EXPLORING ACCESSIBILITY ENHANCEMENT IN PRINTABLE BOARD GAMES THROUGH 3D PRINTING WITH A HEIST BOARD GAME CASE STUDY

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In recent years, 3D printing has emerged as a technology that has the potential to transform various industries. It enables the creation of three-dimensional objects by layering materials based on a digital design. This process has gained widespread attention due to its versatility, efficiency, and possibilities for customization and prototyping. One of these areas in which 3D printing can be transformational is the development of Indie board games or so-called printables. A beneficial aspect 3D printing provides is the ability to add accessibility for visually impaired people into board games by designing game elements that provide haptic feedback. As a case study, we designed a heist board game involving a generated game map assembled using 3D-printed elements that snap together so that an accidental moving of one part does not affect the board. The figures and game elements are also designed as 3D prints so that they can be identified by touch as well as by their visual design. The game also involves cards with a cut edge to signal their orientation and a QR code that enables a mobile app to read the card's content to the player. Producing the game is, however, significantly longer than a standard (2D) printable game since the 3D elements require significant time for printing. The printing time of all elements in full size amounts to 100 hours on a Prusa i3 printer. Thus, the usage of 3D-print technology for producing games is expected to be limited to prototypes or special applications.

Keywords: Accessibility, Tabletop games, Inclusive design, 3D-Printing, Heist board game

1. Introduction

In recent years, there has been a growing recognition of the importance of accessibility in gaming, particularly within the realm of tabletop games. While much attention has been devoted to enhancing accessibility in video games, the needs of visually impaired individuals to enjoy tabletop gaming experiences have often been overlooked. This gap in research underscores the necessity of exploring and addressing the accessibility challenges faced by visually impaired players within the tabletop gaming community. Additionally, advancements in 3D printing technology present an opportunity to create accessible board games with elements identifiable by touch and sight, offering a versatile and efficient process compared to traditional Print & Play games on platforms like BoardGameGeek. Despite the potential benefits, the extended production times associated with 3D-printed games present a significant obstacle to mass production viability. Even moderately small games can demand printing times of up to 100 hours on a typical hobby 3D printer, rendering large-scale production impractical. In addition to the time spent, economic costs for printer hardware, energy consumption, and printing material have to be considered. Consequently, it's unlikely that mass production by publishers and industry-level printers will be supplanted. However, 3D printing opens avenues for niche markets, facilitating the creation of individualized games and, as demonstrated in the accompanying case study, supporting the development of self-printable games with accessibility features.

This paper aims to contribute to the discussion on creating more accessible games, specifically for people with visual impairments, through the utilization of 3D printing technology. As a case study, we present the development of a printable board game prototype designed to be accessible to visually impaired individuals. The paper begins by reviewing existing research in this field, highlighting the need for accessible board and card games. Subsequently, we outline the processes involved in the development, including finding a game idea, designing the game outline and elaborating solutions to make the 2D and 3D parts of the game accessible for all players. The final design also involves an assistant app that helps with game setup and a text-to-speech feature for reading the cards. At the end, we provide a link to access the complete game and ruleset, offering insights into the practical implementation of accessible gaming through 3D printing technology.

2. Related Work

Even though board games enjoy great popularity, several scholars have noticed that research primarily focuses on accessibility in video games (Tomé et al., 2019; Bolesnikov, Kang, & Girourad, 2022). However, this does not diminish the necessity and demand for accessible tabletop games. Tabletop games include "board games, dice games, and card games" (Bhaduri, Tovar, & Kane, 2017, p. 52). One of the most prominent issues in these games concerning accessibility is how players need to rely on visual information to make them playable for visually impaired people (Johnson & Kane, 2020, p. 1). This leads to the majority of tabletop games not being accessible. As Johnson and Kane mention, they "often rely on printed text and visual distinctions such as colors, text, visual textures, and symbols" (2020, p. 1). Another aspect that the authors noticed was the effect of social and competitive aspects concerning playing board games. The authors argue that in non-cooperative games, blind and visually impaired people will need or want to ask other players for help (Johnson & Kane, 2020, p. 1). Since the majority of competitive board games rely on secret information and strategies, requiring help from rival players can make it nearly impossible to have a fair competition. Therefore, cooperative gameplay can offer more fun elements to the players.

Bolesnikov, Kang, and Girourad research in their article "Understanding Tabletop Games Accessibility: Exploring Board and Card Gaming Experiences of People who are Blind and Low Vision" from 2022 what elements are included in inaccessible games. During their study, the authors noticed that due to an inaccessible rulebook, players reached out for sighted assistance as physical game instructions do not include Braille (Bolesnikov, Kang, & Girourad, 2022, p. 5). However, participants of the study also used online manuals (Bolesnikov, Kang, & Girourad, 2022, p. 5). Yet, these often include several accessibility issues such as the inclusion of images (Bolesnikov, Kang, & Girourad, 2022, p. 5).

Another problem is the implementation of inaccessible game content. According to Bolesnikov, Kang, and Girourard (2022), the resulting physical effort of reading texts due to their smaller text size, led to players abandoning the game (p. 5). In addition, making the communication of information dependent on color also led to difficulties in distinguishing elements (Bolesnikov, Kang, & Girourad, 2022, p. 6). While touch being a suitable substitute for blind and visually impaired people, according to the authors' study, several issues can arise in this area, for example, not using physically distinct pieces, or a lack of tactile features (Bolesnikov, Kang, & Girourad, 2022, pp. 6-7).

Johnson and Kane also add the lack of knowledge of the position of pieces and the information on cards to accessibility problems in tabletop games (Johnson & Kane, 2020, p. 7). For example, the board game Monopoly (Hasbro 2023) consists of one board with different fields of color to differentiate between various districts, 2D printed cards and money, and 3D player figures. It does not include any tactile components on the board for people with visual impairment to distinguish between the single fields. While the 3D figures are distinguishable through having different forms, the player can too easily move the pieces on accident due to no restrictions being on the board itself. The same issue applies to the hotels that can be placed on the fields. The information on the cards is also not available to people with visual impairment. The affected player would need to rely and trust on others to read out the written text truthfully. Additionally, while color is included for each district, people with color blindness would not be able to distinguish between them without relying on the text. Monopoly also includes game currency that is only differentiated by the text and color of the 2D printed paper. It would have been beneficial to design the bank notes in different sizes depending on their value. The same issues are also included with the board game Catan - Das Spiel (Teuber 2015). While the board itself is somewhat accessible due to puzzle tiles restricting the movements of the single fields, the 3D pieces can still move freely on the board and a differentiation between what resource each provides is only available through color. Affected people can also not distinguish between the various card types, the numbers on the coins on the board, and the 3D pieces of each player which rely on color. Compared to Monopoly, it is also more difficult to depend on another player due to information such as what resources are in one's hand and what type of development cards one draws, should be concealed from others. All these issues noticed in analog games lead to either player being reliant on others (Johnson & Kane, 2020, p. 7), the abandonment of games (Johnson & Kane, 2020, p. 8), both of which have also been noticed by Bolesnikov, Kang, and Girourad (2022, p. 5), and an unfair gameplay (Johnson & Kane, 2020, p. 8).

Through 3D printing, this problem could partially be diminished by providing a more tactile experience for players. For example, Bhaduri, Tovar, and Kane (2017) researched that most 3D printable artifacts are items for existing games, while rarely providing and distributing original games (p. 53). To be more precise, he considered 3D-printed objects as a means to "improve the accessibility of existing games for people with vision impairments, including 3D-printed Braille dice and tactile overlays for game pieces" (p. 53), For this reason, we designed a printable tabletop game that uses 3D printing to enhance playability for visually impaired people. Tomé et al. provide a guideline on how to create accessible board games in their paper "Let's Play Together: Adaptation Guidelines of Board Games for Players with Visual Impairment" (2019), which was then expanded and compared with Bolesnikov, Kang, and Girourad’s work that centers on the accessibility of mechanics and aesthetics in tabletop games (2022). One aspect Tomé et al. highlight is the usage of tactile feedback. According to the authors, using texture and shapes can help in spatial orienting, and learning and memorizing patterns (Tomé et al., 2019, p. 8). Essential in this case is also the implementation of distinct characteristics for different components so players can distinguish between various items (Tomé et al., 2019, p. 8). Another important aspect is to use fixed components (Tomé et al., 2019, p. 8). This helps to prevent accidental moving (Tomé et al., 2019, p. 8). Various methods are suggested, such as Velcro, magnets, or pegs (Tomé et al., 2019, p. 8). However, when talking to the University's Disability Representative Mark Wassermann, magnets were not recommended due to the fine-tuning necessary of the magnets' strengths to enable the easy movement of items while ensuring stability for components to not fall over easily. (Mark Wassermann, personal meeting, November 7, 2022) The last aspect to add tactile feedback is to use Braille. According to Tomé et al. (2019), this inclusion helps to provide information and to discern different items (p. 8). However, more space is required to communicate information (Tomé et al., 2019, pp. 8-9). Another drawback to this method would be that visually impaired people do not often learn Braille nowadays and rather learn to distinguish between Roman characters as stated by Mark Wassermann (Mark Wassermann, personal meeting, November 7, 2022). This observation is supported by Bolesnikov, Kang, and Girourad (2022, p. 13). For that reason, alternatives need to be applied.

Another aspect that is important to consider is color and contrast. As stated by Tomé et al., highly contrasted colors need to be used to make items easily distinguishable (2019, p. 9). Additionally, due to different varieties of color blindness, one should use more colorblind-friendly palettes so that everyone is able to discern between the colors (Tomé et al., 2019, p. 9). This is crucial information to consider when designing a board game. However, in the end, the most important aspect is that color is not used to convey meaning (Tomé et al., 2019).

After color, the design of information for better communication is necessary to examine. This entails the inclusion of large size fonts, concise text with the eventual usage of keywords, and the incorporation of iconography (Tomé et al., 2019, pp. 9-10). However, the authors also note that enlarging the font is not possible due to space restrictions (Tomé et al., 2019, p. 9). For that reason, modifying components, text, or even restricting them, might be necessary (Tomé et al., 2019, p. 9).

An essential part of a board game to evaluate is the game rules and with that the rulebook. Without being able to communicate these instructions, playing the game will be impossible for visually impaired people. Tomé et al. highlight that many rulebooks make use of images that contain information that cannot be translated via a screen reader (2019, p. 10). For that reason, the authors suggest adding descriptions or including audio and video as alternatives (Tomé et al., 2019, p. 10). Bolesnikov, Kang, and Girourad further recommend providing text that is simple to understand so players can focus their energy on the main aspects of the game (2022, p. 14).

Essential developments in digital technology are helpful to communicate information to visually impaired people. Tomé et al. state that there are various possibilities such as QR code, Radio Frequency Identification, and Near Field Communication (2019, p. 10). These systems make it possible for game elements "to be identified and described using sound," and "identifying changes in game state [...] and communicating these" (Tomé et al., 2019, p. 10). This leads to providing constant feedback during the game (Tomé et al., 2019, p. 10).

Bolesnikov, Kang, and Girourad also highlight the importance of "encourag[ing] autonomy in games," (2022, p. 14). They argue that visually impaired people should not be dependent on sighted assistance (Bolesnikov, Kang, & Girourad, 2022, p. 14). This argument includes all the previous aspects already mentioned as these elements ensure the accessibility of a board game but is important to point out again.

3. Game Design

After deciding to create a printable game based on 3D printing with accessibility in the foreground, we created one mind-map each for two different game ideas to decide what we want to develop. First, we identified which elements are essential for designing a game. These would be “Type,” “Mechanics,” “Game Time” or playtime, “Genre,” “Board,” “Number of Players,” and “Winning Condition.” The result of one mind-map was a cozy game with around 45-60 min playtime that should be able to be played between 1, 2, or 4 players. The design decisions also led to both a competitive and cooperative mode, with the players using action points and tokens to play the game. Due to the printable element, players should be able to play on one board with tiles together and/or separately on individual boards. The win condition should consist of a number of reached victory points. However, after some iterations, the competitive mode was canceled due to being less fun for visually impaired people for the various reasons mentioned above, and the cozy genre was changed because of our choice of theme.

The game's theme was decided to be a heist game where players try to rob a bank vault while avoiding robot guards. The main goal is to make a successful heist, and escape the bank, while cooperating and helping eac

Subsequently, we discussed which elements should be included and what the game should look like in terms of these categories. In the end, we decided on a cooperative game that could last between a short and long game length, depending on each round. The cards and turn-based movements were included for the mechanics from one mind map as well as the tokens from the other. At first, the board would have been one single tray with singular tiles slotted into it, with the winning condition being to reach a specific destination and kill an opponent there. However, after the first prototype was made in the tabletop simulator (Berserk Games 2015), the game was adapted and improved as the play experience was neither satisfying nor exciting. The mechanics needed a more unpredictable element that engages the players. For this reason, dice were included. Even though we liked the decided-upon win condition, we added a more challenging one in which the players must reach an end destination. This means that there are four goals in total: getting keys, reaching destination 1, defeating the opponents, and reaching destination 2.

4. Card Design

The event cards, skill cards, and guard randomizers are distinguished both by the color and by the symbol on the back of the card. A significant color difference has been used to ensure that people with specific color blindness can still differentiate between these. The symbols also establish a high contrast with the back, and due to the black and white coloration, they are easily distinguishable. It was decided to add a colorful background to provide a more aesthetically pleasing style rather than just a black-and-white theme and symbols (see Figure 1). More difficult was the design choice for the front side of the event cards. Due to the already established meaning of colors - red signals danger, while green is associated with a more positive meaning - it was impossible to create a set of cards without losing the aesthetical element for people with, specifically, the red-green blindness. Nevertheless, these cards are still understandable without depicting the right coloration due to the text. They only add a more aesthetically pleasing design. However, after some feedback, adding more contrast to the colors would help to distinguish the cards more easily if wanted.

To add more tactile components, the right top corner is cut off to signal the front of the card. This is helpful for people with visual impairments, as the cut-off corner always has to be on the top right side so that it is turned in the correct direction. This feedback was provided by Mr. Wassermann (Mark Wassermann, personal meeting, November 7, 2022). Additionally, a QR code has been added in the bottom right corner on all cards so that the specific game app can read the provided text out loud. This is helpful for people with low vision. The codes are always placed in the same place to facilitate scanning.

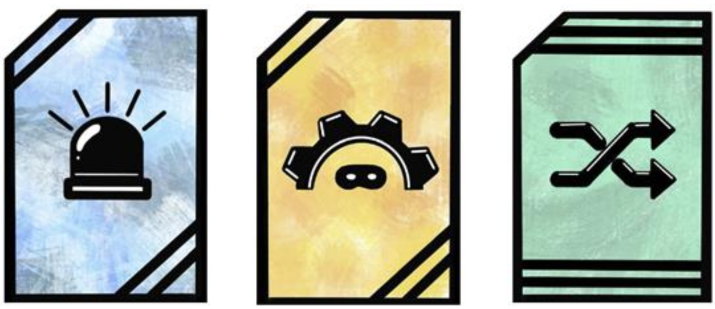

Figure 1. Event, Skill, and Guard Randomizer Cards - Back Design

5. Token Design

Due to efficiency problems concerning 3D printing, a 2D design and print were necessary for various tokens. Instead of 3D-printed weapons, players are able to print out 2D designs of both the lethal and non-lethal weapons. As the guards are robots, an object that looks similar to Tasers was designed to signal the effect of electricity on technology. One difference that distinguishes them from each other is the triangle form at one end of this element. This form is inspired by literature on the aesthetics of game art. According to Solarski (2013), triangles are associated with “aggression, masculinity, [and] force” (n.p). For this reason, due to the connection to more physical energy, lethal weapons have a triangular edge that indicates a more aggressive method of attack. This form is also helpful in identifying each type of weapon for visually impaired people. It ensures that they can feel the differences between both forms while still keeping a similar design (as seen in Figure 2).

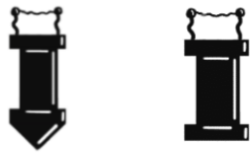

Figure 2. Lethal and Non-Lethal Weapon Design

6. 3D-Printed Parts

The game models are designed to provide a good game feel while being accessible and recognizable for different groups with visual impairments. As the game is intended to be highly replayable, the game board consists of 16 tiles, representing different rooms, each printed separately. The individual pieces include their name written in 3D on top of them, which allows for an easy reading of their label by touch. To keep the game as time and cost effective as possible, the tiles are designed in a way to require a minimum amount of material for printing, while they still maintain and offer the feeling of a board game. To achieve this goal, each tile is printed in an L-shape to only include the two necessary sides for each room, which are then connected with notches on the top left corner to form the entire game board. These parts are designed to fit perfectly together like a puzzle to allow the players an easy setup of any board that is given to them through board randomizer cards or the application. There are also special slots on the tiles designed to attach walls.

Figure 3. Game board consisting of L-shaped connectable tiles

The game uses three figure types: players, enemy robots, and hacked robots. To distinguish all these in the models, different shapes of heads are used. The player pieces have round heads. To add more contrast, a marking that helps to identify the player's number was added on the front side of their bodies, which is also feelable by touch. Compared to these figures, the enemy robots use a square head. The hacked robots have the same shape as the enemy robots, but they have a pointy part on their head.

Figure 4 shows three player pieces and two robot guards as 3D-printed figures. The circles visible on the enemy robots are used as tactile counters for cases where they are t disabled due to events in the game. By putting the figure to its side and rotating it every round, the player can keep track of how many rounds the robot is turned off for and when it should be reactivated and join back the game.

Figure 4. 3D-printed figures with embossed markings

7. Assistant Application

An assistant application was developed to support visually impaired players well through its voice reader function, while also enhancing the game for all players. This app was designed using Flutter Framework (Google 2017) and is targeted for Android devices. The built-in narrator system included in Android devices is utilized to talk and communicate with the users. To support all types of players, well-contrasted colors between background and foreground have been taken into consideration. Using the free applications offered by W3Schools (Refsnes Data AS 1998) and Webaim (Utah State University 1999), the contrast of colors has been checked and confirmed to offer clear visibility also for color-blind people.

With all that in mind, the application includes three parts: QR Reader, Board Randomizer, and Guard Randomizer. The QR Reader is the part designed specifically for visually impaired players. This feature is used to read the cards out loud. For this to work, a QR code is printed on every card used in the game. By scanning the QR codes using the application, the cards' content will be read out to the player due to the voice reader function. The board randomizer takes advantage of the app to provide a better experience for every player while offering an accessible system for the visually impaired. Similarly, the guard randomizer provides variability by generating different scenarios for randomizing guards. The guards and keycards are randomly placed in the game, following placement rules implemented in the app. A narrator is also available to read the setup out loud for players to follow. The same settings as the board randomizer are available for the narrator in this section.

8. Gameplay Example

For better understanding of how the game plays, this section includes one scenario of gameplay. In the following image, the green player is 2 moves away from reaching the Vault, which is the first goal of the game. However, the player is stuck between 2 active guards and due to the rules of the game, is not easily capable of moving out of the room. To move out, they either have to defeat the guards using their available ammunition and throwing the required die or escape by throwing the needed die for that.

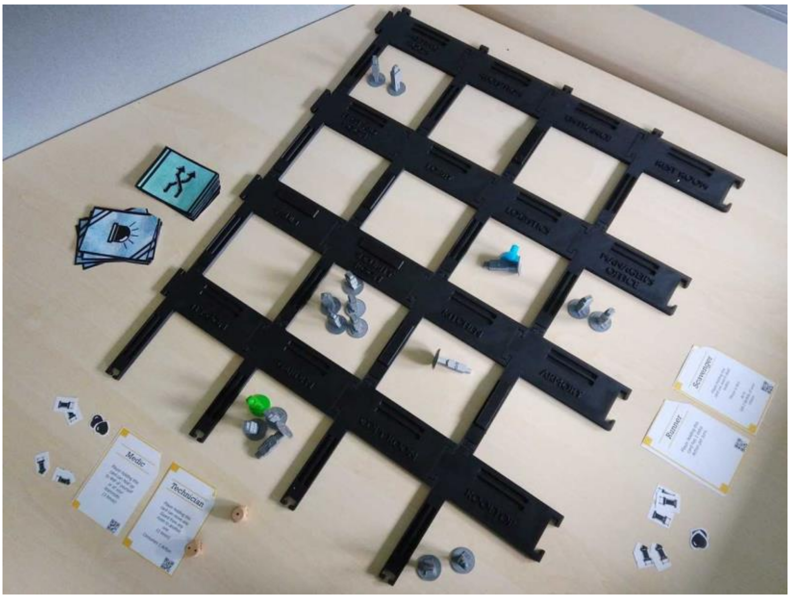

Figure 5. A gameplay scenario from a 2-player game

The blue player, however, is capable of moving due to the single guard present in their room being inactive, but due to the positioning of the walls in this randomly generated scenario, the player does not have a direct and quick path to the Vault and can only move thereby passing through the same room as the green player. Having the Runner skill card makes this easier for them.

The situation shows a relatively easy scenario where players have a few actions in front of them. With good cooperation and smart use of their available skill cards, players are able to get to the Vault and continue forward with their goals.

That being said, with the random event cards in the game, everything can change at any moment for the players, making the situation tough and more challenging.

9. Conclusion

This paper's main contribution is elaborating a method to design and develop a printable board game prototype designed to be accessible to visually impaired individuals. Using 3D printing technology and carefully designed 2D elements, we have addressed the need for accessible board and card games for people with visual impairments in the example of a heist board game. Our considerations highlight the importance of inclusive game design, including large-size fonts, concise text, iconography, and alternative formats like audio and video descriptions. As we have shown in the case study, these things can be well addressed in a homebrew board game, given the availability of a 3D printer and a hybrid game design using an assistant app. The prototype game is a heist game where players aim to rob a bank vault while avoiding guards. While the main goal is to make a successful heist, there is also competition between players to make the most revenue. Thus, the money aspect leads to competitiveness in an otherwise cooperative setting in the game. Overall, this paper offers practical insights for implementing accessible gaming through 3D printing technology, By looking into the accuracy and time and financial resources required for a 3D accessible game, this paper provides a valuable contribution to the field using widely available technology.

The resources of the complete game, including rulebook, 2D and 3D models, assistant app, and sources, are available at https://github.com/farhadk100/3D_board_assistant under a Public domain license.

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