitate the way the original gameplay tasks are used, but rather to provide an alternate, more accessible, digital approach in which users are able to conduct selected gameplay tasks completely through the system. These tools include:

- Score tracking: users are able to track players' scores through the system, which can be accessed any given time and communicated through visuals and audio.

- Dice rolling: as previously discussed in Chapter 3, dice rolling presents considerable accessibility issues to those with visual impairment, due to the difficulty of being able to visualize the dice outcome without influencing its result, especially when considering rolls that involve a large number of dice. The system allows users to roll any number of dice simultaneously, providing the outcome results through visuals and audio. Customization options allow users to define the number of intended dice rolled, the type of dice (number of sides), and to present the outcome of each dice individually or the sum of the combined dice.

- Secret communication: Social deduction games, like Werewolf[2] or The Resistance [3], require some players to secretly communicate with others using only visual cues during the game setup. This task is recurrent in games where players are divided into two teams, where only one of the teams is aware of its members. This option allows for the system to automatically sort players into different teams, and to discreetly communicate to each player which team they are in, removing the need for visual communication between players. The information is communicated via audio, and in turns individually to each player via headphones.

- Simultaneous reveal: As previously discussed in Chapter 3, games that require the simultaneous action of players revealing information, such as those that employ a closed bidding mechanism, are problematic to those with visual impairments as they often employ visual cues to communicate the information. Players are required to communicate at the same time their information to others, such as their bidding amount, to avoid players changing their actions retroactively due to the newly acquired information. This option allow users to, in turn, input their individual information in the system, which is concealed during other players' turn, being publicly read through audio to all players once a specified amount of players have participated.

5.5 Discussion

As previously discussed, the digital system prototype was conceptualized and designed considering the pertinence of investigating an accessibility alternative which is able to improve upon the accessibility of games without requiring considerable resources and expertise, in order to support interested individuals that want to experience non-accessible games. The system investigated the use of visual enhancement techniques and sensory substitution through audio, two of the main approaches used to design accessible products for those with visual impairments,

[2]https://boardgamegeek.com/boardgame/38159/ultimate-werewolf-ultimate-edition
[3]https://boardgamegeek.com/boardgame/41114/resistance

with the addition of considerations regarding the context of play and usual tasks involved with board games, many of which have been explore in-depth regarding their accessibility issues in Chapter 3. Although focus on the system has been placed on board game gameplay, it can also be compatible, to a certain degree, with other analog products and activities that similarly heavily relies on visuals. In addition, since ideally the largest number of persons possible will be reached, multiple customization options were made available, many of which users are able to edit through the system interface, without requiring any coding knowledge.

While the system already contains most of its core functionalities implemented, the current prototype still presents some limitations with respect to its usage for the end user, and it creates new accessibility requirements that need to be considered to further expand the usefulness of the system, and future designed ones. One such limitation is regarding the required setup that users need to undergo in order to fully use the available operational modes and their functionalities. While minimal changes are required to be made to game components, with the main one being the insertion of the ArUco fiducial markers in game components, many of the system functionalities rely on user created data about the games and their components in order to function properly. For example, the audio feedback mode require users to be able to initially transcribe the content present in components to a digital database, which will then be communicated to players during gameplay. Users that are not able to provide such content by themselves will require the assistance of others to use the functionality, with this dependence hindering their perception of autonomy and hurting their experience. One workaround is through the use of crowdsourcing for this task: the community of users can work collaboratively to setup a variety of games, configuring the required content for games and sharing database files with games ready to be played. A similar form of collaborative development related to board games can already be observed through Tabletop Simulator, a Steam platform application that allows users to digitize board game components to enable their gameplay online via a

computer [79]. Tabletop Simulator presents only a dozen of official games that have been released by the original team of developers, while users' contributions account for over twenty-two thousand items [79]. While users can already manually share database files in the current system prototype, it is pertinent that such task can be directly performed through the system, and in an easy manner, to make it more widespread and accessible to all.

The use of fiducial markers for the tracking and identification of real life objects also presents some limitations in the context of board game gameplay. While the insertion of these markers into larger sized components does not pose any major complications, such as game boards and cards, a multitude of other recurrent game pieces do not have sufficient size to properly accommodate markers, such as pawns, miniatures, and resource tokens, and therefore are not able to benefit from the systems' features.

In addition, the effectiveness of the ArUco markers for tracking of the game components also needs to be improved in future updates to the system. While the system is already capable of identifying the markers' position to perform the previously discussed functionalities, such as the vision enhancement of the components, it has been observed that various factors highly influence the performance of operations. These include: ambient light, the speed in which components are moved around, number of markers per component, the device's camera specifications, among others. All of these influence the degree in which markers are identified, and consequently the reliability of the functionalities, negatively influencing its usability and user experience. Further development must be conducted in order to optimize the usage of the ArUco markers in order to provide a more seamless experience when using the system during board game gameplay.

Although the prototype presents its core functionalities implemented, it is still an initial investigation in the development of an assistive digital technology and by no means represents a complete fully-fledged system: the user interface and usability of the system needs to be improved for the end user, and the performance

of ArUco still needs to be optimized. In addition, some of the current tasks can be daunting for those without proper technological experience. For example, while the majority of customization options can already be accomplished through the system's interface, some require users to directly edit external files. While the overall complexity of the tasks are low, they can be perceived as daunting by non-experienced users. In the future, improvements to the current prototype will be added, with improved usability via a more user-friendly interface for both the usage of the app during gameplay and when conducting any of the required game setups, database management, and customization.

It is also pertinent to involve those with visual impairment through user studies to evaluate and improve upon the developed system. In the future, playtest sessions with participants with visual impairment should be conducted to assess whether the system's features are able to improve the accessibility of non-accessible board games. Important aspects to investigate include the evaluation of the different modes present in the system, the analysis of users' customization and preferences options to identify patterns, and to investigate whether the required interactions to use the system are disruptive to the gameplay flow, and if it negatively influences the overall users' experience.

5.6 Summary Chapter 5

This chapter presented the documentation regarding the developed digital assistive technology, designed to enable non-accessible board games to be played by those with visual impairment. The different types of digital assistive technologies were discussed, and a list of goals and requirements that guided the development of the system's prototype were presented.

The developed prototype uses a device's camera to visualize ArUco fiducial markers for the identification of board game components, making them accessible through auditory feedback, vision enhancement, or a combination of both. Users are not required to conduct extensive design modifications to pre-existing

game pieces, and are able to customize the accessibility options on the go to improve upon their personal experience when playing games. Vision enhancement options include commonly used accessibility filters, such as increased contrast and brightness, and auditory feedback uses text-to-speech to communicate written information present in game components through audio. The system also takes into consideration the specific context of board game gameplay and related tasks, with complementary tools to support in-game actions, and system feedback communicated to properly support gameplay.

Some of the current limitations of the prototype were also discussed, such as the required setup prior to gameplay, the limitations of the use of fiducial markers in the context of board games, and the current usability of the prototype. Finally, the need for future user studies to evaluate the system was suggested to improve upon its current set of functionalities and to evaluate its effectiveness to enable board game gameplay.

Chapter 6

Discussion, Conclusion, and Future Work

6.1 Introduction and Summary

This thesis showcased the investigation of the field of board game accessibility, with an emphasis on accessibility for those with visual impairment. Despite becoming a strong genre of games in the past few decades for purposes ranging from entertainment to education and training, current modern tabletop board games are developed without major considerations regarding accessibility, and often times, it is ignored altogether. Those affected by vision impairment are the most affected due to the strong use of visuals in these games, similar to video games, and are often unable to participate in board game activities. While this genre of games existed for thousand of years, limited research has been conducted regarding the different accessibility barriers that prevent those with visual impairment to engage with the activity of board game gameplay, and little has been discussed regarding potential solutions to those issues. As discussed in Chapter 2, substantially more progress has been achieved in related fields, such as video game accessibility, and these results contribute indirectly with insights or potential strategies that can be investigated to improve the accessibility of tabletop board games. However, board games contain series of specific characteristics inherent to their gameplay, includ-

ing a strong social component, that require a more specialized lens when designing accessibility solutions to effectively achieve true inclusion of its participants.

Considering the pertinence of the topic, this thesis provided a deeper investigation into the specific accessibility nuances present in this genre of games. Due to the overall infancy of the research conducted in the area, a broad investigation was conducted, delving into different approaches and pertinent themes of interest to achieve the goal of improving upon the accessibility of the genre. This thesis is a direct continuation of the author's previous initial research into the field of board game accessibility, and presents one of the first formal academic studies carried in the field. This thesis investigated three main areas of interest regarding board game accessibility:

1. The inherent accessibility issues to persons with visual impairment present in pertinent board game elements, such as game components and mechanics, being discussed in Chapter 3.

2. The utilization of board game accessibility guidelines, focusing on the task of issue identification, and its reliability, being discussed in Chapter 4.

3. The development of an affordable and accessible digital assistive technology capable of enabling gameplay without requiring extensive efforts from end users, being discussed in Chapter 5.

This final chapter provides the summaries of the discussions regarding these three aforementioned areas of interest that have been explored in the previous chapters. It revisits this thesis research questions and highlight the contributions across the thesis. Limitations of this thesis are also discussed, and future work in the field is suggested to further contribute with board game accessibility.

6.1.1 Board Game Accessibility Issues

The understanding of the inherent accessibility issues present in board games is fundamental for the development of strategies and technologies that are able to

solve these issues. This task is not straightforward due to the complex nature of these games, which can manifest a plethora of different mechanics, rules, components, themes, and gameplay tasks. Due to the wide variety of elements, a sample of board game elements was collected, more specifically game components and mechanics, based on the degree of popularity of these elements. A heuristic evaluation of these elements was conducted using a previously designed set of board game accessibility guidelines, in order to better understand and highlight any potential accessibility issues present in those elements. Five board game mechanics and seven game components were selected for the evaluation, which led to the discovery of 33 accessibility issues. The current board game accessibility issues list stands as one of the first formal analysis of the accessibility of overall game elements, assisting as a tool for the future development of solutions to accessibility barriers, and the assistance on the development of accessible games. In addition, the findings suggested the presence of recurrent themes of issues across different game elements, and assisted with the improvement of the board game guideline list.

6.1.2 Reliability of Board Game Accessibility Guidelines for Issue Identification

This study evaluated the reliability of the updated board game accessibility guidelines for the task of issue identification, meaning the amount of overlap between evaluators findings. Two distinct board games, Pandemic and Carcassonne, were analyzed by two evaluators using a heuristic evaluation methodology. Evaluators had distinct degrees of expertise regarding accessibility and board games, and used the updated list of accessibility guidelines as a guide in the identification of any potential deterrent to gameplay for those with visual impairment. The results pointed to great reliability not only for the identification of issues, but also for the task of assigning guidelines to the identified accessibility issues, when compared with the average of reliability from related fields.

6.1.3 Digital Assistive Technology for Board Game Gameplay

Considering the pertinence of an overall accessibility solution that does not require extensive modification to pre-existing games by end users, and that takes into consideration the context of board game gameplay, an assistive technology prototype was developed employing vision enhancement and sensory substitution techniques. The prototype employs fiducial markers for the identification and tracking of board game components, which are then visually enhanced in a digital display and communicated through audio to users during gameplay. The developed prototype also provides alternative means to problematic gameplay tasks through digital interaction, further facilitating play.

6.2 Thesis Discussion

Each of the three aforementioned areas of interest explored in this thesis present individual challenges, research goals, and studies, being explored in the past chapters. Each chapter also presents individual discussion pertaining to the chapters content, with additional discussion pertaining the overall findings of all these areas and its general significance to the field being conducted in this chapter. This thesis also highlighted the different challenges regarding the development of game accessibility solutions for those with visual impairments. This thesis presented the initial investigation in the broad aspect of board game accessibility, presenting findings related to recurrent game accessibility barriers, the reliability of accessibility guidelines, and potential digital assistive technology strategies. These findings and discussions provide a necessary foundation for the field.

One of the challenges of board games' accessibility is the lack of awareness by developers, designers, and publishers, regarding accessibility issues present in this genre of games, and the specific characteristics pertaining those with visual impairment. While general accessibility strategies can already substantially improve the accessibility of board games, the complexity of these games, require further

understanding of the tasks involved and the various barriers present in them. The variety of distinct game elements need to be individually considered in order to enable effective solutions, especially to those with more severe impairments. As discussed in the related work explored in Chapter 2, very limited work has been done in the field to improve upon the accessibility of board games, presenting a great research gap into providing an understanding of the field. The in-depth investigation of the board games accessibility barriers showcased in this thesis fills this gap, providing direct guidance for the development of accessible games in the industry. These findings, summarized into a list present in Table 3.4, highlight problematic elements and the related tasks, enabling designers to account for pertinent aspects that should be carefully considered prior to a game's release. Consequently, it may foster the development of accessibility solutions to the field, which can contribute to further expand the knowledge and understanding of the specific tasks pertaining to the field.

While the understanding of the different issues related to board game elements can improve upon the design of accessible games from the beginning (bottom-up), in order to achieve effective inclusion, accessibility needs to be achieved retroactively: participants should be able to consume overall games already present in the market. The understanding of the issues present in individual games is one of the initial steps in the process of improving the accessibility of pre-existing games. This thesis findings suggest that the utilization of a heuristic evaluation methodology along with accessibility guidelines designed considering board game characteristics allows for the reliable identification of issues present in these games. These findings also suggest that participants with limited expertise regarding the topic of board games accessibility are still able to identify major issues present in these games. As previously discussed in Chapter 2, most of the accessibility efforts currently originate from the community of users. The findings, guidelines, and methods elucidated in this thesis suggest a reliable and accessible approach to which the community can further drive the investigation of issues present in

existing games, and the proposal of solutions. In addition, the understanding of issues in a game by game basis also further contributes with the investigation of overall accessibility patterns and themes of interest.

It is also pertinent that solutions to accessibility issues be easy to carry and cost efficient. This is specially important considering that the majority of those with visual impairment also live in low-income settings. Considering this requirement, the author's past research has investigated the utilization of solutions involving design modifications of games, which can be conducted both in the initial development of board games, and in the adaptation of pre-existing games [4]. Despite using accessible and affordable materials, and achieving good results, this approach often requires a considerable amount of effort when adapting games. Improvements conducted in individual games are also hard to transfer to other games. While the overall strategies can be re-used, the physical alteration of objects and components must be carried out in each individual copy of the game. Solutions are also difficult to be directly shared with the community. These challenges create the need for a strategy that better supports interested individuals in the task of adapting pre-existing games. The development of the digital assistive technology documented in this thesis sought to address these issues via a system that supports and improves general board game gameplay. While solutions focusing on issues of individual games potentially result in more optimal accessibility solutions in a game-by-game basis, the developed system explores a fast and flexible approach to improve board game accessibility via the design of features that takes into consideration accessibility recommendations, the context of play, and a variety of recurrent game elements and tasks.

The use of digital technologies also presents advantages when considering challenges that often pertain to the task of designing accessibility solutions. The customization feature present in the system, allowing users to change interactions and communication aspects of the application, contributes with the challenge of achieving specialized accessibility. While general accessibility approaches can im-

prove upon products to a wide variety of the target audience, the complexity involved with visual impairment and its nuances poses the complex challenge of providing solutions that effectively enable all the different types of visual impairment. The digital customization options solve this problem by allowing users to further configure aspects to improve their own personal experience. In addition, the use of digital assistive technologies reveal crowdsourcing possibilities, with the community sharing customization options and further improving upon the development of the system through the web.

6.3 Thesis Contributions

The goal of this research is to further strengthen the foundation of the field of board game accessibility, assisting interested individuals on the development and adaptation of accessible games. The main contributions of this thesis can be summarized in three areas: firstly, the identification of the accessibility barriers present in general board game elements, such as mechanics and components; secondly, the study of the reliability of board game accessibility guidelines for issue identification, and the framework that supports this task; and finally, the initial investigation of a digital assistive technology as a potential solution to enable gameplay to those with visual impairment.

6.3.1 List of Board Game Accessibility Issues

While limited research has been carried in the topic of board game accessibility, most efforts have been focused in the identification of issues and solution of these issues in a game-by-game basis. There has been no previous research which sought to investigate the inherent accessibility barriers found in these games, and how they relate with game elements. The analysis conducted in Chapter 3, and the resulting list presented in Table 3.4 provides an overall look into the accessibility issues pertaining to board games, facilitating the investigation of solutions to the specific issues present in these games. It also allows for future research to be conducted into improving the understanding of themes and patterns surrounding

the topic of accessibility in these games, allowing for the development of more specialized solutions and further accessibility guidelines.

6.3.2 Assessment of Guidelines Reliability for Issue Identification

Ensuring that the majority of accessibility issues present in existing board games are identified is an essential step in order to carry retroactive adaptations of these games into becoming accessible. The updated list of accessibility guidelines, presented in Table 3.5, demonstrated to be a reliable tool for the task of issue identification in these games, when used along a heuristic evaluation framework. Results also suggest that the discussed guideline list enables major issues to be identified despite evaluators limited expertise in the topic of games' accessibility.

6.3.3 Digital Assistive Technology System

This thesis presents the documentation of an affordable and customizable digital assistive technology that seeks to facilitate or enable board game gameplay. While the developed system is still in early development and in prototype form, it has shown potential in regards to the goal of enabling access to a wide variety of different games by taking into consideration the tasks and barriers involved with board game gameplay, which have been explored throughout this thesis. This system removes the need for extensive modifications to be conducted into pre-existing games in order to achieve accessibility, and customization options allow users to configure the application in order to better suit their own individual needs.

6.4 Limitations and Future Work

6.4.1 Further Development of The Digital Assistive Technology

While the current version of the digital assistive technology developed in this work already presents a wide variety of accessibility features to enable board game game-

play, its development is still in infancy. Improvements still need to be conducted in the current prototype to allow for ease of use and to achieve the intended user experience. The current prototype heavily focuses on the functionalities proposed, lacking in the current usability of the interface. Some of its functionalities, such as introducing content to its database, also require users to have basic HTML knowledge, which can be seen as daunting to novice users. Future prototypes will ensure that all functionalities are preserved, while providing an enhanced user experience to end users.

6.4.2 User Testing of Digital Assistive Technology

While the digital assistive technology demonstrated potential into improving the accessibility of board games, user testing must be conducted in order to identify the current strengths and weaknesses present in the system, and the limitations that surround these approaches. Future user studies must be conducted involving participants with varied degrees of visual impairments, and evaluating the performance of the system when considering games with distinct degrees of complexity and game components. These findings will not only provide a better understanding of the reach of the current developed prototype, but also provide a better understanding of the most pertinent aspects to properly support gameplay by users. In addition, user testing can contribute into providing valuable feedback about new features that should be considered, potential new technologies that can be investigated, and current features that should be altered or completely removed.

6.4.3 Further Investigation of the Evaluator Effect

Further research into studying the evaluator effect in the task of issue identification in board games is a possible next step to improve upon the findings regarding the reliability of the guidelines discussed in Chapter 4. A follow-up study can involve a larger number of evaluators with varied levels of expertise regarding board games and accessibility. These evaluators can be grouped based on their level of expertise, and receive varied levels of instruction about board games accessibility prior to

the evaluation. This can help to elucidate the extent in which evaluators previous expertise and the instructions received prior to the evaluation influence with the reliability of results.

6.4.4 Further Investigation of Technologies to Enable Board Game Gameplay

The investigation of other technologies that can be used to support accessibility of board games is a valuable next step that provides a myriad of possibilities. The digital system was limited to the utilization of fiducial markers and image recognition. While the previously discussed requirements that guided the development of this thesis assistive technology limits the use of more expensive and complex approaches, a wide variety of current technologies can still be investigated to further evaluate their contributions to the accessibility of the hobby.

6.4.5 Investigation of Accessibility Solutions to Game Elements

The creation of the list of recurrent accessibility barriers now provides the foundation in which future research can focus on the exploration of the solution to these issues. In addition to the practical accessibility challenges discussed throughout the thesis, games' accessibility presents the unique challenge of the need to preserve the original intended gameplay experience when adapting games that have not been designed accessible from the ground up. While overall visual accessibility improvements are often straightforward and already greatly enhance the experience of those with less severe degrees of visual impairment, adapting games for more severe types of impairment, such as complete blindness, often requires the in-depth understanding of gameplay tasks so to preserve the challenge and entertainment values of the adapted game. It is anticipated that the analysis and list of barriers presented in this thesis provide initial guidance in which accessibility issues

and pertinent gameplay tasks can be understood, leading to the experimentation of varied solutions.

6.5 Conclusions

Tabletop games have been part of human culture for thousands of years, and recent developments in these games' gameplay options and themes have reflected in a constant burst of popularity worldwide in the past few decades, with no indications of it being close to an end. These games have not only become a ubiquitous form of entertainment, but also a tool for education, training, and development of social skills. Unfortunately, the inherent visual characteristics of these games prevent millions of individuals with different degrees of visual impairment from playing these games, and warrants the investigation on how to enable this audience to participate within this activity.

Considering the extremely limited amount of formal research previously conducted in the field, it is important to initially investigate the core aspects and characteristics of these games and their relationship with the audience of those that have visual impairment, to allow for the posterior specialized investigations. The analysis of the accessibility of recurrent board game mechanics and components presented in this thesis provides an essential first step into understanding the diverse challenges faced by those with visual impairment when engaging with board game gameplay, and enables the investigation for related patterns, themes, and solutions to the identified issues.

In addition to investigating barriers pertaining to these game elements, two investigations pertinent to improving the current state of accessibility of games in the market were conducted. The first focused on the use and reliability of board game accessibility guidelines for issue identification, enabling individuals to effectively identify issues present in individual games. The second focused on the development of a digital assistive technology, as a potential approaches into solving

recurrent accessibility issues and quickly enabling gameplay to those with visual impairment.

To summarize, the field of board game accessibility is still in its infancy, and poses a series of new and complex challenges involved with achieving effective inclusion of those with visual impairment in the activity. While further research still needs to be conducted regarding these challenges and to potential solutions, this thesis tackled the broad aspect of board games accessibility to those with visual impairment by exploring the initial elements involved with these goals. In complement to the past research, this thesis fills a pertinent research gap by laying the necessary foundation in which future research can develop upon. These findings seek to directly support future research and investigations, continuously driving the accessibility of this genre of games, and to assist in the development of more accessible games in the industry, improving the experience of those with visual impairment when engaging with the activity.

Chapter 7

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Appendix A

Full Original Board Game Accessibility Guideline list by Tomé et al.

A.1 Tactile Feedback

This category focuses on employing the sense of touch (tactile) to convey information related to gameplay and game components.

A.1.1 Use of tactile patterns to delimit, identify or describe components

Simple tactile patterns, such as embossed geometric shapes and textures, can be used to communicate short and objective information about game components. For example, in a social deduction game, such as Ultimate Werewolf [Appendix1] or The Resistance [Appendix2], the use of different textures on the role cards can communicate a player's team without the need to (visually) read the card. The use of analogies, such as a texture or shape, that resembles the referenced object or game action, can assist with the learning and memorizing of patterns.

Emboss and textures can also assist with spatially orienting players to the position of elements, as they can delimit specific points on a board. Borders on a

game board can include small mounds, created with simple materials (e.g., white glue), and locations can differ with respect to height, and/or texture.

A.1.2 Use of pieces with different physical characteristics to represent different resources or player ownership

Board games often use sets of components (e.g., cubes, discs, chips, miniatures), to track in-game resources and/or units for each player. Color is often solely used by these components to differentiate pieces, thus making it difficult for players who are color blind to distinguish them.

The use of components with different shapes, whereby a resource resembles the simulated object (e.g., a tree trunk to represent a "wood" resource), help to improve accessibility. We used plastic jewelry in our Splendor prototype to provide a range of options to customize and differentiate various game resources.

A.1.3 Use of tactile patterns to differentiate pieces that must keep their original shape

Common in abstract strategy games such as Checkers, or Hive [Appendix3], is the use of pieces that have identical physical structures for all players, and require to maintain its structure for gameplay purposes. These pieces are often differentiated using color only, making it difficult, if not impossible, for players with visual impairment to distinguish the pieces. The use of tactile patterns to slightly change the form of such pieces by, for example, inserting a texture on a piece, allows players to recognize the pieces without compromising gameplay.

For example, the classic game Othello [Appendix4], which includes rounded game pieces with different colors on each side, becomes fully accessible with the addition of a texture on one of the sides of a game piece. This allows players to easily distinguish the smooth or textured side of a game piece.

A.1.4 Use of storage compartments to keep game components organized on the play area

A common characteristic of board games is the use of diverse game elements (cards, cardboard tokens, miniatures, etc.), organized around and/or on top of a board, following a particular spatial logic. The use of accessories such as card shoes, tuck boxes (a small box used to hold a deck of cards), or plastic organizers, such as a plano box, help with game setup, play, and cleanup. Such divisions provide players with quick access to components without accidentally scattering them around the game area.

A.1.5 Fixed game components to prevent accidental moving

The constant spatial manipulation of components to specific places on a board is a difficult task for players with visual impairment, and may hinder their ability to touch pieces for identification as this may accidentally change their position and affect gameplay. Modifying components ensuring that they won't be easily moved, using, for example, Velcro, magnets, or pegs, allows for tactile perception without accidentally changing the game state.

A.1.6 Use of Braille for identification and description of game components

With board games, Braille can act either as an option to communicate text that is usually printed on components, or as a tactile pattern to distinguish different components or spaces (regions on a board). It can be directly added to in-game components or accessories such as card sleeves: small protection films used by players to secure game components. Tools to include Braille with objects, such as the slate and stylus, and Braille stickers, help make this approach more flexible. For example, consider the popular card game Magic The Gathering [Appendix5]. Using a puncher machine to adapt card sleeves by inserting keywords in Braille, allowed a legally blind player to join a tournament and recognize cards during a

match [Appendix6]. However, there are some drawbacks associated with Braille. More specifically, Braille requires much more physical space to represent textual information when compared to Roman characters, and thus impractical when transcribing extensive bodies of text to small, limited spaces.

A.2 Color and Contrast

This category addresses the appropriate use of color and contrast in an inclusive manner. Color and contrast can hinder a player's ability to properly visualize elements, read, or distinguish entire elements particularly player's with visual impairment. With board games, color is often used for aesthetic purposes and to convey important gameplay information. The change of simple graphical elements can make games more accessible to all players and often involves minimum effort [Appendix7].

A.2.1 Don't use color alone to convey meaning

The use of color solely to communicate information poses problems for players that have difficulties perceiving color. The complementary use of text, icons, geometrical shapes, contrast, texture, patterns, and figures can help overcome this difficulty.

A.2.2 Prioritize the use of color blind friendly palettes

Color can be a useful tool to quickly communicate information provided that information is also communicated in another manner to ensure it won't exclude players with visual impairment. Selecting color blind-friendly palettes for gameplay related elements allows for color information to be used in a meaningful manner. Knowing that the most common color blindness is related to the perception of red-green [Appendix8], avoiding the combination of these colors can also make games more accessible to visually impaired players. DeFrisco [Appendix9] suggests six colors that are considerably distinct among themselves when considering

the main types of color blindness, being a good starting point for games that do not use many different colors.

A.2.3 Use of highly contrasted colors

The use of highly contrasted colors makes it easier to identify shapes, read text, and to distinguish different colored components. One of the options to obtain a high contrast is through the use of complementary colors, whereby two colors are chosen such that they have the largest possible contrast between them. However, some adjustment and testing may be necessary to ensure that the level of contrast is appropriate to all players, including those without visual impairment, as a high contrast may lead to visualization difficulties for some players. The use of a black background with text in white or yellow, or the use of a white background with black text presents enough contrast for most people with low vision.

A.3 Information Design

This category focuses on modifications to the graphic design of games to improve the communication of overall visual information. Such modifications can improve gameplay for players with moderate visual impairment. Some recommendations include layout changes and resizing of elements, in order to highlight relevant gameplay information, and increase readability.

A.3.1 Use of larger size fonts and higher readability

Prioritizing fonts with high readability and large size can make it easier to read text present in game components. The American Foundation for the Blind (AFB) recommends a print size of 18 points, and the avoidance of decorative fonts and styling such as Italic fonts [Appendix10]. Mono-spaced sans-serif fonts such as Verdana or Helvetica, provide greater readability for those with low vision [Appendix10]. However, increasing the font size may be difficult to achieve due to limited free space on components. Modifying the writing, enlarging physical components, or

removing irrelevant graphical elements to prioritize text are some alternatives to alleviate this problem.

A.3.2 Enlarging game components whose size doesn't affect gameplay

The size of components, such as cards or boards, is usually defined by industry standards based on manufacturing costs. Increasing a component's size generally ensures the component is easier to identify, read, and manipulate by those who are visually impaired thus, improving their gaming experience. However, it's important to note that in some cases, enlarging the components may make them harder to handle (e.g., cards that are too big to be held/shuffled).

A.3.3 Re-write text to make it concise and/or use keywords

Shortening text, thus making it simpler and more concise, decreases the amount of reading required during gameplay. Some card games such as Magic the Gathering use keywords to compress recurring text, avoiding extensive repetition on many cards. On the other hand, keywords require extra memorization of rules, increasing the game's learning curve. To alleviate this issue, accessible individual player guides can be provided to each player, summarizing and explaining all terms and keywords.

A.3.4 Highlight important graphics related to gameplay

Graphical elements that are present solely for aesthetic purposes must be used in ways that don't conflict with graphical elements directly related to gameplay, prioritizing the communication of the information that is required to play. The use of contrasted demarcations, such as colored outlines, or different levels of image transparency, can quickly convey the hierarchy of information present, and facilitate the identification of elements. Some redesign of components such as cards and boards, to reduce irrelevant graphical elements, may be helpful to provide some players the ability to identify important elements.

A.3.5 Use of iconography complementary to text

The use of complementary iconography allows an element to be quickly identified and its meaning to be understood without the need to read any text. However, it's important that text is still used, as symbols may, at times, be confusing, particularly when players are still learning the rules of the game.

A.4 Game Rules

This category presents modifications of game mechanics, improvements to rules teaching, and promotes behavior change of players. The goal is to improve a player's autonomy and game enjoyment by removing barriers that can hinder a player's ability to properly learn a game or engage during gameplay.

A.4.1 Providing accessible rulebooks

Game rules are usually available in a rulebook, that is, a small textual book found inside the game's box, and also available online. This step can be troublesome for players with visual impairment, as digital versions of rulebooks tend to be incompatible with screen readers. The writing is often targeted to sighted individuals, with information pertaining to game pieces often represented only through images, making them hard to identify in the initial setup of the game for those with visual impairment. The re-writing of rulebooks, including descriptions of the images presented, and proper formatting allow screen readers to be used. Moreover, the use of prerecorded inclusive audio/video is another alternative.

A.4.2 Provide audible feedback about actions performed by players and changes on game state

The recommendation for players to express their actions by talking out loud during a turn is a behavior that can assist players with keeping track of changes occurring between turns. This helps reduce the need to individually check what other actions

players have performed, and how these actions have modified the game state (e.g., changes in resource availability, accessible areas).

A.5 Assistive technologies

This category explores the use of digital technologies and accessories to better accommodate players with visual impairment. Some examples include replacing tangible game components with digital versions, or apps that are able to identify visual information and communicate this information in an alternative manner (e.g., through sound).

A.5.1 Use of an assistive application to identify and read aloud game elements

The use of digital technologies to recognize real objects, such as Quick Response (QR) code, Radio Frequency Identification (RFID), and Near Field Communication (NFC), can be used in board games to allow game components, such as cards, to be identified and described using sound. Moreover, a system capable of identifying changes in game state (e.g., the availability of new cards), and communicating these changes to the players can improve the game experience as it constantly provides feedback to the players without the need for tactile reading. For example, The board game Alchemists [Appendix11] employs a smartphone-based digital app as part of its gameplay and makes use of the smartphone's camera whereby through the use of an image recognition system, the app is able to identify different cards simultaneously and secretly communicate the information to the player.

A.5.2 Conversion of game components and/or analog actions to digital apps

Handling components, such as dice, poses difficulties for the visually impaired as the size of dice tends to be small, slight interactions can modify their value, and checking the result of multiple dice at the same time can be exhaustive. Such components can be converted to a digital app in order to make the gameplay easier.

For example, dice rolls and score tracking can be adapted to digital allowing for sound-based feedback to communicate the results.

Many companion apps are already being developed by publishers to replace or complement tangible components. For example, the official app for the game Dead of Winter [Appendix12] removes the need to use the original "Crossroads Deck" of cards, through the use of a voice acted version of the same deck via the app instead.

Tactile Feedback
TF1 - Use tactile patterns to delimit, identify, or describe components
TF2 - Use pieces with different physical forms to represent different resources or player ownership
TF3 - Use tactile patterns to differentiate pieces that must preserve their original form
TF4 - Use storage compartments to keep components organized on the play area
TF5 - Fix game components to prevent accidental moving
TF6 - Use Braille for identification and description of game components
Color and Contrast
CC1 - Avoid using color alone to convey meaning
CC2 - Prioritize the use of color blind friendly palettes
CC3 - Use highly contrasted colors
Information Design
ID1 - Use fonts with larger size and higher readability
ID2 - Enlarge game components whose size does not directly influence gameplay
ID3 - Re-write text to make it concise and/or employ keywords and tags
ID4 - Highlight important graphical elements related to gameplay
ID5 - Use iconography complementary to text
Game Rules
GR1 - Provide accessible rulebooks
GR2 - Provide audible feedback about actions performed by players and changes on game state
Assistive Technologies
AT1 - Use assistive technologies to identify and read aloud game elements
AT2 - Translate game components and/or analog actions to accessible digital apps

Table A.1: Tomé et al. board game accessibility guidelines

Appendix B

References

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Appendix C

Guideline list changelog

C.1 Guidelines Renamed

- Category: "Tactile Feedback and Organization" [Renamed from "Tactile Feedback"]
- TFO1 - Use tactile feedback to delimit, identify, or describe game elements [Renamed / Old TF1]
- TFO2 - Explore distinct physical shapes to differentiate game elements [Renamed / Old TF2]
- TFO3 - Use storage compartments or game boards to keep game components organized on the play area [Renamed / OLD tf4]
- CLV1 - Do not use color alone to convey meaning [Renamed / Old CC1]
- CLV3 - Use contrasted colors between background and visual elements [Renamed / old CC3]
- CLV6 - Enlarge game components and elements whose size does not directly influence gameplay [Renamed / old ID2]
- GRI2 - Provide audible feedback about gameplay actions and state changes [Renamed / old GR2]

C.2 Guidelines Removed

- AT1 - Use assistive technologies to identify and read aloud game elements [Reason: By itself, this guidelines does not provide any direct guidance. The use of an assistive technology can also be seen as an approach to comply with any of the previously mentioned guidelines.]

- AT2 - Translate game components and/or analog actions to accessible digital apps [Reason: Same as with AT1, the guideline by itself does not provide any direct guidance, only a broad, generic suggestion. Incorporated into the new guideline GRI3, which encompasses strategies that are not only limited to digital assistive technologies]

C.3 Guidelines Combined

- Category: Color, Layout, and Visuals [Incorporated Information Design, previously "Color and Contrast"]

- Category: Gameplay Rules and Interaction [Incorporated Assistive technology topics, previously "Game Rules"]

- INTO TF01: TF3 - Use tactile patterns to differentiate pieces that must preserve their original form [Reason: This guideline was incorporated on TF1 as it just highlights one scenario involved with the task that can happen]. TF6 - Use Braille for identification and description of game components [Reason: This guideline was incorporated on TF1, as it is just a different approach to comply with the goal of guideline TF1]

- INTO GRI3: AT2 - Translate game components and/or analog actions to accessible digital apps. [Reason: The broad aspect of the guideline was incorporated into the newly created guideline now with additional degree of specificity and guidance, not only limited to digital assistive technologies.]

C.4 Guidelines Added

- TFO5 - Ensure all pertinent gameplay information can be communicated through touch [New]
- GRI3 - Provide alternative means to gameplay tasks while preserving the original experience [New, Incorporated old AT2]

Appendix D

Supporting material for Heuristic Evaluation: Guidelines explanation and HE Report

D.1 Tactile Feedback and Organization

D.1.1 TFO1 - Use tactile feedback to delimit, identify, or describe game elements

Tactile patterns, such as embossed geometric shapes and textures, should be used to communicate information through touch about game elements and components.

D.1.2 TFO2 - Explore distinct physical shapes to differentiate game elements

Game elements and components, such as players' pieces and resources, should employ distinct physical shapes to facilitate their visualization and enable identification through tactile perception.

D.1.3 TFO3 - Use storage compartments or game boards to keep game components organized on the play area

The use of accessories such as card holders and plastic organizers improve game setup, play, and cleanup. Such divisions provide players with quick access to components without accidentally scattering them around the play area.

D.1.4 TFO4 - Fix game components to prevent accidental moving

Pertinent game pieces, such as those which its spatiality is important to gameplay, should be partially fixated to enable users to employ tactile perception without accidentally changing the game state.

D.1.5 TFO5 - Ensure all pertinent gameplay information can be communicated through touch

All important gameplay related information should be completely accessible to players irrespective of one's visual ability.

D.2 Color, Layout, and Visuals

D.2.1 CLV1 - Do not use color alone to convey meaning

Color should not be used as the sole communicator of important information, such as gameplay or usability. Color should be used in a redundant manner, with at least one other property communicating the same information.

D.2.2 CLV2 - Prioritize the use of color blind friendly palettes

Colors used in the design to communicate information should be represented in a color-blind friendly pattern, taking into consideration a variety of color blindness conditions, such as deuteranomaly, protanomaly, protanopia, deuteranopia, among others.

D.2.3 CLV3 - Use contrasted colors between background and visual elements

Ensure there is enough contrast between text and background to allow for proper legibility of the information. The contrast ratio is of at least 4.5:1, or 3:1 for large-scale texts. Non-textual visual elements that communicates important information should have increased contrast to allow for proper identification and visualization of the element. The contrast ratio is of at least 3:1.

D.2.4 CLV4 - Highlight important graphical elements related to gameplay

Graphical elements that are present solely for aesthetic purposes must be used in ways that don't conflict with graphical elements directly related to gameplay, prioritizing the communication of the information that is required to play.

D.2.5 CLV5 - Use fonts with larger size and higher readability

Font size should not be size 10 or smaller, with between 12 and 18 being preferable. Line spacing should be at least 1.5 times the font size, and complicated or decorative fonts should is avoided.

D.2.6 CLV6 - Enlarge game components and elements whose size does not directly influence gameplay

Increasing a component's size ensures the component is easier to identify, read, and manipulate by those who are visually impaired, improving their gaming experience.

D.2.7 CLV7 - Re-write text to make it concise and/or employ keywords and tags

Shortening text, and making it simpler and more concise, decreases the amount of reading required during gameplay. Keywords or tags can be used to compress recurring text, avoiding extensive repetition on many components.

D.2.8 CLV8 - Use iconography complementary to text

The use of complementary iconography allows an element to be quickly identified and its meaning to be understood without the need to read text.

D.3 Gameplay Rules and Interaction

D.3.1 GRI1 - Provide accessible rulebooks

Rules, including information regarding game components and gameplay related tasks, should be accessible to players without need for visual ability. Writing used also need to properly describe game elements without referring to visuals. Digital rulebooks should be compatible with assistive technology, such as screen readers.

D.3.2 GRI2 - Provide audible feedback about gameplay actions and state changes

Players should be instructed to provide audible feedback regarding actions conducted in their turns, and any alterations in the game state. Alternatively, an assistive technology should be used to moderate gameplay and communicate pertinent information through audio.

D.3.3 GRI3 - Provide alternative means to gameplay tasks, while preserving the original experience

Another approach to a gameplay task should be available to players for tasks that are inherently non accessible, such as those relying on visual cues, or that can be

overly lengthy and bothersome. Consider alternatives which preserve the original gameplay experience and can be integrated with the default task. Alternatively, an assistive technology should be used to facilitate the task.

D.4 Heuristics Evaluation – Accessibility Issues Report

Instructions:

Write down a short description of the observed issue. Issues should be related to the accessibility aspects of the analyzed design, considering the target audience of persons with visual impairment. Keep in mind that these designs seek to accommodate persons with low vision, color blindness, or that are blind.

If the identified issue violates a specific guideline, please inform the guideline number.

Game:

Identified Accessibility Issue:

Violated Guideline:

Appendix E

Supplemental Material

E.1 Pandemic and Carcassonne master issue lists

Description: Final master list of unique identified issues.

Files:

- "Carcassonne - Problem Matching.xlsx"
- "Pandemic - Problem Matching.xlsx"

E.2 Evaluators Heuristic Reports

Description: Individual heuristic evaluation reports from evaluators for each game.

Files:

- "EvaluatorA - Pandemic - Issues.xlsx"
- "EvaluatorA - Carcassonne - Issues.xlsx"
- "EvaluatorB - Pandemic - Issues.xlsx"
- "EvaluatorB - Carcassonne - Issues.xlsx"

Appendix F

Guidelines presence on evaluator reports.

Pandemic Guidelines	Num. of issues related
CLV3 - Use contrasted colors between background and visual elements.	9
CLV4 - Highlight important graphical elements related to gameplay.	8
CLV6 - Enlarge game components and elements whose size does not directly influence gameplay.	7
TFO1 - Use tactile feedback to delimit, identify, or describe game elements.	5
TFO3 - Use storage compartments or game boards to keep game components organized on the play area.	4
CLV5 - Use fonts with larger size and higher readability.	3

TFO2 - Explore distinct physical shapes to differentiate game elements.	3
GRI1 - Provide accessible rulebooks.	3
GRI2 - Provide audible feedback about gameplay actions and state changes.	3
CLV8 - Use iconography complementary to text.	2
CLV1 - Do not use color alone to convey meaning.	2
TFO4 - Fix game components to prevent accidental moving.	1
TFO5 - Ensure all pertinent gameplay information can be communicated through touch.	1
GRI3 - Provide alternative means to gameplay tasks, while preserving the original experience.	1
CLV2 - Prioritize the use of color blind friendly palettes.	1
Carcassonne Guidelines	Num. of issues related
TFO1 - Use tactile feedback to delimit, identify, or describe game elements.	5
CLV2 - Prioritize the use of color blind friendly palettes.	4
CLV3 - Use contrasted colors between background and visual elements.	3
CLV4 - Highlight important graphical elements related to gameplay.	3
CLV5 - Use fonts with larger size and higher readability.	3

TFO3 - Use storage compartments or game boards to keep game components organized on the play area.	3
TFO4 - Fix game components to prevent accidental moving.	2
CLV1 - Do not use color alone to convey meaning.	2
GRI2 - Provide audible feedback about gameplay actions and state changes.	2
GRI1 - Provide accessible rulebooks.	1
GRI3 - Provide alternative means to gameplay tasks, while preserving the original experience.	1
CLV7 - Re-write text to make it concise and/or employ keywords and tags.	1
TFO2 - Explore distinct physical shapes to differentiate game elements.	1
TFO5 - Ensure all pertinent gameplay information can be communicated through touch.	1

Table F.1: Guidelines presence on evaluator A reports.

Pandemic Guidelines	Num. of issues related
TFO1 - Use tactile feedback to delimit, identify, or describe game elements.	6
CLV3 - Use contrasted colors between background and visual elements.	5

CLV5 - Use fonts with larger size and higher readability.	5
CLV6 - Enlarge game components and elements whose size does not directly influence gameplay.	5
CLV4 - Highlight important graphical elements related to gameplay.	4
TFO3 - Use storage compartments or game boards to keep game components organized on the play area.	4
TFO2 - Explore distinct physical shapes to differentiate game elements.	3
GRI1 - Provide accessible rulebooks.	2
CLV1 - Do not use color alone to convey meaning.	2
TFO4 - Fix game components to prevent accidental moving.	2
GRI2 - Provide audible feedback about gameplay actions and state changes.	1
CLV8 - Use iconography complementary to text.	1
TFO5 - Ensure all pertinent gameplay information can be communicated through touch.	1
GRI3 - Provide alternative means to gameplay tasks, while preserving the original experience.	1
CLV2 - Prioritize the use of color blind friendly palettes.	1
Carcassonne Guidelines	Num. of issues related
TFO1 - Use tactile feedback to delimit, identify, or describe game elements.	5

TFO3 - Use storage compartments or game boards to keep game components organized on the play area.	3
TFO4 - Fix game components to prevent accidental moving.	2
CLV3 - Use contrasted colors between background and visual elements.	2
CLV6 - Enlarge game components and elements whose size does not directly influence gameplay.	2
GRI1 - Provide accessible rulebooks.	2
TFO2 - Explore distinct physical shapes to differentiate game elements.	1
TFO5 - Ensure all pertinent gameplay information can be communicated through touch.	1
CLV1 - Do not use color alone to convey meaning.	1
CLV2 - Prioritize the use of color blind friendly palettes.	1
CLV4 - Highlight important graphical elements related to gameplay.	1
CLV5 - Use fonts with larger size and higher readability.	1
CLV7 - Re-write text to make it concise and/or employ keywords and tags.	1
GRI2 - Provide audible feedback about gameplay actions and state changes.	1
GRI3 - Provide alternative means to gameplay tasks, while preserving the original experience.	1

Table F.2: Guidelines presence on evaluator B reports.