

# Game Changer

## Accessible Audio and Tactile Guidance for Board and Card Games

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### ABSTRACT

While board games are a popular social activity, their reliance on visual information can create accessibility problems for blind and visually impaired players. Because some players cannot easily read cards or locate pieces, they may be at a disadvantage or may be unable to play a game without sighted help. We present *Game Changer*, an augmented workspace that provides both audio descriptions and tactile additions to make the state of the board game accessible to blind and visually impaired players. In this paper, we describe the design of Game Changer and present findings from a user study in which seven blind participants used Game Changer to play against a sighted partner. Most players stated the game was more accessible with the additions from Game Changer and felt that Game Changer could be used to augment other games.

### CCS CONCEPTS

• Human-centered computing • Accessibility technologies

### KEYWORDS

Accessibility, Blindness, Collaboration, Board Games, Visual Impairments, Audio Description

## 1 Introduction

Board and card games have served as a common form of social interaction since the Ancient Egyptians invented Senet in 3000 B.C. [26]. In modern times, board games remain a popular pastime for friends and families, due in part to the added intimacy of playing a game face-to-face vs. looking at screens [8, 23]. Board and card games can serve many roles: as an exciting challenge for peers, as a collaborative social experience between friends, or as a way for family members to spend quality time together.



**Figure 1. A player uses Game Changer's audio guidance and tactile landmarks to explore the board game SORRY!.**

However, the design of many board games may unnecessarily exclude some players. Over 217 million people have moderate to severe vision impairments and 36 million are blind [35]. Like anyone else, blind and visually impaired (BVI) people enjoy playing games with friends, family, and even competitively [21]. Without modifications, the majority of board and card games are not accessible to BVI players as they often rely on printed text and visual distinctions such as colors, text, visual textures, and symbols. While it is sometimes possible to buy accessible versions of games (e.g., [17]), or to modify your own games to be accessible at home (e.g. [30]), the vast majority of commercial board and card games are inaccessible by default, and players may lack the skills, knowledge, or time to make their own games accessible.

Our work here is motivated by the goal of enabling players to easily adapt their existing games to be more accessible. For BVI players, this often involves adding audio or tactile information to a game [3]. Here we explore the use of tangible computing to enhance existing games by adding sounds and textures.

In addition to enabling BVI players to play more games, we must also consider how modifications to a game may affect the social and competitive aspects of gameplay. While in some cases a BVI player may want to ask another player for help, the situation may be further complicated if they are competing with that other player. Thus, building a platform for accessible games involves

both designing an accessible interface to the game as well as ensuring that the accessible interface is fun and fair.

To explore the challenges and opportunities of making board games accessible through tangible computing, we introduce *Game Changer*, a prototype system that supports players in making games accessible by augmenting them with audio descriptions and tactile overlays. We have developed a prototype version of Game Changer that supports three commercially available board games: Hasbro's Monopoly and SORRY!, and the popular children's game Chutes and Ladders. To evaluate the impact of Game Changer on accessibility, we tested Game Changer in a series of test games in which BVI and sighted players played SORRY!. We found that BVI players felt the game was more accessible with the additions from Game Changer and felt that they could use Game Changer to augment other games.

The contributions of this paper include the Game Changer prototype system, which enables users to make board games accessible via accessible audio and tactile feedback, and feedback from a user study in which 7 BVI people tested Game Changer in a game against a sighted opponent.

## 2 Related Work

### 2.1 Accessible Games

Currently, most research focuses on making computer and video games accessible [1, 2, 3, 7, 15, 25]. However, board games are largely still inaccessible to BVI players.

#### 2.1.1. Accessible Board Games.

There have been few research efforts in making board games accessible straight out of the box. For blind players, many games can be made accessible by following common accessibility guidelines [14] such as adding Braille labels and augmenting board elements with tactile shapes and textures.

While these kinds of modifications may be made by players (with appropriate support), some companies have chosen to create and sell modification kits for existing games [17, 24]. Some community members have created accessible game modifications and posted them on 3D modeling repositories such as Thingiverse [30]. These objects, such as an accessible Monopoly board [31], can be printed at home or by a commercial 3D printing service. These 3D-printable objects may have similar functionality to commercial kits at a lower cost, if end users have the technical skills to produce them [6, 12]. While more high-tech accessible games exist, such as Haptic Sudoku played on a haptic display [18], these games are largely limited to research prototypes and are not commercially available.

These accessible game kits offer several limitations. First, players may be restricted to playing games for which accessible versions have already been made [20]. Second, these kits are game-specific, meaning that creating an accessible version of a new game often requires starting from scratch. Given these limitations,

there is value in introducing technologies that work to make multiple games accessible, as we propose here.

### 2.2 Accessible Collaboration

Much research in accessible collaboration has focused on the quality of collaborative interactions between blind and sighted people when conducting tasks at home [10], while shopping [34], in the workplace [11], when programming [29], when navigating [33], and when participating in online communities [12]. A common theme across this research is that technology can both support and hinder interactions between different abilities. When accessible technology is not designed with collaboration in mind, it can isolate people with disabilities or even increase their dependency on their partner to perform tasks for them.

While the primary focus of this work is on making games accessible, our work considers how design decisions about our system can impact the quality of the collaborative relationship between players. Because board games often involve competitive interactions between friends and family, they may present unique challenges to accessible collaboration.

### 2.3 Social Play in Board Games

Researchers have studied how social interactions form during gameplay. Much of this research has focused on the concept of social play, which is defined as active engagement with a game (through use of its controls or through observation and attention to ongoing game play) by more than one person [22]. Games research have found that games must balance social interactions with a feeling of autonomy [28].

Xu et al. [32] observed the social play in board games and categorized five types of social communication that take place during gameplay:

- 1) Chores: interactions arising from activities needed to maintain or update game state;
- 2) Reflection on gameplay: reacting to or reflecting on gameplay after a move;
- 3) Strategies: discussion play before a move;
- 4) Out-of-game interaction: talking about topics outside of the game;
- 5) Discussing the game itself: commenting on the game as an artifact.

Our goal in this work was not to create a new accessible game (as that would only affect one game while leaving others inaccessible), but instead to explore technologies that help make existing games more accessible. In developing Game Changer, we attempt to add accessibility without disrupting any social aspects of the existing game.

## 3 Board Game Accessibility Goals

As mentioned above, designing accessible versions of games carries a unique set of challenges. In making a game accessible, it

is important to not upset the balance of the game design, place players on unequal footing, or reduce the entertainment value of the game. Based on our review of accessible board games frameworks [14, 19, 20], and our iterative design of the Game Changer prototype, we identified the following design goals for our work.

### 3.1 Design Goals

In developing Game Changer, our decisions were guided by the following goals:

**Equal.** Any information that is present in the visual parts of the game should be accessible in other media.

**Fair.** The design of the accessibility features should not give any player who uses them an unfair advantage or disadvantage.

**Fun.** The design of accessibility features should not fundamentally transform the gameplay or the ability to play the game as part of a social interaction.

**Versatile.** The methods used to add accessibility features to the game should be applicable to other games as well.

In addition to these core goals, we identified some secondary goals that informed the design of our prototype:

**Easy to set up.** Any additional work required to manage the game's accessibility features should be simple and quick.

**Use available materials.** Whenever possible, any modifications to a game should use easily available materials, including the original board game and off-the-shelf technologies.

**Reversible.** Any changes made to the game board itself should not impede play for any player. Ideally, any adaptations should be reversible.

**Portable.** Players may wish to play games in a variety of settings or may wish to bring their game elsewhere. The accessible version of a game should be as portable as the original game.

**Tangible.** A part of the appeal of board games is their physicality [8], any accessible game should attempt to maintain the familiar tangible elements such as moving player tokens, drawing cards, and rolling dice.

**Customizable.** Because different players may have different accessibility needs, and because some gaming groups may have house rules, the system should be customizable.

### 3.2 Supported Games and Activities

There are many thousands of board games in existence. For example, the web site BoardGameGeek<sup>1</sup> lists over 100,000 games. These games may differ widely in their physical form, use of visual media, and gameplay mechanics. In developing Game Changer, we considered trade-offs between the level of assistance

provided and the complexity of the resulting system. Following our design goals, we chose to explore solutions that would support specific game types, with the intention that our system could then be applied to other games of that type.

For Game Changer, we focused on the category of “roll-and-move games” in which players roll dice (or spin a spinner) and move pieces around the board. This category includes many popular games; the popular web site BoardGameGeek lists thousands of games in this category, and over 600 that had been reviewed by at least 100 users<sup>2</sup>. Game Changer increases the accessibility of these games by supporting the activities common across most roll-and-move games:

**Recognizing cards and game pieces.** The system should be able to identify and read out any component of the game.

**Describing the game state.** The system should be able to analyze the game board or play area and describe the current state of the game, including the location of any game pieces.

**Describing changes.** The system should be able to identify and describe actions made by the player or by an opponent.

**Directing movement.** The system should support the player in moving game pieces, drawing cards, or taking other actions within the game.

**Supporting random elements.** The system should provide an accessible version of random inputs such as dice or spinners.

## 4 Game Changer

We present Game Changer, a system that combines audio descriptions and tactile landmarks to enable BVI players to independently play board games. Game Changer's primary function tracks game pieces as they move around the game board using an overhead camera. The BVI player uses an attached keypad to query the state of the board, receiving information via text-to-speech (usually via headphones to maintain privacy). In addition to audio descriptions, Game Changer allows players to add tactile annotations to the board.

### 4.1 Supported Games

Our initial prototype of Game Changer was designed to work with Hasbro's SORRY! board game. The objective of SORRY! is to get all three of the player's game pieces around the board and into your respective home zone before your opponents. Players draw cards to determine how far they can move and bump opponents back to their start if they land on the same space or draw a SORRY! card.

We chose SORRY! as our proof of concept for several reasons: because it is playable by younger and older players; because it has

<sup>1</sup> [boardgamegeek.com/browse/boardgame](http://boardgamegeek.com/browse/boardgame)

<sup>2</sup> [boardgamegeek.com/boardgame/mechanic/2035/roll-spin-and-move](https://boardgamegeek.com/boardgame/mechanic/2035/roll-spin-and-move)

a relatively low learning curve; because it is a popular game<sup>3</sup>; and because it contains many elements common to other roll-and-move board games, such as drawing and playing cards and moving game pieces on a board.

In addition to supporting SORRY!, we have used Game Changer to adapt two other board games: Monopoly and the classic game Chutes and Ladders. To demonstrate the ease of extending Game Changer to support new roll-and-move games, code and metadata files for each of these games are included with this paper<sup>4</sup>.

## 4.2 System Hardware

The Game Changer software runs on any laptop computer. The game is tracked by a Logitech C615 webcam, attached to a movable arm. User input is provided via an attached USB 10-key keypad. Figure 2 shows the system hardware as used to augment the board game SORRY!.



**Figure 2. System setup that shows the laptop, webcam, numeric keypad, and game board.**

In designing Game Changer, we faced a decision about whether to limit system feedback to audio feedback only (which would ease setup and perhaps increase generalizability) or to also provide tactile feedback on the game board. Based on our prior experiences creating accessible interfaces, we felt that the advantages of tactile information outweighed the drawbacks, and thus modified the game boards to provide some tactile feedback. For example, on the SORRY! game board, we added tactile dots next to each game space. Currently, it is up to the players to add these tactile features to their own board; while future versions of Game Changer could automatically create tactile overlays for a game board, this approach allows players to add tactile features only in places where the BVI player needs them; for example, a novice SORRY! player may want each space on the board to be

labeled, while a more advanced player may prefer only key spaces to be labeled. Game Changer’s core features (reading cards and describing the location of pieces on the board) can be used regardless of the presence or absence of tactile overlays.

Finally, to support easy tracking of game pieces, and to improve the tactile differentiability of pieces, we fabricated a set of game tokens that were differentiable by touch (Figure 3). These pieces were laser cut from wood and painted, although they could be made using other means such as 3D printing or hand-cut cardboard. These pieces were designed to be generalizable across different types of games, so that they could be fabricated once and used many times.

The Game Changer hardware setup is low-cost and uses materials that are widely available. The webcam we used cost approximately \$70 USD and the tactile elements cost approximately \$20 USD. While our system was developed on a MacBook laptop, the code could be run on a low-cost, single-board computer such as Raspberry Pi (~\$35 USD).

## 4.3 System Software

Game Changer’s code was written in Python. OpenCV [9] is used to capture and process images of the game. We placed ArUco markers [16, 27] on each card and game piece so that they could be easily and accurately tracked.



**Figure 3. Wooden game pieces that have been laser cut into the shape of circles, squares, and pentagons with ArUco markers on them.**

Wherever possible, Game Changer’s code is written to be game-agnostic. Data specific to each game is stored in a comma-separated *game description file*. This file contains text labels for each card and game piece; each game component is associated with a unique ArUco tag ID. This file also contains a map of the board layout describing each space on the board. Each space is labeled with its name or number from the game board; because spaces in SORRY! are not numbered, we numbered the spaces in ascending order from the BVI player’s starting position. See our code<sup>4</sup> for examples of game description files.

Each game file was generated by hand by the first author, who manually labeled regions on an image of the game board and transcribed the game cards. This process took about one hour per game. Fortunately, once this file is created for one game, it could

<sup>3</sup> As of December 20, 2019, SORRY! is the #14 bestselling game on Amazon.

<sup>4</sup> [github.com/gabriellaj45/GameChanger](https://github.com/gabriellaj45/GameChanger)

be shared and reused; e.g., once one person has labeled the standard Monopoly board and cards, other players could use that game description file with their own copy of the game.

When the BVI player requests information about the board, Game Changer captures an image of the board, identifies the board's edges [13], and adjusts the image to correct for the camera position. This corrected image and its ArUco markers are compared to the map in the game description file to determine the location of items on the game board.

#### 4.4 User Interaction

In general, players play the Game Changer-enhanced game as they would the normal game. At any time, the BVI player may press a key on the input keypad to query information about the state of the game. We chose to provide audio feedback only by request (rather than constantly describing the game state) so that it would not interfere with players' conversation, and because a player's hands often occlude the game during their turn.

Game Changer provides a standard set of commands for interacting with the game board, shown in Table 1.

Key	Action	Example Output
1	Describe BVI player's pieces	"The yellow square is at space number 4."
2	Describes other pieces.	"The red circle is at space number 34."
3	Describes all visible pieces.	"The yellow square is at space number 4. The red circle is at space number 34."
4	Reads last drawn card.	"Card 2: Move forward 2."
5	System help.	"Press 1 to hear the location of your game pieces. Press 2 to hear the location of your opponent's pieces. Press 3 to hear the location of all game pieces. Press 4 to read a card. Press 5 for instructions."
9	Reads extended description of the BVI player's current space.	"Slide, move forward 3 spaces."
Enter	Roll dice.	"6"

**Table 1. Game Changer commands and example output.**

While commands generally function similarly across games, Game Changer supports limited customization based on the specific game. For example, because Monopoly may have many different types of pieces on the board, the player can provide additional key presses to query specific pieces (e.g., "71" to read out the location of houses, and "72" to read out the location of hotels). When considering how to extend Game Changer to support multiple games, we noticed that games often use different objects to introduce randomness into the game. For example, Monopoly players roll dice to indicate how many spaces to move,

while Chutes and Ladders players spin a wheel. Rather than create an accessible version of each randomness source, Game Changer players can press ENTER to generate a random number at any time. This random value is different for each game, e.g., 1-6 for Chutes and Ladders, and 1-12 for Monopoly and this information is stored in the game description file.

Depending on the game, spaces on the game board may have special status. For example, in SORRY!, some spaces indicate a slide; if a player ends their turn on that space, they must slide their piece forward or backward. To address these special rules, each space in the game description file has an optional long description. After taking their turn, the player can press the 9 key to hear the long description of any space their game pieces currently occupy.

## 5 User Study

To evaluate the effectiveness of Game Changer in supporting accessible board gaming, we conducted a user study in which BVI adults used Game Changer to play SORRY! against a sighted opponent (played by a member of our research team).

### 5.1 Participants

We recruited seven people with visual impairments (ages 29 to 49, 3 female) through mailing lists and local community organizations. All participants used a screen reader and read Braille at varying levels. All participants had previous experience playing board games; three had previously played SORRY!. Table 2 summarizes the study participants.

### 5.2 Apparatus

Participants used Game Changer to play SORRY!. Because not every participant had played SORRY!, and to reduce the frustration of moving pieces around the board, we annotated important regions of the board with tactile materials (stick-on rhinestones and pipe cleaners). We made the following annotations:

- Rhinestones were placed adjacent to each space on the board. Corner spaces were marked with two rhinestones.
- A large rhinestone was placed at the BVI player's starting position.
- The player's "home base" region was outlined with a pipe cleaner.
- The discard pile for game cards was outlined with a pipe cleaner.

### 5.3 Procedure

Each session took approximately 75 minutes. After consenting to participate in the study, participants took part in a brief interview about their familiarity with technology and about their experience playing board games.

ID	Age	Gender	Level of Vision + Duration	Has played SORRY!?
P1	30	Male	No vision (for 11 years)	Yes
P2	32	Male	No vision (since birth)	No
P3	39	Female	No vision (for 5 years)	Yes
P4	31	Male	Light perception (since birth)	No
P5	29	Female	Light and shape perception (since birth)	No
P6	34	Male	Light perception (since birth)	No
P7	49	Female	No vision (since birth)	Yes

**Table 2. Participants in the user study.**

Next, the participant took part in two rounds of gameplay with a sighted opponent, who was a part of the research team. Because a game of SORRY! can be time-consuming, each round the players only took a sequence of several turns.

### 5.3.1. Game One: Training Phase using Human Helper.

During the first round, the participant played SORRY! on an original, unmarked board. During this activity, the participant was told to ask for help from a neutral human helper. This role was performed by another member of the research team. The human helper answered any questions the participant might have about the game and guided the participants when moving pieces and drawing cards.

The purpose of this round was not to create an A vs. B comparison with Game Changer, but instead to acclimate the player to the rules of the game and to capture any open-ended questions that a player might have about the game. As the goal of Game Changer is to support independent play, the fairest comparison would be to play SORRY! with no help or modifications. However, doing so would be difficult or impossible for most BVI players and so we did not include this condition in our study.

### 5.3.2. Game Two: Play using Game Changer.

Participants played a second round of SORRY! with the Game Changer system. Prior to using the system, the participants completed an exploratory task that introduced the tactile features of the board and allowed them to get familiar with these features prior to using them during this round. The participant had no assistance except for the system and tactile features but was allowed to ask their opponent for information if the system could not provide it.

Following the two rounds of gameplay, participants took part in a brief interview about their experience playing the game.

## 5.4 Data Collection and Analysis

Audio and video data were recorded by the research team. One member of the research team took observational notes. This member was seated next to the blind participant, while another sat next to the sighted participant and moderated the study.

All data collected was analyzed for common themes with regards to each question asked during the pre- and post-interview. The common themes were discovered using affinity diagrams. Each

heading in the following section corresponds to themes identified during affinity diagramming.

## 6 Findings

### 6.1 Current Gaming Activities

In the initial interview, participants described their experiences playing board games. All participants had some experience playing games.

#### 6.1.1. Receiving Help when Playing.

Participants reported several strategies that they had used to make board or card games accessible.

First, several participants mentioned using a sighted person, whether it be a friend or significant other, to read cards for them and provide answers to questions similar to the first round of our study.

P5 explained how they used to “play Catan and Pandemic with my roommates, [who] would obviously help because it was too complicated to make accessible.” P6 played a cricket game but “it was not in Braille so [they] had to have a sibling help [them] move the person.”

Second, participants mentioned that they had purchased accessible games. P2 explained that, “I actually have the Braille Cards against Humanity, but it showed up after we had organized the game night for everyone to come and play Cards against Humanity.” Online stores exist that provide some accessible games but are not convenient. P1, P5, and P7 own a Braille version of Monopoly. P4 used 64oz. Games [17] to print Braille labels to stick on cards. P5 and P6 also have a Braille Apples to Apples and a Braille Scrabble.

Finally, several participants described how they had added Braille or tactile markers to a game board. This approach was often used to label items, such as the number printed on a card or the color of a space.

P1 noted that “for UNO and [others he put] Braille [on] the cards [himself],” he also recently acquired “Monopoly Deal and can’t wait to Braille that and start playing.” P7 explained how she tried to Braille the spots on Candyland, but the “pieces do not sit correctly on the board.”

### 6.1.2. Accessibility Issues when Gaming.

Participants were asked to share their experiences with board games and what accessibility problems encountered when playing board games. With current off the shelf board games, many participants explained that they were not accessible because they do not know the location of the pieces or what the cards say.

P3 explained that, “I don’t know what’s there is the biggest one.” She was referring to the accessibility she encountered in playing games. “Like the Oregon Trail game parts of it I can know, even if they made the cards Braille, I still wouldn’t know the succession of pieces or what’s there.” She continued on, “Even SORRY!, I can feel this piece, but I have no idea what is on the board.”

P1 explained that hidden information is the “biggest barrier for playing board games because pretty much anything else you can have people read. Sometimes games that have a high cognitive load or a very complicated board can be hard as well.”

The inaccessibility of board games prevented some participants from playing many games. P3 “currently [doesn’t] really play board games. [She] tried but couldn’t figure out how to make [them] accessible.” P4 explained that, “There are [games that I haven’t been able to play due to accessibility issues], the problem is I don’t know the names most of the games my friends play because it is not accessible I hear the name and was like oh I can’t play screw it.” P6 stated that, “Most of those board games that are not accessible I don’t even get them anymore. For the most part, I avoid board games other than the ones that I know that are available.”

P4 postulated the board games were often inaccessible because “creators are not thinking about blind people so therefore we have to think about different modifications to make the game accessible.” P4 went on to explain that “Even if the game can be made accessible then the resource to make it accessible is not readily available.”

## 6.2 Gameplay Experience

### 6.2.1. Game One: Human Helper.

During the first round, participants were encouraged to ask the human helper any question about the game. Participants asked the helper a variety of questions such as the label of a card, the action taken most recently by the opponent, and the location of the game pieces.

Three participants relegated the task of moving their game pieces to the human helper, while other participants moved their own piece with assistance from the human helper.

### 6.2.2. Game Two: Game Changer.

All participants were able to use Game Changer to play the game. In most cases, participants made small talk with the opponent, supporting the idea that the system supported social play [32].

During this round, some participants struggled with placing their game piece on the correct space using the tactile features.

However, participants were able to distinguish between their pieces and their opponents. In one case, P6 reached for a piece, recognized it was the wrong shape, and moved on to the correct piece.

Participants experienced some difficulty in learning to use Game Changer. Participants sometimes forgot to use Game Changer’s audio input and reached for the board before remembering to use the system. This issue was particularly important at the end of the turn, as players sometimes forgot to press the 9 key, which checked for the presence of any special, additional actions, before ending their turn. P6 also mentioned that he needed to practice and memorize the keypad commands before he was comfortable using the system. These types of usability issues are not unusual for this type of study, as participants had not used Game Changer or any similar technology before. These usability issues can likely be addressed in future versions of Game Changer.

## 6.3 Experience of Using Game Changer

Following the second round, participants were asked to rate the accessibility of the unmodified game and the modified game (Figure 4). P2 explained that the unmodified game “wouldn’t be accessible because it was all visual” and that “[Game Changer] was a lot more accessible because I could do it on my own and count properly.” P4 said that he would rate the unmodified game “zero out of ten in terms of accessibility. The first one had nothing in terms of accessibility.”

When asked to state which of the two rounds, human helper or Game Changer, was more accessible, six out of seven participants agreed that Game Changer was more accessible.

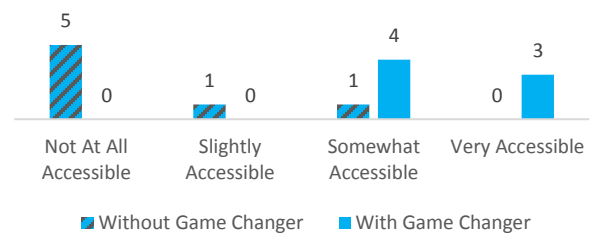


Figure 4. Subjective accessibility ratings of the two rounds.

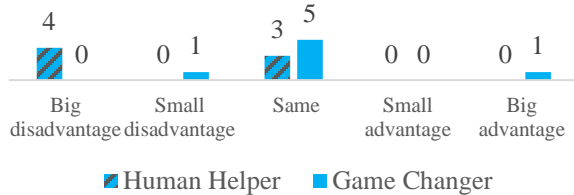
We asked participants whether using Game Changer gave them an advantage or disadvantage relative to their opponent (Figure 5). Participants tended to believe that they were at a disadvantage without Game Changer, and at the same level as the sighted player when using the Game Changer system.

P3 explained that during the unmodified game she was “at a big disadvantage. I felt like I didn’t know what was going on, I know I had a helper but that just makes it feel automatically not fun, so it’s just like a chore versus me actually playing a game. It is the basic thing that I had no idea what was on the board and no idea what the cards said unless I relied totally on someone else, just feels like a huge disadvantage.”

P4 explained that the unmodified game was “kind of a mystery because [I] didn’t know what was happening. I kept asking [the human helper] what card was he playing, what is happening, where things are, how far did he move. I was missing a lot of things, so I was at a disadvantage ... because I didn’t have all the information and if [the human helper] wasn’t here ... you know I could’ve not done anything.”

Some participants noted the contradiction between their sighted counterpart’s role as an assistant vs. an opponent. On this topic, P6 stated, “let’s say there are only two people playing and you have to rely on your opponent to tell you the cards... they could start telling you wrong information and you never know what is happening. You are totally reliant on someone else.”

With Game Changer, participants noted that they often felt themselves to be on a level playing field. P6 noted that, when using Game Changer, “I could know what was on my cards and what was on [the opponent’s] cards. I feel like if I didn’t know what was on her cards like she could do whatever she wanted, and I wouldn’t know and that would be a big disadvantage but the fact that at least I had the information to know I felt pretty similarly.” P7 noted that, when using Game Changer, “I felt we were equal; it was a lot better than the first [round]. I thought I was at the regular playing level, at the same level as my opponent.”



**Figure 5. Perceived advantage or disadvantage vs. a sighted opponent.**

We asked participants whether they felt they would be able to use Game Changer in its current state without a sighted helper: 4 participants agreed, 1 disagreed, and 2 were unsure.

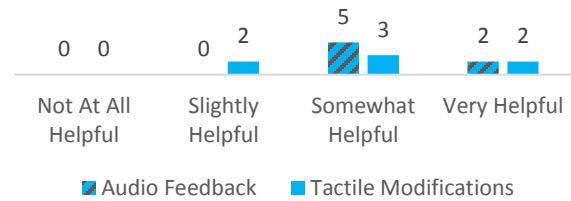
P2 was not sure if he could use Game Changer independently “because I haven’t played it and I got a little confused with zones and things like that”. P3 felt that she would be able to use the system after further instruction, as she had not yet been taught how to set up the system and camera.

### 6.4 Feedback and Suggestions

As Game Changer provides multiple types of feedback, we asked participants to separately rate the feedback modes (Figure 6).

When asked what they most liked about using Game Changer, participants pointed out several features that they found especially helpful. Unsurprisingly, most of the comments addressed the additional information provided by the system, but participants

explained how different aspects of the information affected their experience of the gameplay.



**Figure 6. Perceived helpfulness of the audio and tactile feedback.**

A common theme in the feedback was that Game Changer allowed players to participate in the game independently. P1 noted that “it was fun able to count my own squares.” P4 explained that the tactile features of the board helped him to “[understand] the orientation of where [he was], how things are traveling, and the distance between the squares.”

Participants commented that Game Changer provided a diverse set of information and increased their understanding of the board and the game. P3 explained that she “[knew] where the spaces were so [she] could count them a lot better. I understand the start [area] a lot better with the tactile features.” P5 said that Game Changer helped her to understand “where the spaces were ... where my home was [and] where you put the pawn after you move out of your beginning spot, that was super helpful.”

In some cases, participants noted that Game Changer described items that they did not know were part of the game, and thus did not know that they were missing. P3 noted that Game Changer described “the whole safety zone ... I didn’t even know that was there the first time that we played.”

Finally, some participants noted how the information provided by Game Changer allowed them to engage more deeply with the game. P3 noted the importance of describing both her cards and her opponent’s: “I like that I can know what both cards were. It felt a little more interactive doing that than just only knowing what I was doing.”

After collecting this feedback, we asked participants how the Game Changer system could be improved. The most common theme across this feedback was the usefulness of tactile feedback. Five participants requested raised borders around areas of the board, and all seven participants (all Braille readers) suggested adding Braille labels to the game cards.

Participants in the study only tested Game Changer when playing SORRY!. We asked participants what other games they would be interested in playing. Participants suggested the following games: Monopoly<sup>5</sup> (4 votes); the Game of Life<sup>6</sup> (3 votes); Chutes and

<sup>5</sup> monopoly.hasbro.com

<sup>6</sup> boardgamegeek.com/boardgame/2921/game-of-life



Ladders<sup>7</sup>, Cards against Humanity<sup>8</sup>, Pandemic<sup>9</sup>, Settlers of Catan<sup>10</sup>, and Trivial Pursuit<sup>11</sup> (2 votes each); Clue<sup>12</sup> and Cranium<sup>13</sup> (1 vote each).

## 7 Discussion

Our study demonstrates that Game Changer's approach to making board games more accessible was successful. After a brief training period, all BVI participants were able to play independently using Game Changer, which they would not be able to do without it. Participants valued the ability to follow the gameplay and to play independently, although they felt that Game Changer would be improved by adding additional tactile feedback. Participants were interested in extending Game Changer to work with additional games.

### 7.1 Effects of Experience

While participants were generally interested in Game Changer, we found that their prior experience with SORRY!, and with board games in general, affected their experience using the prototype.

While learning to use the Game Changer system required some effort, participants also sometimes had difficulty learning or remembering the rules of SORRY!. In general, we found that players who were already familiar with the game learned the system quickly, but those unfamiliar with the game sometimes took longer. These participants also sometimes forgot the rules of the game and needed to be reminded of them.

For those participants who had previously played SORRY!, their experience and knowledge of the game affected their use of the system. For example, Participant 1 noted that he had often played SORRY! with his family while growing up. During the game, P1 often asked for specific details about the board, such as the location of slides, that other participants did not ask about.

These examples illustrate the effects of a player's experience on their awareness of the game, and strongly suggest that future versions of Game Changer should provide customizable levels of feedback. Novice players may require more reminders and explicit instructions, and may be overwhelmed by too much information, while more advanced players may attempt to employ strategies that require additional information about the board or about other players.

### 7.2 Audio and Tactile Feedback

We initially developed Game Changer with an emphasis on providing audio feedback, believing that this approach would be robust and generalizable, and would minimize the amount of

effort needed to adapt any specific game. In our preliminary testing, we quickly discovered the usefulness of tactile feedback, and the importance of this feedback was echoed by our participants. The usefulness of tactile feedback is not surprising, as many existing accessible game modifications involve adding tactile features and Braille to existing game components.

While we believe that Game Changer's ability to track the game state, and to provide feedback about the game state, are best presented in audio, future versions of Game Changer could provide additional support for tactile annotations, such as by suggesting tactile augmentations for a given board or generating 3D-printable tactile annotations that could be attached to the game board.

We also note that, while all of our study participants were Braille readers, many BVI people cannot read Braille, or prefer not to. Ideally, a system like Game Changer may be useful in capturing information about the state of the game, by giving players control over how to present that information.

### 7.3 Is Game Changer Useful?

One question that should be considered in evaluating Game Changer is how it compares to existing accessible games and game modification kits, both in usability and accessibility as well as the effort required to make a game accessible.

While some game manufacturers have explored creating accessible editions of their games, such as Uno Braille<sup>14</sup>, the vast majority of games do not offer these accessibility features. Even if accessible editions of games become standard, the large number of existing board and card games are still inaccessible. It is important that gamers with disabilities are not left waiting on the goodwill and resources of game companies to create accessible games; both existing do-it-yourself modification kits and Game Changer provide the ability to make inaccessible games more accessible.

Currently, the type of accessibility provided by Game Changer is not entirely different than existing do-it-yourself game accessibility kits. Adopting suggestions from our study participants (such as adding Braille labels to every card) would further close the gap between these approaches.

We believe that Game Changer provides a number of benefits over existing do-it-yourself game accessibility kits. First, Game Changer enables players to directly adapt games, without ordering additional products or waiting for kits to become available. Second, we have designed Game Changer to streamline the process of adapting a game wherever possible. For example, if someone has created a game definition file for a particular game, other players of that game would be able to download and immediately use that file. Third, Game Changer's interface gives the BVI player additional control over what information is presented and when; we intend to provide even more

<sup>7</sup> [boardgamegeek.com/boardgame/5432/chutes-and-ladders](http://boardgamegeek.com/boardgame/5432/chutes-and-ladders)

<sup>8</sup> [cardsagainsthumanity.com](http://cardsagainsthumanity.com)

<sup>9</sup> [www.zmangames.com/en/games/pandemic](http://www.zmangames.com/en/games/pandemic)

<sup>10</sup> [catan.com](http://catan.com)

<sup>11</sup> [boardgamegeek.com/boardgame/248702/trivial-pursuit-classic-edition](http://boardgamegeek.com/boardgame/248702/trivial-pursuit-classic-edition)

<sup>12</sup> [boardgamegeek.com/boardgame/1294/clue](http://boardgamegeek.com/boardgame/1294/clue)

<sup>13</sup> [boardgamegeek.com/boardgame/891/cranium](http://boardgamegeek.com/boardgame/891/cranium)

<sup>14</sup> [www.mattelgames.com/games/en-us/uno-braille](http://www.mattelgames.com/games/en-us/uno-braille)

customization options in future versions. Finally, by tracking the state of the game using a camera, Game Changer can provide information to a BVI player that would be difficult to access in tactile format alone, such as reaching far across the board, and can provide information about the board without leaking information about the BVI player's areas of interest or game strategy.

## 8 Limitations

As mentioned previously, the current system is limited to a subset of board games. Furthermore, due to the time needed to familiarize participants with the rules of gameplay, participants in our study only tested Game Changer with the game SORRY!. While we believe these choices were the best solution to the challenges of this work, we may be missing out on some undiscovered usability or accessibility challenges. Testing future versions of Game Changer with additional games, and with additional types of games, will broaden our understanding of how our approach can impact the accessibility of board games.

Additionally, the study session involved only a subset of a full game, participants played games against a member of the research team rather than a friend or family member. We invited participants to bring their friends or family along to the study session, but none of our participants chose to do so. Conducting longer studies across multiple sessions, multiple games, and multiple groups would certainly increase our knowledge about board game accessibility and the effects of Game Changer.

## 9 Future Work

Our participants provided a number of useful suggestions for improving the Game Changer system and for extending it to additional games. While we have generally found this approach to be generalizable, at least to other roll-and-move games, adding additional games would likely provide new challenges and opportunities to improve our system. For example, while SORRY! relies upon drawing cards to introduce randomness, Monopoly and Chutes and Ladders both use other game items (specifically dice and a spinner, respectively) to do so. This realization prompted us to add the random number generator feature. We have considered additional features such as an inventory tracker (e.g., for more easily keeping track money in Monopoly) or a feature that summarizes the history of recent moves and will likely explore these ideas in future prototypes.

As discussed in the previous section, our study provided evidence that different players may require different information based on their experience or ability. Future studies will explore how information needs differ across players and how to best give players control over that process.

One limitation noted by our study participants was that the system was set up by a sighted researcher before the study session. While we are confident that Game Changer could be set up by BVI players, we were unable to include this activity in the study. Future versions of the system should provide guided instructions

to enable BVI players to purchase a game, set it up, and play it, all without sighted assistance. We also intend to support end users in creating their own adaptations for games, and to evaluate the experience of doing so.

Finally, while our present work was motivated by the interpersonal and social benefits of playing games together, our evaluation did not provide much insight into the social dynamics of mixed-ability gaming. A future goal of this system is to support fully interdependent play [5], where each player can act independently as well as participate fully in collaborative work. We are curious about whether specific aspects of the game playing experience may influence players' social perceptions; for example, is it more important to a BVI player that they are able to set up the game themselves, or that they can move their own game pieces? Can collaborative, mixed-ability gameplay help players to understand their partner's experience? Now that we have developed a system to support accessible gameplay, we are both able and excited to explore how game designs and interactions may affect mixed-ability collaborative activities.

## 10 Conclusion

Many board games are not accessible to blind or visually impaired people because necessary information is presented visually. Few research efforts have been conducted in this area. To explore the opportunities and challenges of accessible board gaming, we created Game Changer, a system that provides tactile features and audio descriptions of the state of board games to blind or visually impaired people. Our findings show that the combination of audio and tactile feedback can be used to make existing games accessible and that participants valued the ability to play games independently.

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